Assemblage Form: An ontology of the urban generic with regard to architecture, computation, and design.

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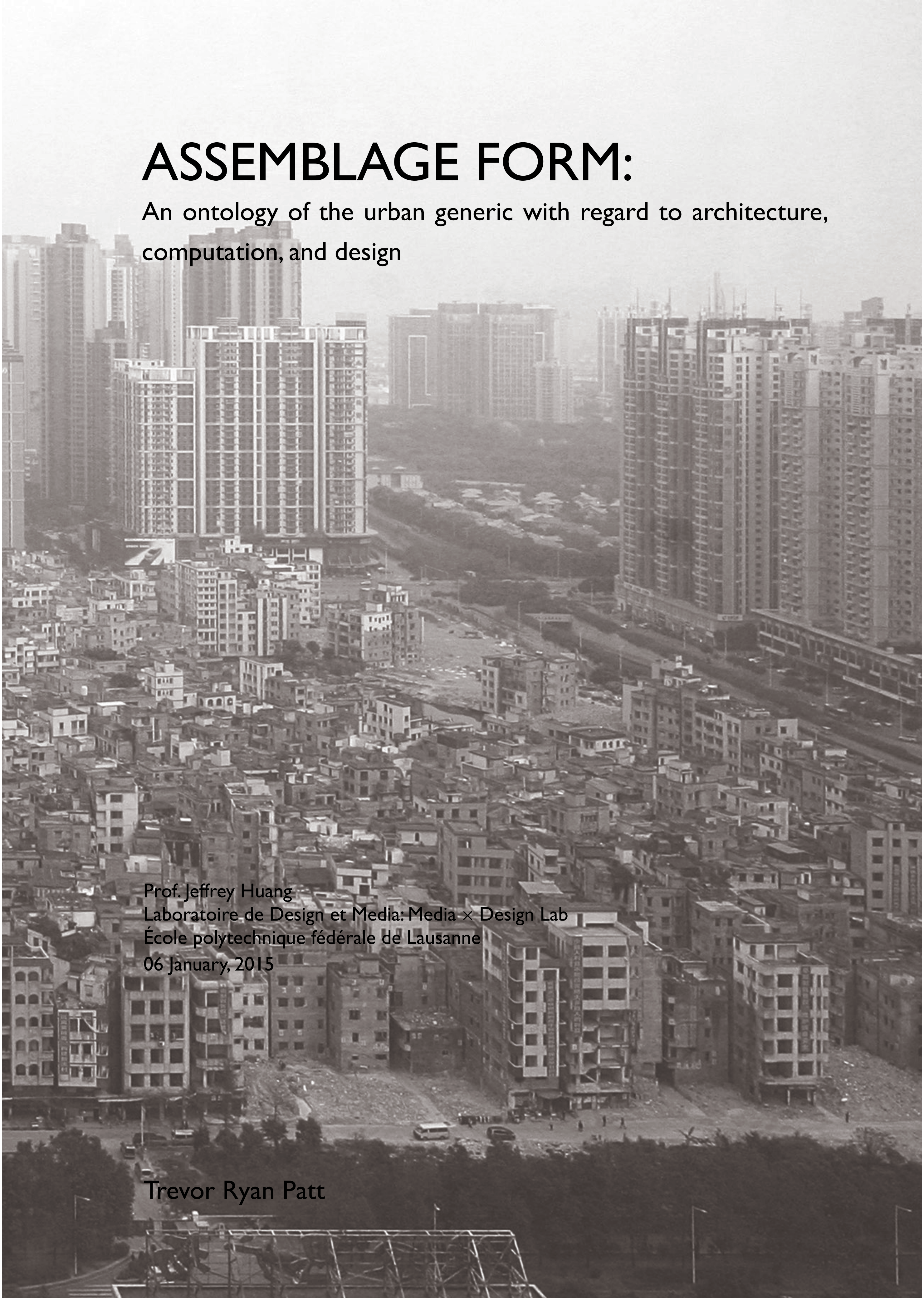

ASSEMBLAGE FORM:

An ontology of the urban generic with regard to architecture, computation, and design

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Agencemet des formes:

Une ontologie décrivant l'urbanisme par rapport à l'architecture, le calcul, et design

Résumé

Ce manuscript introduit une théorie de l'urbanisme comtemporain qui met en parallèle le caractère transformatif de la ville avec une nouvelle perspective computationelle de la conception urbaine dans une description intégratrice du concept d'une organisation genérique. Cette caracterisation décrit la condition urbaine en tant que question ouverte comme décrite par les théoriciens de l'urbanisme d'agencement ("*assemblage urbansim*"). Cette thèse étend les travaux existants dans le domaine de l'urbanisme basés en empirisme vers une théorie opérative qui fusionne ces résultats connus avec une ontologie d'une agence basée-objet qui peut être appliqué en pratique pour la conception. Mes travaux défend l'idée que les processus computationnels sont unique dans la façon dont ils facilitent le design urbain de fonctionner de la même manière qu'une ville réagit à son propre dynamisme et sa répresentation pendant qu'ils mettentwhile l'accent sur la dimension réthorique de systèmes interactifs comme l'urbanisme et les modèles procéduraux.

Les similitudes entre les modèles computationnels et la dynamisme de la ville seront explorés par une série de sujets d'étude qui s'étendent entre l'étude urbaine et la conception urbaine tout en liant des questions sur l'histoire de la dimension numérique dans l'urbanisme. Les quatre thématiques — Interaction, Génération, Réflexion, et Entropique — convergent autour un schéma théorique intégré. Dans ce cadre-là je défends l'influence croissante de l'architecture en tant qu'agent dans le processus de conception urbaine. Je présente des exemples potentiels à ce sujet obtenus à modèles numeriques à côté des arguments théoriques pour renforcer le fait que les contraintes liées à la codification en langage machine sont des determinants significatifs pour la conception tout comme les réalités matérielles le sont pour l'experience urbaine.

Enfin les leçons sont ramenés vers l'urbanisme de telle sorte que l'architecture agit en tant qu'interface pour mettre en prise la ville, permettant l'architecture de participer par le biais d'une interaction qui est mutuellement contingent. Dans ces cas, la ville provoque en continu l'architecture d'interroger a son tour le *status quo* de la situation urbaine et son potentiel changeant. En permettant des résultats indéfinis, l'urbinsme et la conception computationnelle peurent produire le même genre alterité et de irréalité productif.

Mot de cles

agencement, le design computationnelle, inaesthetiques, la philosophie centrée sur l'objet, la monadologie, l'urbanisme procédural

Assemblage form:

An ontology of the urban generic with regard to architecture, computation, and design

Abstract

The thesis proposes a projective theory for contemporary urbanism that equates the active processes of the city and a new orientation for procedural urban design within a single line of thought that delineates the concept of a generic organization—forming heterogeneous assemblages, but resisting the tendency to totalizing systematization. Such a description characterizes the urban condition as an open phenomenon, such as that described by theorists of assemblage urbanism. This thesis extends this work from an analytical or empirical theory to an operative one that can be applied to design practice by combining it with an ontology of encapsulation and object-based agency. I will argue that computational processes are unique in the way that they enable urban design to operate in the same manner as the city with regard to enaction and representation while drawing attention to the rhetorical dimension of interactive systems like urbanism and procedural models.

These parallels are further explored through a series of themes that bridge between urban studies and urban design and that connect to historical concerns in computation and urban design. The four themes—Interactive, Generative, Reflexive, Entropic—coalesce around an integrated theoretical schema. Within this framework, I also argue for an increasingly involved role for architecture as an active agent in the urban design process. Illustrations of how this might occur (as functional code and software screenshots) are presented alongside the arguments to underscore the fact that the material basis of the computational model is as significant a determinant of design practice as the material realities of the city are to the urban experience.

Finally, these lessons are imported back into urbanism with architecture acting as an interface to the city. Procedural engagement allows architecture to participate in urbanism through a mutually contingent interaction. In cases where this occurs, the city continuously prompts architecture to carry out new inquiries into the changing potential of the urban situation. Rather, by allowing the the outcome of the situation to remain undecided, both urbanism and computational modeling can be seen to offer the same productive irreality and alterity: an urban generic.

Keywords

assemblage urbanism, computational design, inaesthetics, object-oriented philosophy, monadology, procedural urbanism

CONTENTS:

INTRODUCTION

§0.1 Introduction

Influences

This thesis gathers up a number of my long-standing interests and preoccupations with the intention to link them together within a single line of thought. Thus while many doctoral theses are hermeneutic in character, developing a new understanding through closely reading and parsing a source, this one has a synthetic nature, bringing together a number of sources and constructing a new category from their assemblage. In particular, I am interested in the agency of architecture on urban design, the extension of its effects over the shaping of the city;[1] the interrelationship of emergent networks and the realist irreducibility of the actors involved, the multiplication of localized behaviors and of informed sites;[2] the rhetorical limits of formalization in such systems; projections of the future potential of the city;[3] and the representation of these potentials.[4] In sum, the thesis concerns how architecture and design can relevantly interact with the complex production of contemporary urbanity.

Goal

Under the name of the 'urban generic', I will come to define a theory for urbanism constructed around an integrated practice of computational design and planning. I will argue that computational thinking is uniquely suited to the challenge of a contemporary theory of urbanism. This assertion is not put forward with the intention of reconstructing the urban so that it follows the recognizable forms of facile algorithmic processes, but to rewrite approaches to design computation *and* urbanism toward their common ground: a procedural network of countless actors and organizations enmeshed in an open-ended interrelationship.

The use of the term 'generic' here is not meant to evoke a convergence of sameness as in Koolhaas' "The Generic City,"[5] but rather the philosophical category of generic as invoked by Alain Badiou[6] to designate the relationship to an untotalisable multiplicity, one that cannot be fully circumscribed within the formal definition of a situation and that "will proceed to reconstruct—locally, to begin with—the whole set of rules by which things appear."[7] This definition of the generic simultaneously affirms the value of formalization in the approach to urbanism while insisting on the irreducibility of the urban to such formalizations.

Motivations

As the actual experience and management of cities are drawn closer and closer toward the computational in their own logics,[8] this thesis contemplates ways in which computational thinking might also be incorporated into the design of cities—not only as a source of formal language or to satisfy the exigencies of the engineer, but in the production of urban planning and design—as an environment of creative becoming. I am especially interested in

1 Patt, "Taipei 2.0.2: Computation and the Urban Generic."

2 Zuezke, Patt, and Huang, "Computation as an Ideological Practice."

3 Maas and La, *Skycar City*.

4 Patt, "The Collective Image: Form, Figure, and the Future."

5 Koolhaas, *S, M, L, XL*. p1248-1265

6 Badiou, *Infinite Thought: Truth and the Return to Philosophy* (London: Continuum, 2004) p28*ff*

Badiou, *Being and Event* (London: Conti, 2006). Meditation 31, p327*ff*

7 Badiou and Hallward, "Beyond Formalisation: An Interview." p131

8 Graham, "Software-Sorted Geographies."

Amin and Thrift, *Cities: Reimagining the Urban*.

Graham and Marvin, *Splintering Urbanism: Networked Infrastructures, Techonological Mobilities, and the Urban Condition*.

delineating a conceptual framework that acknowledges that the urban environment is acutely receptive to bidirectional influence between the small-scale of architectural objects and users and the large-scale urban concerns of policy and planning. Using procedurality as a medium, I propose a model that is inherently dynamic and interactive, and therefore also emphasizes the mutability of plans. Such dynamic enactment allows the urban designer to make the claim for emergent phenomena that exceed the definition of the design, however a committed engagement with processual planning also requires consideration of processes by which future development is indirectly steered and how those processes can be engaged with by designer and citizen alike.[9] To address these concerns it is also necessary to introduce an ontology of urban plenitude into the model of computational design.

§0.2 Structure

Schematic

The structure of the argument is fourfold. Each section will be addressed twice: once, primarily from the theoretical sources. and a second time along a theme related to technical deployment in a computational environment.[10] In addition, there will be four design examples accompanying each technical theme to illustrate aspects of potential applications. The sections are:

1. Procedural Rhetoric – Interactive (Meshes)
2. Object Ontology – Generative (Parcels)
3. Assemblage Urbanism – Reflexive (Buildings)
4. Inaesthetics – Entropic (Paths)

where the second term names the theme (and the object of the design illustration) and the first term a theoretical source of explication or supporting context. The isolation of themes as well as the separation of *theoria* from *technê* is a somewhat artificial one, but one which will allow more focused attention to each aspect of the argument given the diverse set of sources being brought together. When intertwined with the others, each contributes to the understanding of the urban generic (Figure 0.1).

Chapter summary

As a point of entry, chapter 1 will review a current within urban studies, Assemblage Urbanism, which deemphasizes structures of social power in favor of sociomaterial explanations of agency that exist equally for human and non-human actors. In contrast to political–economic structures, assemblages are considered to be especially temporal, even *ad hoc*, for the purpose of dispensing with the hierarchical framework of structuralist critical urban theories. This chapter argues that assemblage urbanism's method for approaching the city as an entity dynamically constructed from its (socio-)material elements emphasizes the responsivity of the city and enables an expanded role for the agency of the inorganic matter of the city independently at various scales. This actant dynamism is a needed addition to urban design practice for both pragmatic reasons of engagement with temporal changes and ideologically to locate changing urban quality as a more significant aspect of urban design.

Chapter 2 recognizes that the efficacy of agency must be supported by an expanded concept of the object (and assemblages as objects) exploring the loose category of Object-Oriented Philosophy (OOP),[11] a recent trend in philosophical thought which seeks a realist ontology independent of human causation—that is, an imminent object agency—and shares a number of concerns with assemblage urbanism. The object properties developed here will be supplemented by a new reading of monadology, to highlight the mode of existence of discrete units, their internal multiplicity, and their engagement with the exterior (or detachment therefrom). Additionally, this section will reference Latour's reintroduction of Tarde with regard to digital profiles and databases and Deleuze's explication of Leibniz and baroque complexity.

In order to combine the situational contingency of assemblage urbanism and the internalization of object properties within object oriented philosophy, it is necessary that the urban situation also initiate autonomous behaviors. Ian Bogost's twin concepts of Unit Operations and Procedural Rhetoric show how such a set of behaviors can produce a system as complex as the city in a non-reductive way, and how procedural representations, like simulation models, stipulate new terms of engagement, drawing on the unique possibilities of autonomous reactions given by computation. As rhetoric, the primary interest of modeling is shifted away from the application of formula toward solving well-delimited scientific problems and refocused on the framing of the cultural potentials of procedurality—that is, to make arguments, to initiate discussions, to persuade constituencies, to structure interactions, to foster engagement, or to suggest possibilities.

In this framework, architecture is situated as an interface of the city, an information threshold that both acts and is acted upon. As an interface, it influences the directions in which identity and information are pointed, though only indirectly. This requires a commitment from the design to the multiplicity of possibilities and the acknowledgment that inputs, whether they are contextual or user generated, are not directly actionable, but always received and translated. Chapter 4 will describe the 'Interactive' as an application of procedurality to the task of incorporating external and extrinsic information (into a system, an assemblage, or an object), the ways that information is managed, and what possibilities its dissemination enables or disables. This section will discuss technical methods for data input and user interaction and will use 'Project 1: Meshes' as an example of interactive methods for organizing contextual inputs into a surface of urban orientations and oriented building volumes as interfaces for types of urban space on a topographic site in Sichuan.

Occupying a position based on such contingent foundations, motivates a substantial reevaluation of authorship. Chapter 5 proposes a transference of design decisions into objects, giving them agent-like autonomous behaviors. Operating in the absence of centralized coordination, the 'Generative' focuses on the encapsulation of internal traits as the identity of an object and the reflection in other units of these external presences. How objects produce extensive series over and across one other leading to emergent orders (including the ability to form larger assemblages which encapsulate new behaviours) and co-implicated networks points the way toward an urban design that does not rely on a single, actor at its head. This chapter will address challenges and potentials that arise from multi-agent systems and will use 'Project 2: Parcels' as an example of generative behaviors applied to the elements of an urban mesh and which develop their virtual identities following a complex extension of traits over a site in peri-urban Beijing.

9 Chatterton, "The Urban Impossible: A Eulogy for the Unfinished City."

10 Complete files will be available to access and download at

http://ahtebha.net/assemlage-form/

11 Also sometimes, 'Speculative Realism' (SR).

The lack of centralized coordination means that a multi-agent system will frequently encounter conflicts and contradictions among its components. The 'Reflexive' function negotiates these incompossibilities while maintaining an agonistic environment. Reflexivity concerns the actualization of the urban field into persistent urban actors and emphasizes the diffuse impact of effects that ripple through an interrelated network. These contingent effects are a source of feedback causality that can act as regulating restrictions or spontaneous catalysts. This chapter will touch on how feedback loops can be incorporated within associative geometry using 'Project 3: Buildings' as an example of assemblages reconfiguring component elements to form collective ensembles between high-rise towers in urban Shanghai.

Iteration of the reflexive function tends toward solutions in static equilibrium, abandoning the definitive characteristic of the city as an open system. It is necessary to introduce a remedial operation which destabilizes identity and returns the focus to procedures of expansion and adaptation. The 'Entropic' is a deterritorializing function which preserves the flexibility and dynamic potential of the system by forgetting or discarding established patterns, structures, or assemblages. Chapter 7 will propose tactics for subverting the tendency of formally explicit computational models toward closed systems and will use 'Project 4: Paths' as an example of productive entropy in networked structures to negotiate the metabolism of an urban village in Guangzhou and the disposition of its public spaces.

The idea of forgetting as de-differentiation is treated above as an important condition for preserving the multiplicity within urban design. The proposed model is an environment that would formulate the contested status of its own inherent complexity as a condition to be extended rather than resolved, that is, to insistently define the urban as the condition of the possibility of the City and not as a solution to the city or a statement on the city. Badiou defines 'Inaesthetics' as the relationship of philosophy to aesthetics such that philosophy does not dictate the agenda of aesthetics, but reflects on its revelations. In particular, he discusses the possibility of aesthetic media being dedicated not to the singularity of Art, but toward providing the conditions for the possibility of an art, through a process of forgetting thar supersedes knowledge or information via enactment. Chapter 8 considers this analogous to the relationship of urbanism and architecture. In this way, the enactment of urban processes can become the means through which they exceed and are not limited to a strict, technocratic definition.

Finally, chapter 9 concludes with a meditation on the 'Generic.' As mentioned above, the generic follows Badiou's adoption of the set-theoretical definition of the generic set by Paul Cohen: the set which cannot be defined through reference to its encompassing set, an untotalisable set, a set which is indiscernible by the situation, which exceeds definition. For Badiou, the generic provides the basis for the possibility of the new. The generic allows one to conceive of formal systems which are not limited to the conditions of their definition but which are capable of open-ended potentiality without compromising their formalization. This thesis draws much of its argument from Badiou's equation of set theory with ontology, but introduces a positive alternative to the 'void' by drawing from the previous discussions of assemblage theory and object oriented ontology forming a new synthesis tuned to the plurality of the urban condition.

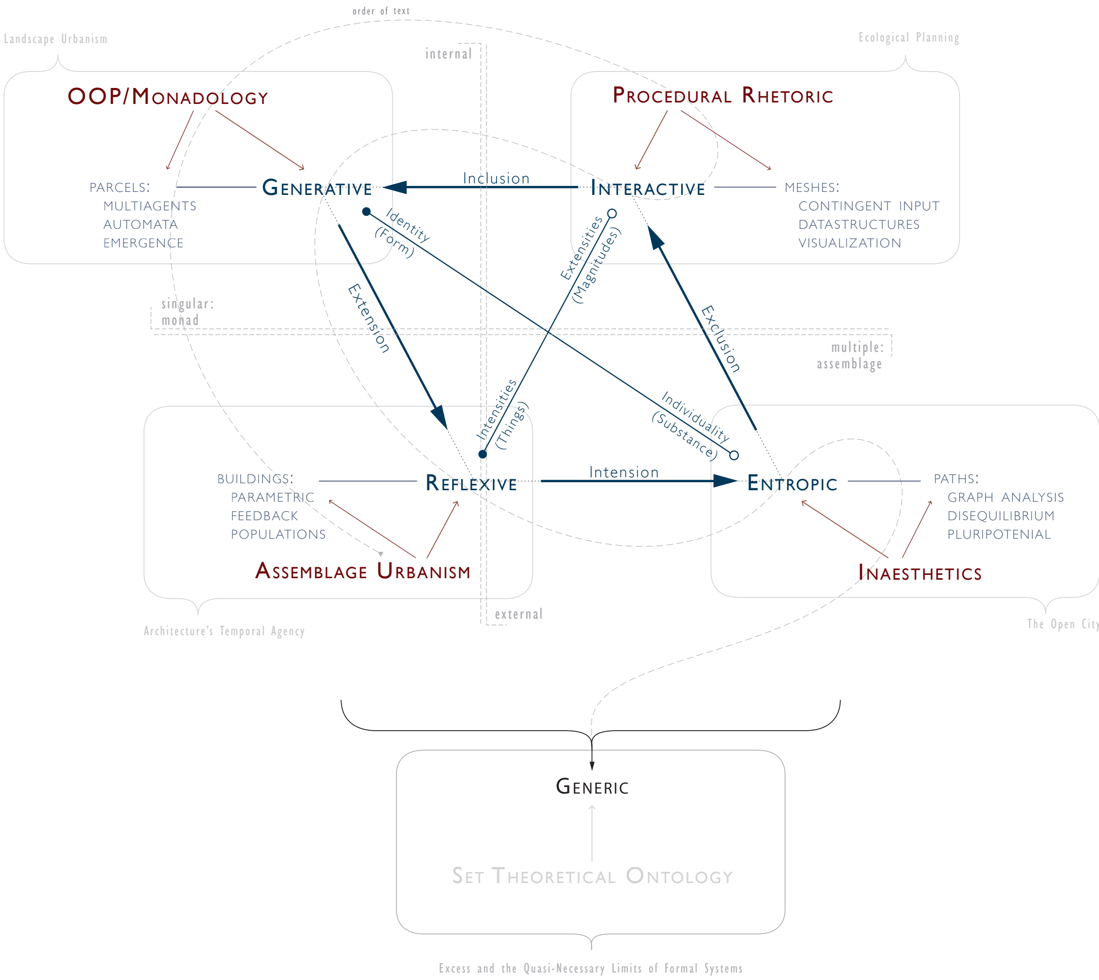

Figure 0.1

This diagram illustrates the schema that relates the various parts of the thesis. The four themes at the center, **Interactive**, **Generative**, **Reflexive**, and **Entropic**, are related to one another as oppositional terms along the diagonal axes and by translations around the perimeter.[11] Interactivity is primarily concerned with extensities: quantitative metrics that will become the component parts for the objects that follow as they are included in the subsequent objects. Generativity addresses the identity of unique objects, withdrawn and yet overlapping and extending their influence over one another in the formation of assemblages. Reflexivity defines these assemblages through the intensional convergence of various objects into a consistent assemblage whose internal relations settle at a stable limit, at which point Entropy is necessary to disrupt these limits and to force the individual to re-engage the virtual.

In this schematic, we have distinguished emphasis on individual, as a monad, and the multiple as an assemblage as well as the internal constitution of the object and its external relations. However, the ontological equivalence between objects and assemblages (all objects are multiple and eaach assemblage can be taken as an individual) means that this diagram can be recursively nested: any quadrant can be taken as a new origin point and the diagram repositioned at that anchor (that is to say that the perimeter sequene is not a necessary order, in fact any entity is always acting in many roles at once).

Each theme is linked to a particular object of urbanism (**Meshes, Parcels, Buildings, Paths**) that will constitute the basis of the design illustrations and that are intended to ground such a metaphysical discussion in the concerns of urban design.

Together, the thematic categories and the design illustrations are infomed by specific theoretical sources that provide a critical context in urban studies and media presentation, though of course, the text does not support such a discrete, one-to-one relationship as is shown here, but the separations become blurred and overlapping.

The sequence of the text itself is traced by the dashed line beginning with Assemblage Urbanism (chapter 1) in the lower left and concluding with Generic (chapter 9) at the bottom center.

11 The terminology is largely drawn from: Deleuze, *The Fold: Leibniz and the Baroque*. Chapter 4: p41-60, especially p 49, 57

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CHAPTER 1
ASSEMBLAGE URBANISM

§1.1 Challenges and Shortcomings of Critical Urban Theory

Critical theory as urban theory

The tradition of critical urban theory can be defined as an abstraction of the urban organization that is "enabled by and oriented towards" its specific context and the normative practices surrounding it while emphasizing "the disjuncture between the actual and the possible."[1] The scope of urban studies has expanded in recent years as urbanization has accelerated and cities themselves have come to be defined more and more by their actions in the global sphere.[2] This has stretched the definition of urban studies "across the entire world economy … at all spatial scales and across the entire surface of planetary space."[3] In particular, it has challenged the relationship of urban studies to critical theory: Brenner argues that urban studies can no longer be treated as a subtopic of applied critical theory,[4] but, because urbanism is the ubiquitous condition in which social, political, and economic relations are organized and enacted, that the two are definitively connected, "that critical theory must necessarily be a critical *urban* theory."[5]

The object of critical urbanism is not the city

Already by 1970 Lefebvre had forecast the ubiquity of urbanization[6] and the displacement of industrial production by the production of urban space as a dominant mode of social development.[7] However, by casting the urban as an abstraction of pure form with "no specific content,"[8] Lefebvre devalues the role of the city, itself, in the final analysis. Ignacio Farías argues that "in the case of critical urban studies, the focus on cities and space is only contingent. What is ultimately at stake in those discussions is the organization of contemporary capitalism."[9] That is to say that critical urban theory is always practiced in service of and bounded by critical theory's project "to investigate the forms of domination associated with modern capitalism" and "to excavate the emancipatory possibilities that are embedded within, yet simultaneously suppressed by, this very system."[10] The division between these two targets has only gotten more complicated in the wake of the dematerialization of the city.[11]

Reduction of urbanism to epiphenomena

Thus while urban matters have taken on greater significance within critical theory, any real effects or processes of urbanism are still held as intermediate outcomes that represent tendencies in global political economy. This results in a discourse that ignores or badly investigates a multitude of questions about the city which cannot be reduced to fundamentally political–economic terms.[12] Though Brenner calls for "a much more systematic integration of urban questions into the analytical framework of critical social theory as a whole,"[13] critical urban theory continues to frame these urban questions under familiar categories and structures. While this offers the benefit of established and tested methodology, "the prevailing spatial imaginary behind this tradition of work has been that of

1 Brenner, "What Is Critical Urban Theory?". p201-203

2 Sassen, "The Global City: Introducing a Concept."

3 Brenner, "What Is Critical Urban Theory?". p205

4 *Ibid*. p206

5 McFarlane, "Assemblage and Critical Urbanism." p205-206

6 Lefebvre, *The Urban Revolution*. p1

7 *Ibid*. p139

Prigge, "Reading 'The Urban Revolution': Space and Representation." p48

8 Lefebvre, *The Urban Revolution*. p118

For Lefebvre, "the form of space is defined as the possibility of encounter, assembly, and simultaneous gathering regardless of what—or who—is gathered."

Stanek, "Space as Concrete Abstraction: Hegel, Marx, and Modern Urbanism in Henri Lefebvre." p73

9 Farías, "The Politics of Urban Assemblages." p367

10 Brenner, "What Is Critical Urban Theory?". p204

11 "as spatial entities, cities have become agglomerations that no longer cohere internally to function as organisms in their own right. Thus, while much of the world can now be read from what goes on in cities, what remains of cities as territorial entities is no longer self-evident. The everyday urban has become part of a world space of many geographies of varying spatial reach and compositions"

Amin, "Re-Thinking the Urban Social."

12 For example, "urban informality, unlike slums and poverty, is neither necessarily a problem nor an effect of capitalism—all cities embody a mix of informality/formality and urbanity requires informality."

Dovey, "Uprooting Critical Urbanism." p351

13 Brenner, "What Is Critical Urban Theory?". p205

territorial or scalar composition"[14] a theoretical framework that has done little to connect urban theory to 'grounded' accounts of everyday occupation of the city drawn from ethnographic or other empirically motivated approaches.[15] "Within such a framework the microscale specificities of urban space, public/private interfaces, pedestrian networks and everyday urban experience are often reduced to epiphenomena of larger scale processes and structures."[16] From the perspective of urban specificity, the critical urban approach seems to reverse the order of inquiry, with a fascination for pre-established scales and contexts that overrules the details of individual urban situations:[17] "space and scale as products that somehow become independent from the practices and processes originating them … in the sense of taking for ontologically autonomous something which is rather a quality of actual networks of practices."[18] At this point, critical urban theory falls back on a weak structuralist ontology to ensure an inroad for political economy in the explanation rather than fully committing to an immanent urbanism.[19]

Restriction of agency within structuralist framework

For the critical urban theorist, the inscription within larger structures defines the roles and agency of actants in the city. These "scalar and spatial fixes" are responsible for providing an agent with its capacity to act or similarly for restricting its action.[20] Two difficulties arise from this model: firstly, the implicit separation of the actant from the motive source of its action; the motivation is now held within the structure and the particular enacting individual is of secondary importance;[21] secondly, the inherent reductionism of such an operation and the limitation of these categorical structures to existing concepts. Not only does this suppress the recognition of unique properties from situation to situation, it discourages the advancement of new configurations. Such reliance on pre-given structures and categories results in relatively narrow definitions of participation and modes of representation that are largely at odds with the contemporary theoretical environment. At the extreme end, this approach assumes "having a privileged access to the real facts, structures and contradictions of urban life," and suggests "that by unveiling these hidden structures, the strength of the powerful will be combated."[22] rather than looking for developing alternatives among the undercurrents.

§1.2 Aims and Characteristics of Assemblage Urbanism

Assemblage urbanism's response

In response to the shortcomings of critical urbanism, there has been a growing trend under the name of 'assemblage urbanism', with three primary objectives. The first goal is to work directly with the dynamic variability of contemporary urbanism and to account for the creation of new entities and *ad hoc* organizations within the city. The second objective is to address these organizations without reducing them to pre-established structures but rather to describe them in ways which follow their contingent formation. Finally, assemblage urbanism aims through these means to identify a broader field of agency for transforming or engaging with the city. This section will review how these goals are characterized as practices among urban theorists and sociologists before then looking at their origins in assemblage theory and defining a particular usage for this study.

The dynamic city

In the last 30 years, cities have demonstrated an accelerated pattern of development that has brought forward a number of new formations to complicate the theorization of the city: incredibly rapid change and growth, massive informal urbanization, divergence between economic models formal and practiced, buy-to-leave property investors, automated technological controls, interdependent service networks—to name a few.[23] Such changes have reiterated the importance of a processual conception of the urban as a mode of becoming. "Rather than focusing on cities as resultant formations, assemblage thinking is interested in emergence and process, and in multiple temporalities and possibilities."[24] For assemblage urbanists, this means "focusing on the dynamic and transactional unit formed by an organism-in-its-environment" in which the acts of dwelling make and unmake the city.[25] In place of a well-defined, bounded totality, the city is redefined as a locus of high connectivity between a multitude of different entities, one which is not without its own historical and spatial contingencies, but that is continuously redefined by processes of interrelation.[26] In highlighting the dynamism of the city, assemblage urbanism emphasizes the fact that the persistencies of the city do not possess privileged control over the trajectory of development, but are simply co-participants, allowing more open projection concerning the potential of the future of the city to be imagined differently.[27]

Instantaneously emergent

In fact, the temporality of assemblages is specifically tuned to recognize "the capacity of events to disrupt patterns, generate new encounters with people and objects, and invent new connections and ways of inhabiting everyday urban life."[28] These moments of emergence engage existing organizations in a continuous process of renegotiation, territorialization, and adaptation. Thus when one speaks of *an* assemblage it is always in the sense of an entity in an ongoing act of assembling itself. "Such territorialization is as much an alignment of connections as a hardening of boundaries,"[29] writes Dovey, pointing to the action of aligning rather than the end product of a boundary. The territory of an assemblage is not a given property around which walls can be drawn, but a topological domain that waxes and wanes. Territorialization (and deterritorialization) thus become interesting indicators of situational activity within an assemblage.

§1.3 Addressing the Organization and Agency of the City without Structure

Against scalar hierarchies

One of the more controversial aspects of assemblage urbanism is the prioritization of a topological space and the perception that this dispenses with scalar differences.[30] We have just seen how the assemblage concept of context is radically differentiated compared to critical urban theory in order to eliminate the reductivism of top-down definition. The introduction of scale as a categorical qualifier is another place where structuralism creeps back in.[31] Rather than follow this sort of tree-like thinking, which is anyway antithetical to urban organization,[32] the intention is to look for "tactics and strategies of power embedded in the morphology of the city and the ways that an assemblage of small-scale adaptations can produce synergistic emergent effects at higher levels."[33] Horizontality, however, does not preclude the existence of different scales,[34] nor does it force all influence to come from the bottom-up. Much more simply, it "provides a progressive basis for a critical reevaluation of spatial categories and scalar dynamics"[35] by diffusing powerful top-down assemblages within the same kind of imminent assemblages as the everyday encounter.[36]

14 Amin, "Re-Thinking the Urban Social." p105

15 Rankin, "Assemblage and the Politics of Thick Description." p563-564

16 Dovey, "Uprooting Critical Urbanism." p348

17 "being used to suggest that details don't matter because meanings are transformed by context and again by the 'context of context'—the hegemony of scale again"

Ibid. p351

18 Farías, "The Politics of Urban Assemblages." p370

19 Smith and Doel, "Questioning the Theoretical Basis of Current Global-City Research: Structures, Networks and Actor-Networks."

20 Farías, "The Politics of Urban Assemblages." p370

21 "since the construction of reality is mostly understood in epistemological terms, the materials and intermediaries involved in the construction are deprived of any active role"

Farías, "Decentring the Object of Urban Studies." p13

22 Farías, "The Politics of Urban Assemblages."

23 Gandy, *Urban Constellations.*

24 McFarlane, "Assemblage and Critical Urbanism." p206

25 Farías, "The Politics of Urban Assemblages." p369

26 Ash Amin, "Re-Thinking the Urban Social." p112

27 McFarlane, "Assemblage and Critical Urbanism." p210

28 *Ibid.* p209

29 Dovey, "Uprooting Critical Urbanism." p348

30 Brenner, Madden, and Wachsmuth, "Assemblage Urbanism and Challenges of Critical Urban Theory." p232

31 "Most urban thinking within the scalar paradigm remains focused on hierarchies of scale and embodies a valorization of the large scale over the small."

Dovey, "Uprooting Critical Urbanism." p348

32 Alexander, "A City Is Not a Tree."

33 Dovey, "Uprooting Critical Urbanism." p348

34 "Assemblage, like place, is a multi-scalar phenomenon that can be understood at the level of the building, street, neighbourhood, district and city."

Ibid. p348

35 Acuto, "Putting ANTs into the Mille-Feuille." p554

36 *Ibid.* p555

The elements of urbanism

While we can speak of the city as a vast assemblage then, this does not confer a simple, organic totality to its persistent parts. Various aspects of urbanism (bureaucratic planning organizations, climatic patterns, aspects of the city's built form, etc…) may follow individual paths into multiple assemblages with all manner of agendas. Because the elements of an assemblage maintain their individuality separate from the larger networks they form, the theorist must account "for all actual entities involved in such processes of construction, whether human or nonhuman, their interactions and transformations."[37] Each element is itself an assemblage and is defined by its emergence and not from outside.[38] The emergence of an urban environment is neither exclusive nor reductive and the assemblage urbanist assays to convey the complexity of this inclusiveness. Ash Amin describes the urban spatiality as "a subtle folding together of the distant and the proximate, the virtual and the material, presence and absence, flow and stasis, into a single ontological plane upon which location—a place on the map—has come to be relationally and topologically defined."[39]

New assemblages

Two points in Amin's description are particularly significant. First, the localization of the urban—each assemblage actively situates itself through its interactions, locality is not an inherent property given by a global structure but a relational construction. Secondly, the plurality of participants and the many modes of engagement allow the preservation of subtle differences within the assemblage, differences that individualize the assemblage. Though not all such idiosyncrasies will be significant, they leave openings for new, *ad hoc* engagements in the future or wrinkles in the assemblage's own development.[40] Unpredictabilities like this preserve the potentiality of the urban assemblage preventing it from collapsing into a set of pre-established possibilities.[41]

§1.4 To Account for a Wider Field of Agency

Alterity

Although new alternatives are a significant feature of critical urbanism's attention—one of the key elements of critical theory (according to Brenner) is to emphasize "the disjuncture between the actual and the possible"[42]—the inscription of alterity within the existing political–economic structures restricts the theorist to the realm of given possibilities. "We still find in much critical theory the negative use of the term power as oppression (power over) rather than power as capacity (power to),"[43] writes Dovey, underscoring how assemblage urbanism focuses on a broader conception of alterity as an active, rather than reactive, process. This follows directly from the act of tracing the actual processes and actions, investigating which are significant and what would have occurred if they had been enacted otherwise.[44] The assemblage method is one of progressive differentiation, not constrained to a particular model[45] but promoting a rich multiplicity.[46]

Difference

Assemblage urbanism does not only operate by differentiation of one state into another, but also through the openings created by the heterogeneous differences embodied within an assemblage.[47] These differences characterize the behaviors of assemblages as nonlinear interactions illustrative of "the transformative potential of multiplicity and experimentation emerging through often irresolvable differences."[48] In this construction, both the agency of the individual elements and the interactive whole are preserved as distinct, "where the agency of both can change over time and through interactions."[49] It is significant that although the formation of the assemblage is "a form of integration, where different elements become aligned in the production of particular effects,"[50] it does not subsume the identity of the part to the will of the new whole, but is set in motion by the tensions that arise between them.

Enaction and agency

In fact, the transformation itself becomes the object of attention in assemblage urbanism's redefinition of power from consolidated resource to the distributed effects of agency. "Agency is thus an emergent capacity of assemblages … it is the action or the force that leads to one particular enactment of the city"[51] Even more radically, one can say that "agency in this reading is less an attribute or property and more a name for the ongoing reconfiguring of the world."[52] This definition bears some similarity to de Certeau's conception of the pedestrian acts of urbanism that have replaced the need for representation with action,[53] however the assemblage position goes further by relocating all agentic acts, whether quotidian or operative, in the realm of enactment. Thus there are not two kinds of agency (imposed power and enacted resistance), but one, albeit a heterogeneous one, insinuated across the entire field of operation.[54]

New characteristics

As a result of the twofold displacement—casting assemblage causality as nonlinear interaction and distributing agency everywhere—the assemblage urbanist is forced to adopt new approaches with more emphasis on inquiry than critique. "In most cases, it is practically impossible to know in advance the definitive list of human and nonhuman actors involved, affected or concerned, the scope of their networks or their actual relationships,"[55] and as a result, the urbanist must also be open to a wider array of possible objects and the new potential forms of agency they imply. Of particular interest is the suggestion of an increased compatibility and engagement with urban design and planning as projective, inquisitive practices.[56] These practices can be profoundly enriched by considering the way that agency is constructed and transformed through connections between people and their environment or between urban processes and constructed space in ways that exceed a simple subject–object relationship.[57] Although there is considerable debate concerning the extent of the repercussions of assemblage theory on urban thinking, the reformulation of these relationships away from any external structure impel not only a methodological break from critical urbanism but an ontological break as well.[58]

§1.5 Tracing the Origins of Assemblage

Deleuze and Guattari

The theoretical foundations of assemblage theory originate from two primary sources, the early writings of Deleuze and Guattari,[59] and the development of Actor-Network Theory following Bruno Latour,[60] though neither used the term in the way it is employed now. The Deleuze–Guattarian current comes by way of the English translation of '*agencement*' as 'assemblage' in Foss and Patton's translation and the subsequent adoption of this term by later translators.[61] The assemblage for Deleuze and Guattari offered an alternative to the dialectical method, which holds apart content-

37 Farías, "The Politics of Urban Assemblages." p369

38 *Ibid.* p369

39 Amin, "Re-Thinking the Urban Social." p103

40 "new and unpredictable directions develop when assemblages encounter novel perturbations. This is a conception of causality that seeks to depart with linearity and to make room for novelty and randomness in emergence. Here, randomness may emerge from multiple sources, such as the volatility of initial conditions, unexpected changes in external environments or the chance relations that emerge as differential properties of existing parts are brought into the assemblage"

McFarlane, "On Context: Assemblage, Political Economy, and Structure." p384

41 "Possibility is a variation implicit in what a thing can be said to be when it is on target. Potential is a the immanence of a thing to its still indeterminate variation, under way"

Massumi, *Parables for the Virtual.* p9, see also p134-137

42 "The task of critical theory is therefore not only to investigate the forms of domination associated with modern capitalism, but equally, to excavate the emanciptory prossibilites that are embedded within, yet simultaneously suppressed by, this very system."

Brenner, "What Is Critical Urban Theory?". p203

43 Dovey, "Uprooting Critical Urbanism." 349

44 Farías, "The Politics of Urban Assemblages." p370

45 McFarlane, "Assemblage and Critical Urbanism." p211

46 Farías, "The Politics of Urban Assemblages." p369

47 "these multiple enactments or multiple becomings are not understood as fluidly following from each other but as discontinuous, even contradictory and mutually exclusive."

Farías, "Decentring the Object of Urban Studies." p14

48 McFarlane, "Assemblage and Critical Urbanism." p211

49 *Ibid.* p208

50 McFarlane, "On Context: Assemblage, Political Economy, and Strcuture." p383

51 Farías, "Decentring the Object of Urban Studies." p15

52 McFarlane, "Assemblage and Critical Urbanism." p218

53 "neither author nor spectator, shaped out of fragments of trajectories and alterations of spaces: in relation to representations, it remains daily and indefinitely other."

de Certeau, *The Practice of Everyday Life.* p93

54 Dovey, "Uprooting Critical Urbanism." p349

55 Farías, "The Politics of Urban Assemblages." p366

56 "Such thinking connects disparate threads of current urban theory as it opens new modes of multi-scalar and multi-disciplinary research geared to urban design and planning practices and therefore to potentials for urban transformation."

Dovey, "Uprooting Critical Urbanism." p347 matter from form-expression through a bizarre structural causation.[62] Rather, for Deleuze and Guattari, content and expression "can be abstracted from each other only in a very relative way because they are two sides of a single assemblage"[63] and neither can one be subordinated as the object of another for "these relations between forces take place ... within the very tissue of the assemblages they produce."[64] This is a significant detail because it points to two defining aspects in the interpretation of *agencement* that risk being lost in the translation. The first is that the assemblage corresponds to notions of becoming insofar as the assemblage cannot be reduced to the elements composing it but rather exists as the event of their co-participation. In light of this, Phillips warns against the tendency to describe assemblage states as statements, disjoining the subject from its enunciation as though the assemblage is separate from the temporal sense of its formation.[65] The second is the act of arrangement that comes from within the assemblage, "an active force of becoming or a will expressed equally *by* and *through* individuals,"[66] which, in addition to the arrangement of entities, also instills the assemblage with an agency. These twinned concepts are summarized concisely in Braun's gloss of *agencement* as "capacity to act with the coming together of things."[67]

Manuel DeLanda

The most rigorous development of assemblage theory in this direction comes from Manuel DeLanda who delves into the framework of assemblage interactions. For DeLanda "the ontology of assemblages is flat since it contains nothing but differently scaled *individual singularities*."[68] Thus all relations of belonging, whether of an individual to a population, or an entity to an organization, are considered equally to produce new individuals and not new types. A flat ontology is supported by the Deleuzian position that entities are not defined by the assemblages they participate in. Such "relations of interiority," where the relations constitute the defining properties of elements—characteristic of organic holism[69]— are contrasted to "relations of exteriority," in which defining properties and "capacity to interact" are separable,[70] allowing individuals to enter or exit assemblages "without the terms changing."[71] This leaves the formation of assemblages contingent on development embedded in the temporal dimension rather than dictated by abstract necessity. The historical generation of the assemblage prompts empirical investigation because "there is no way to tell in advance in what way a given entity may affect or be affected by innumerable other entities."[72] The full capacities of an assemblage may go unexercised and are ultimately unknowable, suggesting a redundancy of causality. Graham Harman sees a difficulty in the fact that assemblages "withhold themselves from their relations with the outer world insofar as they are never fully actualized, and withhold themselves from their own pieces by exceeding those parts and forming a new reality,"[73] arguing that such withdrawal also separates the assemblage from its generative process. His concern is that as an assemblage crystallizes into a particular pattern of existence, the accidents of its formation are no longer differentiating features.[74] Harman forgets, though, the potential for undiscovered capacities to distinguish the assembly in ways that reanimate previously redundant history.

DeLanda is careful to distinguish assemblage ontology from an atomism that only enables causation from the bottom up. He insists on the coexistence of differently scaled assemblages and points out that, though always composed of smaller entities, assemblages are most often composed by larger ones[75] often as effects of other expressive or territorializing actions. Naturally, assemblages are also capable of interacting with one another as well. The implication of this (because the interaction must revolve around some relation of exteriority, and because relations of exteriority constitute assemblages by definition) is that relations always produce new assemblages, however briefly.[76] This excessive access to the novel is, perhaps, the most revelatory strength of DeLanda's assemblage ontology and it helps to return the active, agentic capacity to a description that at times risks becoming overly rigid and schematic. Furthermore, the ties to the material–expressive axis of the assemblage further cement the social character of the assemblage among all those entities which in reality come together to effect the staging or execution of an event.

Figures 1.1; 1.2; 1.3

The construction process in Xiaozhoucun, Guangzhou. First the site is cleared, the existing building is dismantled and the bricks cleaned of mortar. On a cleared plot, new foundations are poured. Because of the narrowness of the passageways, construction equipment must be compact, often a cement truck will wait at the village gate and material will be carried to the site by hand in wheelbarrows. Concrete frame construction enables the site to be rebuilt at higher densities than the previously existing structures.

57 *Ibid.* p348-349

58 Farías, "The Politics of Urban Assemblages."

Wachsmuth, Madden, and Brenner, "Between Abstraction and Complexity: Meta-Theoretical Observations on the Assemblage Debate." p745

59 Most prominently in:

Deleuze and Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia*.

60 Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory*.

61 Deleuze and Guattari, "Rhizome."

Phillips, "Agencement/Assemblage."

62 Deleuze and Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia*. p89-91, 369

63 *Ibid.* p140

64 Deleuze, *Foucault*. p37

65 Phillips, "Agencement/Assemblage." p109

66 Rodowick, *Reading the Figural: Or, Philosophy after the New Media*. p220

67 Braun, "Environmental Issues: Inventive Life." p671

68 DeLanda, A *New Philosophy of Society: Assemblage Theory and Social Complexity*. p28

There is some difficulty reconciling DeLanda's use of the diagram in 'A New Philosophy of Society' within a flat ontology as it reintroduces an absolute division between micro and macro relations. After the effort to combat the "subtler forms of essentialism" (p26) in categorical taxonomy, it is difficult to accept a division which effectively brings back the genus classification as a unique entity.

DeLanda later[68b] opens the possibility that a topologically structured possibility space could instead be an emergent property of the assemblage, *cf.* §4.3b 'State Space.'

68b DeLanda, "Emergence, Causality and Realism:". p391

69 Kwa, "Romantic and Baroque Conceptions of Complex Wholes in the Sciences." p24

70 DeLanda, *A New Philosophy of Society: Assemblage Theory and Social Complexity*. p10

71 Deleuze and Parnet, *Dialogues*. p55

72 DeLanda, *A New Philosophy of Society: Assemblage Theory and Social Complexity*. p10

73 Harman, "The Assemblage Theory of Society." p185

74 *Ibid.* p192

75 DeLanda, *A New Philosophy of Society: Assemblage Theory and Social Complexity*. p39

76 "If two jets collide in mid-air and fly away burning, we normally think of this situation in terms of mutual qualitative effects on two independent entities. A better analysis, in DeLandian terms, would be that the two jets briefly formed a new entity, which damaged both of them through the assemblage power known as "retroactive effect on parts," then decomposed into separate entities again, this time fully aflame."

Harman, "The Assemblage Theory of Society." p198

Bruno Latour

The other primary strand of thinking in assemblage theory follows Bruno Latour's description of Actor-Network Theory.[77] Latour is similarly motivated by a desire to remove the over-arching frameworks that reduce the specificity of the case at hand[78] in favor of situated non-linear interactions between actors. "when a force manipulates another, it does not mean that it is a cause generating effects; it can also be an occasion for other things to start acting."[79] The actor is induced to act, but the diverse ways in which the agency of the action is figured[80] (in connection with many actors) is highly contingent.[81] Though the actor-network branch has produced some of the more ontologically radical assemblage urbanists,[82] Latour's development of Actor-Network Theory is much more methodological—primarily emphasizing how a researcher or theorist can remain committed to a flat ontological grounding—while remaining intentionally quiet about existence within this ontology. He gives almost no description of groups themselves,[83] offering only the performative definition that the assembling (or disassembling) of groups is itself the mapping of social context and that the groups do not exist outside of this action.[84] Latour sees no inherent difference between this action and the acts of a researcher, concluding that "the network does not designate a thing out there… It is nothing more than *an indicator of the quality of a text* about the topics at hand."[85] What does exist for Latour is nothing if not concrete, however these actants "are fully relational in character, with no distinction between object and accident, object and relation or object and quality … to change one's relations is to change one's reality."[86] Again assemblage theory promotes a prodigious new production of entities, but through the complete inverse of what we find in DeLanda. Furthermore, it means that there is no place for withheld properties, all actants are, in this case, defined by their efficacy.[87]

Despite these contradictions, actor-network theory does illuminate some relational aspects which can be incorporated with the approach adopted in this text, in particular, the production of scale through the construction of linkages or the action of an individual.[88] Even more promising is the potential reversibility of scale relations, by which an individual can incorporate larger assemblages that it may even belong to itself.[89] These topics will return in the next chapter[90] to establish how the reserve complexity of objects prevents a reduction to merely relations and how the effectuality of relations establishes the social interplay that generates difference and preserves the agency of actors.

§1.6 Common Assemblage Foundations

Inorganic agency

From the various interpretations or applications of assemblage thinking discussed above, there are a few common elements which provide a foundation for the following chapters. The first is a recognition of inorganic assemblages and the increased emphasis given to them in the mapping of urban milieux.[91] As Amin argues, "technology, things, infrastructure, matter in general, should be seen as intrinsic elements of human being, part and parcel of the urban 'social', rather than as a domain apart with negligible or extrinsic influence on the modes of being human."[92] Thus, inquiry cannot be limited to or explained away by interpersonal interaction alone, but is distributed across the social and the material. One description "would summarize 'sociomateriality' as things in their mediating role."[93] In fact, this is not necessarily a project which breaks from the critical urban tradition, conventional critical urbanism can operate through this lens and has occasionally done so well.[94] Assemblage urbanism pushes this concept further, suggesting that things mediate among themselves in addition to mediating human experience. In fact, inorganic material assemblages constitute an intersubjective field by virtue of "the efficacy of objects in excess of the human meanings, designs, or purposes they express or serve."[95] Acknowledging and including this excess enables the consideration of the urban from a more ecological sensibility and elevates the significance of the built environment in its particular configurations.

Figures 1.4; 1.5

New concrete frame construction receives infill of bricks like those reclaimed in Figure 1.1

Other *ad hoc* constructions on the city—whether electrical, plumbing, or carpentry—make equally apparent the role of material agency in the informal urbanism of the Village-in-the-City.

77 Farías and Bender, *Urban Assemblages: How Actor-Network Theory Changes Urban Studies*.

78 Latour, "Irreductions."

79 Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory*. p60

80 *Ibid*. p53

81 Latour provides the best description of this much later in a summary passage: "not by transporting a force that would remain the same throughout as some sort of faithful intermediary, but by generating transformations manifested by the many unexpected events triggered in the other mediators that follow them along the line." *Ibid*. p107

82 Farías, "The Politics of Urban Assemblages."

83 "the word 'group' is so empty that it sets neither the size nor the content. It could be applied to a planet as well as to an individual."

Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory*. p29

84 *Ibid*. p32, 35

85 *Ibid*. p129

86 Harman, *Prince of Networks*. p104

87 Latour, "Irreductions." p158

88 "Scale is the actor's own achievement"

Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory*. p185

89 Law, "And If the Global Were Small and Non-Coherent? Method, Complexity and the Baroque."

90 *cf*. §2.6 'Environment'

91 McFarlane, "Assemblage and Critical Urbanism." p216-217

92 Amin, "Collective Culture and Urban Public Space." p8

93 Angelo stipulates three components of this definition: "(1) physically different material referents with different properties; (2) as containing and constitutive of both subjective (mental) and objective (material) dimensions of social life; and (3) as physical mediation between individuals and larger scale structures in the urban everyday."

Angelo, "Hard-Wired Experience: Sociomateriality and the Urban Everyday." p570

94 Reeh, *Ornaments of the Metropolis: Siegfried Kracauer and Modern Urban Culture*.

95 Bennett, *Vibrant Matter: A Political Ecology of Things*. p20

Immaterial objects

Additionally, the inclusion of object excess can be extended to immaterial objects—the virtual, the potential, the anticipatory. This element can be credited in part to the potential within DeLanda's assemblage theory for capacities (and therefore possibly entire assemblages) to go unexercised if they do not encounter the right interactions or detection without being any less real.[96] That assemblages operate "between the possible—the unstable flows of materials and substances—and the prescribed—the imposition of functional, stable structures,"[97] allows assemblage urbanists to propose new points of articulation that support new ways for "urban histories and everyday life to be imagined and put to work differently"[98] before these forms have fully materialized, as a generative critique that to some extent prefigures the emergence of its object.[99]

On a more prosaic level, the acknowledgment of immaterial objects also extends to the shaping role of the technological strata of the city, the software protocols, which, of course depend on material assemblages to be enacted, but which can be changed and reoriented without modification of their material expression.[100]

Flat ontology

Finally, as mentioned above, the idealization of a flat ontology in which no object is more fundamental than another is a common concept shared by all forms of assemblage urbanism. Characteristics of flat ontologies, such as the distinct multiplicity of different layers and scales, the exclusion of expressions that would reduce one to a side-effect of another, and the replacement of inherited, or unchanging, structural relationships for ones that are emergent and constructed have been discussed already. In the context of the last paragraphs, it is also worth mentioning that these characteristics apply equally to the relationships between humans and the world. In a flat ontology this relation is neither "a form of metaphysical relation different in kind from other relations between objects" nor does it treat the "subject-object relation as implicitly included in every form of object–object relation."[101] The flatness in such an approach thus enables one to speak of human–object and object–object (as well as object–human) relations without having to impose a global hierarchy between them as separate modes.

§1.7 Responsivity, Assemblage Urbanism, and Engagement with the City

Individual engagement and constituency

The first motivation for enlisting an assemblage urbanism approach is to begin from a model that encourages and valorizes engagement with the city by individuals or groups, by emphasizing the new forms of participation enacted on a continuous basis,[102] and by "countering politically paralyzing pictures of the unity of capital with notions of a more open social field."[103] So far, we have considered how assemblage urbanism recasts spatial and scalar contexts as effects of assemblage production, how distributed agency destabilizes linear causality and the identity of belonging, and how a flat ontology supports an ecological understanding of the urban through both human and non-human actants. Ultimately, this culminates in a model which cannot discount any assembling action as a source of potential change, but complements these actions with the ability to trace or project possible effects through pragmatic means.[104] Assemblage urbanism pushes us toward an agonistic pluralism[105] expressed by diverse constituencies,[106] but also constructs diverse public places.[107]

Technological agency

In addition, there is a new technological agency, which enforces boundaries, regulates rhythms, and supports infrastructures within the city.[108] Assemblage urbanism enables the city to be thought processually alongside them and to encounter "other powerful social effects of the urban technological unconscious."[109] Thus, we increase the number of connections between large technical systems while also opening up their functions from within black boxes to illustrate points of articulation[110] and precariousness.[111] Rather than monolithic, controlling entities, technological agency can be located in a prepositional mode of being which "set up what comes next without impinging in the least on what is actually said."[112] Though this study will not go into topics of real-time sensing and controls,[113] in later sections we will develop this parallel between the procedural enactment of the city and the procedural enactment of code.

Interface for new interactions

As an actively constructive theory,[114] assemblage urbanism, helps mitigate the danger of translating an analytic method into a generative one.[115] The projective nature implict in assemblage theory, of "linking the actual with potential,"[116] makes it more welcoming to design input and the very real impacts which small-scale modifications can bring about. Finally, assemblage urbanism establishes the beginnings of a framework that perpetuates new urban interactions: a reflexive operation by which such impacts feed back into the urban field as immanent causes.[117] Within the urban field, each individual assemblage also functions as an interface for potential engagement.

96 DeLanda, *A New Philosophy of Society: Assemblage Theory and Social Complexity*. p10

97 Simone, "The Surfacing of Urban Life." p357

98 McFarlane, "Assemblage and Critical Urbanism." p209

99 Chatterton, "The Urban Impossible: A Eulogy for the Unfinished City." p236

100 Amin and Thrift, *Cities: Reimagining the Urban*.

Graham and Marvin, *Splintering Urbanism: Networked Infrastructures, Techonological Mobilities, and the Urban Condition*.

101 Bryant, *The Democracy of Objects*. p246

102 Amin and Thrift, *Cities: Reimagining the Urban*. p142

103 Rankin, "Assemblage and the Politics of Thick Description." p564

104 Pragmatic here is taken in the sense of C.S. Peirce's definition of difference based on practical consequences. Though assemblage theory exceeds this definition in the case of redundant causality, such properties are hidden from the researcher (and in any case, Peirce anticipates such possibilities and does not exclude them).

Peirce, "How to Make Our Ideas Clear."

105 Mouffe, "Deliberative Democracy or Agonistic Pluralism."

106 Somol and Whiting, "Notes around the Doppler Effect and Other Moods of Modernism."

107 Dovey, *Becoming Places: Urbanism/Architecture/Identity/Power*.

108 Graham and Marvin, *Splintering Urbanism: Networked Infrastructures, Techonological Mobilities, and the Urban Condition*.

109 Amin, "Re-Thinking the Urban Social." p110

110 Graham and Marvin, *Splintering Urbanism: Networked Infrastructures, Techonological Mobilities, and the Urban Condition*. p180-183

111 Bennett, "The Agency of Assemblages and the North American Blackout."

112 Latour, "Reflections on Etienne Souriau's 'Les Différents Modes D'existence'." p309

113 Shepard, *Sentient City: Ubiquitous Computing, Architecture, and the Future of Urban Space*.

114 "The critic is not the one who debunks, but the one who assembles… the one who offers the participants arenas in which to gather"

Latour, "Why Has Critique Run out of Steam? From Matters of Fact to Matters of Concern." p246

115 Dovey, *Becoming Places: Urbanism/Architecture/Identity/Power*. p43-50

116 Dovey, "Uprooting Critical Urbanism." p349

117 McFarlane, "On Context: Assemblage, Political Economy, and Structure." p384

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CHAPTER 2
MONADOLOGY

§2.1 A Concept for Objects

The expanded object

The conceptual advantages of utilizing assemblage urbanism are strongest and most apparent when the urban situation under observation involves surprising or unexpected combinations of objects, actions, and scales.[1] As argued above, preserving the complexity of these situations requires an approach that examines the reality of their entanglements[2] instead of reducing difficult concerns to explanations that conform with established structures. The second motivation introduced was to account for the activity of the city, or the agency to act upon it that issues from non-human sources or without human intervention—automatic technological protocols as well as the more quotidian interactions of matter and objects—in order to further advance an ecological definition of the city.[3]

In order to fully describe the city in this way, one also requires a more detailed theory of objects that expands on what assemblage theory provides. Assemblage urbanism is always able to compare against empirical observation to fill in any conceptual gaps, and so tends to produce definitions of assemblages which do not impinge on their objects of observation.[4] This thesis is interested in projective or speculative design practice, anticipating that the designer's empirical research will be less thorough and that objects or object properties may also need to be invented or assumed.[5] In these cases, a stronger conceptual model of how assemblages function and behave *as objects* is necessary.

Assemblage urbanism's contribution

In the first chapter, we spoke mostly of how assemblage urbanism reframes the primary aspects of urban studies without spending much time on the description of assemblages themselves. The use of assemblage theory by urbanists primarily as a methodological (and not an ontological) explanation has allowed the notion of the assemblage to remain indistinct. In fact, assemblage urbanists actively promote a less circumscribed invocation as a resistance of pluralism against a dogmatic enforcement of 'proper' use.[6]

From assemblage theory, objects can be characterized as heterogeneous assemblages that cannot be reduced to their parts and whose component elements similarly are not subsumed within the totality of the object. Furthermore, being an element in a larger assemblage does not render an object inferior to the larger assemblage or prevent it from interacting with it directly and independently nor is the larger assemblage considered derivative of its parts. All objects are considered ontologically equal on a flat plane of existence regardless of their size or scale, their complexity or their simplicity.

1 Farías, "The Politics of Urban Assemblages."

2 Barad, *Meeting the Universe Halfway: Quantam Physics and the Entanglement of Matter and Meaning*. p146*ff*

3 Farías, "The Politics of Urban Assemblages." p369

4 Tonkiss, "Template Urbanism: Four Points about Assemblage."

5 "While design can be conceived as superficial, in this broader sense it is a process of assembling possibilities out of actualities. Design connects us with vision, image and imagination; it produces hope and is productive of desire."

Dovey, "Uprooting Critical Urbanism." p350

6 Anderson and McFarlane, "Assemblage and Geography." p145

Expanding on this base, there are three aspects to consider about the assemblage as an object which will be explored through some of the recent philosophical work on object-oriented ontology and developed further by a new reading of monadology that it enables. These three points are the interior existence of objects, the external relations of objects to others and to their environments, and the connection between objects and causation.

§2.2 Object-Oriented Philosophy

Overview

As the most active branch of what has been named 'Speculative Realism', object-oriented philosophy shares the realist[7] and anti-reductionist[8] positions of assemblage urbanism. Perhaps the best summary of the objective of object-oriented philosophy is the desire "to think a *subjectless* object, or an object that is for-*itself* rather than an object that is an opposing pole before or in front of a subject … an object for-itself that isn't an object for the gaze of a subject, representation, or a cultural discourse."[9] Naturally, this attitude of "a universe made up of objects wrapped in objects wrapped in objects wrapped in objects"[10] lends itself well to a flat ontology like the one proposed by Manuel DeLanda[11] and covered in chapter one.[12] This can be seen in one of the core problematics of object-oriented philosophy, the question of access to objects:

> "On the other hand, where the anti-realists have obsessively focused on a single gap between humans and objects, endlessly revolving around the manner in which objects are inaccessible to representation, object-oriented philosophy allows us to pluralize this gap, treating it not as a unique or privileged peculiarity of humans, but as true of all relations between objects whether they involve humans or not. In short, the difference between humans and other objects is not a difference in kind, but a difference in degree."[13]

Here, Levi Bryant lays out two establishing operations. First, the multiplication of significant relations from only those that involve human interpretation to include the entire field of inter-object relations,[14] and second, the leveling of all these relations into the same register in order to *preserve* their specific characters.[15] Though aimed at the nature–culture divide in particular, this excerpt combats the argument of a world constructed by human experience and intentionality, more generally. By widening the scope of relations to include every sort of relata, object-oriented philosophy calls attention to the huge array of contingent relations that accompany an assemblage. It is not that objects are defined by how they appear to humans, but even strictly cultural objects rely on and involve inorganic objects: "collectives involving humans are always entangled with all sorts of nonhumans without which such collectives could not exist."[16]

Being as difference

Nor are objects defined by their relations with one another as a general case, rather object-oriented ontology asserts the more pragmaticist definition that "to be is to make or produce differences" or that "there is no difference that does not make a difference."[17] Though this seems at first glance to produce a contradiction—being-as-difference must surely be relational, mustn't it?—we draw here from Deleuze's description of difference-in-itself[18] that distinguishes itself from the ground yet without the ground also performing a reciprocal distinction. If "all things equally exist, yet they do not exist equally,"[19] then the question one must answer is how to describe the asymmetry between difference-in-itself and the extrinsic differences between two objects. Deleuze holds that "extensity does not account for the individuations which occur within it."[20] Thus in the following we sketch an outline of the object: first addressing the characteristic of extensive qualities; then defining the role of intensities, or endo-relations, distinct from actualization; and finally unpacking the implications for relations with external objects and the environment. In all this, the goal is to preserve the equal ontological status of individuals and to avoid reductionist arguments that would smooth away the tension between assemblages and their (equally individual) parts.[21]

§2.3 Internal Existence

Definitively withdrawn

From the principle of redundant causality we know that "within open systems or entanglements of objects, the powers of discrete objects are often veiled or inactive."[22] If these extensive entanglements were given the power of defining the identity of objects, they would never be capable of asserting clear independence, always remaining muddled, unable to identify whether an object exists or not, only able to suggest possible objects.[23] Furthermore, this would be akin to the ground differentiating *from* the object and would contradict the difference-in-itself. Thus, "objects must also be thought in terms of their endo-relations or their inter-ontic structure as radically *independent* of their exo-relations or their inter-ontic relations."[24] The endo-relations of an assemblage encapsulated within the object form an interior existence which is never entirely accessible to an external object. This is considered a definitive property of objects: "there are no objects characterized by full presence or actuality. Withdrawal is not an accidental feature of objects … but is a constitutive feature of all objects regardless of whether they relate to other objects."[25]

Characteristics and qualities

Those aspects of an object which are not withdrawn but are accessible and relate to other objects—its qualities—are freed from carrying the responsibly to define identity. Classical concepts of substance had difficulty splitting qualities from objects because there weren't any additional differentiations beyond the object's qualities to individuate it,[26] but in an object-oriented ontology, "objects are not identical to their qualities but are rather the ground of qualities."[27] Qualities are no longer the building blocks or quanta of being, but actualizations of the object. "Objects can be fully concrete without locally manifesting themselves or actualizing themselves in qualities … Local manifestation is something that objects can do, but an object that does not locally manifest itself is not lacking in some way, nor is it somehow incomplete."[28] As such, extensities are not constrained to formal or necessary roles in the object, but can follow diverse potential behaviors.[29] It is more appropriate, therefore, to think of an object's extensive qualities not "as something an object possesses, has, or is, but rather as acts, verbs, or something that an object does."[30] Qualities can be responsive to the idiosyncrasies of their contexts—both internal and external—in ways that properties of identity would resist.[31] Perceived from the point of view of two separate external relations, an object can even enact contradictory or incompossible qualities based on the properties "that emerge as a result of the manner in which the object relates to other objects."[32]

7 Harman, "The Road to Objects."

8 "since an object's parts can't fully express the object, the object is not reducible to its parts. [Object Oriented Ontology] is anti-reductionist. But OOO is also anti-holist. An object can't be reduced to its "whole" either."
Timothy Morton, "Objects as Temporary Autonomous Zones." p150

9 Bryant, *The Democracy of Objects*. p19

10 Harman, *Guerrilla Metaphysics: Phenomenology and the Carpentry of Things*. p85

11 DeLanda, *Intensive Science and Virtual Philosophy*. p47

12 Though not always the case:
Harman, "The Road to Objects." p178

13 Bryant, *The Democracy of Objects*. p26

14 "to be a speculative realist, one must abandon the belief that human access sits at the center of being, organizing and regulating it"
Bogost, *Alien Phenomenology: Or, What It's Like to Be a Thing*. p5

15 "To the same degree that natural entities ought not be reduced to cultural constructions, social, semiotic, and cultural entities ought not be reduced to natural entities. This requires us to shift from thinking in terms of reduction or grounding one entity in another, to thinking in terms of entanglements."
Levi Bryant, T*he Democracy of Objects*. p32

16 *Ibid*. p25

17 This position is sometimes referred to by the neologism 'onticology'
Bryant, "The Ontic Principle: Outline of an Object-Oriented Ontology." p263, 269

18 Deleuze, *Difference and Repetition*. p28*ff*

19 Bogost, *Alien Phenomenology: Or, What It's Like to Be a Thing*. p11

20 Deleuze, *Difference and Repetition*. p186-187

21 "to account for the difference between objects and their qualities, accidents, relations, and moments, without oversimplifying our work by reducing objects to any of these. For all of these terms make sense only in their strife with the unified objects to which they belong."
Harman, "On the Undermining of Objects: Grant, Bruno, and Radical Philosophy." p24

22 Bryant, *The Democracy of Objects*. p48

23 "an object may drift into events and unleash its forces there, but no such event is capable of putting the object fully into play. Its neighboring objects will always react to some of its features while remaining blind to the rest. The objects in an event are somehow always elsewhere."
Harman, *Guerrilla Metaphysics: Phenomenology and the Carpentry of Things*. p81

24 Bryant, "The Ontic Principle: Outline of an Object-Oriented Ontology." p273

25 Bryant, *The Democracy of Objects*. p32

26 *Ibid*. p84-85

27 *Ibid*. p68

28 *Ibid*. p121

29 "the members of a set determine their configuration but not their behavior."
Bogost, *Alien Phenomenology: Or, What It's Like to Be a Thing*. p28

Organization and endo-relations

Having peeled away the qualitative dimension, there remains the internal structure of the object. Object-oriented ontology contends that "objects are not merely aggregates of other objects, but have an irreducible internal structure of their own."[33] This topological organization is not common for all or even a group of assemblages, which would suggest an organization based on a shared predicate,[34] nor is it fixed and immutable. In fact, the intensive is caught up in a transitional immediacy of a relation to its own indeterminancy. "Withdrawn into an all-encompassing relation with what it will be. It is in becoming, absorbed in occupying its field of potential"[35] That is, while any transition within an assemblage's internal relations transforms the field of potential emergent properties, it still remains "an operationally closed object that relates to the sub-multiples of which it is composed or the multiples that it composes only in terms of its own internal organization"[36] and "cannot be determinately indexed to anything outside itself."[37] Mereologically, the object's internal being still remains independent from any assemblages it might be a part of and even those out of which it is composed.[38] It can be properly said that this independence exceeds everything that can be known about the object through its relations.[39]

This nonqualitative structure follows Deleuze's concept of the virtual;[40] however, Bryant critiques Deleuze's insistence that the virtual is pre-individual, arguing that "the virtual is not something that produces the individual, but rather must strictly be a dimension of the individual."[41] This is done to preserve the agency of the object in causal interactions and to locate production as an act of the individual rather than the individual as the residue of production,[42] harking back to the assertion earlier that to be is to make or produce difference. If objects are to exist, they do so as differentiation engines.[43] Bryant refers to this virtuality of the individual as the 'virtual proper being'.

§2.4 Exterior Relations

Information passes and is translated between objects

Because objects cannot be reduced upwards into controlling structures nor downward atomistically into their parts, neither is there an *a priori* global container, "There is no world … that connects things together. All such connections must be emergent properties of the objects themselves."[44] The internal withdrawal of objects and the location of their potency within the virtual clearly complicates the ways by which such connections are able to form. To remain consistent with the ontological formation advanced thus far, any possible relation forgoes direct contact: it must derive from the individual object and issue from its own agency.[45] Bryant proposes that exo-relations can be characterized as translations of information—with the understanding that "information is thus not something that exists in the world independent of the systems that 'experience' it, but is rather constituted by the systems that 'experience' it … Information is, as it were, a genuine event that befalls a substance or happens to a substance."[46]

A few significant aspects of this concept are worth detailing. First, the information of a relation does not have its own, separate being, but is enacted by the emitting object as a property, a quality, or an event and received by the second object in an act of sensing or perceiving: "information is object-specific, whereas the same perturbation can affect a variety of different objects while producing very different information for each object."[47] Relations are highly sensitive to the affective capability of objects.[48] Second, because these information-events are translated into being only through the apperception of various objects, there is no 'original meaning' or 'pure interpretation'.[49] Third, in a nicely symmetrical moment, this fact holds true even for the originating object, from which the quality is a self-othering event.[50] (We can confirm this by following Deleuze's argument that the virtual does not in any way resemble the actual.[51]) Taken together, these points prevent the the relation-as-information from devolving into mere simulacra,[52] thinking it instead "as force-signs of deterritorialization and of reterritorialization."[53]

Exo-relations form new assemblages

Meanwhile, objects are always joining together to form larger assemblages. In fact, Harman has written that "when two objects enter into genuine relation, even if they do not permanently fuse together, they generate a reality that has all of the features that we require of an object … they create something that has not existed before, and which is truly one."[54] However, this would effectively reduce all relations to endo-relations and the assertion that "there are properties of objects that emerge as a result of the manner in which the object relates to other objects"[55] would have to be modified to acknowledge that those properties occur only as the result of the top-down influence of an encompassing assemblage. Though we want to facilitate the production of new objects as much as possible, we will hold off from extending objecthood to such an extent, preferring to leave open the possibility of horizontal relations between objects that remain merely relations. Even stable patterns of relations should be permitted without automatically conflating the relationship with a new object.[56] Rather, a new object occurs "when exo-relations among other objects manage to attain operational closure such that their aggregate or multiple composition becomes capable of encountering perturbations as information in terms of their own endo-consistency."[57] While this qualification risks being misinterpreted as saying that all objects are strictly defined intensionally, by a shared property or predicate, the earlier specification of the virtual proper being as a dimension *subsequent* to the individual, allows objects to be defined extensionally by naming or enumeration as well.

Causation

The problems of external relation and the formation of new assemblages both raise questions about causality, or, the efficacy of assemblages. Timothy Morton seemingly implies that the withdrawal of objects away from one another produces a "disturbing illusory play of causality."[58] This would be an understandable position if one focuses on the interior being within an object as a split that divides "vertically from the implicate to the explicate."[59] Through this lens it would appear that the virtual within an object that is acted upon constructs effects that are detached from their source. Rather, returning to the dictum that "difference is an *activity* … existence is thought as a sort of doing or movement,"[60] it is apparent that such a reading confuses the agency of the object with its reception. "No object can transfer a force to another object without that force being transformed in some way or another,"[61] but this does not mean that the force is not exerted or that the transference is only an illusion. The agency of an object is measured by its effecting of the world, a process that is always messy and complexly negotiated, not by distilling the legibility of intent away from any interferences.

30 Bryant, *The Democracy of Objects*. p89

31 *Ibid*. p69

32 Bryant, "The Ontic Principle: Outline of an Object-Oriented Ontology." p272

33 Bryant, *The Democracy of Objects*. p214

34 Badiou, *Being and Event*. p44

35 Massumi, *Parables for the Virtual*. p5

36 Bryant, *The Democracy of Objects*. p218

37 Massumi, *Parables for the Virtual*. p7

38 Bryant, *The Democracy of Objects*. p31

39 Bogost, *Alien Phenomenology: Or, What It's Like to Be a Thing*. p30

40 Deleuze, *Difference and Repetition*. p208

41 Bryant, *The Democracy of Objects*. p103

This is also a critique of Badiou's: Badiou, *Deleuze: The Clamor of Being*. p51-52

42 Bryant, *The Democracy of Objects*. p100-103

43 *Ibid*. p88

44 Morton, "Objects as Temporary Autonomous Zones." p151

45 "systems or substances only relate to themselves. Put differently, while substances can enter into exo-relations with other substances, they only do so on their own terms and with respect to their own organization."

Bryant, *The Democracy of Objects*. p147

46 *Ibid*. p155

47 *Ibid*. p156

48 Bryant, "The Ontic Principle: Outline of an Object-Oriented Ontology." p274

49 "no object is capable of representing another object or of functioning as a pure carrier of the perturbations issued from another object. This is because objects always transform or translate perturbations."

Bryant, *The Democracy of Objects*. p156

50 "information differentially links an object to itself in a relation between the withdrawn virtual proper being of the object and its local manifestations … information affects a self-othering in the object whereby the virtual dimension of the object simultaneously withdraws and a quality is produced."

Ibid. p156

51 Deleuze, *Difference and Repetition*. p209

52 Contra Badiou's argrument about the actual as simulacrum

Badiou, *Deleuze: The Clamor of Being*. p43-53

53 Alliez, *Diagram 3000 [Words]/Diagramm 3000 [Worte]*. p13

54 Harman, *Guerrilla Metaphysics: Phenomenology and the Carpentry of Things*. p85

55 Bryant, "The Ontic Principle: Outline of an Object-Oriented Ontology." p272

56 Bryant, *The Democracy of Objects*. p218

57 *Ibid*. p273

58 Morton, "Objects as Temporary Autonomous Zones." p153

59 Bryant, *The Democracy of Objects*. p102

60 Bryant, "The Ontic Principle: Outline of an Object-Oriented Ontology." p273

61 Bryant, *The Democracy of Objects*. p175

In fact, the opposite is true. If there were a medium or metalanguage by which information were transferred without alteration, there would be no action—that is, no difference—remaining in the act itself but only within the mediator.[62] Just as all connections emerge from the objects themselves, so too are communications produced through patterns of encounters, based on "the records of actions antecedent in the production of consequents"[63] and are perpetually challenged by new divergences.[64] Neither is causality effected by the machinery of an underlying structure, but it manifests as a phenomenon that emanates from and repositions objects in new spatio-temporal contexts.[65]

§2.5 Monadology

Pure interiority

Deleuze describes Leibniz's concept of the monad in similar language as "the autonomy of the inside"[66] and "a unity that envelops a multiplicity, this multiplicity developing the One in the manner of a 'series.'"[67] As a pure interiority, the monad is withdrawn from direct connections, which "must retain the distinction of its details and its own individuality in the hierarchy in which it enters."[68] Again, there is agreement that local manifestations, or 'inclinations', of the monad are non-necessary[69] traits that occur as "an act, a movement, a change, and not the state."[70] Inclinations are qualitative but not attributive, "the predicate is above all a relation and an event, and not an attribute,"[71] therefore predicates do not ground the monad, they are *included* in the monad. More than anything else, Deleuze forcefully emphasizes this point. It is established in the very first sentence of his text on monadology referring "not to an essence but rather to an operative function,"[72] a detail adamantly repeated throughout his analysis: "Inflection is the event that happens to the line or to the point;"[73] "not defined by an attribute, but by predicates-as-events;"[74] "the spontaneity of manners replaces the essentiality of the attribute."[75]

Extension

As these events proliferate, they gain series of entanglements with other objects whereby they extend into or over one another.[76] The way the monad includes its predicates determines a harmonization of the monad with the adjacent and component objects, with regard to the production of the world around it.[77] The monad's withdrawn virtual being—or its intrinsic singularities, to use Deleuze's term—generates the events that include relations within the object. Meanwhile there is a second, reflexive operation which directs these series of inclinations inward toward convergence as intensities.[78] As such, the propagation of relations is not a constriction of the object but a continuous prolongation[79] with regard to the world it engages. "Even compressed, folded, and enveloped, elements are powers that enlarge and distend the world."[80] In the same way, architecture extends into a frame that "itself becomes detached from the inside, and establishes relations with the surroundings so as to realize architecture in city planning."[81]

Objectile

The extension of monads and the inclusion of additional inflections gives the monad a changing 'texture' of qualities and potentials. "Extensions effectively are forever moving, gaining and losing parts carried away in movement; things are endlessly being altered; even prehensions are ceaselessly entering and leaving variable components."[82] The example of architecture's extension into urbanism cited above illustrates how the object gains new arenas of influence as it attunes to new inflections. "This area of interindividual, interactive clustering is quite agitated, because it is an area of temporary appurtenances or of provisional possessions."[83] Continouous differentiation of the developing assemblage feeds back into the withdrawn being of the object such that the object "no longer refers … to a relation of form–matter—but to a temporal modulation that implies as much the beginnings of a continuous variation of matter as a continuous development of form."[84] Michael Guggenheim has demonstrated how architecture is incapable of being restricted to a single domain, but is always an object acting in multiplicity of associations,[85] making it uniquely suited to the model of the *objectile*,[86] where "fluctuation of the norm replaces the permanence of a law."[87] Following this concept, we will show how architecture activates and intensifies the urban dynamic by including its perception of the unlocalizable rhythms of the city as inflected predicates.

§2.6 Environment

Inclusion

Inclusion, according to Deleuze, is formed by the monad's apperception. Inclusion carries events into the monad,[88] enabling exo-relations and prompting individual manifestations. Because identity for the objectile is not a reciprical definition but always a vector,[89] perceptions advance differentially: infinitesimal variations of perceptions that develop inclusion.[90] Of the different types of inclusion,[91] we are interested here in how the monad includes the world within itself. Consistent with the object-oriented position, there is no object which functions as a universal world, one that can contain all others. Despite the fact that, for Leibniz, *every* monad includes the whole world, the "the reason of the series … is not. The limit remains *extrinsic* and appears only in a harmony *preestablished* among the monads."[92] In this formulation, every monad is a singular subject; however, these subjects are themselves without objects, "these are minute perceptions lacking an object, that is, hallucinatory microperceptions."[93] Despite the inversion of intent, the result retains a correspondence with the object-oriented goal of "subjectless objects" because no monad is thrown under another subject as its correlate, but each exists only for itself.[94] What is changed in an object-oriented ontology is that there is no longer a guarantee nor a necessity of overall harmonious convergence across the totality of monads.

Incompossibilty

For Leibniz, the convergent harmonization of these series was required by the imperative of a single compossible world that is sharply delineated from all others. Deleuze, drawing from Riemannian manifolds, introduces "a fibered conception according to which 'monads' test the paths in the universe and enter in syntheses associated with each path... a world of captures instead of closures"[95] In this model "bifurcations, divergences, incompossibilities, and discord belong to the same motley world,"[96] or rather, a plurality of non-exclusive worlds.

62 *Ibid.* p153
63 Grant, "Mining Conditions: A Response to Harman." p44
64 Bryant, *The Democracy of Objects*. p184-185
65 Morton, "Objects as Temporary Autonomous Zones." p151
66 Deleuze, *The Fold: Leibniz and the Baroque*. p28
67 *Ibid.* p23
68 *Ibid.* p103
69 *Ibid.* p70
70 *Ibid.* p53
71 *Ibid.* p53
72 *Ibid.* p3
73 *Ibid.* p41
74 *Ibid.* p42
75 *Ibid.* p56
76 *Ibid.* p70
77 *Ibid.* p60
78 *Ibid.* p70
79 *Ibid.* p66
80 *Ibid.* p124
81 *Ibid.* p123
82 *Ibid.* p79
83 *Ibid.* p115
84 *Ibid.* p19
85 Guggenheim, "Building Memory: Architecture, Networks and Users."
86 Cache, *Earth Moves: The Furnishing of Territories*. p96
87 Deleuze, *The Fold: Leibniz and the Baroque*. p19
88 *Ibid.* p41
89 Smith, *Essays on Deleuze*. p44
90 Deleuze, *The Fold: Leibniz and the Baroque*. p90
91 "We therefore have three types of inclusion: auto-inclusions, reciprocal inclusions, and unilateral inclusions that can be localized at their limits."
"We thus face a fourth type of inclusion. Inclusion of the world in the monad is surely unilateral, but cannot be localized. It cannot be localized at the limit, since the limit is outside of the monad."
Ibid. p48, 51
92 *Ibid.* p51
93 *Ibid.* p86
94 Smith, *Essays on Deleuze*. p48-49
95 Deleuze, *The Fold: Leibniz and the Baroque*. p81
96 *Ibid.* p81

Construction

The relation of object to world is a complex one: "there is always a double antecedence: the world is virtually first, but the monad is actually first."[97] To clarify, we would say that the point of view of the monad precedes the individual object[98] as a potential series of interaction between the monad and surrounding objects, but that the world, or environment[99] that it occupies does not pre-exist as such. Part of the generative ability of objects includes their "active role in constructing their environment, both through determining relevancies in the environment and through actively changing their environment."[100] For each and every object, therefore, there is a unique environment, which it includes.[101] However, in the same way that objects that become components of an assemblage do not give up their distinct identity or agency to become mere docile parts, so do the environmental conditions "exceed the object, they are equally the conditions involved in other existing objects, and that cannot therefore be specified as belonging to that object alone, nor as terminating in it."[102] In particular one can say that "while objects construct their openness to their environment, they do not construct the events that take place in their environment"[103] but relate to it in a feedback cycle of construction and constraint.[104] The need for objects to form "contingent strategies for contending with the environment"[105] constitutes the ground of exo-relations.

Cultivation

Though Deleuze employs the metaphor of the fold to convey the complexly implicated interior of the monad,[106] the virtual dimension from which objects are unfolded is not a pre-individual stratum that is continuous like a sheet of fabric. Instead it is like an entangled knot or rhizome: not everywhere continuous but, through a complex selection, continuously interconnecting. "This genesis is a genesis *from* other objects or discrete individuals, and in many instances is productive of new individual entities."[107] It is perhaps better to use Leibniz's own images of every portion of matter as teeming with individuals "like a garden full of plants and like a pond full of fishes"[108] in order to remind ourselves of the complex plenitude of components at every scale. As an alternative to assembling or constructing, then, we might also speak of objects as 'cultivating' their environments.

97 *Ibid.* p52

98 "The point of view is not what varies with the subject, at least in the first instance; it is, to the contrary, the condition in which an eventual subject apprehends a variation … It is not a variation of truth according to the subject, but the condition in which the truth of a variation appears to the subject."

Ibid. p20

99 The term 'environment' is preferred to 'world' as it better conveys the pluralistic, overlapping, and specialized aspects given here. This use of environment can be traced to Luhmann, who uses it as a contrasting term to system: "must distinguish between the *environment* of a system and *systems in the environment* of this system." The distinction that the environment is included in the monad but is not an intensive part of the monad is preserved.

Luhmann, *Social Systems*. p17

100 Bryant, *The Democracy of Objects*. p200

101 *Ibid.* p146

102 Grant, "Mining Conditions: A Response to Harman." p43

103 Bryant, *The Democracy of Objects*. p205

104 *Ibid.* p31

105 *Ibid.* p146

106 Among the benefits of Deleuze's metaphor is the fact that 'fold' is also a verb.

Deleuze, *The Fold: Leibniz and the Baroque*. p1

107 Bryant, "The Ontic Principle: Outline of an Object-Oriented Ontology." p270

108 Leibniz, *The Monadology and Other Philosophical Writings*. §67, p256

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CHAPTER 3
PROCEDURAL RHETORIC

§3.1 Introduction

Constituent characteristics

The urban model that we put forward, then, must proceed from assemblages that satisfy the parameters set out in the previous chapters: sensitive to various contingencies and able to develop alongside the surrounding environment through a mutual production of the city[1] but yet not simply relational entities defined entirely from without. Rather they must possess an internal consistency through which external pressures are absorbed, translated, and made sense of. Unlike some recent applications of object-oriented philosophy within urban design, we are not especially concerned with classifying the type of object that best represents the city,[2] nor do we advance a naïve formal figure of objects based on a kind of metaphorical materiality.[3] Instead the imperative is to develop an urban model whose components possess degrees of individual autonomy from the urban plan as a whole.[4]

Model autonomy

In particular, it is necessary that the constituent urban assemblages are able to react freely to situational conditions so as to enable the kind of spontaneous formation that is the goal of Assemblage Urbanism. "The indeterminacies of the formative processes of urbanism require methods which specify its propositions provisionally."[5] For this reason, while the city or masterplan as a whole does constitute an assemblage of its own, such a frame is less appealing to this thesis, as it renders all of its responses subject to a single endo-consistency. The aim, then, is not only that the assemblages afford some possibilities,[6] but that the internalization of behaviors and affects ground an object agency that registers its own apperception and exercises a decision-making capacity with significant impact both on its own development and as an action or force "that leads to one particular enactment of the city."[7] Additionally, the elements of the model must be discrete individuals independent from one another, in order to establish their identities through the selective inclusion or cultivation of their environment, their parts, their relations, and their characteristics.[8]

Nonlinear interaction

The effect of inconsistent assemblages engaged with one another is the ecology of nonlinear interaction needed to provide our urban model with an analogue of the dynamic behaviors of actual, lived urbanism. The key is in enacting meaningful, responsive[9] interaction, that is, responses that "make a difference"[10] in their execution. These interactions stand in sharp contrast to the perfectly coordinated responses of linear effects that do not sufficiently distinguish between individuals but are more typical of the *internal* actions of a highly regulated assemblage. As we said earlier,[11] urbanism operates also through the openings created by the heterogeneous differences embodied within an assemblage and the potential for transformation present when assemblages

1 Farías, "The Politics of Urban Assemblages." p369-70

Amin, "Re-Thinking the Urban Social." p112

2 Peter Trummer calls the model of the contemporary city the "assembled object" city and characterizes it by the state of *architecture* providing the ground for further architecture rather than exporting that role to territory or a larger scalar figure (such as the grid) which we do agree with.

Trummer, "The City as an Object: Thoughts on the Form of the City."

3 Wiscombe, "Discreteness, or Towards a Flat Ontology of Architecture."

4 The implication of this is that the model maintains an autonomy from the designer as well. *cf.* §3.3 'Authorship'

5 Verebes, "Osaka: A Distinctive Urbanism." p160

6 "The theory of affordances suggests that there is a particular action or set of actions afforded by a tool or object … This is not to say that the tool or object has agency as such. In other words the tool or object does not have the capacity to actually 'invite' or 'prevent' certain actions. Rather it simply 'affords' certain operations that it is incumbent on the user to recognize, dependent in part on a set of pre-existing association that have been made with that tool or object."

Leach, "There Is No Such Thing as Digital Design." p152

7 Farías, "Decentring the Object of Urban Studies."

8 Deleuze, *The Fold: Leibniz and the Baroque*. p48-49

9 Bogost, Ian, Persuasive Games: The Expressive Power of Videogames, 2007. p40,42

10 *cf.* §2.2, "Being as difference"

11 *cf.* §1.4, "Difference"

12 "Procedurality in this sense refers to the core practice of software authorship. Software is composed of algorithms that model the way things behave … Procedural systems generate behaviors based on rule-based models; they are machines capable of producing many outcomes, each conforming to the same overall guidelines. Procedurality is the principal value of the computer, which creates meaning through the interaction of algorithms.

Bogost, *Persuasive Games: The Expressive Power of Videogames*. p4

13 "This ability to execute a series of rules fundamentally separates computers from other media"

Ibid. p4

14 Venhuizen, *Game Urbanism: Manual for Cultural Spatial Planning*.

15 Lorenzo-Eiroa, "From Coding to Representation, to Formal Autonomy, to Media Representation: Four Levels of Architecture Agency." p211

16 Allen, "Mapping the Unmappable: On Notation."

17 "More specifically, procedurality refers to the practice of encapsulating specific real-world behaviors into programmatic representations."

Bogost, *Unit Operations*. p13

18 *Ibid.* p14

19 Bogost, *Persuasive Games: The Expressive Power of Videogames*. p9

encounter unexpected or conflictual reactions. Apart from conflicts and effects of translation, the interaction between model elements become nonlinear when they do not follow a single generative timeline or scalar progression, but operate at multiple levels simultaneously or feed impacts back onto the process prompting a readjustment of the current state.

§3.2 Unique Traits of Computation

Formalization and automation

While certainly not the only solution to these criteria, computational modeling is uniquely suited to provide insight to the task of a complex, autonomous, urban design. As an inherently,[12] even uniquely,[13] procedural medium, it is well-suited to simulating behaviors. Furthermore, in the automation and wide variety of possible responses, computation is more capable of producing formal, yet complex, systems than other methods (for example participatory or game-based planning[14]). Lorenzo-Eiroa argues that computation has "shifted the mapping of extrinsic content to the coding of emergent content or agency."[15] That is, in place of translating external forces from the environmental, technological, or political realm into notational representations that inform design,[16] these forces are being explicitly formalized as starting points that are increasingly absent from the representational aspect of computational modeling, which in turn has shifted its attention to the result of playing out these forces (and others).[17]

Representation and enaction

Procedural representation, as a medium, is not quite that simple, however. "Procedural systems like computer software actually represent process with process. This is where the particular power of procedural authorship lies, in its native ability to depict processes."[18] In this sense, the representational mode of computation is not constrained to the outcome of a simulation but is at the same time, an enaction.[19] This allows a representation to more closely parallel its objects and produces a more tangibly comprehensible image of the logics depicted,[20] while it also stands on its own as an active environment[21] that can be engaged with independently of its role as a representamen.[22] While representation is always a creative process,[23] putting forth an "independent object" that "defines an agency,"[24] computation hones this point by establishing a self-reflexive representation: aspects of the program are represented within the code to other elements or objects within the program. In the same way, the computational model "represents a formal logic which governs the formation of a category or type," and simultaneously "a unique solution."[25] In contrast to instances that become "problematic when there is no agency at a representational level, such as when the content represented is extrinsic to the performance of its medium,"[26] computational agency is located precisely in the representational register. This fact motivates the close focus "on the emergent quality of code"[27] and the particular attributes and constraints it engenders as a form and as an "autonomous logical system."[28]

§3.3 Authorship

Split agency

One of the defining features of computational design is that it is inherently marked by a divided or displaced authorship. "To write procedurally, one authors code that enforces rules to generate some kind of representation, rather than authoring the representation itself."[29] The rules then generate a specific instance through the "intervention of some additional agency that may be other than, and even unrelated to, the … designer."[30] Mario Carpo defines this relationship as the 'split agency' of computational design and, though he typifies the product as an "an open-ended algorithm, or a generative, incomplete notation,"[31] he confers a hierarchical blessing on this objectile[32] naming the programmer as the "primary author"[33] or the "real digital author."[34] Meanwhile the user or operator of the system is relegated to becoming an 'interactor'[35] who "exerts only a limited and ancillary form of agency"[36] in adjusting the scenario to a specific case or to personal taste.

Manifold agency

Immediately, however, we recognize that this simple division does not hold in any practical sense. Carpo admits that "in practice, these two stations of agency are often merged into one, as a single agent often does both jobs – first designing the general program, then finalizing one or more specific objects designed and made with it. This is normal and to some extent inevitable."[37] Yet, this still ignores the fact that the programs that he portrays as determining are themselves always designed within the constraints of other software or coding languages and are often functionally extended into unintended directions through independently developed plug-ins or libraries,[38] or more prosaically through user scripts.[39] Moreover, there is no room in the two-level split agency for cases where the computer plays out its own scenarios through programmed automation or a generative solver.[40] These cases highlight the fact that in all events, the model itself exercises an agency that does not properly belong to either of Carpo's two agents. Neither the programming nor the application able to detach from the other as an entirely inclusive, self-controlled activity, but both are conducted as inter-active acts.[41]

§3.4 Unit Operations

Configurative systems

By considering computational models as complex manifold of actions and agencies, we position the model closer to the conceptual idea of the city as an endlessly reconfigurable assemblage (of assemblages) not structured by an overarching law. This does, however, create some difficulty in assessing the success or weaknesses of an urban design. Ian Bogost introduces the concept of 'unit operations' as an interpretive tool that engages with procedural media on their own terms.[42] As is the assemblage in assemblage theory, the unit in unit operations is very loosely defined: "In essence, a *unit* is a material element, a thing. It can be constitutive or contingent, like a building block that makes up a system, or it can be autonomous, like a system itself. Often systems become units in other systems."[43] More significant is the way that multiple units relate to one another within a work. In contrast to hierarchical systems that "regulate meaning for their constituents,"[44] these units aggregate into "a configurative system, an arrangement of discrete, interlocking units of expressive meaning."[45] The important detail here is that the level of operational control remains in the individual unit and though these units may be said to form systems, the systems themselves do not become structuring forces but are "the spontaneous and complex result of multitudes."[46]

20 *Ibid.* p7

21 One which may be materially identical to the software-sorted agency in operation controlling the actual city.

Graham, "Software-Sorted Geographies."

22 Peirce, "Logic as Semiotic: The Theory of Signs." p99

23 Hays and Trotter, "Re-enchanted Architecture."

24 Lorenzo-Eiroa, "From Coding to Representation, to Formal Autonomy, to Media Representation: Four Levels of Architecture Agency." p212

25 "simultaneously both the diagram of a procedural method and the quantitative record of an individual instance" or, following Peirce, both a legisign and a sinsign.

Zuelzke, Patt, and Huang, "Computation as an Ideological Practice." p193

Peirce, "Logic as Semiotic: The Theory of Signs." p101

26 Lorenzo-Eiroa, "From Coding to Representation, to Formal Autonomy, to Media Representation: Four Levels of Architecture Agency." p212

27 *Ibid.* p211

28 *Ibid.* p213

29 Bogost, *Persuasive Games: The Expressive Power of Videogames*, 2007. p4

30 Carpo, "Authors, Agents, Agencies, and the Digital Public."

31 *Ibid.*

32 *cf.* §2.5 "Objectile"

33 Carpo, *The Alphabet and the Algorithm*. p126

34 Carpo, "Authors, Agents, Agencies, and the Digital Public."

35 This terminology is attributed to Janet Murray, whose separation seems more apt as she was writing about digital narrative where the author/audience divide is distinguished by very different tasks in a way that might not translate to a designer/designer divide

Murray, *Hamlet on the Holodeck: The Future of Narrative in Cyberspace*.

36 Carpo, *The Alphabet and the Algorithm*. p126

37 Carpo, "Authors, Agents, Agencies, and the Digital Public."

38 See, for example, the various add-ons to Grasshopper at Food4Rhino:

http://www.food4rhino.com/grasshopper-addons

or the libraries for Processing:

https://processing.org/reference/libraries/

the majority of which are user-contributed in both cases.

39 Like those in this text.

40 DeLanda, "Deleuze and the Use of the Genetic Algorithm in Architecture."

41 Chapter 4 will develop the concept of the Interactive with regard to both the prepositional influence that the designer has over the end products of a computational model, and also the reciprocal influence which the constructed model has in interpreting the inputs of the designer.

Distributed units

Thus "rather than attempting to construct or affirm a universalizing principle, unit operations move according to a broad range of diverse logics, from maximizing profit to creating new functional capacity."[47] The diversity of logics in play requires close attention to the ways that individual units are positioned within the system as well as how their influence spreads through the network. In the first case, rather than trying to interpret the overall meaning of a network, one might analyze how a particular point of view manifests itself within the context of the network. In the second case, a study of the indirect effects that arise from an isolated action may be called for, or tracking of how the coherence of specific information changes over time.[48] In either case, the emphasis shifts to an exploratory or interpretive response of the situation and away from the "attitudes or values that inform the approaches that created the systems in the first place."[49]

§3.5 Procedural Rhetoric

Engagement

Following from this logic, we observe that unit analysis produces a unique mode of engagement and representation. The lack of holistic or consensus meaning in the system suggests a complex interaction for the critic, author, or user, but this is not necessarily new. The combination of such open-ended meaning with the dynamic aspect of computational models, however, is. Procedural media "have to be operated. They are not static objects, but active devices, machines rather than texts."[50] As such, the understanding of the model must occur through interaction and occur "with an eye toward identifying and interpreting the rules that drive that system"[51] not just an assessment of the end results. This is a particularly salient point in design fields, which are accustomed to separating process from product and to seeing products as singular artifacts rather than series of multiples.[52] Bogost argues that scenario modeling constitutes "more abstract representations about the way the world does or should function"[53] than do conventional verbal or visual discourses because the familiarity of those modes of communication have made their tropes more deeply ingrained. At the same time the active response of a computational model can create a more encompassing engagement that prompts further response and deeper attention than a conventional image.[54]

Representation and semiotics

The goal of procedural representation, then, is to maintain the active dimension of the simulation, directing the user's attention from the product, which is just one contingent state of many, and toward a consideration of the logic behind the scenario being played out, and the simulation that supports it. That is, to encourage computational thinking. "Computation is representation, and procedurality in the computational sense is a means to produce that expression … computer processes are representational, and thus procedurality is fundamental to computational expression."[55] Computation represents itself best through processes and aims to likewise be interpreted as process rather than images or words.[56]

This immediately calls to mind the work of Charles Sanders Peirce, whose semiotic model was not based on a dialectic between the signified and signifier[57] but on a triadic interplay between the representamen, the object, and the interpretant[58] in which the image of the sign brings forth a new image in a process that extends into an infinite series.[59] In this model the interpretation of the sign is not given as meaning but as a continuation of representation.[60] This process, which Peirce called "pure rhetoric,"[61] was not seen as a degradation of, nor affront to, the real,[62] but as a creative process of reproduction in kind.

42 Bogost points out that the unit operations mode of critique is not solely applicable to digital media, but can be applied to literature, film, or any other work that might struggle to fit within a holist interpretation.

Bogost, *Unit Operations: An Approach to Videogame Criticism*.

43 *Ibid*. p5

44 *Ibid*. p4

45 *Ibid*. ix

46 That is, the system is not structural with regard to its components. Systems may act as units (encapsulated, black-boxed, counted-as-one) in their relations with other units; unit analysis is not an atomistic theory.

Ibid. p4

47 *Ibid*. p8

48 *cf*. §7.4 'Nonlinear Dynamics'

49 Bogost, *Unit Operations: An Approach to Videogame Criticism*. p6

50 McCollough, "4k Formalism: An Interview with Ian Bogost."

51 Bogost, *Persuasive Games: The Expressive Power of Videogames*. p63-64

52 Carpo, *The Alphabet and the Algorithm*. p103

53 Bogost, *Persuasive Games: The Expressive Power of Videogames*. x

54 This is not to discount the interactive potential of images:

Patt, "The Collective Image: Form, Figure, and the Future."

55 Bogost, *Persuasive Games: The Expressive Power of Videogames*. p5

56 *Ibid*. p63-64

57 de Saussure, *Writings in General Linguistics*.

58 Peirce, "Logic as Semiotic: The Theory of Signs." p99

59 "The object of representation can be nothing but a representation of which the first representation is the interpretant. But an endless series of representations, each representing the one behind it, may be conceived to have an absolute object at its limit. The meaning of a representation can be nothing but a representation. In fact, it is nothing but the representation itself conceived as stripped of irrelevant clothing. But this clothing never can be completely stripped off; it is only changed for something more diaphanous. So there is an infinite regression here. Finally, the interpretant is nothing but another representation to which the torch of truth is handed along; and as representation, it has its interpretant again. Lo, another infinite series."

Peirce, Charles Sanders, *The Collected Papers Volume I: Principles of Philosophy*. §2.339

60 "The interpretation of the sign is not, for Peirce, a meaning but another sign; it is a reading, not a decodage, and this reading has, in its turn, to be interpreted into another sign, and so on ad infinitum … Only if the sign engendered meaning in the same way that the object engenders the sign, that is, by representation, would there be no need to distinguish between grammar and rhetoric."

de Man, "Semiology and Rhetoric." p29

61 Peirce, "Logic as Semiotic: The Theory of Signs." p99

62 Baudrillard, *Simulacra and Simulation*.

63 Bogost, *Persuasive Games: The Expressive Power of Videogames*, 2007. p2-3

64 McCollough, "4k Formalism: An Interview with Ian Bogost."

65 Peirce, "Logic as Semiotic: The Theory of Signs." p99

Rhetoric of simulation

Suggestively, Ian Bogost, has proposed the name "procedural rhetoric" to cover techniques "for making arguments with computational systems and for unpacking computational arguments others have created."[63] Following the category of "expression that represents processes or systems with processes or systems,"[64] (and Peirce's thesis that the interpretant further produces new representations[65]), procedural rhetoric covers both how "simulation authors … think about their objects as systems and consider which are the laws that rule their behaviors," and the ways in which "people who interpret simulations create a mental model of it by inferring the rules that govern it,"[66] neatly bridging the problematic split between the designer and user discussed above. Ultimately, the confrontation between the authorship of the creator against the application by the user is flattened out in the jump to infinite series enabled by the authority of the simulation itself.[67]

Bogost frames procedural rhetoric as a persuasive tool, with a primary interest in how videogames can be employed as a medium of critique or political statement.[68] From this perspective, he writes, "Persuasion is related to the player's ability to see and understand the simulation author's implicit or explicit claims about the logic of the situation represented."[69] Interacting with a simulation, requires one to make attempts to understand the logic[70] and "to analyze, contest and revise the model's rules according to his personal ideas and beliefs."[71] Though many procedural media restrict the possibility of rewriting the logical rules of the simulation itself, such calibration of procedures, responses, and degrees of freedom is often possible within—even typical of—a computational design process. "The iterative, reductive blending of the model's system of transition functions over the course of the design process produces an explicitly structured and strategically searchable solution space."[72] This 'intention space' formalizes the model's ideological position, and reframes the persuasive role of procedural rhetoric "from the simple achievement of desired ends to the effective arrangement of a work so as to create a desirable possibility space for interpretation."[73] These interpretations (or interpretamen) reflect the Peircian rhetorical mode, and can themselves be related to one another diagrammatically as a non-Euclidean spatial figure,[74] which can illustrate trends or groupings of potential parameter states. A better understanding of the parameter space can be used in a more traditional argumentative role to construct a more explicitly comprehensible parameter space[75] and "to address the logic of a situation in general, and the point at which it breaks down and gives way to a new situation in particular."[76]

§3.6 Model and Agency

Matters of concern

Although we earlier referred to the model's authority, this wrongly suggests that the model is the ultimate arbiter of design decisions. In fact, "a computational engine is not a conclusion but an evolving document which formalizes, refines, and clarifies its authors' intents."[77] Moreover, the potential stimuli reactions and invariant relations built into the model are activated to highlight significant concerns and direct the attention of subsequent users toward particular issues, what one might call the 'bias' of the simulation.[78] When the computational model assembles a heterogeneous array of unit operations "that simultaneously embed material, functional, and discursive modes of representation,"[79] it is capable of transitioning from purely quantitative matters of fact into matters of concern[80] that also incorporate associations and intentions.

In contrast to the 'parametricist' approach,[81] the goal is not a correlation of diverse data into a single communicative platform,[82] but to only to frame this information such that it can be positioned[83] within a single conversation. The imperative on the designer is thus to afford multiple types of interaction simultaneously against a changing background. In contrast to a conventional design process, the computational model is not structured as stages with distinct solutions but as an integrated model where different kinds of information engage the designer to address from many angles a single, complex situation.[84]

Agency

Finally, we argue that the expanded field of rhetoric provides a more substantial support for design agency, as "a purposeful inclusion of critical practice and the architectural project but also of the more specific use of artificial intelligence techniques in a design setting,"[85] Just as a rhetorician first establishes an argument and then engages in a discussion or debate, so design agency is exercised first as authorial intent asserted through the construction of a configurative model,[86] and then again through an *interactive* engagement of that system that develops a relational understanding of the situation from a particular point of view.[87] In the chapters immediately following we will examine various way by which a designer might work in this mode. Following that, we will return the question of why this is especially needed in urban design and argue that this thesis is not limited to computational design but can be extended to a general theory of urbanism.

66 Frasca, "Videogames of the Oppressed."

67 "The player or critic could make appeals to authorship or origin, but such an act isn't necessary—it's equally satisfactory to reflect on the role of a strange, unfamiliar machine."

McCollough, "4k Formalism: An Interview with Ian Bogost."

68 "Procedural rhetoric … has possible use well outside of games. . . certainly in computation more generally, but also in domains that use modeling as their representational mode. That can include physical models, for example, or demonstrations, or perhaps even scientific experimentation"

Ibid.

69 Bogost, *Persuasive Games: The Expressive Power of Videogames*, 2007. p333

70 *cf.* §4.2 'Interactive concerns epistemology' where we argue that interaction is primarily concerned with understanding.

71 Frasca, "Videogames of the Oppressed."

72 Zuelzke, "Digital Model-Making and the Encoding of Design Intent: Notes on the Computational Synthesis of Form." p97

73 Bogost, *Persuasive Games: The Expressive Power of Videogames*, 2007. p20

74 Zuelzke, "Digital Model-Making and the Encoding of Design Intent: Notes on the Computational Synthesis of Form." p98

75 *Ibid.* p97

76 Bogost, *Persuasive Games: The Expressive Power of Videogames*, 2007. p333

77 Zuelzke, Patt, and Huang, "Computation as an Ideological Practice." p194

78 Bogost, *Unit Operations: An Approach to Videogame Criticism*. p97

79 *Ibid.* p105

80 Latour, "Why Has Critique Run Out of Steam? From Matters of Fact To Matters of Concern."

81 Schumacher, "Parametricism: A New Global Style for Architecture and Urban Design."

82 Schumacher claims: "Employing associative logics correlates the the different urban and architectural subsytems in ways that make them representations of each other. Everything communicates with everything. This is not a metaphysical assertion about the world, but a heuristic principle for parametric design under the auspices of parametricism."Schumacher, "Parametric Semiology: The Design of Information Rich Environments." p178

83 *cf.* §4.5 'Forms of Output'

84 "Architectural design, practiced computationally, possesses a unique temporality which escalates the traditionally iterative process of design by drawing together initial premises, processes, and effects produced simultaneously. Such integrated, self-informing feedback gives the impression of automation, but in fact allows (even sometimes requires) the architect to reexamine, reassemble, and elaborate upon the early assumptions rather than accepting them as values givens."

Zuelzke, Patt, and Huang, "Computation as an Ideological Practice." p195

85 Gerber, "Parametric Tendencies and Design Agencies."

86 Zuelzke, Patt, and Huang, "Computation as an Ideological Practice." p187

87 *Ibid.* p191

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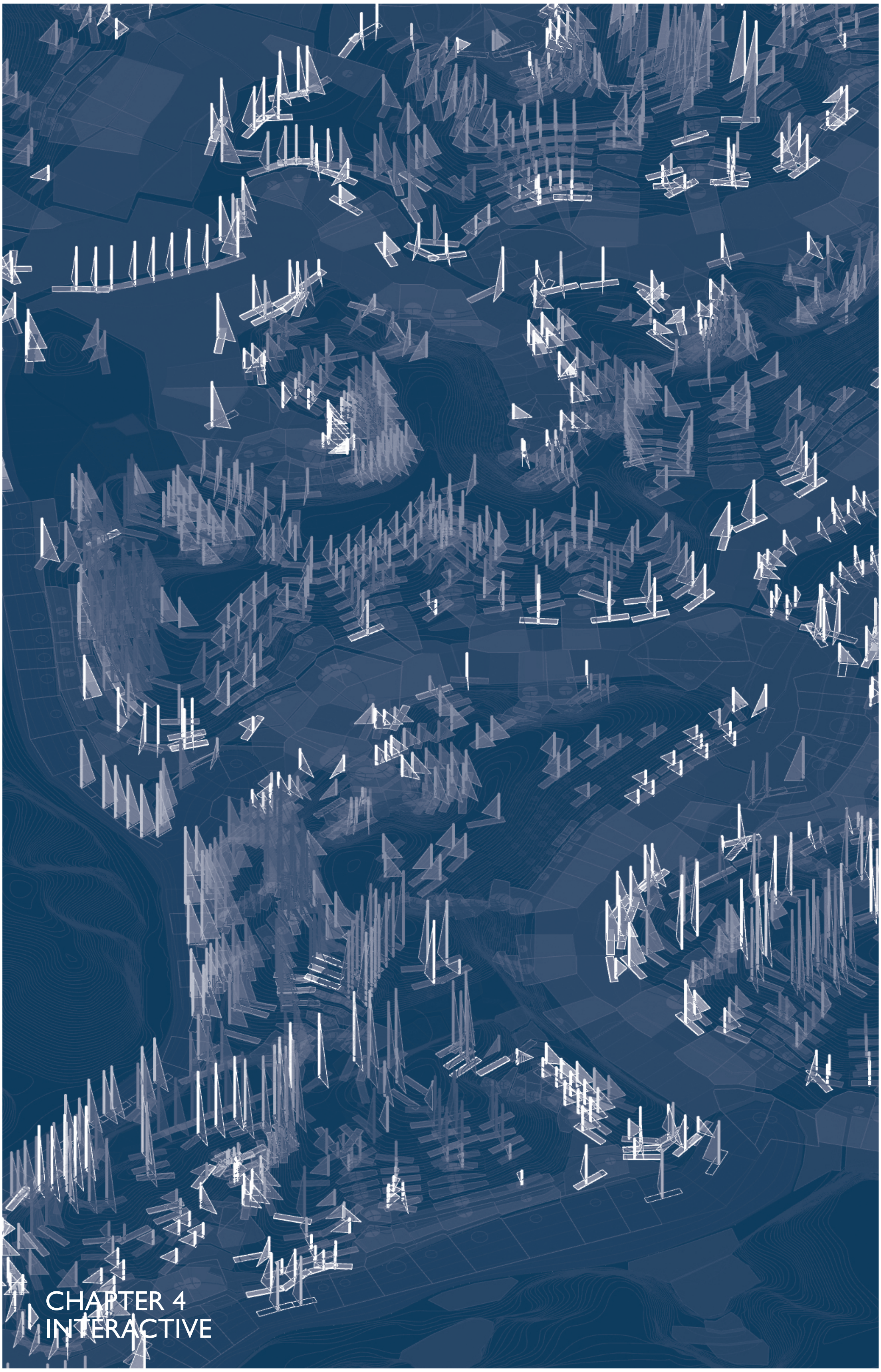

CHAPTER 4
INTERACTIVE

§4.1 Introduction to Part II

Operative criticism

In the following sections we will trace out a project for urban design that leverages procedurality as a medium for discarding the boundary between macro- and micro-scales or between urban and architectural design stages. This project will be the product of bundling together the theoretical sources that have just been covered into a framework in which they relate to one another as complementary moments of an attitude toward the city. This framework constructs a correspondence between the processes and developments of the contemporary urban condition and the processes and enaction of a computational design model, bridging the gap between analytic and operative theory.[1] We will exposit this attitude through four thematic aspects of computation, building up in complexity of dynamism and temporal interrelation. This chapter continues the discussion of procedural rhetoric from chapter 3 into a discussion of the interactive nature of computational models and the ways in which interactivity both expands and constrains the possibilities of the computational model. Following this, we will examine the generative potential of locally situated behaviors as encapsulated in agent-based models as an extension of the analysis of monadology from chapter 2 and the emergence of virtual orders that result from a reflexive feedback of these behaviors as theorized by assemblage urbanism in chapter 1. Finally, we will introduce an entropic function to counter the overdetermined, teleological tendency of computation and reorient toward the goal of the open city.

Design illustrations

Borrowing a phrase from Gilbert Simondon, one could say that "this mentality is developing, and therefore incomplete and at risk of being prematurely considered as monstrous and unbalanced. It requires a preliminary attitude of generosity towards the order of reality that it seeks to manifest"[2] For this reason, each theme is accompanied by a design example that will be used to illustrate and develop key aspects of each theme. These exercises are themselves also incomplete: fragments that emphasize one particular aspect of a computational urban design attitude, though they could not avoid participating in each theme to some degree. These design exercises will also enable the discussion of actual techniques for producing computational models through real, working code examples.[3] When possible, these will be presented within the text though some supporting code will be relegated to appendices or omitted in order to preserve legibility and a consistent thematic flow.

1 "What is normally meant by *operative criticism* is an analysis of architecture (or the arts in general) that, instead of an abstract survey, has as its objective the planning of a precise poetical tendency, anticipated in its structures and derived from historical analyses programmatically distorted and finalized. By this definition operative criticism represents the meeting point of history and planning. We could say in fact that operative criticism plans past history by projecting it towards the future. Its verifiability does not require abstractions of principle, it measures itself, each time, against the results obtained, while its theoretical horizon is the pragmatist and instrumental tradition"

Tafuri, *Theories and History of Architecture*. p141

2 Simondon, "Technical Mentality." p17

3 The projects described have all been produced using Grasshopper, a visual programming environment and plugin for Rhinoceros. The computational excerpts presented here have all been written as GhPython modules, which allow for customized textual coding within the node of a Grasshopper component. An ellipsis (. . .) denotes that a single line of code has been continued onto the next line because of length. Note that GhPython can process broken lines implicitly and that the ellipsis is only employed here as a graphic aid.

The projects will not be presented in their entirety, rather individual GhPython codes will be shown and their significance and role within the overall definition will be commented on. A map that situates each code fragment within the project definition will be included at the beginning of each of the appendices. The entire Grasshopper definitions will also be available for download at :

http://ahtehha.net/assemlage-form/

Code examples will be identified in the text by the symbol ≒ and references to individual lines will be identified in parentheses with a colon thus (:10).

4 Batty, "Fifty Years of Urban Modeling: Macro-Statics to Micro-Dynamics." p11

5 *Ibid.* p11

6 McHarg, *Design with Nature.* p34-35

Steinitz, *et al.* point out that while the map overlay process was relatively common by this time, there was previously very little documentation or explanation that would make the design and analysis processes more explicit. McHarg is noted for putting the focus on the process not simply the final maps.

Steinitz, Parker, and Jordan, "Hand-Drawn Overlays: Their History and Prospective Uses." p446

7 McHarg, *Design with Nature.* p105

8 *Ibid.* p105

9 *Ibid.* p105

10 *Ibid.* p93

11 *Ibid.* p104

12 *cf.* §5.1 'Genetic Ontology'

13 McHarg, *Design with Nature.* p104

14 "there is an urge to literally reground the environment with an intelligence of place—interpreted not so much in the conservative sense of Martin Heidegger's and Christian Norberg-Schultz's *genius loci* but more in Elia Zenghelis's contemporary interpretation of uncovering existing logics of reality and finding a site's capacity by distinguishing the junk from the potentials."

Shannon, "From Theory to Resistance: Landscape Urbanism in Europe." p147

§4.2 Introduction to Interactive

Rhetorical models

In recounting a brief history of urban modeling, Michael Batty argues that the trend of computational urbanism from the mid-1980s turned toward “building models that informed, extended our understanding, focused us on key issues,”[4] that is, toward the development of rhetorical models that enfranchised bottom-up, decentralized urban formation. By focusing on “how spatial structures might emerge”[5] through agent-based interactions driven by individuals rather than aggregates, urban modeling found a way to rigorously approach the dynamic and unexpected changes observed in cities in a speculative way if not yet operationally.

Already in 1969, Ian McHarg made a similar point about his use of overlay mapping for land use planning:[6] that although the empirical and overt methods he used were significant, so too was the fact that this process opened up space for the community to insert their own wishes and aims.[7] Inasmuch as his clearly delineated and categorical maps effect a persuasive rhetoric in themselves, McHarg's methods are mobilized to make the “obscure and covert”[8] criteria of the planner or designer explicit so that they can be engaged with directly. More precisely, his methods allowed the designer to present a model which could lead to various outcomes following discussion. McHarg repeatedly comments that none of the case studies presented in *Design With Nature* can be considered plans in themselves. “A plan includes the entire question of demand and the resolution of demand relative to supply, incorporating the capacity of the society or institution to realize its objectives,”[9] but are at most “an expression of physical, social and economic goals.”[10] In fact, this is the element of McHarg's work that we are most interested in here: over, and in place of, a plan, the collection of empirical facts from sited processes and the translation of them into a framework that engages with adaptable or nondeterministic goals.

Processes as values

Rather than a plan, which gives only the image of an expected end, the goal is to construct a new definition of the site that can be engaged with in explicit terms. For McHarg this meant that “the place is a sum of natural processes and that these processes constitute … values.”[11] That is, to aggregate the significant processes occurring at each location in a way that enables comparison between them and between different locations on multiple criteria.[12] McHarg called this the “intrinsic suitability”[13] of a site, what today may be more often referred to as the “local intelligence”[14] of the site. The significance of local intelligence is twofold. First, it establishes a datum of objectivity to the site definition that deftly moves the conversation beyond foundational matters and toward operational responses instead (while refraining from fixing these responses—changes can still be made or supplements introduced to the source data). Second, it puts forward an alternative to ‘geometrical’ planning based on *a priori* principles.[15]

Still, it would not be much of an improvement to simply substitute local intelligences for geometric principles within a conventional plan. It is important that this process also enacts a translation of processes into values, of empirical data to operational logics, of matters of fact into “matters of concern.”[16] Thus, it is important to frame these values relationally as contingent on the initial site definition as well as the proposed application, and as reactive to changes in the model over time. “For certain land uses the maximum condition will be preferable, for others it will be the minimum that has the highest value … In addition, in certain cases some factors will be conducive to specific land uses while others are restrictive.”[17] Similarly, there will be sites that are equally suited for multiple uses that may only be decided through the influence of tertiary processes.[18] These sites of multiplicity are also interesting for suggesting more complex considerations of hybridized uses[19] or occupation by phased progression through multiple states.[20] Rather than absolute values then, the site is really defined as a set of tendencies, each of which implies certain costs or benefits to pursue.

Interactive concerns epistemology

Interactivity, in this case, is the exploration of potential tendencies and a testing of their possible realizations.[21] The interactive is an experimental moment and it is equally an experiential moment. The experience of the action and response separates interactivity from merely reading an analysis. As Bogost described, the definitive feature of interactivity occurs when one engages with a model as a means of comprehending its inner workings.[22] Thus we link the interactive to epistemological concerns.

In the following, we will examine three aspects of this mechanism. First, there is a particular interest in how information is made and presented as a concern—the identification of relevant data and the interpretation of its significance within the structure of the design question. Second, there is a the question of how information can be added to the model—whether as an organizational method by the designer or as a configurational input from other external sources. Third, is the need for information to be shared or translated from one domain to another for example, formatting the output of the model so that information can be passed between different operations or to further resonate in the social world where it can be viewed and assessed.

Conclusion

The interactive dimension arises through these three aspects and through an arena of mixed impulses: the internal dispositions of the logical units of the model, tendencies of the environment, and individual actions; temporary states and provisional behaviors;[23] expressions and translations within the model and beyond. One of the most significant aspects will be the selection and recombination of different data sources to produce new, synthetic interpretations. McHarg had already seen the potential of that computational methods could bring to this problem,[24] though the challenge today is not with technological capability, but grappling with the question of how the model shapes our understanding of the city.

§4.3 Significance of Information Interaction

Prepositional mode of being

In defining the model, special attention must be given to the means of interaction and the combinatorial modes that they support. If the variability of the model is reduced to simply providing templates or dictating a narrow set of options, the concept of interaction as a means of understanding or making expressing concerns is significantly compromised by the reduced role of procedurality and the short-circuiting of emergent results.

The mechanisms by which the interactive operates—that is, the interfaces between different datasets—do not supply information or have meaning in themselves, but establish the modes of translation between objects.[25] They "set up what comes

15 "The geometric planner offers another alternative, that the city be ringed with a green circle… but it appears that nature outside the belt is no different from that within, that the greenbelt need not be the most suitable location for the green activities of agriculture or recreation. The ecological method would suggest that the lands reserved for open space in the metropolitan region be derived from natural process lands, intrinsically suitable for "green" purposes: that is the place of nature in the metropolis."

McHarg, *Design with Nature*. p56

16 Latour, "Why Has Critique Run Out of Steam? From Matters of Fact to Matters of Concern."

17 McHarg, *Design with Nature*. p107

18 "we seek to find not only intrinsic single uses, but also compatible coexisting ones and areas of competitions … Those shown as coequally suitable for more than one use may either compete or coexist. By abandoning absolute economic values that cover only a small range of price values, and employing a relative system of most to least, it is possible to include all of the important factors that defy pricing by economists."

Ibid. p115

19 *Ibid*. p115

20 Verebes, *Masterplanning the Adaptive City*. p90-95

21 "the instantaneity of the tendency only means that the instant itself is a tendency, not an atom, and that it does not disappear without passing into the other instant: that is why it is up to the tendency, or the inner unity of movement, to be recreated or reconstituted at each and every instant"

Deleuze, *The Fold: Leibniz and the Baroque*. p117

22 Bogost, *Persuasive Games: The Expressive Power of Videogames*. p63-63

23 Deleuze, *The Fold: Leibniz and the Baroque*. p115, 117

24 "Certain technical problems are inherent in the method. The first of these is the ensurance of the parity of factors. The results will be qualified if the factors are of disproportionate weights … It may be that the computer will resolve this problem although the state of the art is not yet at this level of competence."

McHarg, *Design with Nature*. p115

The question of weighting different combinations of overlays was already addressed by a procedural framework in:

Alexander and Manheim, *The Use of Diagrams in Highway Route Location: An Experiment*.

The application of computer processing to the question of map overlays was also already underway at Harvard's Laboratory of Computer Graphics using the SYMAP program.

Steinitz, "The Beginnings of Geographical Information Systems: A Personal Historical Perspective."

Steinitz, "Meaning and the Congruence of Urban Form and Activity."

25 *cf.* §2.4a 'Information passes and is translated between objects'

26 Latour, "Reflections on Etienne Sourau's '*Les Differents Modes d'Existence*'." p309

27 *Ibid*. p309

28 *Ibid*. p310

next without impinging in the least on what is actually said,"[26] in a pre-positioning that is "light but also decisive."[27] The significance of this point is again to establish the product of the interaction as an object created through the information process. "The finished work is always a novelty, discovery, or surprise,"[28] it is not a type given in advance or imposed by the designer, but as argued earlier,[29] the designer "welcomes, gathers, prepares, explores, and invents the form of the work"[30] through the procedural medium.

Such a 'work' can be said to always be in the process of formation, which means that the instantaneous state of the design is equally acting as a source of information, highlighting the fact that the initial conditions themselves have been taken up *in media res*, at an arbitrary point.[31] Rather than being troubled by the arbitrariness of starting or stopping points,[32] we note that this gives a consistency to our objects: there is no separate species of *a priori* conditions that are free from historical or temporal contingency. The design "is arbitrary and contingent, but from that moment on it becomes a part of the contrasts that we will have to make use of in order to sort things out."[33] For as long as the model itself remains continuously reactive, the status of the situation, its tendencies, and trajectory are traced out by the receptivity to influence of the assembled objects and the character of their responses. The capacity of each model to produce a unique ontological assemblage of objects is established through the prepositional mode of its interactive dimension.[34] To fully understand the agency of the model requires a commitment to the indirect diffusion of actions and the complex multiplicity of influences that result from continuous and ongoing processing to information.

State space

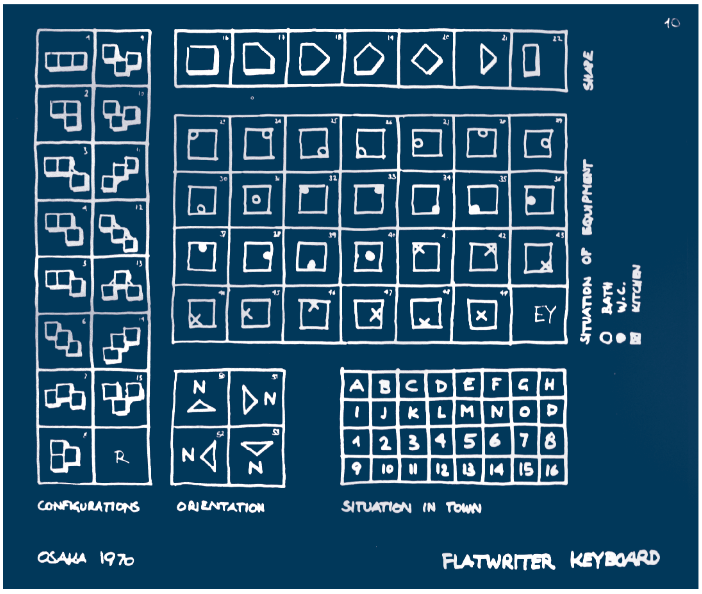
In contrast to the typical parametric model that is defined by a quite rigid and hierarchical structure,[35] we are calling for a much more radically open definition of the relations that allows transformation of the organizational logic of the urban model. Parametric models have long been characterized through the concept of 'state space', a topological map of all values of a system's degrees of freedom comprising a diagram of every possible outcome.[36] This operation reveals how deterministic parametric modeling can be inasmuch as it accounts for all possibilities in advance. However, as an analytical—rather than definitive—tool for differentiating the current state of a model from others, or for reading and comprehending the intricacies of internal relations, state space can be quite useful. Though the global configuration of the state space may yet be subject to dramatic changes, the current state's local neighborhood of possibilities can reveal how the model might be positioned to change in the immediate future or if it is subject to recurring behaviors.[37] Representating the fluctuations of model state is an important aspect of instrumentalizing complex models.[38]

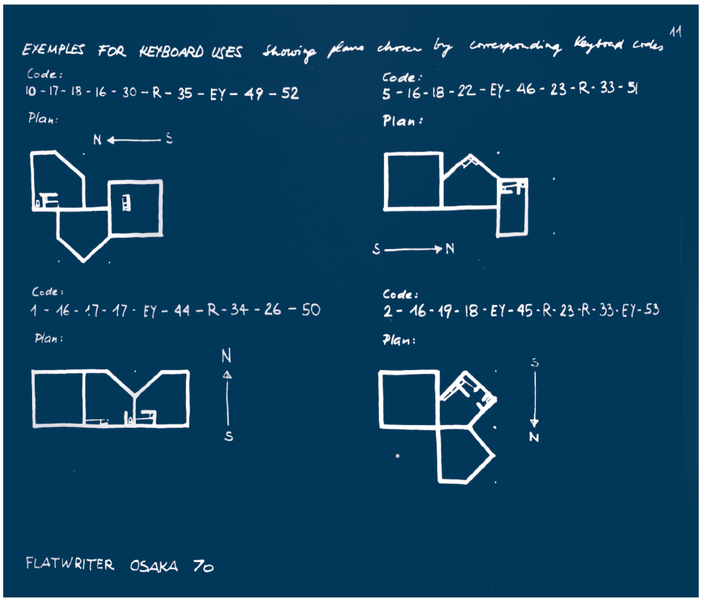
§4.4 Modes of Input

Flatwriter

Contemporaneous with the publication of *Design with Nature* was one of the first projects to explicitly link digital, computational methods to an open-ended, interactive design product,[39] Yona Friedman's *Flatwriter*,[40] a computer model, "which follows certain rules of composition inspired by the urban regulations. This computer shows visually (in a master plan) the city which will be composed little by little according to the visitors of the exhibition handling *Flatwriter*. This visualization will be made by means of cathode ray monitors placed above *Flatwriter*."[41]

Friedman ran up against the computational limitations of his day—the project was never realized, even after the '70 Osaka World Fair it had been proposed for had passed[42]—but it was described in sufficient detail that it could be reproduced.[43] Given Friedman's preference for a "nonpaternalist"[44] system (one that does not interject its own judgments, but defers to the user input) that enables not-specialist individuals to design their own dwellings, *Flatwriter* was developed almost entirely through interactive elements with minimal predefined logic. Friedman envisioned it as "an application of a new information process between the future user and the object."[45] The kernel of the project is in the implementation of a set of simplified symbols representing elements and transformations that can be understood immediately[46] and the input





Figures 4.1; 4.2
Flatwriter, 1968. Keyboard inputs and unit outputs
Friedman, *La Planification Urbaine*. p10; 11

of the user's desired apartment configuration through a keyboard that corresponds to these symbols.[47] Any additions or changes to the master plan can be shared with all users through analytic charts that relate quantitative and qualitative aspects of the plan's current state.[48] Here we clearly observe the three aspects of interactivity that we highlighted earlier: that of understanding concerns, of adding data to the model, and of sharing or translating information.[49]

29 *cf.* §3.3b 'Manifold agency'

30 Latour, "Reflections on Etienne Sourau's '*Les differents modes d'existence*'." p311

31 "The modes of being are contingent. Each one taken as the original can call for such another in dialectical fashion. but each one taken in turn as original is arbitrary."

Souriau, *Les différents modes d'existence.* p120

quoted in and translated by Latour, "Reflections on Etienne Sourau's '*Les differents modes d'existence*'." p315

32 Lynn, *Animate Form.*

33 Latour, "Reflections on Etienne Sourau's '*Les differents modes d'existence*'." p326

34 *Ibid.* p316

35 "While the parameters may easily be changed, the model itself consists in the highly constrained relationships between the various geometrical schemata and their dependencies."

Hanna, "Defining Adequate Models for Adaptive Architecture." p95

36 DeLanda, "Real Virtuality." p145-146

37 DeLanda, *Intensive Science and Virtual Philosophy*. p14

38 *cf.* §4.5 'Forms of Output'

Zuelzke, "Digital Model-Making and the Encoding of Design Intent: Notes on the Computational Synthesis of Form." p99

39 Similar research was also occurring at the Architecture Machine Group, notably *URBAN5*, "a machine that discusses urban design."

Negroponte, "URBAN 5—An On-Line Urban Design Partner."

Negroponte and Groisser, "URBAN5: A Machine That Discusses Urban Design."

As well as Carl Steinitz and Peter Rogers' work building off of regional studies with the SYMAP software.

Steinitz and Rogers, *A Systems Analysis Model of Urbanization and Change: An Experiment in Interdisciplinary Education.*

Steinitz, "Computer Mapping and the Regional Landscape."

40 Friedman has dated *Flatwriter* to 1967 the project was first published in 1968 (see below).

Friedman, *Yona Friedman: Drawings & Models/Dessins & Maquettes*, 1945-2010. p324

41 « *qui suivra certaines règles de composition inspirées des règlements urbains). Cet ordinateur montrera visuellement (en plan masse) la ville qui se composera petit à petit en fonction des visiteurs de l'exposition maniant le* « flatwriter » *Cette visualisation se fera par l'intermédiaire d'écrans cathodique placés au-dessus du* « flatwriter ». »

Friedman, *La Planification Urbaine*. p15

42 Friedman, "The Flatwriter: Choice by Computer." p99

In *Yona Friedman: Drawings & Models*, some physical models, dated 2002, have been attributed as having been "made with *Flatwriter*," but it is not clear that the software interface was ever involved as the models shown have quite a different look to them. Friedman also suggests that *Flatwriter* was to be reconsidered for the Shanghai World Expo in 2010, though this does not seem to have occurred.

Friedman, *Yona Friedman: Drawings & Models/Dessins & Maquettes*, 1945-2010. p790-791, 324

Individual input

The influence of *Flatwriter* is still apparent in the computational design landscape of today. For example, *VillageMaker*, by MVRDV and The Why Factory,[50] proceeds much like *Flatwriter*: values are added by a user one-by-one through a series of inputs selected from a menu of options, and as individual users accumulate, the master plan emerges as an aggregation. The results are produced by a very algorithmic process whereby a change in the values requires a return to the beginning to re-enter the new values when prompted. The rise of purpose-built parametric modeling softwares has decreased the need for such a linear process,[51] while also increasing the number of available input mechanisms and their complexity.

As Mario Carpo has warned, reliance on the set of available mechanisms can be somewhat restrictive to the designer,[52] however most mature software platforms include the ability to customize the software's functionality to various degrees or to add or write new functions.[53] For example, the *GraphMapper* component in Grasshopper allows the direct manipulation of a law curve,[54] but the interface only allows automated inputs for the independent variable, requiring manual editing for any of the curve parameters or graph dimensions. The following example, ≒4.4.1, uses a Python script to access the active components from the Grasshopper environment (:10) and identify the desired component by type (:12) and by a *.Nickname* attribute (:13). Once identified and saved, this component's properties can be modified as an active parameter as in ≒4.4.2.

Molar input

Often it will be inefficient or impossible to enter all values directly and large sets of data will need to be imported into the model at once, particularly on urban-scale projects. David Gerber recounts how, working on the proposal for the *One North* masterplan, "we were confronted with the need for managing vast data bases which required the fast visualization of the modifications."[55] The invention of a planning tool was considered an essential aspect of the deliverable product[56] as well as an active ingredient in the design process.[57] The result was a software which allowed input and editing of planning tables within a spreadsheet and translated that data to models of three-dimensional form. The direct relationships between data and form a establishes *One North* as one of the first instances of parametric[58] urbanism in practice,[59] and it demonstrates the need for a control mechanism to coordinate or parameterize those relationships. Projects 2, 3, and 4 will all involve importing large external data sets from different file formats.[60]

43 In addition to the sources above:
Friedman, *Pour Une Architecture Scientifique*. p70-77, 79-112

44 Negroponte, *Soft Architecture Machines*. p96
This is in contrast to *URBAN5*, which assumes an architect as operator and more aggressively enforces resolution of conflicts in the model.
Negroponte, *The Architecture Machine*. p71, 85

45 Friedman, "The Flatwriter: Choice by Computer." p100

46 Friedman, *Pour Une Architecture Scientifique*. p51*ff*
In particular, the planar maps inspired by the graph theory of Frank Horary.
Vardouli, "Performed by and Performative for: Rethinking Computational Models for User Participation in Design."

47 Of the 53 keys, 15 provide possible room configurations, 7 provide individual room shapes, 28 define location of internal facilities, and 5 control orientations. Location within the master plan can be chosen with an alpha-numeric keyboard that corresponds to grid cells of the infrastructural matrix.
Friedman, *La Planification Urbaine*. p14, 16
Friedman, "The Flatwriter: Choice by Computer." p100

48 Friedman, "The Flatwriter: Choice by Computer." p99, 101

49 *cf.* §4.2d 'Conclusion'

50 MVRDV and The Why Factory, *The Vertical Village*. p420-469

51 For the purposes of distinction, 'algorithmic' models are those characterized by the step-by-step flow of most scripting operations, while 'parametric' models are processed in a more synchronous way, with all parts of the code editable at any point in time. Variable values are typically interdependent so that a change in single parameter controls effects in many attributes. 'Associative' models are similarly synchronous but may lack the condensed control mechanisms of a parametric model. Associative models tend to be geometry-forward and the editable parameters are often embedded in the geometric object. Despite the fact that *VillageMaker* was conceived in Grasshopper (a parametric environment), its structure is more algorithmic. For a good definition of 'parametric' modeling and various usages of the term:
Davis, "Modelled on Software Engineering: Flexible Parametric Models in the Practice of Architecture." Chapter 2

52 Carpo, *The Alphabet and the Algorithm*. p126

53 Indeed this has been true since the earliest CAD softwares:
Sutherland, *Sketchpad: A Man-Machine Graphical Communication System*.

54 "A Law Curve is essentially a geometrically defined 'function,' which returns values for Y (the dependent variable) given a range of values for X (the independent variable) and a curve that defines the relationship between X and Y."
Aish, "Exploring the Analogy That Parametric Design Is a Game." p207

55 Gerber, "Towards a Parametric Urbanism." p157

56 "In the winning competition proposal Hadid's team included the idea of developing and delivering a piece of custom technology that was called a planning tool"
Gerber, "Parametric Practices." p102

≒4.4.1 GraphObjects

```
0   INPUTS: nickNames As List of string
    #FIND OBJECTS AND METHODS AT:
    #    gh.Kernel.Graphs.GH_GraphContainer.xxx
    #CALL BY:
    #    obj.Container.xxx
5
    import scriptcontext
    import Grasshopper as gh

    graphObj= [False for x in xrange(len(nickNames))]
10  for obj in ghenv.Component.OnPingDocument().Objects:
      #SEARCH BY TYPE AND BY NICKNAME
      if type(obj) == gh.Kernel.Special.GH_GraphMapper:
        if nickNames.Contains(obj.NickName):
          ndx=nickNames.IndexOf(obj.NickName)
15        graphObj[ndx] = obj

    scriptcontext.sticky["graphObjects"] = graphObj
    OUTPUTS: None
```

This code creates a 'sticky' python list of Grasshopper Graph objects from the canvas:

https://github.com/mcneel/rhinopython/blob/master/scripts/samples/sticky.py

Note: Grasshopper components' *.NickNames* are accessible as the first line in the right-click menu. By default, GraphMapper components are named 'Graph'.

Reference: Marcus & Hannes Leschke:

http://www.grasshopper3d.com/forum/topics/sliders-and-python-to-change-output-range-of-graph-mapper

02 Reminder note for finding Graph methods.

04 Reminder note for Graph object namespace.

09 Create an empty list, *graphObj*, with a length equal to number of items in *nickNames*.

10 Loop through all objects on the Grasshopper canvas, looking for *GH_GraphMapper* objects (:12), and saving them in *graphObj* (:15) if their *.NickName* value has a match in the *nickName* list (:13).

17 Save list to *sticky* dictionary, callable by other Python script components as *graphObjects*.

≒4.4.2 ModifyGraphX

```
0   INPUTS: X1 as list of float, refresh as Item
    import scriptcontext

    graphObj = scriptcontext.sticky['graphObjects']
    for i, graph in enumerate(graphObj):
5     graph.Container.X1= 2*X1[i]
    OUTPUTS: None
```

Modify the internal parameters of GraphMapper objects on the canvas, (namely their *.X1* value) remotely from a separate script component:

Note: boolean button input *refresh* triggers recalculation if script component has not properly updated.

01 *scriptcontext* module allows access to sticky dictionary.

03 Import *graphObjects* from sticky dictionary to this script component.

04 Loop through GraphMappers in *graphObjects* and reassign *.X1* value from input list *X1* (:05).

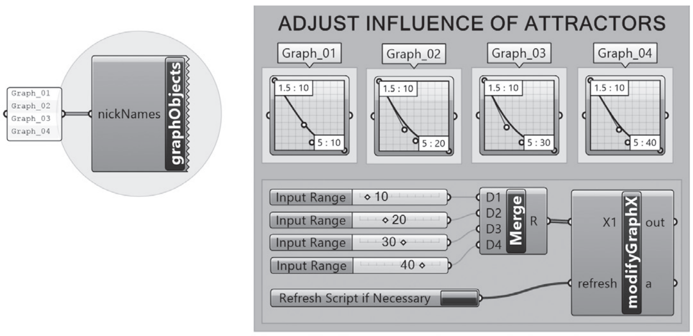


Figure 4.3
View of the Grasshopper canvas with four GraphMappers and the GhPython components for ≒4.4.1 and ≒4.4.2.

≒4.4.3 TopoPoint

```
05  ...
    #====================================================================#
    class TopoPoint:
      #class EXTENDS Point3d WITH TARGET AND CONTINUITY DATA
      #FOR JAGGED ARRAY
10    """TopoPoint extends Point3d:
      adds source/trgt point index (i,j,k) or if none (False)
      """

      def __init__(self, pt,s,t,f,v):
15      self.xyz= (rhG.Point3d(pt))
        self.src= s
        self.trgt= t
        self.tan= v
        self.aggr= f
20
        self.slp= False
        self.pln= False
        self.sol= False
        self.solHrs= False
25
        self.attr= [False,False,False,False,False]
        self.fit= [False,False,False,False,False]
        self.typ= [False,False]
        self.ornt= [False,False]
30
        self.vvv = False
        self.area = False
        self.ntwrk = []
        self.nchr= []
35  #====================================================================#
    ...
```

Create a new class that contains a point location and any additional localized metadata:

07 This class is located within the code for the *TopoFlow* component (≒4.6.1, :07-32) and many of its methods refer to this script.

14 The initiation operation takes multiple arguments. Because Python is dynamically typed, these and the methods below can be filled with default values (i.e. *False*) then changed on the fly throughout the code, to suit needed purposes. For example, a variable might be initialized with a Boolean as a check to test whether the expected value has been assigned yet.

The typical uses of these methods are as follows:

.xyz contains the point location.

16 *.src* records the indices of the previous point along the flowline from this point, *cf.* ≒4.6.1 for this and the following five methods.

17 *.trgt* records the indices of the next point along the flowline from this point.

18 *.tan* contains the tangent vector along the topographic curve at the point *.xyz*.

19 *.aggr* contains an aggregate value that increases as a flowline lengthens or merges with another.

21 *.slp* contains a vector that points from the point at *.src* and the point at *.trgt*.

22 *.pln* contains a plane oriented to the slope and tangent of the topography.

23 *.sol* records a value for solar incidence calculated in a separate script component as the degree between the normal vector and the average daytime sun angle.

24 *.solHrs* records the number of hours of direct sunlight at the location *.xyz*.

26 *.attr* processes the proximity to various features of the site, *cf.* ≒4.7.1.

27 *.fit* converts site values into fitness values according to input parameters, *cf.* ≒4.8.1.

28 *.typ* records the indices of the two highest fitness values, *cf.* ≒4.8.1.

29 *.ornt* stores a plane that blends various site orientations based on the point type, *cf.* ≒4.8.1.

31 *.vvv* holds an area polygon calculated from the voronoi diagram.

32 *.area* evaluates the area of the voronoi cell.

33 *.ntwrk* stores lines that connect each point to its adjacent points.

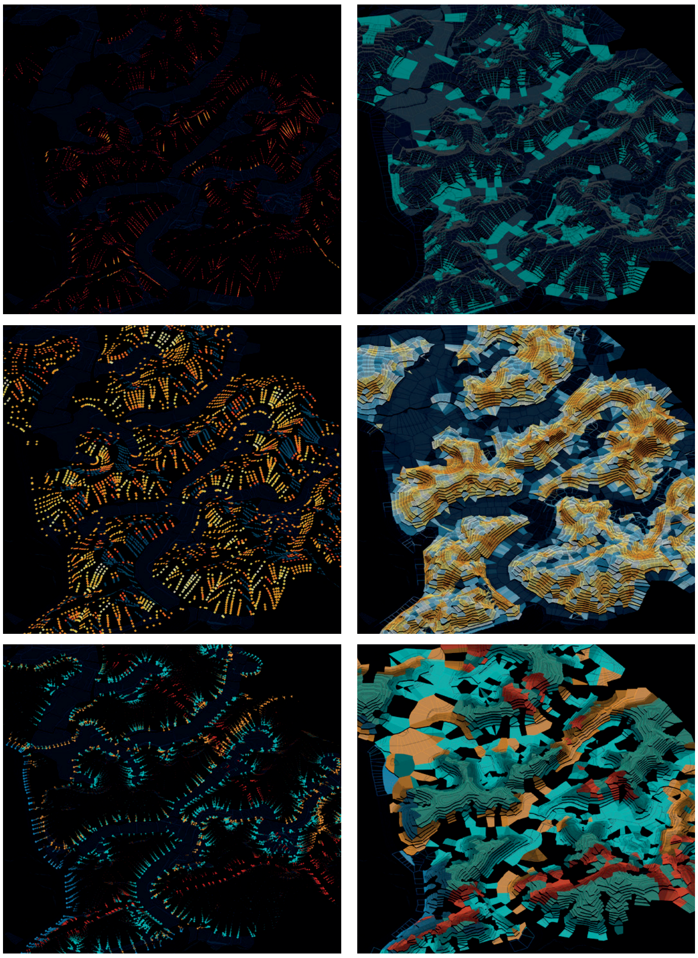


Figure 4.2

Visualizations of various site data that is stored in the *TopoPoint* class.

a) slope (:21)

b) areas of high runoff (:19)

c) average solar incidence (:23)

d) cell area (:32)

e) attractor vectors colored by type (:26)

f) type (:28)

Derived values

Finally, within the parametric model, processes will accept input data that is computed automatically by other processes. The graphical interface of Grasshopper is built around the concept of explicitly visualizing these events and structures the flow of data from left to right. One way of extending the possibilities for receiving input data is to create object classes with attributes to store various information. Using GhPython, these object attributes can be modified by any script component and the changes are reflected in any other component that accesses that object,[61] effectively short-circuiting the linear flow of the Grasshopper graph. In ≒4.4.3, we create a class for storing a list of properties about a topographic location its xyz-coordinates (:16), its position relative to other points (:17,18), and a number of analytic measurements (slope (:22), solar incidence (:24), proximity to external influences (:26)) as well as values that will be used later to define its role in the masterplan (:27). As the project develops complexity, new attributes and methods can be added by the designer at will. Conversely, some of this metadata may never be accessed or even assigned a value, but the object is still prepared to receive certain information.

§4.5 Forms of Output

Metadata and datastructures

For data that is going to continue playing an active role in the model, it is clearly necessary to make this information easy to retrieve and also to make sense of. This is especially important if one anticipates frequent reference from diverse sources within the code or at sporadic intervals as one can expect from complex and nonlinear processes of urban design. Saving location-based analyses as attribute data is convenient because one typically compares or synthesizes many features of a single location with one another. Keeping this information as metadata of a class ensures that the data for one location will not be mixed with that of another as a result of, for example, differently sized lists. Another strategy is to use the data's position within a datastructure to convey information or identify a set of data. Frequently, we will use an object's position within a list as an identifier such that other processes can access by means of the list index.[62] More explicit, is the dictionary datastructure[63] in which each value is entered alongside a key that can later be used to recall it. This key can take any value (provided it is unique within the dictionary). Constructing a class to extend the dictionary class allows Python scripts in Grasshopper to transfer data from one component to another without the need of reformatting in a native Grasshopper format. In the following examples we show how to construct such an extension of the *defaultdict* class[64] (≒4.5.1) and then how that class can be used to sort a list of topographic curves using their elevation as the key value (≒4.5.2).

57 "The planning tool was developed in parallel with the project and was meant to have acted as a design participant"
Gerber, "Towards a Parametric Urbanism." p159

58 Gerber categorizes the project as "pseudo-parametric" because the planning tool was uni-directional.
Gerber, "Parametric Practices." p102-103

59 *Ibid.* p104

60 Appendix.5.1 importing from a .csv text file, Appendix.6.1 importing from an image map, and Appendix.6.2 importing from an .osm text file.

61 The change will occur when the component is prompted to update by its explicit input parameters, thus requiring some coordination in the definition to prevent contradictory values.

62 *cf.* ≒5.4.1 *Half-Edge Mesh*

63 *https://docs.python.org/2/tutorial/datastructures.html*

64 The main distinction between *dict* and *defaultdict* is that the latter creates a key value automatically if one attempts to reference a key that doesn't yet exist in the dictionary. This is convenient when the values are lists as they are in ≒4.5.2 because we can move straight to the list functions (*.append* in (:13) for example) without first needing to check that the list exists.
https://docs.python.org/2/library/collections.html#collections.defaultdict

≒4.5.1 ghDefaultDict

```
0  INPUTS: None
from collections import defaultdict
import scriptcontext

#====================================================================#
5  class ghDefaultDict():
  """custom class:ghDefaultDict
  EX: myDict= scriptcontext.sticky['ghDefaultDict'](defaultdict()list)
  """

10   def __init__(self,defD):
    self.d= defD

  def ToString(self):
    strLen= str(len(self.d.keys()))
15     return ("ghDefaultDict with " + strLen + " keys")
#====================================================================#

scriptcontext.sticky["ghDefaultDict"]= ghDefaultDict
print(ghDefaultDict.__doc__)
20  OUTPUTS: None
```

Creates a new class allowing Python's *defaultdict* to be exchanged between Grasshopper script components directly without reformatting:

Reference: Benjamin Golder & Giulio Piacentino:

http://www.grasshopper3d.com/forum/topics/exchanging-basic-python-types-between-separate-python-components

Additional thanks to: Jason Lim:

http://www.grasshopper3d.com/forum/topics/trying-to-exchange-a-defaultdict-python?commentId=2985220%3AComment%3A1019226&xg_source=activity

01 import Python's *defaultdict*.

05 Begin new class definition, this must be placed in the code above the first instance of it being called.

06 Text to print when the *.__doc__* method is called (as in :18). Here, an identification of the class and a reminder of how to instantiate a new *ghDefaultDict*.

10 Instantiation operation includes a defaultdict in its arguments. This is accessed through the method *.d* (:11).

13 Method to print number of keys in a *ghDefaultDict*.

18 Save this class to sticky dictionary to be accessible to other script components.

≒4.5.2 dictTopoCurves

```
0  INPUTS: topoCrvs as List of Curve
import Rhino.Geometry as rhG
from collections import defaultdict
import scriptcontext

5  #====================================================================#
#fnct SORTS TOPO CURVES BY HEIGHT INTO A DICTIONARY
def SortCrvsToDictionary(crvList):
  #DICTIONARY (key=ELEVATION)
  crvDict= scriptcontext.sticky['ghDefaultDict']...
         (defaultdict(list))
10 
  for i, iCrv in enumerate(crvList):
    pt= rhG.Point3d(rhG.Curve.PointAt(iCrv,.5))
    crvDict.d[round(pt.Z)].append(iCrv)

15   return crvDict
#====================================================================#

#BODY OF CODE
srtdCrvs= SortCrvsToDictionary(topoCrvs)
20 
print(srtdCrvs.ToString())
print("KEYS:")
print(srtdCrvs.d.keys())
25 
pyDict= srtdCrvs
OUTPUTS: pyDict
```

Example of *ghDefaultDict* used to sort topography curves. The benefit of using *defaultdict* is that lists of curves can be saved to a single key—in this case, the curves' elevations, allowing convenient organization of topocurve sets with multiple peaks.

01 Import *Rhino.Geometry* module to access RhinoCommon

06 Define a function that creates a new *ghDefaultDict* for sorting topographic curves (:8). Like classes, functions must be located in the code above the line where they are called for the first time.

11 Loop through all input Curves (:10), and find a Point to evaluate for height (:11).

13 Save curve using the *.Z* value of Curve Point as the key (:12).

15 Functions return a value to the line they are called from (:19)

21 Print the *.ToString()* function: (≒4.5.1 :13)

23 Print the list of keys in *srtdCrvs.d*. Note that these are not sorted, but appear in the order that they were added to the *defaultdict*.

User feedback

Within the design process there is also the need for "some mediating series of mechanisms which operate on the messages sent between model and author."[65] Without a means for the model to communicate detailed information abut its state or processes, the designer has limited ability to interact with it in a meaningful way. The visual display of quantitative data is a necessary part of making informed decisions[66] when confronted with the amount of data which an urban model is likely to contain and the fact that active processes might be continuously altering this data only compounds the problem further.[67]

The Grasshopper environment is predisposed to visual representation of geometric forms in one window while displaying more technical information on the editing canvas. The divide between geometry preview and process operation sometimes makes it difficult to intuit the connection between the two and hinders the performance of the model as an interactive medium. Though a great deal of urban modeling can exist in a purely quantitative mode, the scale of urban design which is under discussion here involves spatial and formal data as an integral, even motivating influence on the success or failure of the model. The projects which we present will emphasize the presentation of quantitative measures as spatially differentiated as the properties of geometries or superimposed on them.

Datascapes

Such mapping of quantitative data over actual spatial information calls to mind the datascapes pioneered by MVRDV[68] in a method that seemed to elide the distinction between the forces shaping the project and its ultimate form or organization. Bart Lootsma describes datascapes as "visualizations of laws, rules, norms, and statistical probabilities, and as such they constitute representations of … bureaucratic systems where the trust in the system as well as the people, institutions and machines that represent it, lies in one's confidence in certain specialized expertise."[69] Datascapes are therefore ultimately rhetorical statements, "in that they image data in knowingly selective ways. They are designed not only to reveal the spatial effects of various shaping (e.g. regulatory, zoning, legal, economic, and logistical rules and conditions), but also to construct a particular eidetic argument."[70] As we have argued, the rhetorical dimension is a key aspect of a procedural model, when this is expressed through processes and behaviors, interaction and response rather than simply an image. This task requires going beyond the limits of the datascape, not simply to ground an authority based in sublimated pragmatics,[71] but as a constructed framework that enables the procedurality of the model to be expressed. An interactive model cannot pretend to embody the 'correct' results in itself, but must be enacted in coordination with a series of parameters and inputs that explore and invent the final form.

65 Zuelzke, "Digital Model-Making and the Encoding of Design Intent: Notes on the Computational Synthesis of Form." p60

66 Tufte, *Visual Explanations: Images and Quantities, Evidence and Narrative*.

67 The adoption of HTML5 has widened the field of experimentation with data visualization, prompting the adaptation of graphical methods to interactive processes. The biggest transformation being the possiblity to present large datasets in their macro context while allowing individual information to be selected and isolated to highlight specific details.

One exemplary visualization is this chart of job number timelines separated by industry and then plotted against their average wage values. The overall trends are visible, but each individual line graph can be selected and individual data values read off from within a pop-up frame that appears to highlight the graph and visually distinguish it from the background noise.

http://www.nytimes.com/interactive/2014/06/05/upshot/how-therecession-reshaped-the-economy-in-255-charts.html?abt=0002&abg=1

68 MVRDV, *FARMAX: Excursions on Density*.
MVRDV, *Metacity/Datatown*.
Amoroso, *The Exposed City: Mapping the Urban Invisibles*. Chapter 3

69 Lootsma, "The Diagram Debate, or the Schizoid Architect." p22

70 ssssssss71 MVRDV, *FARMAX: Excursions on Density*. p102

Customizing the display

The following code examples define methods for interrupting Grasshopper's default display pipeline and modifying how the program renders geometry previews. The first, *customLineDisplay*, addresses the display of curves (≑4.5.3) or line segments. It enables a lineweight function in addition to the display color, giving more expressive capability, useful in the creation of bar graphs, or simply for visual emphasis (Figure 4.5).[72] As a complement to this, *customMeshDisplay* (≑4.5.4) makes it possible to display texture and transparency maps on a mesh surface. This allows more visual differentiation of surfaces, or the use of notational textures such as a hatch pattern to denote material patterns or a gradient of intensity. The texture maps used in Figure 4.6 are tileable patterns registered to a global position, giving them a consistent continuity independent of the mesh position. In contrast, the pop-up screens, which are drawn in front of the geometry and oriented toward the view camera, have their image maps registered to a corner of the mesh so that the ideogram remains centered when the camera moves and the geometry is redrawn. The creation and positioning of these screens is detailed in (≑4.5.5).

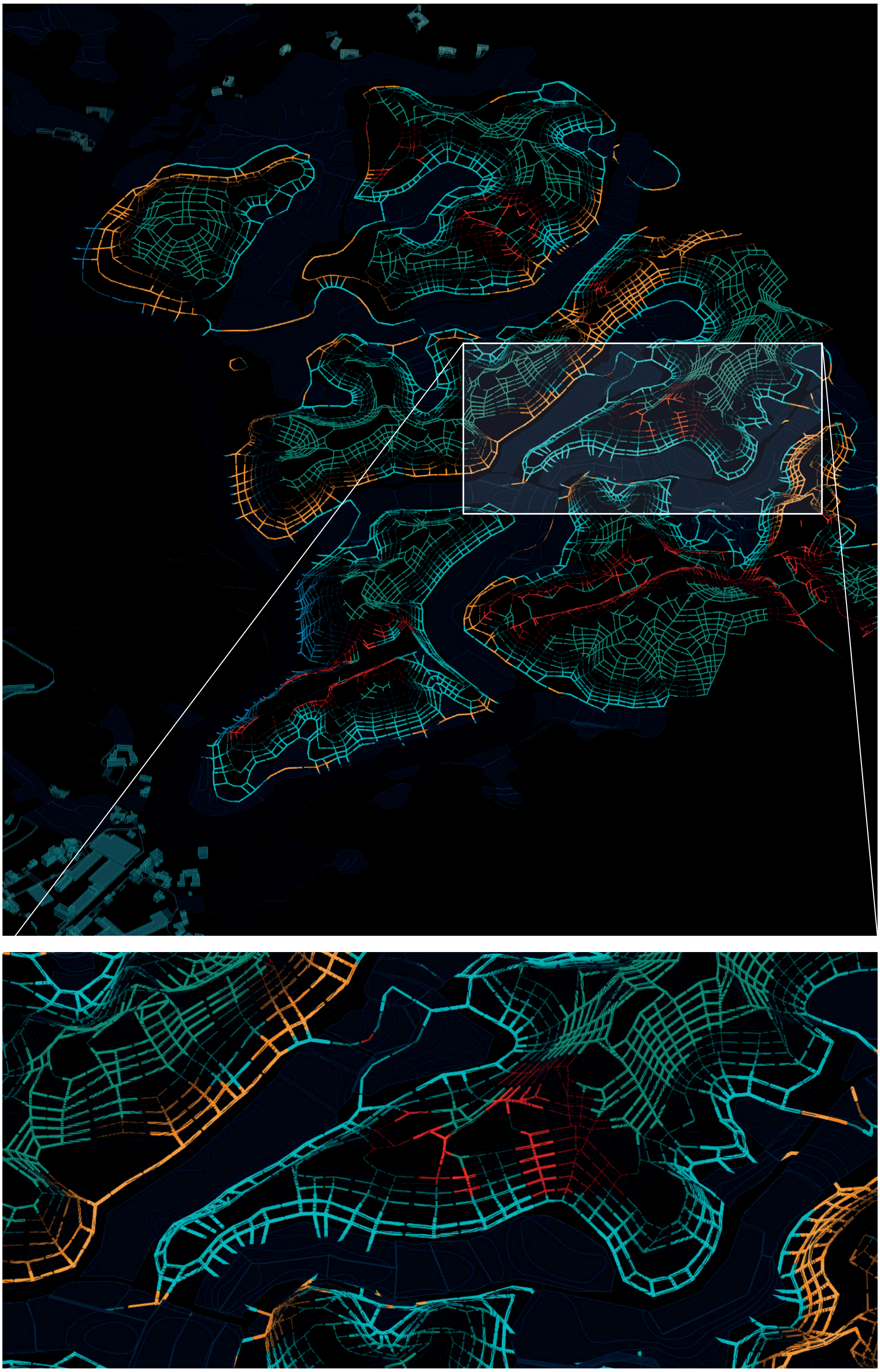
Archive

It will also occasionally be necessary to export data to a static form for archiving or to exchange with another program, for example to export geometry compatible with rendering software. The method of 'baking' geometry is a fundamental feature of Grasshopper and even the more customized baking operations are easily managed with available plug-ins, so this will not be covered here. Sometimes, in order to produce computationally intensive analyses, it is more convenient to record the data to an external file so that it can be analyzed in a separate operation. An example of this processs will be covered in Project 4 where a text file is created to save calculated values that will later be brought back into Grasshopper for visualization purposes and as active data reassociated with the model.[73]

72 Beyond the preview visualization, this method is also helpful for final documentation at high-resolutions where the default lineweights can become too faint to read clearly.

73 *cf.* §7.3a 'Network Depth'

Figure 4.5
This map assigns different colors to separate categories and a gradient of lineweights (in a range from 1-6) to intensities.



≒4.5.3 customLineDisplay

```
0     INPUTS: custDraw, crvs, c, w as Lists
      import Rhino as rh
      import Rhino.Display.DisplayPipeline as rhDisP

      #==================================================================#
5     class CustomObjectDraw():
        def __init__(self, drawCrvs):
          self.geometries= []

          for crv in drawCrvs:
10          #GET GEOMETRY FROM ID
            geoID= ghdoc.Objects.Find(crv).Geometry
            if (geoID != None):
              self.geometries.append(geoID)

15            #CALCULATE BOUNDING BOX FOR UPDATED OBJECTS
              self.UpdateGeometries(self, drawCrvs)

              #CALCULATE NEW DISPLAY BOUNDING BOX
              rhDisP.CalculateBoundingBox+= self.MyDisplayCalBBox
20
              #DRAW OBJECTS
              rhDisP.PostDrawObjects+= self.MyDisplayPostDrawObjects

              #THIS SHOULD REMOVE PREVIOUS CONDUITS
25            ghenv.Component.PingDocument+= self.RemoveHandler

        def UpdateGeometries(self, objects, Arg):
          self.temp_objects= []
          self.temp_objects_bbox= None
30
          for object in self.geometries:
            #UPDATE THE BOUNDING BOX
            temp_object = object

35          if(temp_object!=None):
              if self.temp_objects_bbox == None:  #FIRST OBJECT
                self.temp_objects_bbox= temp_object.GetBoundingBox(False)
            else:
              self.temp_objects_bbox= rh.Geometry.BoundingBox.Union( ...
...             self.temp_objects_bbox, temp_object.GetBoundingBox(False))
40            self.temp_objects.append(object)

        def RemoveHandler(self, sender, e):
          #REMOVE THE EXISTING CONDUIT
          rhDisP.PostDrawObjects-= self.MyDisplayPostDrawObjects
45        rhDispP.CalculateBoundingBox-= self.MyDisplayCalBBox

        def MyDisplayPostDrawObjects(self, sender, e):
          for i, geometry in enumerate(self.temp_objects):
            #ONLY CURVES
50          try: e.Display.DrawCurve(geometry, c[min(len(c)-1,i)], ...
...                w[min(len(w)-1,i)] )
            except: pass

        def MyDisplayCalBBox (self, sender , e):
             if (self.temp_objects_bbox != None):
55              e.IncludeBoundingBox(self)
      #==================================================================#

      def main():
        if len(crvs) > 0:
60        CustomObjectDraw(crvs)

      #==================================================================#
      #BODY OF CODE
      if custDraw:
65      main()
        print("Custom Display")
      else: print("Typical Display")
      OUTPUTS: None
```

Replaces the default display pipeline for given curves allowing customization of colors and lineweight.

Reference: Mostapha Sadeghipour Roudsari:

http://www.grasshopper3d.com/forum/topics/how-to-remove-objects-drawn-by-displaypipeline-postdrawobjects-in?commentId=2985220%3AComment%3A726699

based on the example 'starMaker' by Steve Baer:

http://python.rhino3d.com/entries/42-StarMaker-An-advanced-sample

(Note: this link no longer exists.)

01 import Python modules. *Rhino.Display.DisplayPipeline* namespace contains the event handlers for geometry previewing.

06 This class manages the events of drawing geometry within the display pipeline and overriding the default display (:**25**).

50 This script will only work on Curves, other geometry included in *crvs* will be ignored (:**52**). If the geometry, color, and lineweight lists (*crvs*, *c*, *w*) are not of the same length, the script will use the 'longest list' matching method by repeating the last entry of the shorter list (this allows, for example, a single color or lineweight to be input, in place of a long list of identical values).

65 The boolean input *custDraw* must be *True* for the display to preview. Similarly, it must be *False* to hide the display or the component must be disabled. Simply setting the Python script component to 'Preview Off' will not remove the preview. Neither will switching to a different definition or closing (without unloading) the Grasshopper window.

≒4.5.4 customMeshDisplay

```
0    INPUTS: custDraw, pts, select, xy, fD, fA, c, t, wires, lnwt, refresh
     import Rhino as rh; import Rhino.Geometry as rhG
     import Rhino.RhinoDoc as doc
     import rh.Display.DisplayPipeline as rhDisP
...
40   #=====================================================================#
     class CustomObjectDraw():
       def __init__(self, drawMesh):
         self.geometries= []
         drawMesh= CustomObjectCreate(pts,xy,sel).meshes
45
         for mesh in drawMesh:
           #ADD GEOMETRY INTO SELF
           self.geometries.append(mesh)

50       #CALCULATE BOUNDING BOX FOR UPDATED OBJECTS
         self.UpdateGeometries(self, drawMesh)

         #CALCULATE NEW DISPLAY BOUNDING BOX
         rhDisP.CalculateBoundingBox += self.MyDisplayCalBBox
55
         #DRAW OBJECTS
         rhDisP.PostDrawObjects += self.MyDisplayPostDrawObjects

         #THIS SHOULD REMOVE PREVIOUS CONDUITS
60       ghenv.Component.PingDocument += self.RemoveHandler

       def UpdateGeometries(self, objects, Arg):
         self.temp_objects= []
         self.temp_objects_bbox= None
65
         for object in self.geometries:
           #UPDATE THE BOUNDING BOX
           temp_obj= object
           if(temp_obj != None):
70           if self.temp_objects_bbox == None: #FIRST OBJECT
               self.temp_objects_bbox= temp_object.GetBoundingBox(False)
             else:
               self.temp_objects_bbox= rhG.BoundingBox.Union( ...
...                 self.temp_objects_bbox, temp_obj.GetBoundingBox(False))
               self.temp_objects.append(object)
75
       def RemoveHandler(self, sender, e):
         #REMOVE THE CONDUIT
         rhDisP.PostDrawObjects -= self.MyDisplayPostDrawObjects
         rhDisP.CalculateBoundingBox -= self.MyDisplayCalBBox
80
       def MyDisplayPostDrawObjects(self, sender, e):
         for i,geometry in enumerate(self.temp_objects):
           newmat= rh.Display.DisplayMaterial()
           newmat.Diffuse= c[min(len(c)-1,i)]
85         newmat.Transparency= t[min(len(t)-1,i)]

           #ASSIGN TEXTURE MAPS TO SELECT MESHES
           if i in select:
             newmat.SetBitmapTexture(fD[min(len(fD)-1,i)],True)
90           newmat.SetTransparencyTexture(fA[min(len(fA)-1,i)],True)

           #ONLY WORKS ON MESHES
           try: e.Display.DrawMeshShaded(geometry,newmat)
           except: pass
95         if wires: e.Display.DrawMeshWires(geometry, ...
...                          c[min(len(c)-1,i)],lnwt[min(len(lnwt)-1,i)])
           rh.Display.DisplayMaterial.Dispose(newmat)

       def MyDisplayCalBBox (self, sender , e):
100      if (self.temp_objects_bbox != None):
           e.IncludeBoundingBox(self)
     #=====================================================================#

     def main():
105    if len(geo) > 0:
         CustomObjectDraw(ps,xy,select)

     #=====================================================================#
     if custDraw:
110    main()
       print("Custom Display")
     else: print("Typical Display")
     OUTPUTS: None
```

Replaces the default display pipeline for given meshes allowing customization of colors and texture maps (transparency and bitmap).

44 Calls the *CustomObjectCreate* class to create the pop-up screen, *cf.* ≒4.5.5.

83 Create a new display material.

84 Assign the diffuse and the transparency (:85) values to the material from input lists *c* and *t*.

89 For select meshes (full size screens, the rest are small arrows) assign bitmap and transparency (:90) maps from input lists *fD* and *fA*.

93 Mesh faces and edges are drawn separately. Edges can be drawn with variable lineweights by *e.DisplayDrawMeshWires()* or omitted (:95).

≒4.5.5 createPopUpScreen

```
5    ...
     #===================================================================#
     class CustomObjectCreate():
        def __init__(self, anchors, size, sel):
           vwpt= doc.ActiveDoc.Views.ActiveView.ActiveViewport
10         oPln= vwpt.GetFrustumNearPlane()[1]

           self.meshes= []
           for i,pt in enumerate(anchors):
              dim= 6
15
              if i in sel: dim= size
              xVal= (dim/2)*1.5
              rectX= (0,10,xVal,xVal,-xVal,-xVal,-10)
              rectY= (-10,-20,-20,-20-dim,-20-dim,-20,-20)
20
              pL= rhG.Polyline(4)
              scrPt= vwpt.WorldToClient(pt)

              for x,y in zip(rectX,rectY):
25               diagPt= (vwpt.ClientToWorld(scrPt+rhG.Point2d(x,y)))
                 pL.Add(diagPt.PointAt(.99))
              pL.Add(pL[0])
              m= rhG.Mesh.CreateFromClosedPolyline(pL)
              oPln.Origin= pL[2]
30            mapping= rh.Render.TextureMapping.CreatePlaneMapping(oPln, ...
...              rhG.Interval(0,7.5),rhG.Interval(0,7.5),rhG.Interval(0,7.5))
              if i in sel:
                 w= pL[2].DistanceTo(pL[5])
                 h= pL[2].DistanceTo(pL[3])
                 mapping= rh.Render.TextureMapping.CreatePlaneMapping( ...
...                 oPln,rhG.Interval(0,w),rhG.Interval(0,h),rhG.Interval(0,w))
35
                 m.TextureCoordinates.SetTextureCoordinates(mapping)
                 self.meshes.append(m)
     #===================================================================#
     ...
```

Draws meshes to the camera frustum as an information graphic display.

Reference: Human plugin, Render Mesh to Screen

http://www.food4rhino.com/project/human

05 This code exists in the same GhPython component as ≒**4.5.4**.

10 Get the plane of the near face of the frustum from the active viewport.

14 The vertical dimension of the pop-up screen, *dim*, has a default size 6, which will draw an arrow.

18 The relative x- and y-coordinates (:**19**) of the pop-up screen perimeter points in pixels. Note that screen y-coordinates count downward from the top so lower y-values are higher on the screen.

22 Collect the screen position of the anchor point *pt*.

25 To define the mesh perimeter points, find their screen postion (relative to *scrPt*) and project back into 3d space. This returns a diagonal line along the ray of the camera projection that will be seen as a point.

26 Select a point on that line very, very close to the near frustum and save it to the polyline that will define the perimeter.

29 Reassign the origin of *oPln* to the corner of the pop-up screen so that the texture maps can be calibrated to display properly

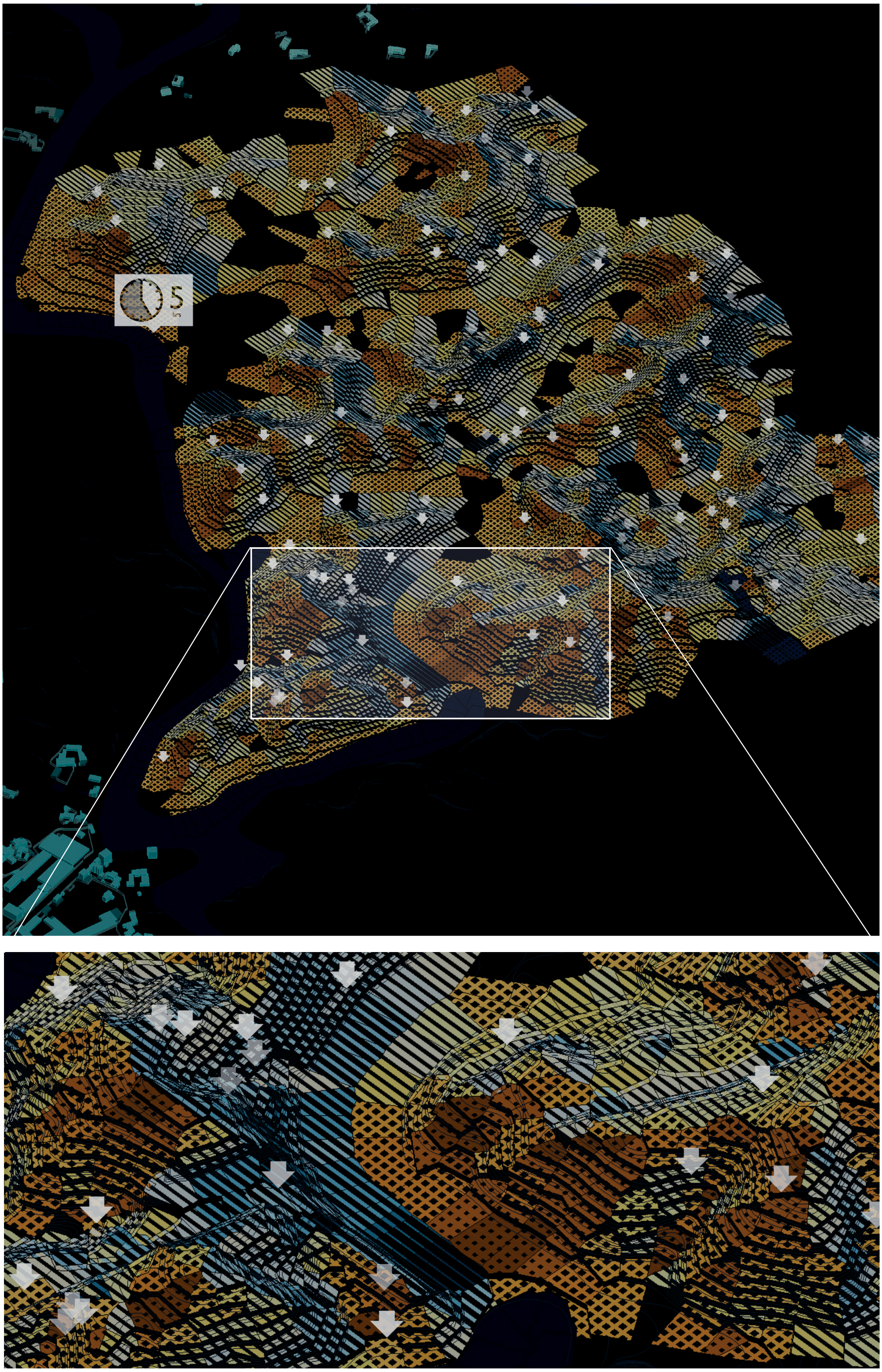
32 Calculate the width and height (:**33**) of the pop-up screen.

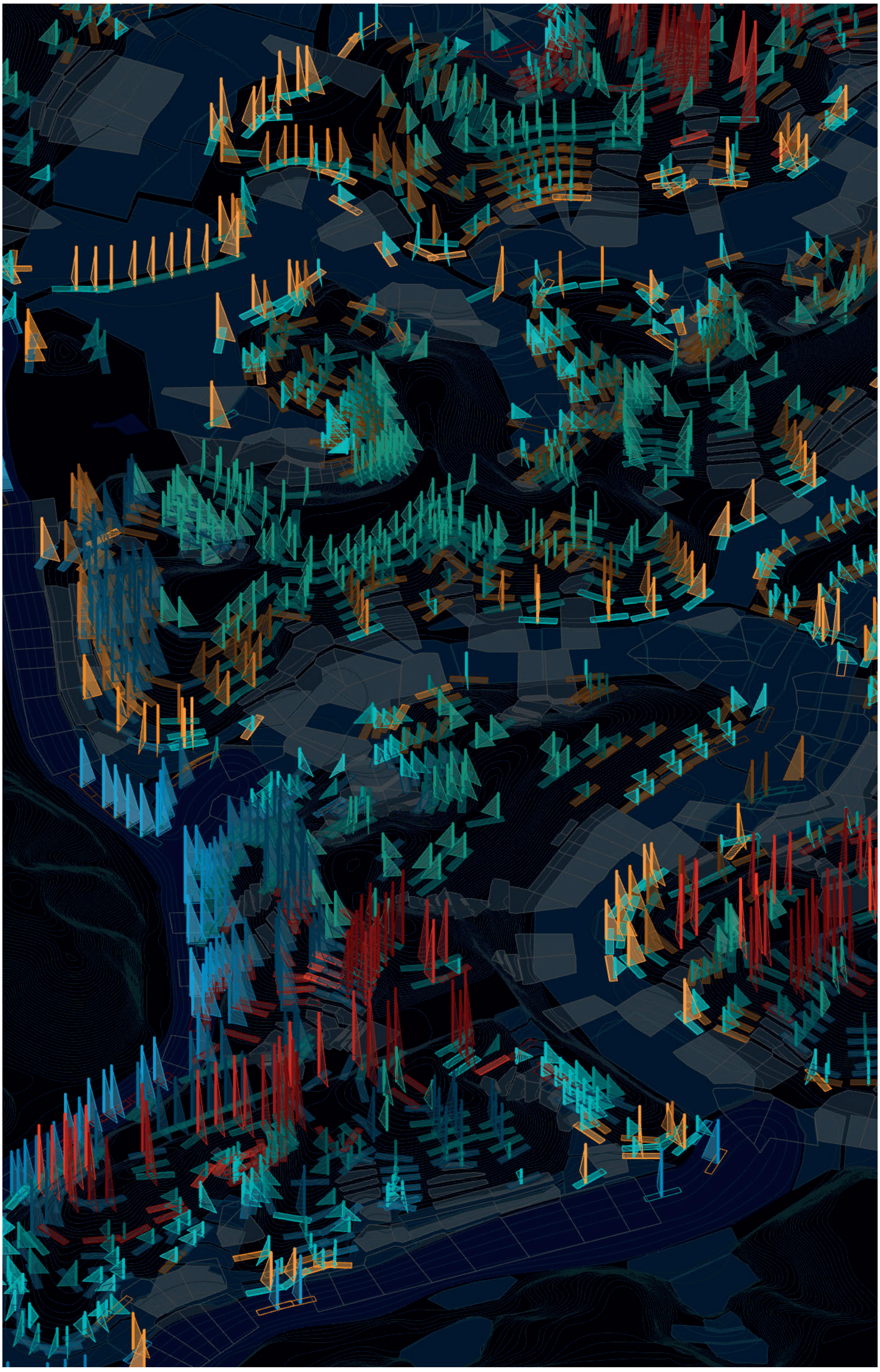
34 Create a TextureMapping using *oPln* for orientation and the mesh width and height for scale. Non-selected meshes (*i* not in *sel*) will not have a texture map, so the scale is irrelevant and filled with a default value.

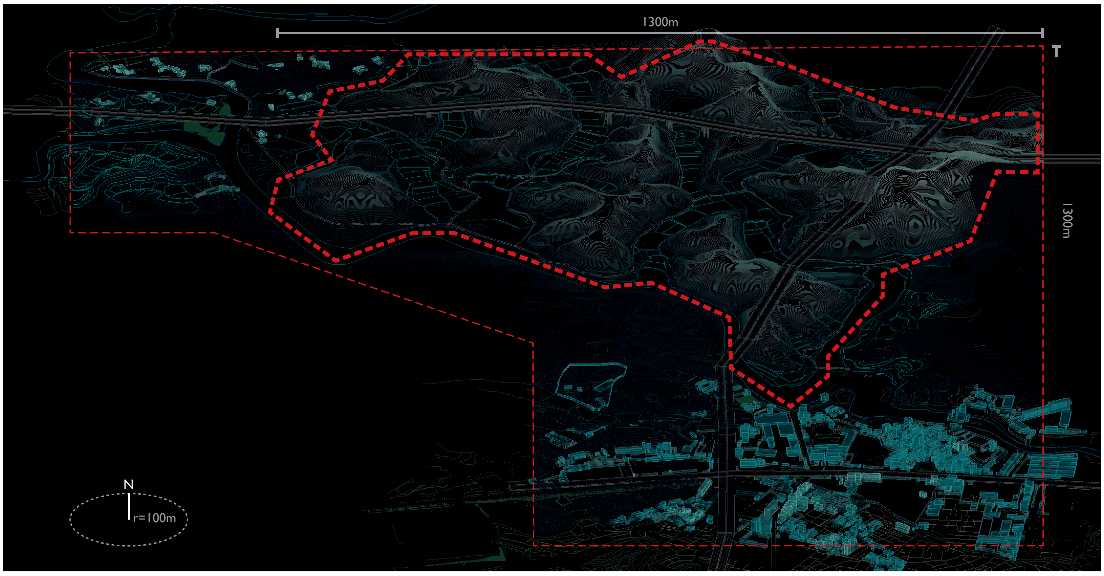
36 Assign the TextureMapping to the mesh.

Figure 4.6

A gradient of hatches combined with color value displaying the hours of solar incidence *.solHrs* (≒**4.4.3**, : **24**). The popup screens are located at random, selecting one of them, draws a large screen showing the hours of direct sunlight at that location.


5
hrs





Project 1: Meshes (Leshan)

This project is located to the northwest of Leshan in Sichuan province, approximately 140 km south of Chengdu. The site is currently covered with small, but very steep hills averaging between 40 and 50 meters tall.[74] Between the hills are extensive rice paddies. The intent of this design exercise is to inscribe a mesh that organizes contextual inputs into a guide that defines urban orientations and the location of building volumes in alignment with ecological forces as an alternative to the imposition of a modernist grid. Special attention is given to the hydrology[75] of the site and the attempt to integrate new construction alongside productive agricultural land. This motivates the use of the hillsides as the primary building zones, leaving the rice paddies below intact.[76]

The result is a multilayered meshwork that responds to different concerns. One layer addresses building orientation, another erosion control, another access and circulation. Each layer is derived from the same environmental data, however it is filtered through differing criteria and assessed by different values. The sensitiviry to one input or another can be adjusted and a new set of meshes produced through various interactive methods, many of which will reappear in the following projects as well.

74 Leshan site data courtesy of Turenscape.
Base vector map of China above (and in subsequent chapters) via WikiMedia (user Wlongqi).
Source: http://commons.wikimedia.org/wiki/File:China_Blank_Map_with_Province_Names.svg

75 Yu, "China's Water Crisis."

76 Yu, "Beautiful Big Feet: Toward a New Landscape Aesthetic."

Figure 4.7
Detail of Project 1: localized orientation vectors

Figure 4.8
Site condition and boundary

Figure 4.9
Orthophoto of Leshan from Google Maps

§4.6 Positioning

Differentiation and specification

The foundation of the project is to construct a geometric armature of points, anchors from which subsequent operations can be launched. As we established earlier, the initial move may be arbitrarily chosen,[77] but, once incorporated into the sequence, will resonate through contingently implicated relationships.[78] Logically, the first operation should identify a distinguishing feature of the available data and make explicit the many ways which that data is differentiated. The distinguishing feature of this site in Leshan is the topography, represented in the file as topographic curves cut at one meter increments.

Adaptive pointcloud

The irregularity of the ground, however, does pose a challenge. The slope descends in every direction, with saddle points, plateaus, and concave recesses. The topographic curves are wildly different lengths, with no common alignment, so subdivision of these curves into points produces a very poor coverage of the site. To account for the complexity of this ground and to attempt to incorporate such complexity in the results, this project begins by calculating lines of flow down the steepest paths of the hillsides. This now familiar method[79] is commonly used in landscape urbanism projects as a regulating line in much the same way as Peter Eisenman once used superimpoesd traces,[80] as a dense set of lines whose intersections and orientations contribute to generative geometries. This use was largely limited to a visual application, as the convergence of lines was not in any sense controlled or interrelated. The method in ≒4.6.1 improves on this by giving the code the ability to collapse traces into a single path when they grow too close (:176, 190, 195) and to insert new traces when they diverge too far from their neighbors (:53), yielding a much more complete site coverage (Figure 4.10). Additionally, each point is sorted among adjacent points on the same level and related to the points above and below it on the same trace through the *.src* and *.trgt* pointers in the *TopoPoint* class (≒4.4.3). The result is a very adaptive pointcloud with control over density averages and extrema that is highly indexed. The illustrations that follow feature an iteration with around 5,600 points, stepping down the hillsides in four meter increments initially spaced 10 meters apart horizontally. The traces are adjusted whenever the spacing expands to more than twice or compresses to less than half this measurement.

77 *cf.* §4.3a 'Prepositional mode of being'

78 One calls to mind Peirce's characterization of formal systems as "quasi-necessary."

Peirce, "Logic as Semiotic: The Theory of Signs." p98

79 The first proper example of this method that I am aware of comes from Jorge Ayala's diploma project in the AA Landscape Urbanism Programme: 'Ecotransitional Urbanism' 2008-2009:

http://www.ayarchitecture.com/ecotransitional-urbanism

We had independently began using it during the Fall 2010 *Organicités* studio.

It has probably received the most widespread attention through the work of GroundLab (e.g. 'Recovering Landscapes' 2012) and the workshops of Eduardo Rico and Enriqueta Llabres.

80 Bédard, *Cities of Artificial Excavation: The Work of Peter Eisenman*, 1978-1988.

≒4.6.1 TopoFlow

```
0    INPUTS: topoDict, topoRng as Interval, topoInt, divDist, maxSpan,
...  maxAng, adjBool as List of Boolean, adjRto as List of Float
     import Rhino as rh; import Rhino.Geometry as rhG
     import Grasshopper as gh
     from Grasshopper.Kernel.Data import GH_Path
     import scriptcontext; from collections import defaultdict
5    import math

     #=================================================================#
...  class TopoPoint:  <...>
     #=================================================================#
35
     #fnct CHECKS ANGLE TO NEXT POINT
     def CheckAngle(pt0,pt1,pt2,testPt):
        vecTan= rhG.Vector3d(pt2.xyz-pt0.xyz)
        vecDir= rhG.Vector3d(testPt-pt1.xyz)
40      ang= rhG.Vector3d.VectorAngle(vecTan,vecDir)
        return ang

     #fnct SAVES POINTS TO DICTIONARY AND SETS src/trgt
     def SetPoints(dict,i,j,pt,ct,boolC):
45      dict[i][j].append(TopoPoint(pt.xyz, pt.src, boolC, pt.aggr, pt.tan))
        ijPth= GH_Path(i,j)
...     segTree.Add(rhG.Line(dict[pt.src[0]][pt.src[1]][pt.src[2]].xyz, ...
                   pt.xyz),ijPth)
        #ADJUST PREVIOUS LEVEL .trgt
        dict[pt.src[0]][pt.src[1]][pt.src[2]].trgt=(i,j,ct)
50      return True

     #fnct ADDS POINTS ON SUBCURVE
     def InsertPoints(crv,dir,tVal):
        ptList=[]
55
        #SIMPLE CASE
        if dir:
           subCrv= crv.Trim(rhG.Interval(tVal[0],tVal[1]))
           subCt= int(subCrv.GetLength()//divDist)
60         if subCt > 0:
              subDivT= subCrv.DivideByCount(subCt,False)
              subDivPt= map(subCrv.PointAt,subDivT)
              subDivTan= map(subCrv.TangentAt,subDivT)

65            for m in range(1,len(subDivPt)-1):
                 ptList.append((subDivPt[m],subDivTan[m]))

        #COMPLEX CASES
        else:
70         #CHECK IF CURVE IS CLOSED OR NOT
           if crv.IsClosed:
...           subCrv= map(crv.Trim, [rhG.Interval(tVal[0],1), ...
                             rhG.Interval(0,tVal[1])])
              jnCrv= rhG.Curve.JoinCurves(subCrv)
              subCt= int(jnCrv[0].GetLength()//divDist)
75
              if subCt > 0:
                 subDivT= jnCrv[0].DivideByCount(subCt,False)
                 subDivPt= map(jnCrv[0].PointAt,subDivT)
                 subDivTan= map(jnCrv[0].TangentAt,subDivT)
80
                 for m in range(1,len(subDivPt)-1):
                    ptList.append((subDivPt[m],subDivTan[m]))
           else:
              #OPEN CURVE
85            #GET INTERVAL FROM POINT TO END
              subCrv= crv.Trim(rhG.Interval(tVal[0],tVal[1]))

              if subCrv:
                 subCt= int(subCrv.GetLength()//divDist)
90               if subCt > 0:
                    subDivT= subCrv.DivideByCount(subCt,False)
                    subDivPt= map(subCrv.PointAt,subDivT)
                    subDivTan= map(subCrv.TangentAt,subDivT)

95                  for m in range(len(subDivPt)-2, 0, -1):
                       ptList.append((subDivPt[m],subDivTan[m]))
        return ptList
     #=================================================================#
```

Calculates the path continuously perpendicular to a series of topographic curves: uphill, this gives the steepest climb; downhill, the path of water runoff over a landscape.

01 Import Python modules

07 *TopoPoint* class: code elided, see ≒**4.4.3**

37 A function to calculate the angle between the current slope tangent and the next possible point. Angles near 90° occur on a constant slope, extremely acute or obtuse angles suggest landscape anomolies that must often be removed or adjusted for.

44 A function that saves points to the dictionary as *TopoPoints*, while setting preliminary associated values.

45 Because the *.trgt* value has not yet been calculated, the *TopoPoint* is instantiated with a boolean value. After rows are added, the previous rows' *.trgt* values are updated accordingly (:**48**)

47 This function also creates lines in the dataTree of geometry, *segTree* for preview display.

53 This function handles exceptions where new source points need to be added into the list because adjacent paths have diverged too far from one another (relative to *maxSpan*).

57 Rhino's handling of curve geometry introduces discontinuities in the parameter (*t*-) space of curves at the endpoints, even on closed curves. The simplest condition is when the interval needing new source points is located entirely on the interior of the curve with no discontinuities.

Complex conditions occur when the interval crosses the endpoints, for which separate strategies are needed for closed (:**70**) and open (:**84**) curves.

```
100  def main(srtdCrvs,ptD):
       #LOOP THROUGH CURVES AT INITIAL ELEVATION
       for j, jCrv in enumerate(srtdCrvs[zSt]):
         ptD.d[zSt].append([])
         kCt= int(jCrv.GetLength()//divDist)
105      rhDivT= jCrv.DivideByCount(kCt,False)
         rhDivPt= map(jCrv.PointAt,rhDivT)
         rhDivTan= map(jCrv.TangentAt,rhDivT)

         for k, kPt in enumerate(rhDivPt):
110        ptD.d[zSt][j].append(TopoPoint(kPt,False,True,.05,rhDivTan[k]))

       #LOOP FROM ELEVATION (i) TO NEXT ELEVATION (i+topoInt)
       for i in range(zSt,zEn-topoInt,topoInt):
         tmpPts= []
115      #LOOP THROUGH CURVES ON NEXT LAYER AND PREPARE EMPTY LISTS
         for m, mCrv in enumerate(srtdCrvs[i+topoInt]):
           ptD.d[i+topoInt].append([])
           tmpPts.append([])

120      #NOW LOOP THROUGH CURVES AT CURRENT ELEVATION
         for j, jLst in enumerate(ptD.d[i]):
           #LOOP THROUGH POINTS ON CURVE
           kCt= len(jLst)
           for k, kPt in enumerate(jLst):
125
           #SEARCH FOR NEXT POINT IN PATH
             if kPt.trgt:
               #FIND CLOSEST POINTS ON EACH OF NEXT CURVES
               kCPts= []    #LIST HOLDS CLOSEST POINTS ON MULTIPLE CURVES
130            dupSrtdCrvs=srtdCrvs[i+topoInt]
               for m, mCrv in enumerate(dupSrtdCrvs):
                 cT=mCrv.ClosestPoint(kPt.xyz)
                 cPt=mCrv.PointAt(cT[1])

135              #SAVE AS TUPLE: (DISTANCE, INDEX, POINTS, tVAL)
                 kCPts.append((cPt.DistanceTo(kPt.xyz),m,cPt,cT[1]))

               #FIND CLOSEST FROM SET OF kCPts
               kCPts.sort()
140
               #ADD CLOSEST POINT TO tmpPts IF dist<maxSpan
               if (kCPts[0][0]<maxSpan):
                 if kCPts[0][2] is not None:
                   #CHECK VECTOR ANGLE
145                ang= CheckAngle(jLst[(k-1)%kCt], ...
...                            kPt,jLst[(k+1)%kCt],kCPts[0][2])
                   if abs(ang-(math.pi/2))<(math.pi*maxAng) or kCt<3:
                     tanVec= rhG.Vector3d( ...
...                      dupSrtdCrvs[kCPts[0][1]].TangentAt(kCPts[0][3]))

                     tmpPts[kCPts[0][1]].append(TopoPoint(kCPts[0][2],...
...                      (i,j,k),False,kPt.aggr+(kCPts[0][0]*.05),tanVec))
150                else:
                     kPt.trgt=False

         #LASTLY WITHIN i-LOOP, CHECK PROXIMITY BETWEEN NEIGHBORS
           for j, jLst in enumerate(tmpPts):
155          kCt= len(jLst)
             trgtCt= 0
             skipDbl= -10

             dupSrtdCrvs= srtdCrvs[i+topoInt]
160          srtdPts= [(t[1],n) for n,t in enumerate(...
...           map(dupSrtdCrvs[j].ClosestPoint, (pt.xyz for pt in jLst) ))]
             srtdPts.sort()

             #LOOP THROUGH POINTS IN tmpPts
             for k, kX in enumerate(jLst):
165            kPt= jLst[srtdPts[k][1]]
               kPrev= srtdPts[(k-1)%kCt][1]
               kNext= srtdPts[(k+1)%kCt][1]
               #CHECK SPACING AND SAVE tmpPts
               distCk= [kPt.xyz.DistanceTo(jLst[kPrev].xyz), ...
...                     kPt.xyz.DistanceTo(jLst[kNext].xyz)]
```

100 The function *main()* executes the bulk of the analysis. The *ghDefaultDict* of *TopoPoints* goes by the variable name *ptD* within this function. The dictionary is at the method *.d* as it was defined in the sticky class.

126 The next layer could have more than one topography curve, so the script must calculate the closest point from each (loop at :131) and then check that the nearest in this set is within the distance threshold (:142) and the angle threshold (:146).

150 If no point fits the criteria, change the *TopoPoint*'s *.trgt* value to *False* to signal the end of a path.

160 This is a complicated line of code for those not familiar with the condensed style of Python. The *map()* tool in Python runs a function—here *.ClosestPoint()*—on a list (or other sequence) without having to invoke loop syntax.

Because this function takes a Point3d and the list *jList* contains a different datatype, *TopoPoints*, the sequence field is filled with a generator expression that extracts the Point3d at *.xyz* from each *TopoPoint* (a generator expression operates like a list comprehension but returns each element individually instead of a list of all elements and is denoted by parentheses rather than braces).

The list returned by the *map()* operation is then itself used as the basis of a list comprehension that makes a tuple of the t-Value, *t[1]*, of the calculated closest point and its index within the list, *n* (which corresponds to its position in *jLst*).

161 By sorting the resultant list of tuples, the points can all be referenced in sequential order along the curve regardless of the order they were added (:196, :197).

```
170         #ENOUGH SPACE ON BOTH SIDES: ADD PT AS CONTINUOUS
            if (distCk[0] > divDist*adjRto[0] and ...
...                 distCk[1] > divDist*adjRto[0]) or not adjBool[0]:
              SetPoints(ptD.d,i+topoInt,j,kPt,trgtCt,True)
              trgtCt+=1

175         #ONLY PREVIOUS POINT TOO CLOSE
            elif (distCk[1] > divDist*adjRto[0]):
              if not skipDbl == srtdPts[k][1]:
                halfPt= rhG.Point3d((kPt.xyz+ jLst[kPrev].xyz)/2)
                transF= kPt.aggr+jLst[kPrev].aggr
180             avgVec= rhG.Vector3d((kPt.tan+jLst[kPrev].tan)/2)
                ptD.d[i+topoInt][j].append( ...
...                      TopoPoint(halfPt,False,True,transF,avgVec))
                trgtCt+= 1
                #REMOVE aggr FROM NEIGHBORS
                ptD.d[i+topoInt][j][trgtCt-2].aggr= .01
185             kPt.aggr= .01
                SetPoints(ptD.d,i+topoInt,j,kPt,trgtCt,False)
                trgtCt+= 1

            #ONLY NEXT POINT TOO CLOSE
190         elif (distCk[0] > divDist*adjRto[0]):
              SetPoints(ptD.d,i+topoInt,j,kPt,trgtCt,False)
              trgtCt+= 1

            #BOTH POINTS TOO CLOSE
195         else:
              kPt.aggr+= (jLst[kPrev].aggr+jLst[kNext].aggr)
              SetPoints(ptD.d,i+topoInt,j,kPt,trgtCt, True)
              trgtCt+= 1
              #REMOVE aggr FROM NEIGHBORS
200           ptD.d[i+topoInt][j][trgtCt-2].aggr= .01
              jLst[kNext].aggr= .01
              skipDbl= kNext


205       #TOO MUCH SPACE UNTIL NEXT POINT
          if (distCk[1] > divDist*adjRto[1]) and adjBool[1]:
            newPts= []
            del newPts[:]

210         #DIRECTION OF COUNT WILL ALWAYS BE IN DIRECTION OF CURVE
            t1= 0; t2= 0
            t1= dupSrtdCrvs[j].ClosestPoint(kPt.xyz)
            t2= dupSrtdCrvs[j].ClosestPoint(jLst[kNext].xyz)

215         #FIX SIMPLE tVal==0/1 CONFUSION
            if t2[1] == 0: t2= (True, 1)

            if t1[1]<t2[1]:  #SIMPLE (SPAN DOES NOT CROSS ENDPOINT)
              newPts=InsertPoints(dupSrtdCrvs[j],True,(t1[1],t2[1]))
220           #INSERT POINTS RETURNS LIST OF DOUBLES (Pt, Tan, Vec)

            else:       #COMPLEX (SPAN CROSSES ENDPOINT)
              newPts= InsertPoints(dupSrtdCrvs[j],False,(t1[1],t2[1]))

225         for m, mPt in enumerate(newPts):
              ptD.d[i+topoInt][j].append(TopoPoint(mPt[0], ...
...                      False,True,.05,mPt[1]))
              trgtCt+= 1

      #CHECK FOR CURVES WHICH HAVEN'T BEEN INTEGRATED YET
230   for j, jCrv in enumerate(srtdCrvs[i+topoInt]):
        if len(ptD.d[i+topoInt][j]) == 0:
          kCt= max(int(jCrv.GetLength()//divDist),2)

          rhDivT= jCrv.DivideByCount(kCt,False)
235       rhDivPt= map(jCrv.PointAt,rhDivT)
          rhDivTan= map(jCrv.TangentAt,rhDivT)
          for k, kPt in enumerate(rhDivPt):
            ptD.d[i+topoInt][j].append(TopoPoint(kPt, ...
...                                      False,True,.05,rhDivTan[k]))
   return ptD
```

173 If the spacing between the current point and its neighbors to either side falls within the accepted range, the point is saved to the dictionary (:44).

175 When only the previous point is too close to the current point, add a new source point halfway between the two (:208) with the combined *.aggr* value (:209) and an averaged tangent vector *.tan* (:210).

To prevent confusion, the other points' *.aggr* values are reduced to ≈0 (:214, 215) and the current point is saved as a discontinuous point at the end of a path (*.trgt* value *False)*.

189 When only the next point is too close to the current point, this point is saved as a discontinuous point.

194 When the points on both sides of the current point are too close, the center point is kept continuous, but it takes on the sum of the three *.aggr* values (:226), while both neighbors are reset to ≈0 and marked discontinuous (:230, 231).

202 *skipDbl* is a variable that alerts the code that the point at index *kNext* has already been accounted for to prevent it from thinking it should be reprocessesd as a previous-point-too-close case (:207).

206 When too much space exists between two points the *InsertPoints* function (:53) is called to generate new source points in the gap.

213 Finally, some curves—local maxima or minima—may not have been reached by any of the existing paths and need to be added into the dataset.

```
270 #====================================================================#
271 #BODY OF CODE
272    #SET DIRECTION OF FLOW FROM topoInt
273 zSt = int(topoRng[0]); zEn=int(topoRng[1]+1)
274 if (topoInt<0):
275    zSt=int(topoRng[1])
276    zEn=int(topoRng[0]-1)
277 
278    #DICTIONARY (key=ELEVATION, value=LIST BY CURVE (points nested))
279 ptDict=scriptcontext.sticky['ghDefaultDict'](defaultdict(list))
280 segTree=gh.DataTree[rhG.Line]()
281 
282    #TEST THAT topoDict IMPORTS CORRECTLY
283 print("Landscape spans "+ str(len(topoDict.d.keys())) + " meters")
284 
285    #main FUNCTION TAKES DICTIONARY OF SORTED TOPO CURVES
286 mainReturnDict= main(topoDict.d, ptDict)
287 
288 
289    #PYTHON FORMATTED OUTPUT
290 pyDict= mainReturnDict
291     #GH FORMATTED OUTPUTS
292 pts= DataTreeFromIJKDict(mainReturnDict.d,0)
293 aggr= DataTreeFromIJKDict(mainReturnDict.d,3)
294 trgt= DataTreeFromIJKDict(mainReturnDict.d,2)
295 segs= segTree
OUTPUTS: pyDict, pts, aggr, trgt, segs
```

273 This sets the direction of analysis (uphill or downhill).

279 Initializing the *ghDefaultDict* from the sticky class.

286 Call the function *main()*.

292 For the sake of brevity the trivial function *DataTreeFromIJKDict()* has been omitted from this text; ≒4.7.1 (:41) includes a similar function using list comprehensions.

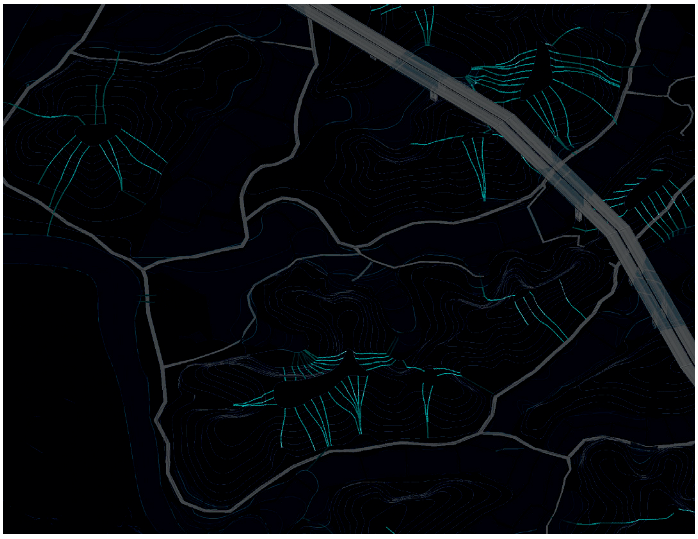
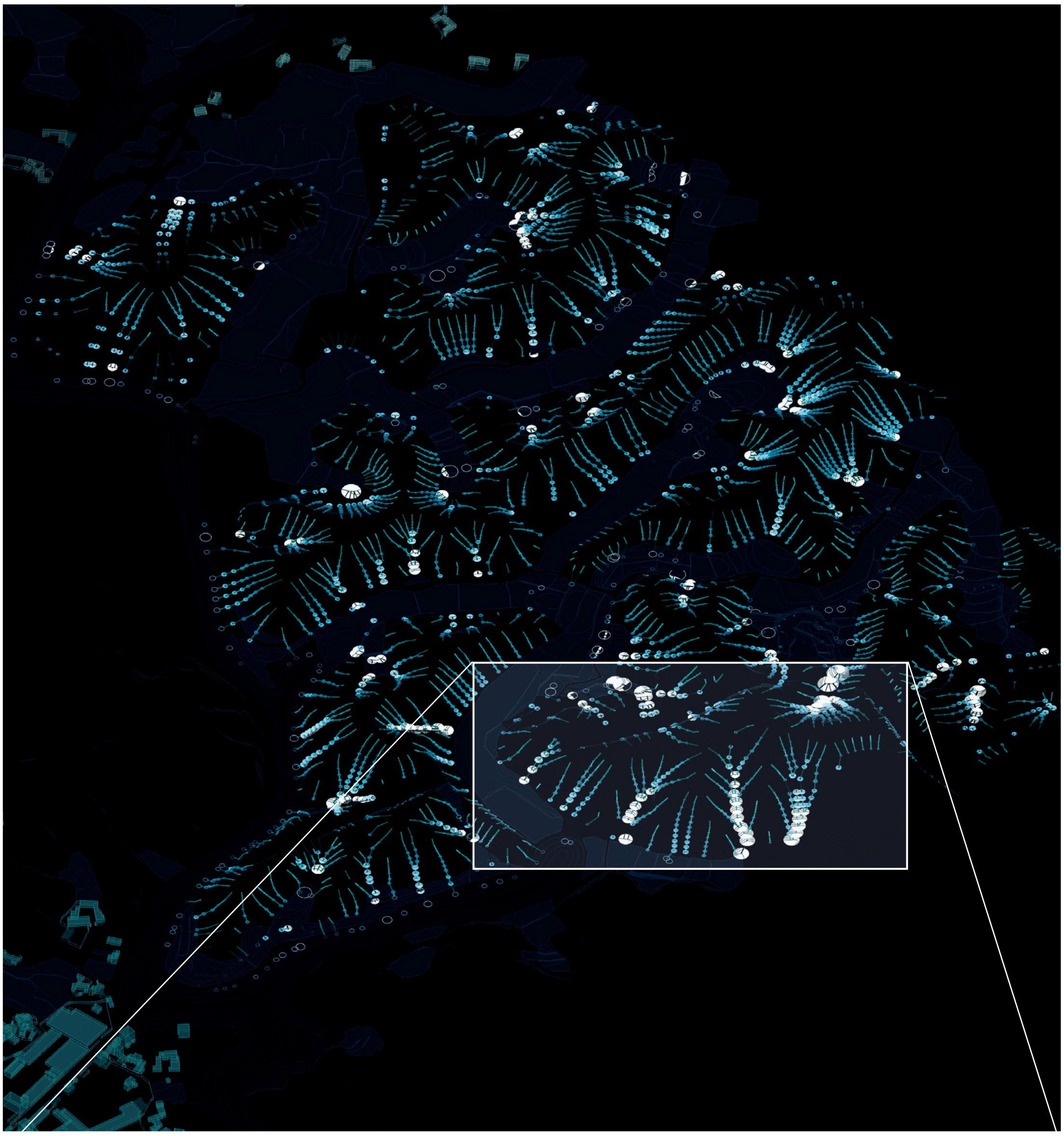
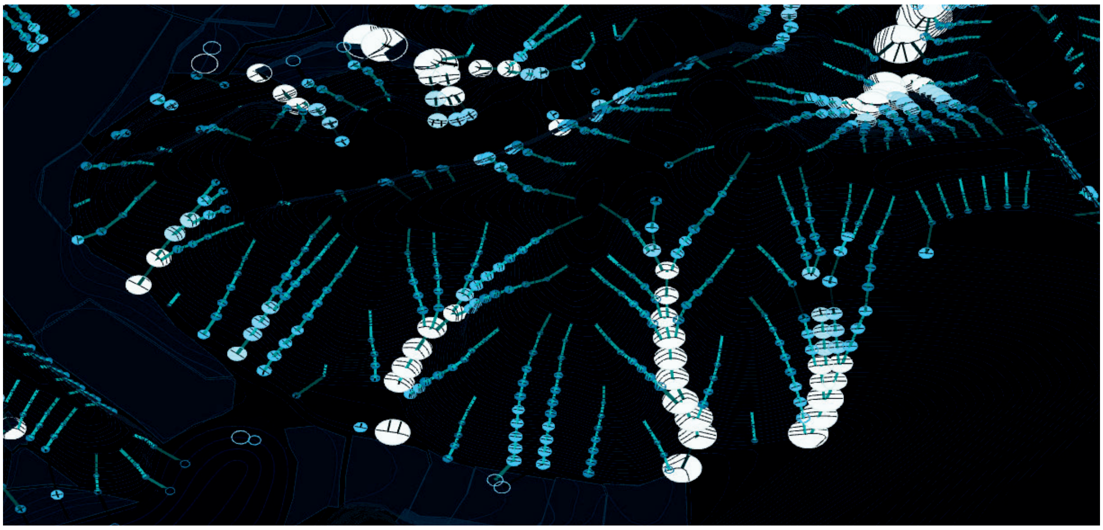


Figure 4.10
The above image shows of the *TopoFlow* script run without adding or collapsing lines. The inflection of the topography quickly directs most traces together while ignoring the majority of the site. Below, with these functions added, the coverage is much more complete and even.

Figure 4.11
The radius of the circles illustrates the *.aggr* values at each *TopoPoint*. When the flow direction is set downhill this approximates waer runoff. The zoom-in shows how *.aggr* values combine when paths are joined together as well as the introduction of new paths at lower levels on the slope.





Accumulative information

A sophisticated base of information provides not only internal consistency and easier representation, but also allows the datapoints to develop additional information—and thus differentiation—for themselves. For example, the control of internal relationships and adjacencies in the *TopoFlow* code allows for cumulative runoff values to be calculated along the length of the trace, and combined when two traces are collapsed together. Naturally, a consistent and thorough datastructure (in combination with a receptive object class) also makes it possible to synthesize analyses that take place at different moments in the model.

§4.7 Localization and Spatialization

Developing locality

At each point, a number of quantitative or geometric analyses are calculated—the average solar incidence; slope magnitude, direction, and normal vector; total runoff; distance and direction to nearby roads, the river, or rice paddies; an area polygon defined by a planar voronoi diagram—and applied to the point in its metadata. Some of these quantities are calculated as byproducts of ≒4.6.1,[81] while other are added through later operations.[82] In ≒4.7.1 we show how the proximity of various site features and infrastructures are recorded in the point. Here, a set of polyline curves denotes the edge of rivers, streets, and agricultural fields. A vector is created from each point to the nearest curve in each category. The amplitude of these vectors is remapped according to the graphs from ≒4.4.1 and saved in the *.attr* attribute allowing us to consider mediated influence—the radius of influence of a highway is not necessarily equal to than that of a small road—and to control how that influence manifests itself in a given location.

Inclusion

Referring back to the object ontology developed in chapter 2, we should note that such localization involves the association of extensities[83] to the the landscape object such that this information is included[84] within the apperceptions of the object.[85] Again, the individual object is not identically defined by its qualities.[86] Rather than necessary components, the qualities themselves are actualizations of the point in the environment through which the landscape also enacts itself[87] procedurally "as a relation of knowing, perception, and apprehension."[88] More precisely this differentiation is a process of interaction, because it elides the distinction between subject and object or between figure and ground. It is for this reason that we link the interactive dimension to questions of epistemology. And yet, this is not to say that localization is an empirically driven process.[89] The landscape is not at all a pre-existing, continuous, objective space but an assemblage of discrete monadological objects. As each individual comes to occupy a point of view[90] so also does the cultivated assemblage that is the environment.

81 (:149) etc…

82 As mentioned earlier (note 61), Python allows these to operate in parallel, all writing to the same objects.

83 "extensity does not account for the individuations which occur within it. No doubt the high and the low, the right and the left, the figure and the ground are individuating factors which trace rises and falls, currents and descents in extensity. However, since they take place within an already developed extensity, their value is only relative"

Deleuze, *Difference and Repetition*. p229

84 *cf.* §2.6a 'Inclusion'

85 "A percept is precisely nonsubjective"

Wylie, "Depths and Folds: On Landscape and the Gazing Subject." p529

86 *cf.* §2.3b, 'Characteristics and qualities'

Bryant, *The Democracy of Objects*. p68

87 *cf.* §2.3c-d 'Construction' and 'Cultivation'

88 Wylie, "Depths and Folds: On Landscape and the Gazing Subject." p530

89 *cf.* §4.9

90 Deleuze, *The Fold: Leibniz and the Baroque*. p19

≒4.7.1 Attractors

```
0     INPUTS: topoDict; hwyCrv, rdCrv, rvrCrv, agCrv as List of Curve;
...   refresh as Boolean
      import Rhino as rh; import Rhino.Geometry as rhG
      import Grasshopper as gh; from Grasshopper.Kernel.Data import GH_Path
      from collections import defaultdict; import math
      import scriptcontext
5
      #==================================================================#
      def ClosestAttractorPts(args):
        pt, crvs, g, ndx= args
        ptXYZ= pt.xyz
10      cPts= [rhG.Curve.PointAt(iCrv, rhG.Curve.ClosestPoint(iCrv, ...
...                                          ptXYZ)[1]) for iCrv in crvs]

        d= map(ptXYZ.DistanceTo,cPts)
        toSort= zip(d,cPts)
        toSort.sort()
15      attrVec= rhG.Vector3d(toSort[0][1]-ptXYZ)
        ckVec= rhG.Vector3d(attrVec.X, attrVec.Y,0)

        dist= toSort[0][0]
        #NEGATE PLANES TOO CLOSE TO HWY
20      if ndx == 0 and ckVec.Length<17: dist+= 300
        #MAP DISTANCE TO GRAPH VALUE TO SET AMPLITUDE
        amp= g.Container.ValueAt(dist)

        if (dist>g.Container.X1):
25        amp+= ((g.Container.X1)-dist)*.002
        elif (dist<g.Container.X0):
          amp+= ((g.Container.X0)-dist)*.002

        pt.attr[ndx]= (attrVec* (amp/dist))
30      return attrVec
      #==================================================================#

      def main(dict,hw,rd,rv,ag,tree,grObj):
        for iKey in dict.d:
35        for j, jLst in enumerate(dict.d[iKey]):

            map(ClosestAttractorPts, ((tPt,hw,grObj[0],0) for tPt in jLst))
            map(ClosestAttractorPts, ((tPt,rd,grObj[1],1) for tPt in jLst))
            map(ClosestAttractorPts, ((tPt,rv,grObj[2],2) for tPt in jLst))
40          map(ClosestAttractorPts, ((tPt,ag,grObj[3],3) for tPt in jLst))

            [tree.AddRange(kPt.attr,GH_Path(iKey,j,k)) for k,kPt in  ...
...                                                      enumerate(jLst)]
      #==================================================================#

45    graphObj= scriptcontext.sticky['graphObjects']

      #BODY OF CODE
      vecTree= gh.DataTree[rhG.Vector3d]()
      main(ptDict, hwyCrv, rdCrv, rvrCrv, agCrv, vecTree, graphObj)
50
      pyDict= ptDict
      vTree= vecTree
      OUTPUTS: pyDict, vTree
```

This function measures the distance from each point to geographic features such as roads, rivers, rice paddies, and highways and maps them onto functions of influence.

10 List comprehensions make it simple to evaluate the test point against the entire set of curves.

13 Then the found points are zipped together with their distance measure and sorted (:14) to determine the nearest. This sequence is similar to the one used in ≒4.6.1 (:160).

22 The distance to the closest point is mapped onto a value by the GraphMapper component from ≒4.4.1.

37 The *attrVec* values are attached to an object method of the *TopoPoint* (:29) so there is no need to save the result of the *map()* function into a list variable.

42 Here the list comprehension is used to output the attractor vectors to a *DataTree* for visual confirmation.

49 Reducing the number of global variables by placing operations within functions that limit variable scope is one way of making functions more memory efficient.

§4.8 Instantiation

Procedural identities

The development of object qualities is thus also a movement toward the question of identities. Or rather, to avoid suggesting the introduction of any essential definitions, it may be better to say that it introduces a process of identification. Identification in place of identity places the emphasis on the acts of receiving, interpreting, and translating information in ways that are also contingent on the actors that are identifying and their means of querying.[91] Identifying objects is an extensive process of naming or categorizing,[92] separating a gradient of similar objects into discrete selections which can be associated with other roles, functions, or behaviors as instances of a given type. These instantiations reveal themselves as "exploratory or interpretative responses"[93] to inquiry, and are projected back onto the object as situated and contingent tendencies rather than permanent, static properties. As such, they can help the designer align aspects of the site to unit operations within the model.

Categorizing distributing, filtering, and sorting

Like McHarg's method of overlapping maps to filter out unsuited territory and to reveal regions of potential, this project constructs a series of filters to sieve through the data and identify certain patterns of spatial relations and quantitative values. In the case of the Leshan site, we want to instantiate a set of situated orientations that each follow the same evaluation process, but with adjustments to the parameters that define different attitudes toward the ground. Each operation will produce a set of connected territories with a unique form and configuration.[94] Five open categories are proposed to correspond to the different types of attractor geometry and differing environmental requirements. For each point created in ≒**4.6.1** a fitness value is calculated from the input parameters. The code in ≒**4.8.1** details how values for attractor strength, accumulation of water runoff, solar incidence, and overall slope are given unique weighted significance for each category and the two highest values recorded. Following this (≒**4.8.2**), an orientation plane is calculated, again from a list of weighted inputs according to the dominant fitness type and the disposition of these planes compared to interlink the mesh when appropriate. The explicitness of these processes requires the designer to anticipate certain formal or spatial decisions—a slab building may imply an orientation that follows the topography at a constant level, while steep slopes suggest terraced massings—in the early stages of the design process and to test the repercussions of these decisions in the model.

91 *cf.* §2.4a 'Information'

92 The distinction between extensive and intensive sets is treated in more depth in §5.6b 'Intensional and extensional sets'

The question of types and categories is raised in §6.4b 'Type and populations'

93 *cf.* §3.4b 'Distributed units'

94 "digital topographies that include in their modeling "data" that would normally be separately diagrammed—the flows of traffic, changes in climate, orientation, existing settlement, demographic trends, and the like. Formerly these would be considered by the designer as "influences" to be taken into account while preparing a "solution" to the varied problems they posed. Now, however, they can be mapped synthetically as direct topographical information, weighted according to their hierarchical importance, literally transforming the shape of the ground. The resulting "map," however hybrid in conception, is now less an icon to be read as standing in for a real territory than a plan for the reconstitution of its topographical form."

Vidler astutely notes how this transforms the semiotic role of the diagram, but where he sees an evacuation of anything behind the image, we argue that this is instead a translation from the representational to the rhetorical.

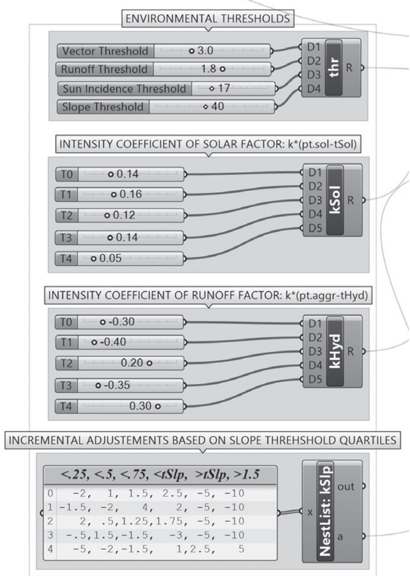
Vidler, "Diagrams of Diagrams: Architectural Abstraction and Modern Representation." p17

4.8.1 calcFitnessValues

```
0  INPUTS: ptDict; thr, kSol, kHyd, kSlp as List of Float
   import Rhino.Geometry as rhG
   import scriptcontext; from collections import defaultdict
   import math

5  #==================================================================#
   class CalcTypeFitness(pt, t, kSol, kHyd, kSlp):
     tVec, tHyd, tSol, tSlp= t

     #INCREASE FITNESS VALUE FOR HIGHEST ATTRACTOR VALUE
10   vLng= [v.Length for v in pt.attr]
     pt.fit[vLng.index(max(vLng))]+= 2.5

     #ATTRACTOR MAGNITUDES AS TYPE FITNESS FACTOR
     thrChk= 0
15   vecOrnt= rhG.Vector3d(0,0,0)
     for m, vec in enumerate(pt.attr):
       #ADD TO FITNESS VALUE FOR HIGH-VALUE ATTR
       if vLng[m] > tVec:
         pt.fit[m]+= min( (vLng[m]-tVec)/2, 4)
20       thrChk+= 1

       #SUM CUMULATIVE .attr VECTORS AND SAVE TO .ornt AFTER LOOP
       if vLng[m] > 0:
         vecOrnt+= rhG.Vector3d(vec.X,vec.Y,0)
25   pt.ornt[0]= vecOrnt

     #IF NOT TWO HIGH ATTR: ADD FITNESS FOR EROSION CONTROL
     if thrChk < 2: pt.fit[4]+= 2.5*(2-thrChk)

30   #SOLAR INCIDENCE AS TYPE FITNESS FACTOR
     if pt.sol!=180:
       for m, fit in enumerate(pt.fit):
         pt.fit[m]+= kSol[m] * (tSol-pt.sol)

35   #RUNOFF AS TYPE FITNESS FACTOR
     for m, fit in enumerate(pt.fit):
       pt.fit[m]+= kHyd[m] * (pt.aggr-tHyd)

     #SLOPE ANGLE AS TYPE FITNESS FACTOR
40   if pt.slp:
       slpAng=-math.degrees(math.asin(pt.slp.Z/2))
       for m, fit in enumerate(pt.fit):
         #VERY, VERY STEEP SLOPES (1.5× THREHSHOLD)
         if slpAng>tSlp*1.5:
45         pt.fit[m]+=kSlp[m][5]
           #SLOPES AS QUARTILES OF THRESHOLD
           else:
             qrtl= int(min(math.floor(slpAng/tSlp)*4),4))
             pt.fit[m]+=kSlp[m][qrtl]
50 #==================================================================#

   typNdx=[0,1,2,3,4]
   ptOut=[]
   vecOut=[]
55 #LOOP THROUGH ALL POINTS IN ptDict
   for i, iKey in enumerate(ptDict.d):
     for j, jLst in enumerate(ptDict.d[iKey]):
       for k,kPt in enumerate(ptDict.d[iKey][j]):
         vecSum= 0; thrChk= 0
60       vLng= [v.Length for v in kPt.attr]
         maxNdx= vLng.index(max(vLng))

         for m, fit in enumerate(kPt.fit):
           kPt.fit[m]=0
65       CalcTypeFitness(kPt, thr, kSol, kHyd, kSlp)

         if sorted(zip(kPt.fit,typNdx))[-1][0] > 0:
           kPt.typ[0]= sorted(zip(kPt.fit,typNdx))[-1][1]
         else:  kPt.typ[0]=- 10
70       if sorted(zip(kPt.fit,typNdx))[-2][0] > 0:
           kPt.typ[1]= sorted(zip(kPt.fit,typNdx))[-2][1]
         else:  kPt.typ[1]=- 10

         ptOut.append(kPt.xyz)
75       vecOut.append(kPt.ornt[0])
   pyDict= ptDict
   pt= ptOut
   v= vecOut
   OUTPUTS: pyDict, pt, v
```

Fitness values are calculated for different types of use. The list inputs are coefficients attached to sliders allowing the user to customize how sensitive each category is to environmental inputs (below, Figure 4.12).

07 The *t* variable is brought into the class as a list of all four threshold values. For clarity and legibility it is immediately split into four individual named variables rather than referred to by list indices.



11 The fitness values, *.fit*, are calculated by summing a number of incremental adjustments.

68 After the fitness values have been caclulated (:65), the maximum values are saved as the points primary and secondry (:71) types in *.typ*.

≒4.8.2 orientationMesh

```
0   INPUTS: ptDict; vecSol as Vector3d; kDir as List of Float; nDim as List
... of Point3d; x as List of String; thrMrg as Float
    import Rhino.Geometry as rhG
    import scriptcontext; from collections import defaultdict
    import math; import random as r
    r.seed(2)
5
    #==================================================================#
    def MergePoints(pt, ckPt, thr, mLst):
        for mPt in pt.nchr:
            for n, nPt in enumerate(ckPt.nchr):
10              if mPt.DistanceTo(nPt) < thr:
                    ckPt.nchr[n]= mPt
                    mLst.append(mPt)
    #==================================================================#

15  ptOut= []
    typ0= []
    nchrOut= []
    mrgPt= []

20  #FOR EACH POINT
    for i, iKey in enumerate(ptDict.d):
      for j, jLst in enumerate(ptDict.d[iKey]):
        for k, kPt in enumerate(ptDict.d[iKey][j]):
          kPt.nchr= []
25        typ= kPt.typ[0]

          #COMPUTE ORIENTATION AND LINK ANCHORS
          if kPt.slp and typ >= 0:
            vecTemp= rhG.Vector3d((kDir[typ][0]*kPt.slp) +
...             (kDir[typ][1]*kPt.tan) + (kDir[typ][2]*kPt.attr[typ]/) +
...             (kDir[typ][3]*vecSol))
30          kPt.ornt[1]= rhG.Plane(kPt.xyz, vecTemp, rhG.Vector3d.ZAxis)

            X= nDim[typ].X; Y= nDim[typ].Y; Z= nDim[typ].Z
            kPt.nchr.append(kPt.ornt[1].PointAt(X, Z, Y))
            kPt.nchr.append(kPt.ornt[1].PointAt(-X, Z, -Y))
35
            if x[typ] == "Mirror":
              kPt.nchr.append(kPt.ornt[1].PointAt(X, Z, -Y))
              kPt.nchr.append(kPt.ornt[1].PointAt(-X, Z, Y))
            elif x[typ] == "Cross":
40            kPt.nchr.append(kPt.ornt[1].PointAt(Y, Z, -X))
              kPt.nchr.append(kPt.ornt[1].PointAt(-Y, Z, X))

            #CHECK PREV
            kCt= len(ptDict.d[iKey][j])
45          #COMPARE AND MERGE CLOSE POINTS
            MergePoints(kPt, ptDict.d[iKey][j][(k-1)%kCt], thrMrg, mrgPt)

            #CHECK UPHILL
            if isinstance(kPt.src, tuple):
50            ct= len(ptDict.d[kPt.src[0]][kPt.src[1]])
              for z in xrange(-1,1):
                zPt= ptDict.d[kPt.src[0]][kPt.src[1]][(kPt.src[2]+z)%ct]
                MergePoints(kPt, zPt, thrMrg, mrgPt)

55          #CHECK DOWNHILL
            if isinstance(kPt.trgt, tuple):
              ct= len(ptDict.d[kPt.trgt[0]][kPt.trgt[1]])
              for z in xrange(-1,1):
                zPt= ptDict.d[kPt.trgt[0]][kPt.trgt[1]]
...                                              [(kPt.trgt[2]+z)%ct]
60              MergePoints(kPt, zPt, thrMrg, mrgPt)

    #FOR EACH POINT
    for i, iKey in enumerate(ptDict.d):
        for j, jLst in enumerate(ptDict.d[iKey]):
65          for k, kPt in enumerate(ptDict.d[iKey][j]):
                for mPt in kPt.nchr:
                  nchrOut.append(mPt)
                  typ0.append(kPt.typ[0])
                  ptOut.append(kPt.xyz)
70
    pyDict= ptDict
    pt= ptOut
    t0=typ0
    n=nchrOut
    OUTPUTS: pyDict, pt, t0, n
```

Each point is given a primary orientation based on its currently assigned type (≒4.8.1), some anchor points are placed on an oriented plane, and anchors that overap with neighbors are compressed to the same location to create an interlinked mesh.

25 These operations would normally be repeated for the secondary orientation *.typ[1]* but have been omitted here for space

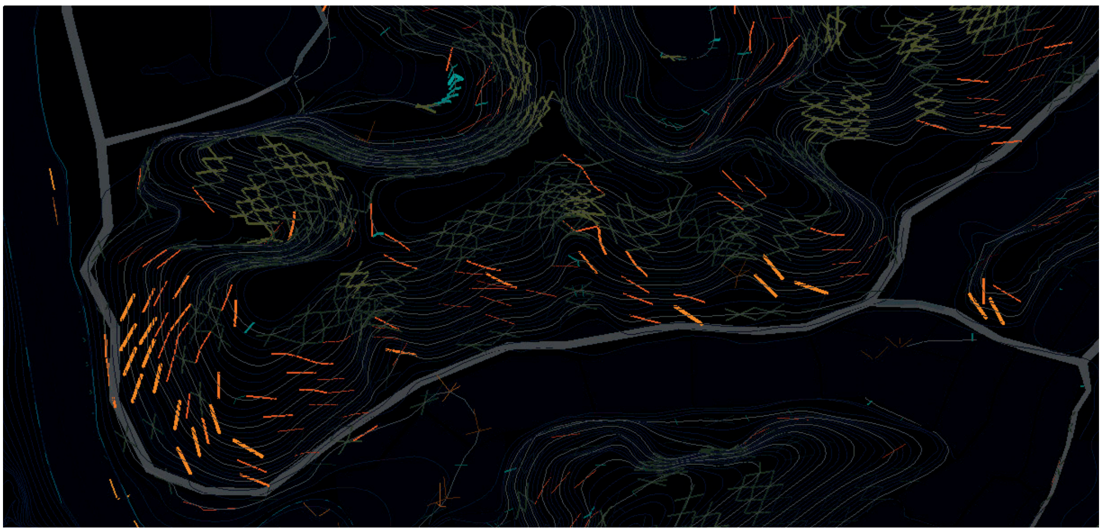
29 Each influencing Vector is multiplied by an input coefficient and combined into an aggregate orientation. Vectors have all been unitized elsewhere, so their length coming into this script is 1.

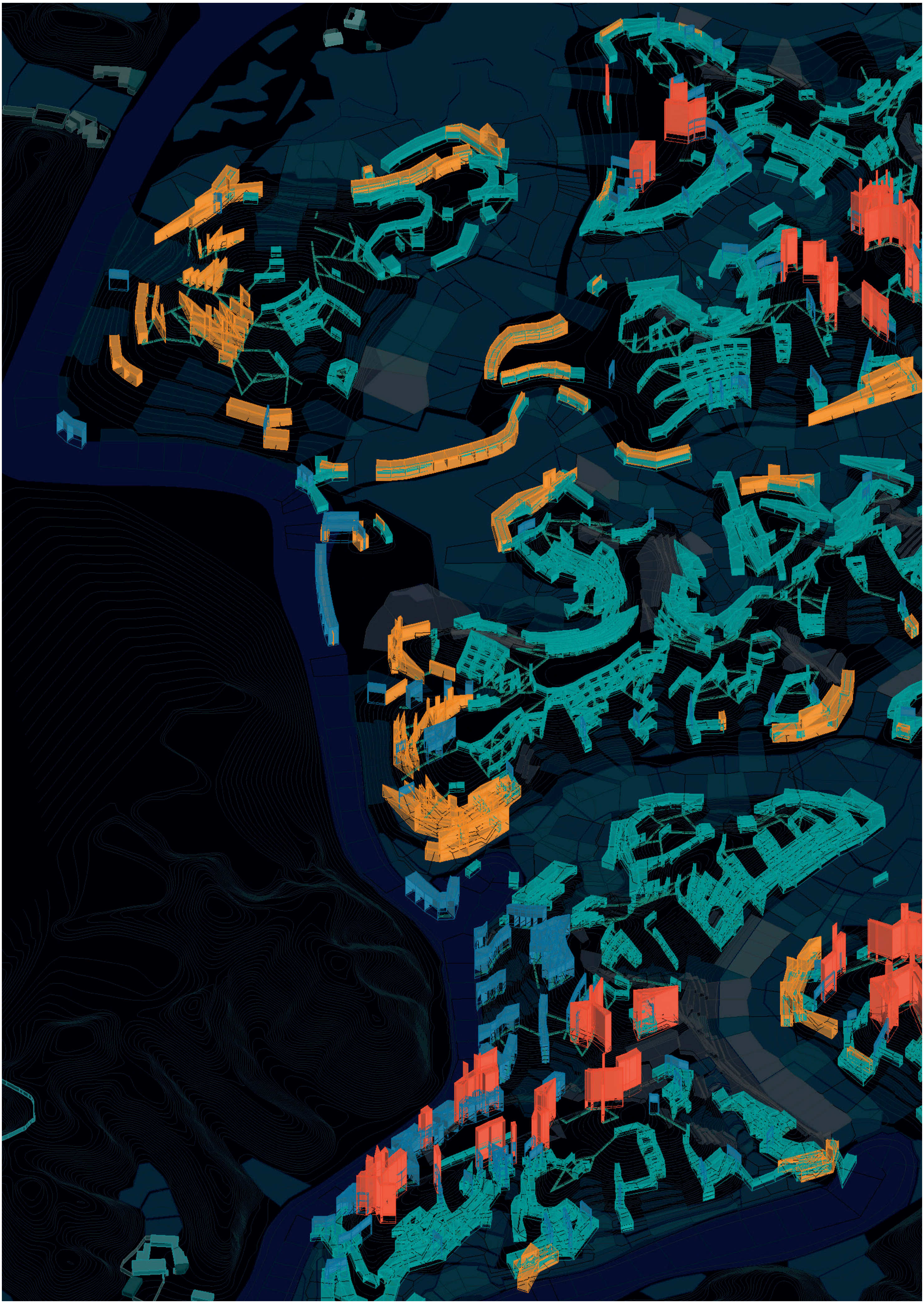
33 The coordinates seem to be mixed up here because the Plane *.ornt[1]* is aligned vertically with the World ZAxis as its YAxis (:30). This eliminates the need to calculate an orthogonal Vector which this Plane will producre anyway.

36 "Mirror" and "Cross" (:39) are options for adding four anchor points. The attempt here is to limit the number of inputs required, so each set of anchor points can be built from a single vector input, *nDim*, rather than separately for each anchor.

Figure 4.13
The output of the *orientationMesh* function showing overal linkage and regions with particular dominant uses

Figure 4.14 (*over*)
The Leshan site mesh with initial massing volumes applied.





§4.9 Concept of Model

Introduction

At this point it would be beneficial to reflect more critically on the specific meaning of 'model' that we want to advance and its relation to the category of the interactive. Alain Badiou writes that "the model is that which allows us to think through participation,"[95] providing a useful entry point to the analysis he presents in *The Concept of Model*. Here, Badiou is specifically discussing (logico-)mathematical models so some caution is called for before applying his words[96] to the much less rigorously circumscribed use of model in urban design or architecture. However, there are enough similarities that we can absorb these arguments as commentary, if not as definitive statements.

To precisely follow Badiou's usage, the model would designate the way of presenting an urbanism's organization as such, the collection of ways by which architecture might participate in the urban. Thus, a model would comprise the framework for resolving urbanism and computation (that is, it would cover the scope of this entire thesis). Such criteria would seem to be far too expansive to be applicable to individual urban design models, but we will argue[97] that a thoroughly consequent computational model constitutes these concerns as in a microcosm, making this approach appropriate to individual models as well.

Types of models

On a more limited level, Badiou identifies two primary groups in the use of models: abstract models and material assemblages.[98] The first are scriptural objects, assemblages of hypotheses held together by a common code; the second includes graphs, diagrams, physical models and automata. It is apparent that the computational model includes aspects of all of these modes and thus participates in a general concept of modelness. As we have discussed in this chapter, the necessity to "spatially present non-spatial processes in a synthetic fashion"[99] through graphs, datascapes, or other means is significant aspect of engagement with computational models, and while physical models may not always be employed, the spatial visualizations on-screen fall within Badiou's definition of "realiz[ing] formal structures, that is to transfer scriptural materiality to another 'region' of experimental inscription."[100] Procedurality as a medium also encompasses the definition of automata as the class of models that "aims to imitate behaviours"[101] Finally, the entire model is formally recorded in code, each command of which operates as an individual hypothetical unit.

Badiou's purposes regarding models

Badiou's goal throughout *The Concept of Model* is "to isolate the scientific – i.e., logico-mathematical – concept of model from its notional envelopment by the categories of bourgeois epistemology"[102] or, put another way, to interrogate the relationship between empiricism and formalism[103] in order to establish that the modeling function "is not an *a priori* formal science grounding the empirical sciences' access to reality but rather the paradigmatic instance of a productive experimental praxis."[104] This insight is born of a subtle distinction made in order to prevent the conflation of the production of a model and "the technical regulation of concrete processes"[105] in such a way that would obscure the materialist history to which the model relates. For these reasons, Badiou disapproves of the epistemological modeling of economic (which propounds a contingent, "integrated technical image"[106] as though it were an "atemporal necessity"[107]) as well as cybernetics' naturalized epistemology (which becomes lost in an idealist "structure of structures"[108]).

An inventive praxis

Instead, Badiou emphasizes the artificial or "irreal"[109] character of the model as an experimental enchainment,[110] "wholly assembled"[111] in such a way that its mechanics are rendered more transparent. Doing so, one is able to decouple the model from empiricist concerns with the result of emphasizing its productive and inventive dimension. In this way, the model is freed from the scrutiny of proof, as such, given over to the "inventive freedom of artifice"[112] whereby the model bestows objects their universality and their limits.[113] Although the standards of assessing the model are changed the standard is no less high: resemblance alone can no longer be assumed to be sufficient, but the conditions of correspondence between the model and the real must be created and explicitly defined alongside the model.[114]

Representation and formalization

This brings us to the second, related point of emphasis: to establish formalization as an operation that distances the model from a representational function.[115] Badiou's equation of formalization in mathematical modeling with the tracing out of an ontology strengthens this argument: if an ontology were only assessed for its ability to analogize a situation, it would be "subservient to some prior concept of what is at stake in analysis"[116] and lack the force of thought that is inherent to the category of ontology. For Badiou, then, the relationship of the model to the real must not be representational, but rather the presentation of a unity that exists only within the formal system of the model.[117] This is to say that the defined correspondences between model and object do not proceed from predefined empirical existence, as such, but are actively created. The representational mode is not productive, but exhausts itself,[118] whereas formalization invents new identities and unities. This is consistent with the position advanced in the previous chapter that procedural simulation could not be reduced to conventional representational categories but was instead a creative presentation of particular scenarios and modes of engagement.[119]

Participation

According to Badiou, models have traditionally (and naïvely) been interpreted to flow alongside scientific inquiry in a way that, at its worst, can obscure the facts of their construction and disguise an ideological framework as a natural process.[120] The separation of the model from representational purposes and toward rhetorical ones[121] avoids this obscurantism and embraces the idea of "thinking through participation." At the same time, this moves the model into a much more interesting position as a product of inquiry as well as a means of production.[122] "The productive value of formalization lies in its double inscription … that of using and reproducing certain knowledges … at the same time as constructing specific models to produce new knowledge"[123] While an overall

95 Badiou, *The Concept of Model.* p92

96 "Any attempt to export the concept of model outside the mathematical realm violates this necessarily intra-mathematical relation and is thus illegitimate."
Brassier, "Badiou's Materialist Epistemology of Mathematics." p144

97 *cf.* §4.10b 'Architecture as urban interface'

98 Badiou, *The Concept of Model.* p11-12

99 *Ibid.* p12

100 *Ibid.* p13

101 *Ibid.* p13

102 Brassier, "Badiou's Materialist Epistemology of Mathematics." p137

103 "It's clear enough that empiricism and formalism, here, have no other function that to be the terms of the couple that they form. What constitutes bourgeois epistemology is neither empiricism nor formalism, but the ensemble of notions by which we designate, now, their distinction, and now, their correlation."
Badiou, *The Concept of Model.* p5

104 Brassier, "Badiou's Materialist Epistemology of Mathematics." p137

105 *Ibid.* p139

106 Badiou, *The Concept of Model.* p12

107 *Ibid.* p17

108 *Ibid.* p17

109 *Ibid.* p10

110 "formal systems constitute the experimental moment, the material concatenation [*l'enchaînement*] of proof, after the conceptual concatenation of demonstration"
Ibid. p43

111 *Ibid.* p10

112 *Ibid.* p15

113 *Ibid.* p92

114 *Ibid.* p19

115 "formalization allows mathematical practice to achieve an indifference to representation"
Fraser, "The Category of Formalization: From Epistemological Break to Truth Procedure." xxxi

116 Tho, "The Consistency of Inconsistency: Alain Badiou and the Limits of Mathematical Ontology." p73

117 "being does not provide its own means of unity, all unity comes from without. What this means, most importantly, is the indifference of being to ontology, that is, being's independence from the differences (the distinctions that ontology designates) that constitute ontology."
Ibid. p74

118 Somol, "All Systems GO! The Terminal Nature of Contemporary Urbanism."

119 "What must be presumed for the possibility of ontology is not the consistency of being, but that of presentation. This would be the consistency of ontology's own presentation. That is to say, ontology is possible as a particular and not as a general structure."
Tho, "The Consistency of Inconsistency: Alain Badiou and the Limits of Mathematical Ontology." p76

120 Badiou, *The Concept of Model.* p17

121 *cf.* §3.5 'Procedural Rhetoric'

model of urbanism is what we endeavor to define, individual, experimental models can, in practice, anticipate these developments, leveraging the gap between implicit understanding of urban processes and their eventual formalization.[124] Brassier emphasizes that it is through this combination of "retrospective causality" and "anticipatory intelligibility" that the model becomes an engine of differentiation.[125] Similarly, within the individual model, parameters are anticipated or put forward before a fixed value can be entirely decided on and these conditions can be recursively modified based on their subsequent interactions. Badiou's definition of a model requires this progressive differentiation because "no formalisation can claim to encompass the totality of the consequences of the event that it draws upon"[126] and so the initial conditions must be revisited again and again.

§4.10 Conclusion

Projective models

Finally this brings us to two conclusions. The first is the need to acknowledge and even emphasize the fact that the model "cannot be mistaken for its empiricist representation or conflated with an ambient scientific worldview, a diffuse ideological distillate synthesized from various scientific disciplines,"[127] but is a constructed, formal system that occupies a particular point-of-view. At the same time, the model includes a level of flexibility and indeterminacy such that, despite its imminent autonomy, it is also contingently situated and inclusive. This necessitates that a computational model must not be merely representative of empirical data, but projective in a way that exceeds systematization and is open to the effects of competing contingencies.[128] To the extent that interaction involves the application of procedurality to the task of incorporating external information and localized details within an aggregate organization, it must be a model that enables interaction

Architecture as urban interface

Secondly, we posit that in lieu of representational similarity, the model and the real are linked through a correspondence of analogous operations. In this conceptualization of the city, the urban realm operates as an untotalizable, but structured, organization: one which is itself highly responsive to local perturbations and which enables individual participation via certain prepositional modes. This pushes architecture into the position as the medium through which we can singularly act on[129] and participate in the urban realm. Architecture then can be conceptualized as an interface onto the urban realm that anticipates and helps bring into being a collective urban form, and that is also retroactively acted on by its environment and context.

122 "a theory of model governs a dimension of the sciences' practical immanence—a processs, not only of the production of knowledge, but of the reproduction of the conditions of production"

Badiou, *The Concept of Model.* p44

123 Feltham, *Alain Badiou: Live Theory.* p26

124 *Ibid.* p24

125 That is, the ability to link a model as an object to the parameters in a greater system after the model has been formalized, and the contingent acceptance of those parameters as a potential model before formalization.

Brassier, "Badiou's Materialist Epistemology of Mathematics." p145-146

126 Badiou and Hallward, "Beyond Formalisation: An Interview." p118

127 Brassier, "Badiou's Materialist Epistemology of Mathematics." p146

128 Patt, "The Collective Image: Form, Figure, and the Future." p150

129 "In approaching a singular point, one must always begin with its singularity. This does not mean that singularity is incompatible with a general analysis. However, it's not the general analysis that gives this singular point its political value, but rather the political deployment, experienced as a possibility, of its singularity."

Badiou and Hallward, "Beyond Formalisation: An Interview." p121

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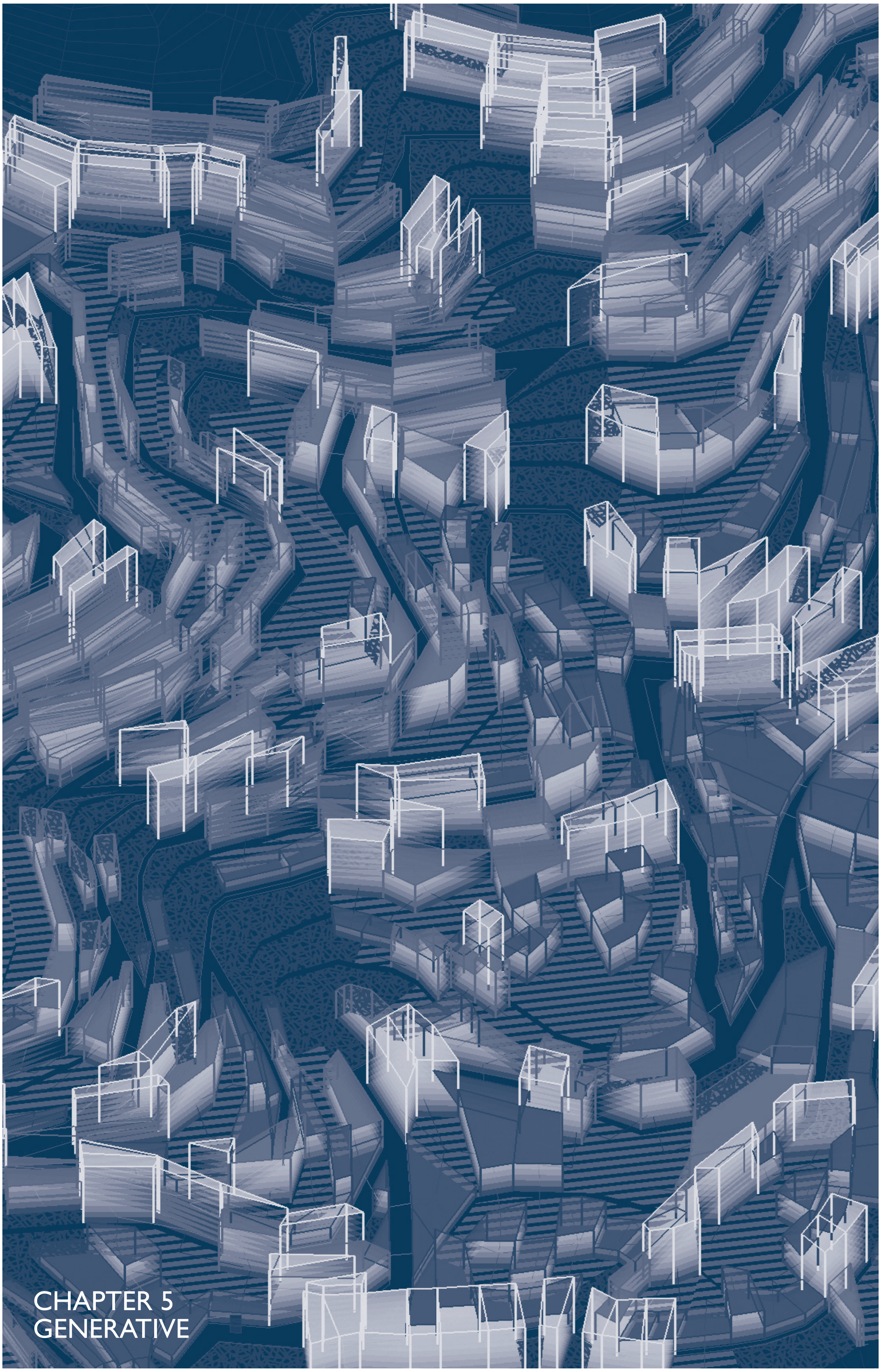


CHAPTER 5
GENERATIVE

§5.1 Generative Ontology

Definition of objects and forms

Where the interactive addressed epistemology and how interaction reveals procedural logics, the generative concerns the ontological dimension of objects themselves and their internal definition. In chapter 2 we described an object-oriented ontology featuring an irreducible withdrawn interior[1] that achieves objecthood when individuals assemble together and their inter-relationships "attain operational closure … capable of encountering perturbations as information in terms of their own endo-consistency."[2] Additionally, the monadic interior of the object is a constantly changing texture of "temporary apppurtenances and provisional possessions."[3] In contrast to purely relational ontologies,[4] this "continuous development of form"[5] is defined by the limits of the individual[6] and as its inflections. However developments can be instigated by interactions between objects as well as intra-actions. Graham Harman describes this occurrence as a phenomenon where the encounter between two objects draws out aspects that might have previously been entirely interiorized[7] or which were only dimly perceived. This potential for encapsulated behaviors to manifest surprising reactions and the capability of objects' extensive qualities to provoke reactions combine as a generating function that catalyzes new situations.

Means of interaction

The extension of one object over its neighbors will be a major topic of investigation in this chapter,[8] in particular the implication of diffusely redistributing the design agency within the situation, as well as the reception of exterior stimulations, and the preparation of the object to receive these influences through encapsulated behaviors. The reciprocal relationship that forms between encapsulation and extension forms an interesting inside-out tension alluded to by Deleuze's reference to a "double antecedence"[9] that exists between the monad and its world. A similar occurrence can be observed among digital entities as Latour makes clear in his description of the monadic qualities of digital profiles. In this example, the individual's contexts—organizations, institutions, associations—are included in that individual as features or qualities,[10] while at the same time, the context, as an object itself, also contains the individual as a component member.[11] In this example, neither object is subsumed into the other nor can either be functionally replaced by the other. This exact situation will arise later in the code examples (≒**5.6.1**, **5.6.2**). The argument behind Latour's digital monad is that the reversibility of the monad[12] prevents analysis from drifting to generalizations when dealing with large groups but forces it to move "from particular to more particulars."[13] As a result, context or networks do not belong to "a second level added to that of the individual, but exactly the same level differently deployed,"[14] which closes off the possibility of an all-encompassing totality.[15] In place of

1 Bryant, *The Democracy of Objects*. p32

2 *Ibid.* p273

3 Deleuze, *The Fold: Leibniz and the Baroque*. p79

4 Actor-Network Theory for example,
Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory*.

5 Deleuze often uses the terms Form or Identity for what we are calling objects.
Deleuze, *The Fold: Leibniz and the Baroque*. p19

6 *Ibid.* p48

7 Harman, *Circus Philosophicus*. p1-10

8 *cf.* §5.5 'Extension'

9 *cf.* §2.6 'Environment' note 97
Deleuze, *The Fold: Leibniz and the Baroque*. p52

10 "The set of attributes—the network—may now be grasped as an envelope—the actor—that encapsulates its content in one shorthand notation."
Latour et al., "The Whole Is Always Smaller Than Its Parts: A Digital Test of Gabriel Tarde's Monads." p593

11 *Ibid.* p593

12 *Ibid.* p599

13 *Ibid.* p599

14 *Ibid.* p593

15 In fact, Latour goes so far as to suggest that organizations are simply side effects of interpreting datasets:
"the notion of 'context' might be as much an artifact of navigational tools" and "institutions … are just a trajectory through data starting from a different entry point in the database."
Ibid. p599, 609

16 "every time an entity is associated with a new monad, it's individualized through the previous associations gathered by that monad"
Ibid. p608

17 "by proposing such a navigation we move away from the dream of simulation and prediciton and explore another path, that of description where the added value is no longer the power of prediction, bu the progressive shift from confusing overlaps to successive clarifications of provisional wholes."
Ibid. p605

18 Latour, *Science in Action: How to Follow Scientists and Engineers Through Society*. p3

19 Witt, "A Machine Epistemology in Architecture: Encapsulated Knowledge and the Instrumentation of Design." p56

a centralized control, each overlap (or extension) of an individual acts on the other to further individualize it.[16] Attention to the ecology of interactions gives us both a better understanding of each individual object and of the emergent complexities of the plan as extensive series.[17]

§5.2 Multiagent systems

Encapsulation

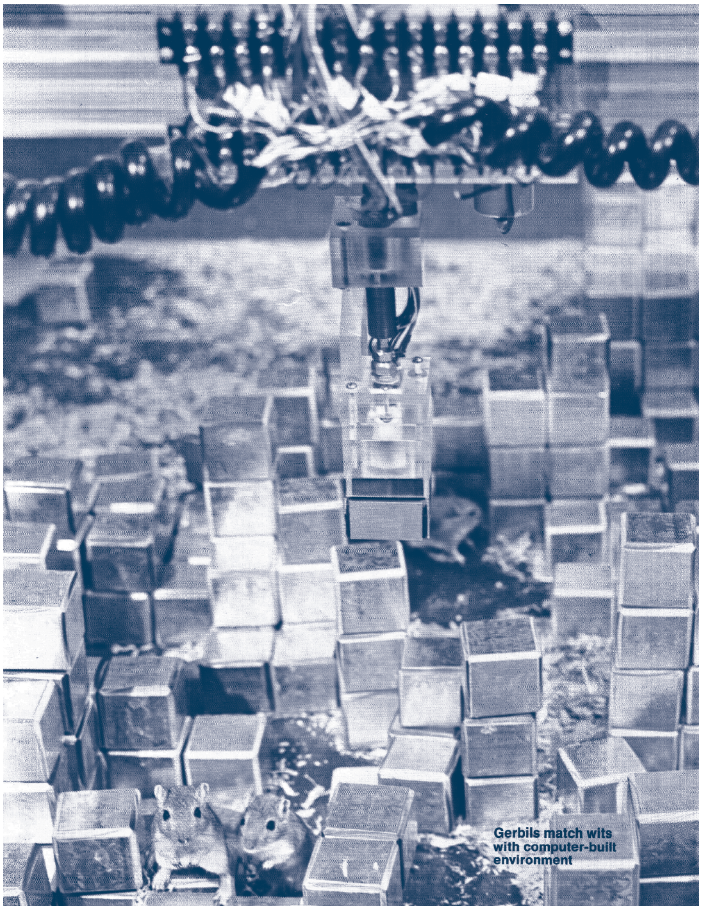
The operative character of the digital monad is established by the definition of an interior realm that may contain a set of qualities or behaviors. By encapsulating these properties, the object closes them off somewhat, detaching or veiling their operation from the external world.[18] The obvious benefit of encapsulation is that it removes the need for oversight of these operations and for an overseer to guarantee them, which simplifies the external relationships and frees up the designer to consider other concerns.[19] Behaviors can be addressed through a design stance rather than requiring a technical description of every interaction.[20] Furthermore, "the ability of the monads themselves to assess and to calculate" on their own establishes a "background of 'calculable forces'"[21] that confers a rich multiplicity and heterogeneity that simply cannot be achieved through direct control.[22] From a programming perspective, encapsulation is a common feature of object-oriented programming as we have seen in the previous chapter,[23] but the concept can be extended further if we consider each computational object as an autonomous agent.[24]

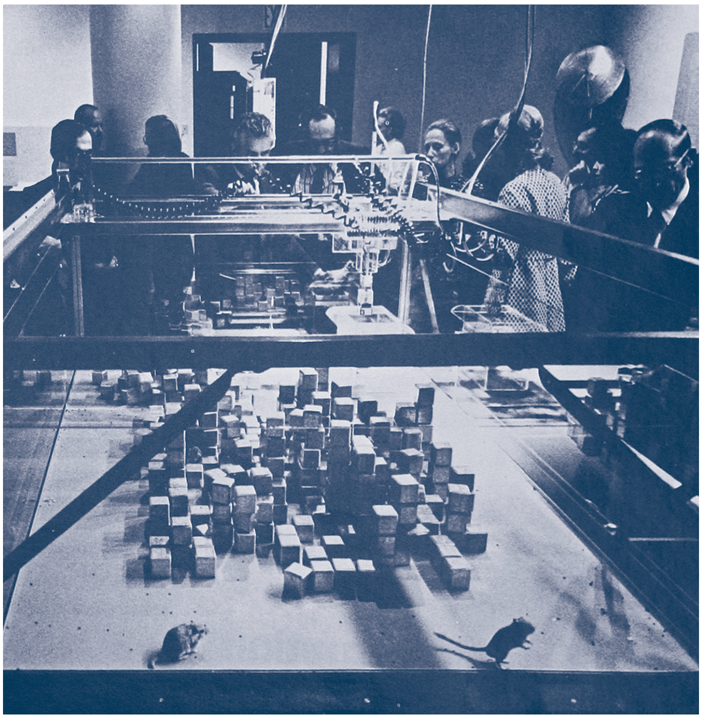
SEEK

In pure cases of multiagent systems, the autonomy of agents would be complete—each agent an entirely distinct computer system[25]—necessitating mechanisms for communication, synchronization, and interpretation between agents.[26] An intriguing take on this scenario was proposed by Nicholas Negroponte and Leon Groisser's Architecture Machine Group as a continuation of the microworld research of *URBAN5*.[27] and exhibited at the SOFTWARE exhibition in 1969.[28] This project consisted of a grid of five hundred cubic blocks[29] on a 5×8 foot tabletop. The blocks could be moved or repositioned one at a time by a robotic arm mounted on a gantry above the tabletop.[30] Constantly disrupting the configuration of this environment were a number of agents in the form of "a small colony of gerbils."[31] The central conceit of *SEEK* was that the gerbils' actions stemmed from an encapsulated intentionality, and though these intentions were inaccessible to the programmer, the computer could learn the generative pattern behind the gerbils actions by interpreting and reacting to the transformations that occurred.[32] The arm was equipped with sensors to read the current position of the blocks,[33] which it compared to its internal model. Small disturbances could be realigned to the grid, while larger discrepancies were noted and reacted to more deliberately. In addition to accepting the alterations wrought by the gerbils, the software could also propose new configurations and generate layouts,[34] either to "purposefully correct or amplify gerbil-provoked dislocations."[35] The interesting aspect of this setup is that there was no direct communication between the agents, but instead each communicated solely by acting on the environment and interpreting the traces of actions left by others.

Learning from multiagent systems

The animal/machine divison in *SEEK* effectively illustrates many of the characteristic traits of multiagent systems. Because discrete agents are limited to local knowledge and agency,[36] perceptions, interpretations, and models of the environment can vary widely: "the fact that agents may observe different things makes the world partially observable to each agent, which has various consequences in the decision making of the agents."[37] Such multiplicity and incompleteness can be an advantage especially when data or expertise is already unevenly distributed or when the environment is "open, or at least highly dynamic, uncertain or complex."[38] However, in design contexts, it is quite unlikely to find scenarios that truly require multiagent systems. Much more common is a complex object-oriented system that has been constructed to simulate a multiagent system in order to model a problem on societal metaphor. These simulations can avoid many of the technical challenges of implementing multiagent systems by having some common centralized





Figures 5.1; 5.2
SEEK, 1969.
Burnham, *SOFTWARE - Information Technology: Its New Meaning for Art*. cover, p9

20 Wooldridge, *An Introduction to Multiagent Systems*. p29-30

21 Latour and Lépinay, *The Science of Passionate Interests: An Introduction to Gabriel Tarde's Economic Anthropology*. p40

22 *cf.* §3.4 Unit Operations

23 *cf.* §4.4d-4.5a 'Derived values, Metadata and datastructures'; ≒**4.4.3** *TopoPoint*

24 "An agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives."

Wooldridge, *An Introduction to Multiagent Systems*. p15

25 *Ibid*. p26

26 *Ibid*. p9

27 Steenson, "Architectures of Information: Christopher Alexander, Cedric Price, and Nicholas Negroponte & MIT's Architecture Machine Group." p203

28 Organized by Jack Burnham at the Jewish Museum in New York:

Burnham, *SOFTWARE - Information Technology: Its New Meaning for Art*.

29 Negroponte, *Soft Architecture Machines*. p47

30 Burnham, *SOFTWARE - Information Technology: Its New Meaning for Art*. p23

31 *Ibid*. p23

32 Steenson, "Architectures of Information: Christopher Alexander, Cedric Price, and Nicholas Negroponte & MIT's Architecture Machine Group." p204

33 The exhibition catalog describes "an electromagnet, several micro-switches, and pressure-sensing devices" and states that the machine will "be used with many different detachable heads as a general purpose sensor/effector"

Burnham, *SOFTWARE - Information Technology: Its New Meaning for Art*. p23

Other descriptions state "The device has multiple attachments (magnets, photocells, markers, etc.)" and suggest that the SEEK environment may have been used in coordination with a computer vision system, the Minsky/Papert eye.

Negroponte, *The Architecture Machine*. p105, 107

34 "It ran six programs: Generate, Degenerate, Fix It, Straighten, Find, and Error Detect, used to randomly lay out, reconfigure, align, and correct the blocks environment, using its arm and plastic attachments to stack, move, and vibrate the blocks into place"

Steenson, "Architectures of Information: Christopher Alexander, Cedric Price, and Nicholas Negroponte & MIT's Architecture Machine Group." p205

35 Burnham, *SOFTWARE - Information Technology: Its New Meaning for Art*. p23

36 "In most domains of reasonable complexity, an agent will not have complete control over its environment. It will have at best partial control, in that it can influence it."

Wooldridge, *An Introduction to Multiagent Systems*. p16

37 "agents may observe data that differ spatially (appear at different locations), temporally (arrive at different times), or semantically (require different interpretations)."

Vlassis, *A Concise Introduction to Multiagent Systems and Distributed Artificial Intelligence*. p2

38 Wooldridge, *An Introduction to Multiagent Systems*. p225-226

control system for basal functions such as synchronizing actions on a common run-time clock or ensuring that communications between agents are broadcast successfully. These approximations of multiagent systems are natural given that object-oriented methodologies are among the common starting points for the analysis and design of multiagent systems[39] and so many of the lessons of multiagent systems are still applicable.[40] For example, agent behavior can be separated into reactive and proactive capabilities, the combination of which can prove difficult to successfully balance.[41] The advances made in multiagent systems, where this balance cannot be effected by with a central control intelligence but must be tested and negotiated, can push object-oriented models to incorporate additional flexibility and autonomy into their definitions.

§5.3 Diffuse agency

Multiagent approximations

Among the most applicable agent-based methods[42] are models that use entities that move across the environment analyzing, marking, or modifying the ground to produce traces of reactive organization. At their simplest, these may simply be purely reactive path-finding elements.[43] A more complex scenario instrumentalizes the agents' paths to modify the environment, allowing agents to communicate with one another indirectly, transforming a naïvely aggregative logic into a stigmergic one.[44] With the use of large agent populations, these models can be categorized as swarm intelligences.[45] According to Neil Leach, swarm urbanism "involves seeding design intent into a set of autonomous design agents which are capable of self-organizing into emergent urban forms"[46] and "to encode intelligence into urban elements and topologies."[47] Swarm intelligence is often seen as a useful way to replicate or work within informal urban settlements because it reproduces the localized logics and adaptation that occur in the absence of a guiding masterplan.[48]

A similar but somewhat simplified modeling technique is based on the use of cellular automata.[49] Cellular automata models "consist of an array of cells, each with a finite set of possible states … The state of the cells evolves synchronously in discrete time steps as a function of its state and a set of rules which relates the cell to other cells in the system."[50] Each cell then acts as a fixed actor,[51] which is typically distributed within an orthogonal grid[52] and whose state responds to the state of its neighbors following a set of transition rules.[53] In the simplest systems, the cell states are boolean values, but the number of state values can be increased to give more nuance to the simulation, for example, to project multiple land-use classes.[54] In the same way, other facets of the 'conventional' model can be changed to introduce more complex conditions or to model conditions in a more intuitive way.[55] Among these modifications: the definition of neighbor can be expanded beyond directly adjacent cells to effect more dispersed influence;[56] transition rules can be layered as multi-pass operations.[57] To modulate the model granlarity, multiple cellular automata operating at different spatial[58] or temporal[59] scales can be linked, or the cellular automata can be embedded within an agent-based model,[60] or have a multiagent system overlaid on itself.[61] The many variations on the model illustrate the fuzzy boundary between a multiagent system and a cellular automata, but even in its simplest forms cellular automata "are parallel, discrete and dynamic computational frameworks."[62] where "the rules built in to the model are replicated in all the discrete components of the model"[63] and thus a potential approximation of a multiagent system.

Hybrid and distributed agency

In both cases described above, the desire is to leverage the operative and instrumental nature of the diagram[64] and to multiply its mechanisms—not as a *plan générateur*,[65] but "as a modulator of synthesis"[66]—in a generative environment. Instead of a centralized control of power, and a singular structure, "their internal relationships are transposed: moved part by part into the new organizational context"[67] resulting in distributed agency and "emergence exploration"[68] as Negroponte put it. This exploratory attitude toward emergence is significant, because it points beyond the configuration of new objects to the structure of the parameter space that is assembled and which can support the formation of other objects within itself.[69] It is this extension and weaving together of internal identities into an environment that cultivates new assemblages and enables new actualizations that will constitute the generative function.

39 *Ibid.* p226

40 Miranda and Coates, "Swarm Modelling: The Use of Swarm Intelligence to Generate Architectural Form."

A significant difference is that "in the standard object model, there is a single thread of control in the system" whereas "a multiagent system is inherently multi-threaded." Further, "the locus of control with respect to the decision about whether to execute an action is thus different in agent and object systems. In the object-oriented case, the decision lies with the object that invokes the method. In the agent case, the decision lies with the agent that receives the request" To achieve a closer approximation in an object-oriented case, one "can build some kind of decision making about whether to execute a method into the method itself, and in this way achieve a stronger kind of autonomy for our objects."

Wooldridge, *An Introduction to Multiagent Systems*. p26-27

41 Wooldridge, *An Introduction to Multiagent Systems*. p23-24

42 Another common application of agent-based modeling is in the technical simulation of crowds, typically for analysis of a given building or public space, a branch of research which will not be considered here however.

43 "Micro-Oases: Ecology Networking", Jeanne Wellinger, Aurélie Monet Kasisi

Patt and Media×Design Lab, EPFL, "Multi-Agent Sytems: Generative Design Structures for Architecture and Planning." @11:50

44 Meyboom and Reeves, "Stigmergic Space."

45 Within the computer science realm this category must be used carefully as there are competing definitions of what constitutes swarm intelligence or swarm systems, including those which are primarily concerned with optimization of a solution space and less concerned with the behavior of the agents themselves.

Eberhart, Shi, and Kennedy, *Swarm Intelligence*.

46 Leach, "Swarm Urbanism." p61

47 *Ibid.* p59

48 PanahiKazemi and Rossi, "Spatializing the Social: Computational Strategies for Integrated Design in Informal Areas in Istanbul."

49 Batty, *Cities and Complexity*.

50 Dijkstra and Timmermans, "Towards a Multi-Agent Model for Visualizing Simulated User Behavior to Support the Assessment of Design Performance." p223

51 "Basic cellular automata models have actors fixed in particular locations, one actor per cell"

The use of the term 'actor' may be significant here. Few researchers will refer to CA cells as 'agents' even when drawing parallels to agent-based models because the simple state transition that cells undergo do not display the kind of autonomy sought in agent-based models.

Ibid. p225

52 Coates and Derix, "Parsimonious Models of Urban Space." p337

53 *Ibid.* p338

54 Hagen-Zanker, "Sensitivity Analysis of a Cellular Automata Land Use Model through Multiple Metrics of Goodness-of-Fit." p2

55 Couclelis mentions many of the directions which urban models may find it productive to deviate from conventional cellular automata practices.

Couclelis, "From Cellular Automata to Urban Models: New Principles for Model Development and Implementation."

56 Typically with a weighted decay at greater distances, this is implemented both within the cellular lattice:

Slager, de Vries, and Jessurun, "Methodology to Generate Landscape Configurations for Use in Multi-Actor Plan-Making Processes." p10

or by absolute distance:

Li and Yeh, "Urban Simulation Using Principal Components Analysis and Cellular Automata for Land-Use Planning." p345

57 Coates and Derix, "Parsimonious Models of Urban Space." p338

58 Cecchini and Rinaldi, "The Multi-Cellular Automaton: A Tool to Build More Sophisticated Models. A Theoretical and a Practical Implemetation."

59 König, "Generating Urban Structures: New Town Planning with Cellular Automata."

60 Kuo and Zausinger, "Scale and Complexity: Mulit-Layered, Multi-Scalar Agent Networks in Time-Based Urban Design."

61 Dijkstra and Timmermans, "Towards a Multi-Agent Model for Visualizing Simulated User Behavior to Support the Assessment of Design Performance."

62 Popov, "Generative Sub-Division Morphogenesis with Cellular Automata and Agent-Based Modelling." p168

63 Coates and Derix, "Parsimonious Models of Urban Space." p335

64 "The mediating ingredient of the diagram derives not from the strategies that inform the diagram, but from its actual format, its material configuration. The diagram is not a metaphor or paradigm, but an 'abstract machine' that is both content and expression. This distinguishes diagrams from indexes, icons and symbols. The meanings of diagrams are not fixed. The diagrammatic or abstract machine is not representational. It does not represent an existing object or situation, but it is instrumental in the production of new ones."

van Berkel and Bos, *Move*. p324-325

65 Le Corbusier, *Towards a New Architecture*. p45

66 Alliez's entire essay on the the diagram is relevant here, but will be treated at more length later, *cf.* §8.4 'Lines of Flight'

Alliez, *Diagram 3000 (Words)*. p9

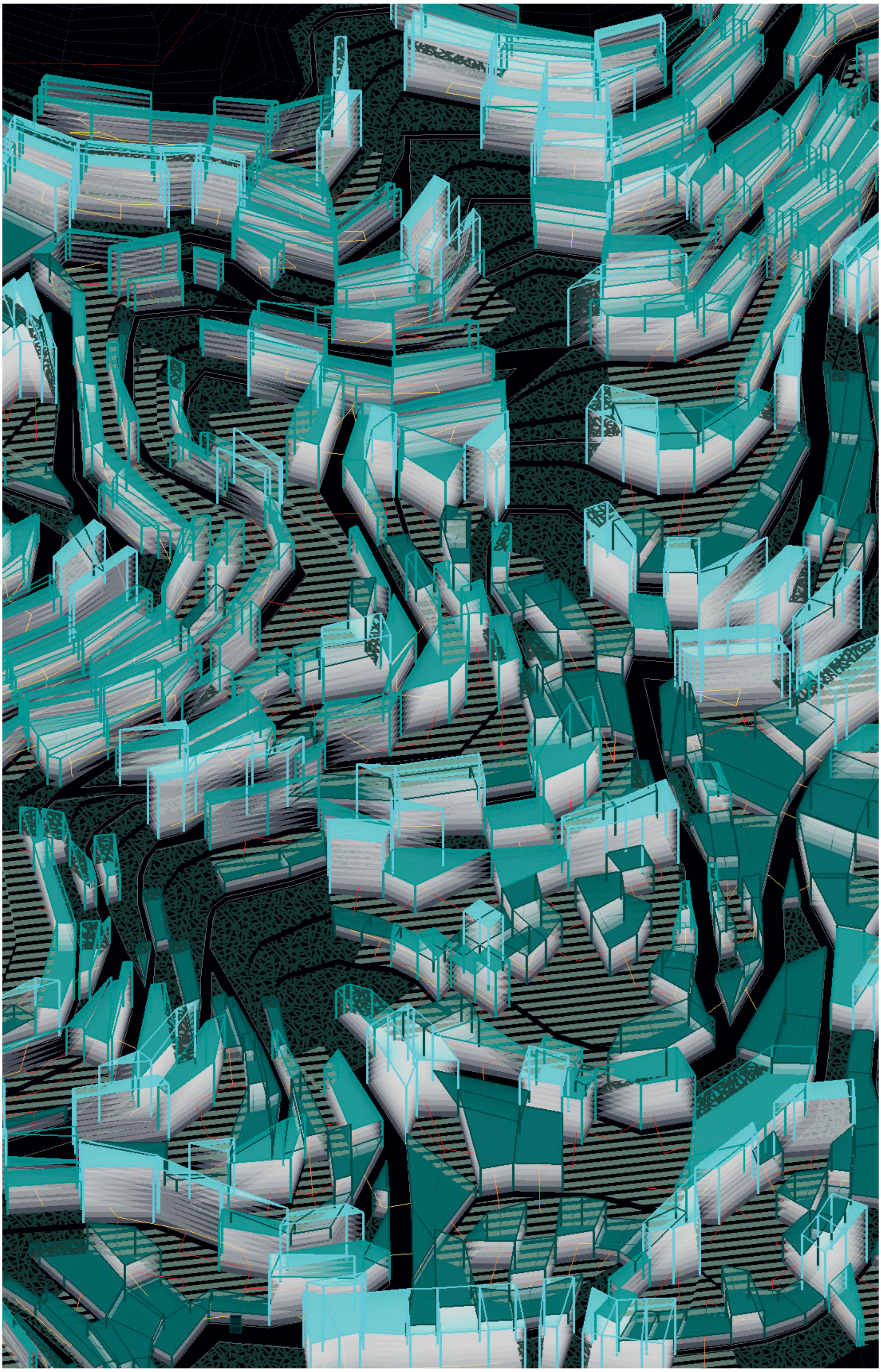
67 Allen, "Mapping the Unmappable: On Notation." p32

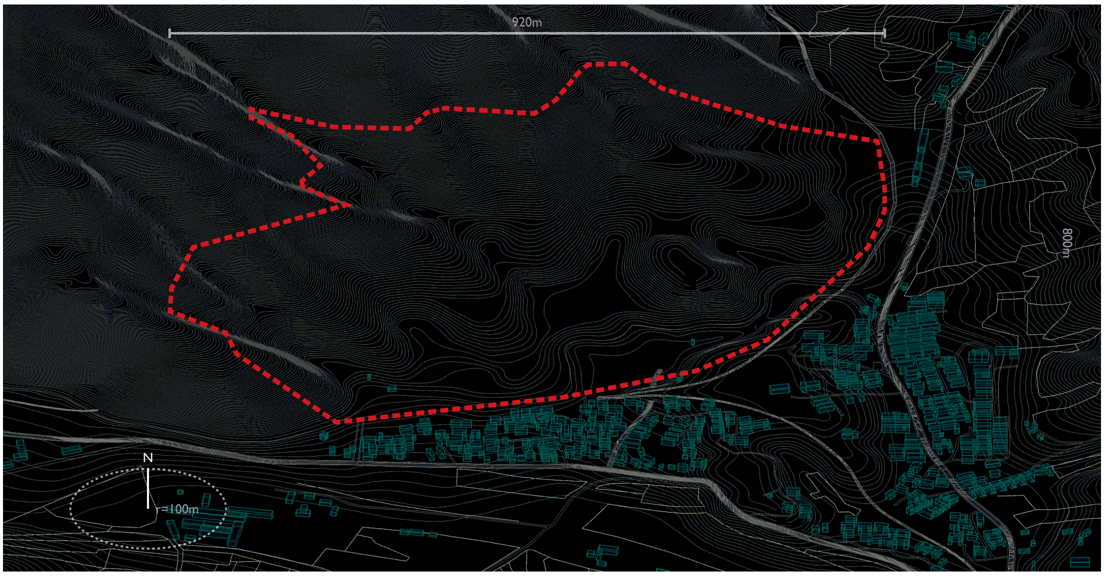
68 Negroponte and Bolt, "Data Space Proposal to the Cybernetics Technology Office, Defence Advanced Research Projects Agency." p7

as cited in:

Steenson, "Architectures of Information: Christopher Alexander, Cedric Price, and Nicholas Negroponte & MIT's Architecture Machine Group." p176

69 DeLanda, *Philosophy and Simulation: The Emergence of Synthetic Reason*. p5





Project 2: Parcels (Beijing)

Qinglonghu is located on the remote periphery of Beijing just outside the sixth ring road around the reservoir for which it is named. The area is characterized by its location in the foothills of the western mountains and this project proposes to occupy these foothills,[70] densifying the village there rather than converting farmland to developable land.[71] The specific site of focus, above the small village of Xinkaikoucun, is approximately 1000×500m in plan on a sharply rising terrain with an elevation change of 80m.[72]

The project begins with a mesh already derived from a topographic analysis (Figure 5.6) and will investigate the generative potential in addressing individual parcels of land as discrete agents with associated traits and behaviors. By staging interactions between neighboring parcels, including the construction of larger assemblages, the project will shed light on how the extension of of objects over one another can negotiate a bottom-up urban strategy. In particular, we are interested in drawing parallels between landscape and architectural uses, rather than separating the two disciplines, and how strategies linking the development of new housing to the ground might establish resistances to the complete engulfing of urban villages by the formal city while still increasing density and quality of living.[73]

70 Yu, Kongjian, Adrian Blackwell, and Stephen Ervin. Qinglonghu Foothill Strategy: Peri-urban Development Alternatives for Southwest Beijing.

71 Lai et al., "Rethinking Property Rights and Industrial Development." p62-63

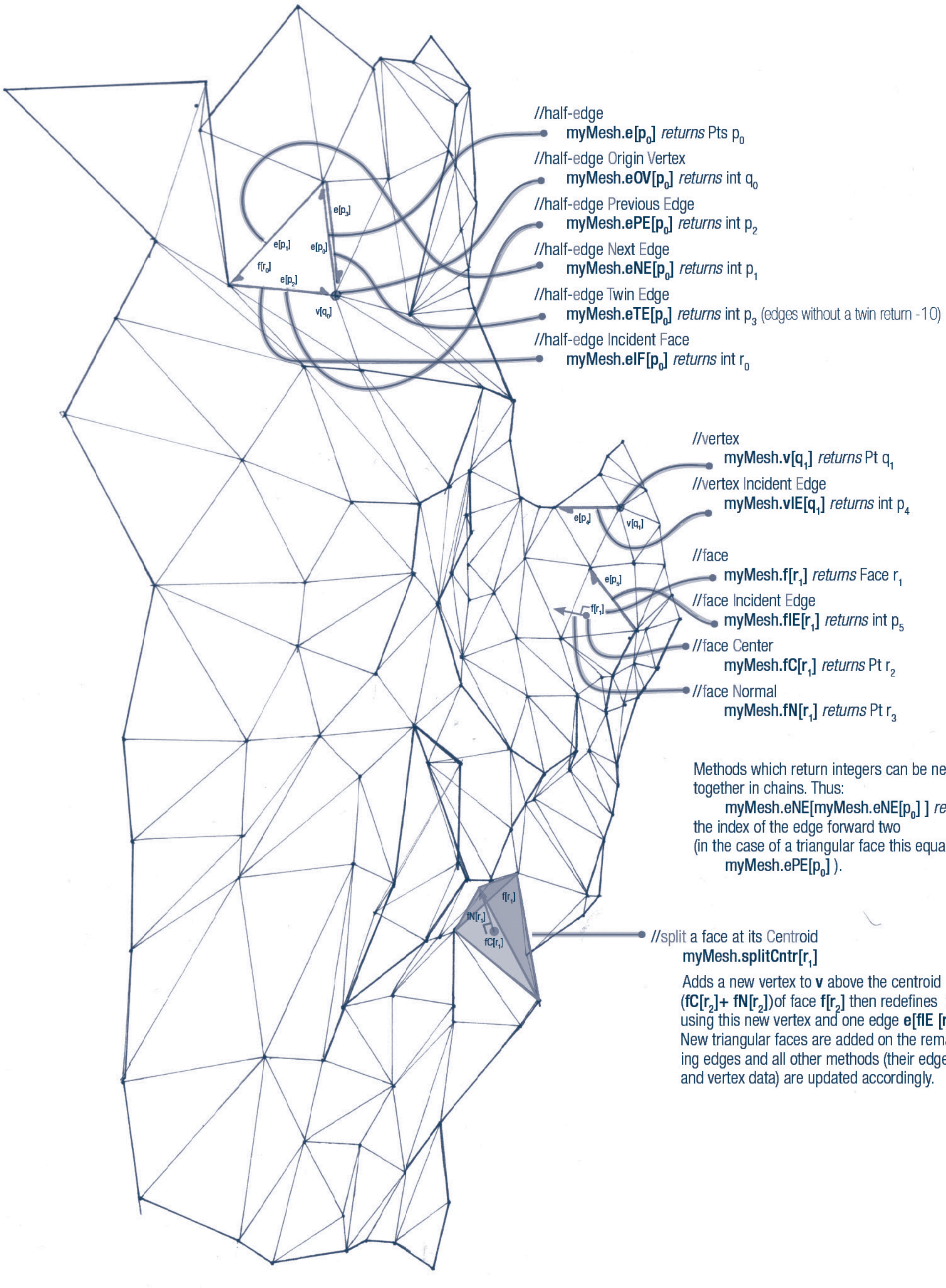
72 Qinglonghu site data courtesy of Turenscape

73 Shannon et al., "Reconsidering Village in the Expanding City – Taihu." p121

Figure 5.3
Detail of Project 2: generative massing study

Figure 5.4
Site condition and boundary

Figure 5.5
Orthophoto of Xinkaikoucun from Bing Maps



Methods which return integers can be nested together in chains. Thus:
myMesh.eNE[myMesh.eNE[p_0]] *returns* the index of the edge forward two (in the case of a triangular face this equals **myMesh.ePE[p_0]**).

Adds a new vertex to **v** above the centroid (**fC[r_2]+ fN[r_2]**)of face **f[r_2]** then redefines f[r_2] using this new vertex and one edge **e[fIE [r_2]]**. New triangular faces are added on the remaining edges and all other methods (their edge and vertex data) are updated accordingly.

§5.4 Discretizing the ground

Half-edge mesh implementation

We will not introduce mobile agents until the next chapter; in order to focus on the aspects of extension and encapsulation, this project will restrict itself to stationary, location-based agents, defined as parcels of land. A mesh of polylines derived from a topographic analysis, similar to those created in Project 1, was drawn on the site. Certain segments of this mesh were coded as roads and pathways, but the rest of the site was left undefined. In order to convert this mesh into discrete units, we will first translate the various segments into a half-edge mesh datastructure (Figure 5.6).[74] The half-edge mesh is so called because each segment, or edge, in the mesh is represented by two elements oriented in facing directions along the edge. The half-edge mesh datastructure contains a list of all of the half-edges, vertices, and faces (or enclosed loops) in the mesh and uses pointers to identify relations between them. Half-edges, for example, record the indices of the vertex at their origin, the face which they belong to, the half-edges before and after them in the sequence of that face, and their twin half-edge.[75] Each vertex records the index of one edge that has that vertex as its origin, while each face also records one of its constituent half-edges.[76]

First among the advantages of this datastructure is the ability to forgo a predefined geometric structure and adopt to irregular and unordered configurations while still maintaining excellent command of adjacencies and network relationships.[77] Additional benefits include the low memory levels required, the ability to quickly locate a point with regard to the mesh, and the flexibility to travel across it either along edges, vertex-to-vertex, or across faces using the half-edges' twins to identify the bordering face.[78]

Agency of the ground

As a datastructure, the half-edge mesh doesn't exhibit any particular agency in itself, it is simply a record of existing geometry. However, we will elaborate on this substrate to construct a multiagent system with agents that over time will calculate a tendency toward and fitness for potential land-use from their geographic and geometric properties, will seek to influence their neighboring parcels according to local behavior diagrams, and will form assemblages with their neighbors when they are in agreement. This project will effectively satisfy the definition of a cellular automata: the faces are discrete entities with state values that change over time in response to itself and adjacent faces.[79] However, in most aspects of its implementation, the procedures chosen will diverge substantially from the properties of a classical cellular automata, generating a more complex ecology as we will detail in the following sections.

74 Also referred to as a doubly-connected edge list. This implementation follows the method described in:

de Berg et al., *Computational Geometry: Algorithms and Applications*. Chapter 2

75 A half-edge's twin is the one that lies on the same edge, but with the inverse direction. A half-edge endpoint is its twin's origin vertex and vice versa.

76 ≒5.4.1 (:12-21)

77 The half-edge mesh datastructure also enables transformations, *cf.* §7

78 The enchainment of various index calls is what enables the half-edge mesh to operate with such a low number of variables. The task described here, of finding an adjacent face can easily be accomplished with the nested sequence *eIF[eTE[fIE[n]]]*, which in natural language equates to, "the face incident to the twin ½-edge of a ½-edge that is incident to the current face, *n*."

79 Dijkstra and Timmermans, "Towards a Multi-Agent Model for Visualizing Simulated User Behavior to Support the Assessment of Design Performance." p223

Figure 5.6
The data fields of the half-edge mesh and their corresponding geometry.

≒5.4.1 HalfEdgeMesh

```
0  INPUTS: seg as List of Curve, bnd as UVInterval, sbdv as Int
1      #IMPORT MODULES
2  import Rhino as rh; import Rhino.Geometry as rhG
3  import Grasshopper as gh; from Grasshopper.Kernel.Data import GH_Path
4  import scriptcontext; from collections import defaultdict
5  import math
6  
7  #==================================================================#
8    #class STORES HALF-EDGE MESH DATASTRUCTURE AND POINTERS
9  class HEM:
10   """Half-Edge Mesh"""
11   def __init__(self):
12     self.e=[]
13     self.eOV=[]
14     self.ePE=[]
15     self.eNE=[]
16     self.eTE=[]
17     self.eIF=[]
18     self.v=[]
19     self.vIE=[]
20     self.f=[]
21     self.fIE=[]
22 
23     self.eDeg=[]
24 
25 def EdgeDirection(eCurr,m):
26   #FIND DIRECTION OF EDGE
27   deg=0
28   if eCurr.Direction.X==0:
29     deg= (90* (eCurr.Direction.Y/abs(eCurr.Direction.Y))) +360
30     deg= (360+deg) % 360
31   else:
32     deg= math.degrees(math.atan(eCurr.Direction.Y/eCurr.Direction.X))
33       if eCurr.Direction.X<0: deg+= 180
34       if eCurr.Direction.X>0: deg= (360+deg) % 360
35   m.eDeg.append(deg)
36   m.eDeg.append((deg + 180) % 360)
37 
38 def CheckSortVertex(eCurr,t,dom,div,dict,m,ct):
39   #VERTEX SPATIAL KEY AND CHECK DUPLICATES
40   ptCk= rhG.Point3d(eCurr.PointAt(t))
41 
42   #POINT KEY
43   keyX= math.floor((ptCk.X-dom.U0) / ((dom.U1-dom.U0)/div))
44   keyY= math.floor((ptCk.Y-dom.V0) / ((dom.V1-dom.V0)/div))
45   keyX= min(max(keyX,0), div-1)
46   keyY= min(max(keyY,0), div-1)
47 
48   #CHECK ALREADY ADDED VERTICES
49   for val in dict.d[keyX,keyY]:
50     if isinstance(val,tuple):
51       vtx,ndx=val
52       if ptCk.DistanceTo(vtx)<.01:
53         ct=(ct[0],ndx)
54         break
55   #IF NOT ALREADY PRESENT, THEN ADD
56   if ct[1]<0:
57     m.v.append(ptCk)
58     dict.d[(keyX,keyY)].append((ptCk,ct[0]))
59     ct=(ct[0]+1, ct[1])
60   return ct
61 
62 def LoopFace(m,n,init,ct,tree):
63   if n!=init:
64     m.f[ct].append(m.e[n].PointAt(0))
65     tree.Add(m.e[n].PointAt(0),GH_Path(ct))
66     m.eIF[n]=ct
67     LoopFace(m,m.eNE[n],init,ct,tree)
68 #==================================================================#
```

This code organizes a list of line segments into a Half-Edge Mesh Datastructure, with edges, vertices, faces, and the necessary pointers saved as methods of the HEM class.

Note: This version anticipates a mesh which is roughly parallel with the world XY-plane, which it uses for sorting the edges radiating out from a vertex into anticlockwise order. Intersections which do not occur at an endpoint will not be included in the half edge mesh.

Reference: de Berg et al., *Computational Geometry: Algorithms and Applications*. ch.2

12 *.e* contains all the half-edges as geometry.

13 *.eOV* saves the index pointing to the originating vertex which is at the start point of the edge.

14 *.ePE* saves the index of the previous edge on the same face.

15 *.eNE* saves the index of the next edge.

16 *.eTE* saves the index of the twin edge, the edge in the same place but pointed the opposite direction and belonging to the adjacent face.

17 *.eIF* saves the index of the incident face that that the edge belongs to.

18 *.v* contains all the vertices as points.

19 *.vIE* saves the index of the incident edge that has this vertex as its starting point.

20 *.f* contains the face geometry as a list of points from which a polyline or surfacce can be made.

21 *.fIE* saves the index of the first incident edge adjacent to this face.

23 Not strictly a part of the Half-Ede Mesh dataclass, *.eDeg* save the angle (in degreess) which an edge is pointed to save on further calculation later.

36 This function calculates the angle of the direction of an edge and saves it in the *.eDeg* list. The second value (:36) is the angle of the twin edge—in this definition an edge and its twin are always entered in sequential indices (:79-80).

43 This function applies a simple bin sorting to the vertices by 2D intervals to speed up the identification of shared vertices (remember that only the segments are taken as inputs). These are saved in a *ghDefaultDict* (:58) using the grid numbers as the keys.

67 This is a recursive function which follows from one edge to its next edge (*.eNE*) until it has recorded all the vertices around a face and returned to the initial edge (:63)

```
70  #BODY OF CODE
71  segCt=0
72  hem=HEM()
73  ef=[]
74
75  #****FOR EACH SEGMENT, ADD EDGE AND ITS REVERSE (twin) TO edgeList****
76  for i, iSeg in enumerate(seg):
77    if iSeg.PointAtStart.DistanceTo(iSeg.PointAtEnd)>0:
78      #ADD EACH SEGMENT AND ITS REVERSE
79      hem.e.append(rhG.Line(iSeg.PointAtStart,iSeg.PointAtEnd))
80      hem.e.append(rhG.Line(iSeg.PointAtEnd,iSeg.PointAtStart))
81      #ADD TWIN EDGE INDEX
82      hem.eTE.append((segCt*2)+1)
83      hem.eTE.append(segCt*2)
84
85      #NEGATIVE INDEX VALUES INDICATE NOT YET ASSIGNED VALUES
86      [hem.eIF.append(-10) for x in xrange(2)]
87      [hem.eNE.append(-10) for x in xrange(2)]
88      [hem.ePE.append(-10) for x in xrange(2)]
89      EdgeDirection(hem.e[len(hem.e)-2],hem)
90      segCt+=1
91
92
93  vtxDict=scriptcontext.sticky['ghDefaultDict'](defaultdict(list))
94  [[vtxDict.d[i,j].append([]) for j in xrange(sbdv)] ...
... for i in xrange(sbdv)]
95
96
97  vCt=(0,-10)
98  vIElst=[]
99  fTree=gh.DataTree[rhG.Point3d]()
100
101 #************CONSTRUCT VERTEX LIST FROM LIST OF HALF-EDGES************
102 for i, iSeg in enumerate(hem.e):
103   vCt=(vCt[0],-10)
104   vCt=CheckSortVertex(iSeg,0,bnd,sbdv,vtxDict,hem,vCt)
105   #IF A NEW VERTEX WAS ADDED, THEN ADD EDGE INDEX TO vIE, vIEall, eOV
106   if vCt[1]<0:
107     hem.vIE.append(i)
108     hem.eOV.append(vCt[0]-1)
109     vIElst.append([])
110     vIElst[len(vIElst)-1].append((hem.eDeg[i],i))
111   else:
112     hem.eOV.append(vCt[1])
113     vIElst[vCt[1]].append((hem.eDeg[i],i))
114
115
116 #****************FROM EACH VERTEX, SORT EDGES RADIALLY****************
117 for i,iLst in enumerate(vIElst):
118   iLst.sort()
119   for j, (deg,ndx) in enumerate(iLst):
120     hem.eNE[hem.eTE[ndx]]= iLst[(j+1) % len(iLst)][1]
121     hem.ePE[iLst[(j+1) % len(iLst)][1]]= hem.eTE[ndx]
122
123
124 faceCt=0
125 #****************FROM EACH HALF-EDGE, LOOP AROUND FACE****************
126 for i, iSeg in enumerate(hem.e):
127   if hem.eIF[i]<0:
128     hem.f.append([])
129     hem.f[faceCt].append(hem.e[i].PointAt(0))
130     fTree.Add(hem.e[i].PointAt(0),GH_Path(faceCt))
131     hem.fIE.append(i)
132     hem.eIF[i]=faceCt
133     LoopFace(hem,hem.eNE[i],i,faceCt,fTree)
134     faceCt+=1
135
136 pyHEM=hem
137 e=hem.e
138 v=hem.v
139 f=fTree
140 OUPUTS: pyHEM, e,v,f
```

86 This and the following lines use generator expressions to add placeholder values into the *.eIF*, *.eNE*, and *.ePE* lists two at a time (*in xrange(2)*). These values will be assigned later and out of order as the script uncovers the various relationships.

94 Generator expression to populate the bin sort dictionary with a square array of keys as lists.

98 A variable for storing the face geometry from *.f* in a grasshopper datastructure for output

103 This counter saves the number of vertices in its first term and the second term denotes (by a negative number) if a new vertex is added or (by a positive number) the index of the existing vertex if a point at that location has already been saved (:59, 53).

110 *vIElst* is a temporary list that saves the indices of all the edges leaving each vertex and their degree so that they can be sorted radially (:116) allowing the code to determine their succession (:118, 119).

§5.5 Extension

Agent definition

Like the *TopoPoint* (≒4.4.3), the *FaceAgent* class includes a list of attributes for storing metadata values related to geometric properties and topographic analysis.[80] In contrast to that class, which mostly served a recording function, the *FaceAgent* also includes within itself the functions that define its behaviors. The result is that the functional code that directs the flow of the script becomes very short, but following the script now means reading from two different locations: first the function call in the sequential code ≒5.5.1 (:40) and then moving to the object definition ≒5.5.2 (:64*ff*). As objects accumulate multiple functions, some additional attention to how these functions interact with one another is required given their dispersion within the code. Wooldridge describes a layered architecture for agents wherein functions are given an order of priority, with the initial functions also acting as gates to the subsequent functions.[81] The *FaceAgent* class has three main behaviors. It first calculates a series of values that indicate fitness for various uses based on its environment.[82] When one of the fitness values reaches a sufficiently high value, the face takes on the designated use and begins to influence its neighbors. Finally, if the face has maintained a use for a certain duration, it can look to its neighbors and attempt to form clusters with them. The transition from one function to the next is regulated by the value *.lyr* attribute which is evaluated at the end of each function (:113*ff*).[83]

The *.use* value in this example is comparable to the state variable in a cellular automata, it gives the physical outcome and the overall pattern. Though cellular automata states are most often defined by a simple patterns of adjacent cells, there is a precedent for defining the transition rules through a synthesis of multiple criteria.[84] Here, we calculate the fitness for each face by adding up incremental adjustments throughout ≒5.5.2 in the *ftAdjst* variable and then applying the sum of those adjustment values to the face's *.ftns* values. In this process, the initial frames are more sensitive to the static site properties like the slope, solar incidence, and elevation (:76), while the later frames respond more to dynamic inputs such as the position of attractor curves that can be controlled by the user while the simulation is running (:92ff). The matrix of the adjustment values and the way they impact uses differently can also be controlled by the user through a spreadsheet as illustrated in Figure 5.7.[85]

80 These have been elided in the presentation of ≒5.5.2 for considerations of space, but will be identified in the code comments when they appear if they have not been explained yet.

81 Wooldridge, *An Introduction to Multiagent Systems*. p97

82 These uses are simple volumetric or surface categories:

1) high-rise of around 8 stories;

2) mid-rise of 3-5 stories;

3) low-rise of 1-2 stories;

4) open green space that is potentially a courtyard or garden space; and

5) open void space that remains unused.

83 While the transition criteria is determined within the object functions, this implementation is unlike Wooldrige's example in that the actual layer transition is evaluated outside the object domain (:36).

84 An example of multiple criteria:

Katoshevski, Arentze, and Timmermans, "Simulating Urban Dynamics Using a Combination of Cellular Automata and Activity-Based Models."

and multi-step transition rules:

Coates and Derix, "Parsimonious Models of Urban Space."

85 Importing the spreadsheet data from a .csv file is described in detail in Appendix.5.1.

≒5.5.1 enactFaceAgents

```
0    INPUTS: mf, coeff as List; dnsAttr, openAttr as List of Curve;
...  hardReset, stepClock, run as Boolean
     import scriptcontext as sc

     #============================TIMER SETUP============================#
     #ADD COUNTER TO sticky
5    if "fitCounter" not in sc.sticky:
       sc.sticky["fitCounter"]= 0

     #SINGLE FRAME STEP COUNTER IF stepClock
     if stepClock:
10     print("step")

     #RESET VALUES IF hardReset
     if hardReset:
       sc.sticky["fitCounter"]= 0
15     for f in mf:
         f.dur= 0
         f.ftns= [0,0,0,0,0]
         f.use= -10
         f.sens= 1
20       f.clstr= -10
         f.lyr= 0
       run= False

     #==============================MAIN================================#
25   graphObj= sc.sticky['sensitivityGraphs']
     # INCREMENT WHEN run
     if run:
       sc.sticky["fitCounter"]+= 1

30     #LOOP THROUGH ALL FACES
       for i,fN in enumerate(mf):
         #EXCEPT THE OUTER FACE
         if fN.area < 9000:

35         #CALCULATE FITNESS VALUE IF lyr==0
           if fN.lyr == 0:
             fitCk= 0
             if fN.age < graphObj[0].Container.X1:
               fitCk= graphObj[0].Container.ValueAt(fN.age)
40           fN.CalcFitness(coeff, [0,0,0,0,0], fitCk, [dnsAttr,openAttr])
           fN.age+=1

         #CHECK BEST FIT, UPDATE .use AND LAYER
         fN.CheckUse(graphObj[1].Container.X0)
45   pyMF=mf
     OUTPUTS: pyMF
```

A frame counter is setup to allow incremetal iteration of the code with a timer, slider animation, or through manual prompts.

Reference: *http://www.grasshopper3d.com/forum/topics/c-timer-to-python-timer?commentId=2985220%3AComment%3A908171*

05 The frame counter variable *fitCounter* is saved to *sticky*. Note that if more than one counter is being used in a Grasshopper definition, they must take different variable names.

10 The *stepClock* input is a boolean Button. When triggered, the code will run once.

13 *hardReset* is also a boolean Button, which resets the frame count when pushed. The aggregate object properties must also be reset (:16-21) or the next running of the script will start from a biased position.

27 *run* is a boolean Toggle, which allows better stop/start control when timers are attached.

36 Every face begins the simulation with *.lyr* value at 0. While they remain at this layer, they calculate adjustments to their fitness values each frame (:40) through a call to an object function, *.CalcFitness()* (≒5.5.2).

44 *.CheckUse()* is another object function, not reprinted here, that identifies whether the maximum *.ftns* value is high enough to indicate a *.use* value and to effect a transition to the next *.lyr*.

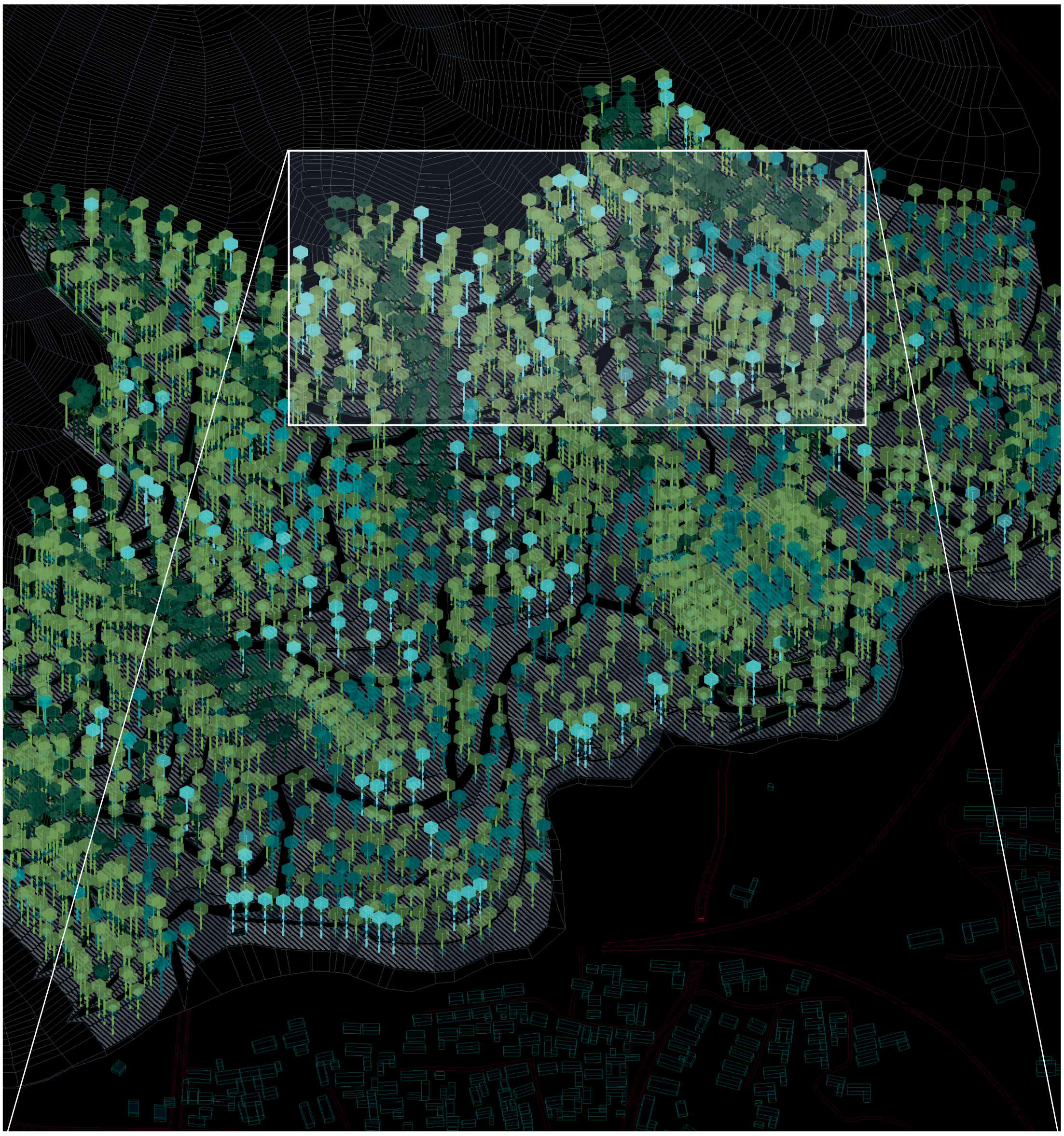
Fitness Coefficients:	HI	MI	LO	GR	∅
Slope **<15°**	0.15	0.25	0.1	0.2	-0.2
Slope **<30°**	0	0.1	-0.1	0.35	0
Slope **<90°**	0.25	0	-0.3	0.5	0.6
Solar Incidence **<30°**	0.15	0.25	0.1	0.2	-0.2
Solar Incidence **<60°**	0	0.1	-0.1	0.35	0
Solar Incidence **<90°**	-0.2	0	-0.3	0.2	0.3
Elevation **<105m**	0	0	0.2	0.2	0
Elevation **<135m**	0	0.4	0.1	0.25	0
Elevation **<160m**	0.2	0.1	0	0.3	0
Excessive **Runoff**	-1	-0.75	-0.5	-0.25	1
Very Small Parcels	-1	-0.75	-0.25	-0.5	0.75
Very Large Parcels	-0.75	-0.5	-0.1	0.2	0.15
Road Adjacent: **0 Edges**	0	0.1	0	0.3	0
Road Adjacent: **1 Edge**	0.3	-0.1	0.1	0.2	0
Road Adjacent: **2 Edges**	-0.2	-0.1	0	0	0.3
Density Attr: **Very Near**	1.5	1	0	0	0
Density Attr: **Near**	1	0.5	0	0	0
Openness Attr: **Very Near**	-0.5	0	0.5	1.5	2
Openness Attr: **Near**	-0.25	0	0.25	0.75	1

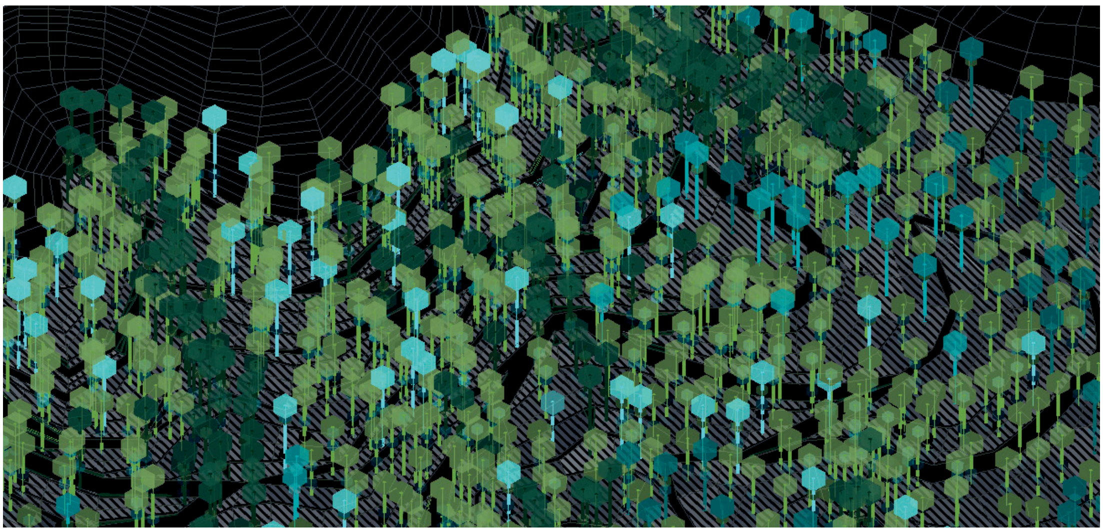
Figure 5.7

In order to facilitate user input and adjustment of large quantities of related data, this project uses formatted spreadsheets (LibreOffice *.ods* files) where values tables of data can be quickly set and compared to one another. The spreadsheet manager can automatically color the cells by a value gradient to allow visual comparison. This replaces an unweildy set of text panels and sliders as in ≒4.8.1 and Figure 4.12.

This spreadsheet lists a number of environmental conditions in the first column and asks the user to judge how these properties impact a parcel's fitness for five different use cases (*cf.* note 82 above). The *FaceAgent.CalcFitness()* in ≒5.5.2 will apply these coefficients to the parcel's *.ftns* values as incremental incentives (positive values) or disencentives (negative values) each frame of the simulation until a suitable use is determined.

Importing and formatting these data files in *GhPython* is described in Appendix 5.





≒5.5.2 FaceAgent class, CalcFitness

```
5      ...
       #==================================================================#
       class FaceAgent:
         "MeshFace IS A SITUATED, LOCALIZED AGENT"
         def __init__(self, f,n):
...        ...
50         #PHASING AND DEVELOPMENT
           self.age= 0
           self.sens= 1
           self.dur= 0
           self.fin= 0
55         self.attch= 0
           self.phase= 0
           self.use= -10
           self.ht= 0
           self.clstr= -10
60
           self.ftns= [0,0,0,0,0]

         #================================================================#
         def CalcFitness(self, coeff, ftAdjst, k, attr):
65         #FITNESS ADJUSTMENT COEFFICIENTS
           slopeAdj= coeff[0]; solAdj= coeff[1]; elevAdj= coeff[2]
           runoffAdj= coeff[3]; smallAdj= coeff[4]; largeAdj= coeff[5]
           rdAdj= coeff[6]; attrAdj= coeff[7]

70         #SELECT APPROPRIATE SLOPE/SOLAR/ELEVATION COEFFICIENTS
           slopeCk= int(min(math.floor(self.slp/15), 2))
           solCk= int(min(math.floor(self.sol/30),2))
           elevCk= int(min(math.floor((self.ofs[0].Z-80)/25), 2))

75         #SELECT ENVIRONMENTAL COEFFICIENTS
           siteSum= [k*(sl+sol+el) for sl,sol,el in ...
...                 zip(slopeAdj[slopeCk], solAdj[solCk], elevAdj[elevCk])]
           #ADD TO ftAdjst
           ftAdjst= [f+s for f,s in zip(ftAdjst, siteSum)]

80         #CHECK THRESHOLD OVERRIDES AND ADD TO ftAdjst
           if not self.runoff:
             ftAdjst= [f+r for f,r in zip(ftAdjst, runoffAdj)]
           if self.area < 27:
             ftAdjst= [f+sm for f,sm in zip(ftAdjst, smallAdj)]
85         elif self.area > 500:
             ftAdjst= [f+l for f,l in zip(ftAdjst, largeAdj)]

           #ROAD ADJACENCIES
           if self.rd > 0:
90           ftAdjst= [f+r for f,r in zip(ftAdjst, rdAdjst[rdCt])]

           #CHECK ATTRACTORS: DENSITY CENTERS, OPEN SPACE CENTERS
           attrK= (1.15-k)*.25
           if self.age > 30:
95           if self.cntr:
               cPts= [rhG.Curve.PointAt(iCrv, ...
...            rhG.Curve.ClosestPoint(iCrv, self.cntr)) for iCrv in attr[0]]
               d= map(self.cntr.DistanceTo, cPts).sort()
               if d[0] < 40:
                 ftAdst= [attrK*(f+d) for f,d in zip(ftAdjst, attrAdj[0])]
100            elif d[0] < 80:
                 ftAdst= [attrK*(f+d) for f,d in zip(ftAdjst, attrAdj[1])]

               cPts= [rhG.Curve.PointAt(iCrv, ...
...            rhG.Curve.ClosestPoint(iCrv, self.cntr)) for iCrv in attr[1]]
               d= map(self.cntr.DistanceTo, cPts).sort()
105            if d[0] < 40:
                 ftAdst=[attrK*(f+d) for f,d in zip(ftAdjst, attrAdj[2])]
               elif d[0] < 80:
                 ftAdst= [attrK*(f+d) for f,d in zip(ftAdjst, attrAdj[3])]

110        for i,adj in enumerate(ftAdjst):
             self.ftns[i]+= adj*k
         #================================================================#
```

The *FaceAgent* class. One *FaceAgent* is instantiated for each face in the HalfEdgeMesh (≒5.4.1) with geometric and topographic metadata (:10-49). This class encapsulates the behaviors the faces will use to analyze their fitness and determine their state transitions. The first function is included here, others will follow (≒5.5.4).

66 The coefficient values from **Figure 5.7** are imported as a single, nested list and here split into separate (sometimes still nested) lists for improved legibility.

71 The slope coefficients have three gradations (<15°, 15-30°, and >30°). The *slopeCk* variable converts the *FaceAgent*'s own *.slp* value into an index for selecting the appropriate set of coefficients. The same thing happens for solar incidence (:**72**) and elevation (:**73**).

76 Using list comprehensions with the *zip()* function, all three coefficient lists can be summed up and applied to the *.ftAdjst* list (:**78**). The *k* value comes from an evaluation of a *graphMapper* component (≒**5.5.1 :25**) exactly like the one in ≒**4.4.1**. This allows the impact of different properties to change over time.

96 Curve attractors can be introduced into the model during the simulation runtime to produce targeted densification (*attr[0]*) or voids (*attr[1]*, :**103**). The *attrK* variable is defined as the inverse of *k* (:**93**) so that the attractors begin with low impact alllowing the fixed environmental conditions to act and then increase in effect as the others wane. This allows the initial site conditions to influence the placement of attractor curves.

111 When all the fitness adjustments have been added up they are added to the *FaceAgent*'s *.ftns* values.

Figure 5.8
The fitness landscape as a compound bar graph a few frames into the simulation. The fitness values at each face are marked in the z-dimension with a small hexagon. The largest value is shown by a larger hexagon and dictates the color of the bar

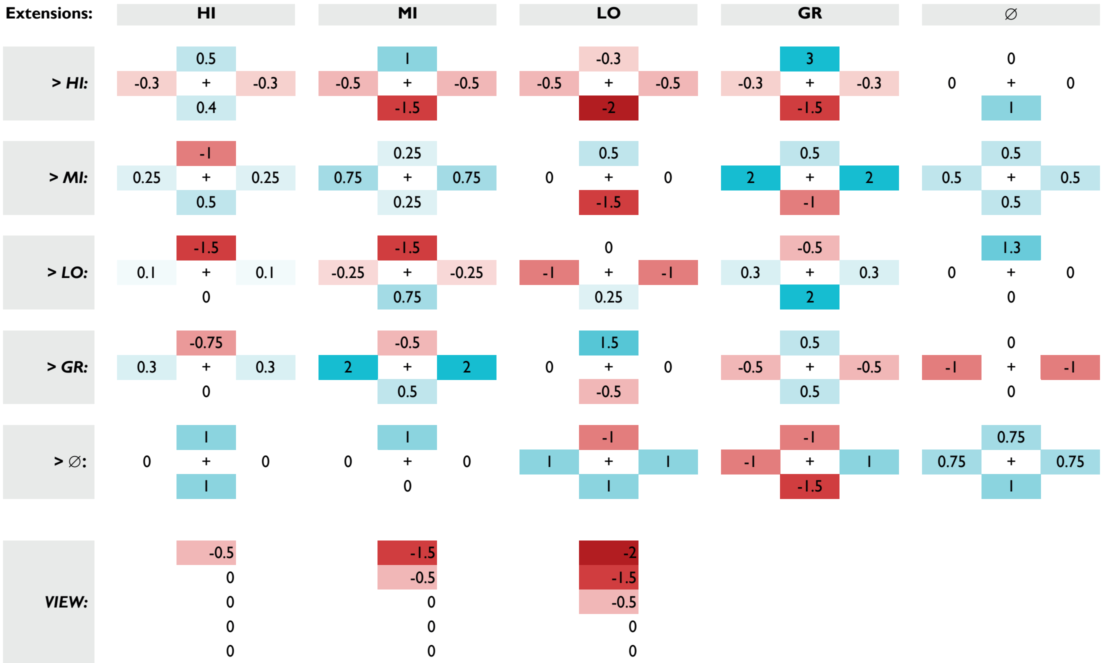


Figure 5.9

Another spreadsheet is used to input the magnitudes of adjacency behaviors. The same process of incremental adjustment is used, but here there is also a spatial condition.

For each use case that a parcel may take (vertical columns) there is a set of adjustments that it applies to its neighbors' *.ftns* values (horizontal rows) to try to effect a change. The adjustment values will vary depending on the orientation of the neighbor parcel from the current one. These values are arrayed in a compass rose around each '+'.

If, for example, the current parcel has a *.use* value of 0, it is tending toward a high-rise massing (HI) and it will read from the first column. Any parcel to the north of it will receive an adjustment to its *.ftns* values of [.5, -1, -1.5, -.75, 1]. This is motivated by a desire to discourage mid-rise (>MI) or low-rise (>LO) buildings from being placed in its shadow but to allow the next parcel to also be a high-rise (>HI) or a non-garden open space (>∅).

The VIEW value refers to an orientation parallel to an input vector that defines a desirable view, in this case downhill toward the village.

Adjacency behaviors

As the the landscape of fitness values develops and parcels with *.use* values emerge, these faces continue to the next behavior layer, *.CalcAdjacency* (≒5.5.2) in which their *.use* value influences the cells neighboring it. At this point, the active faces are analogous to the seed of a cellular automata with the added distinction that new seed cells may emerge independent of the adjacency behaviors since the fitness functions continue to run on faces that have not yet established a *.use* value.[86]

One significant departure that distinguishes this model from a classical cellular automata is that the cells do not have a regular shape or distribution. This fact contributes, of course, to the differentiation of parcels in the calculation of fitness values but it also has an effect here. Earlier, in the *FaceAgent* class definition, we compiled a list of data about each face's direct neighbors[87] in the *.fDeg* attribute (:153). Looping through this list, we again apply incremental adjustments to the *.ftns* values of the neighboring cells, following an matrix of patterns (Figure 5.9) that define desirable or undesirable adjacencies for the current face and its current projected use. The spreadsheet for inputting this matrix is formatted to allow the direction of the neighboring face (:155) to influence the response, biasing certain orientations,[88] for example to avoid placing a low building in the shadow of a taller one. Other location-based data can also be considered, for example, opening up a view corridor from taller buildings (:170) or altering behaviors based on relative elevation (:163). In this way, the abstract behaviors of a cellular automata are translated into more concrete conditions that will likely be more immediately useful to the designer while maintaining the generative, bottom-up complexity of localized behaviors.

86 König also describes a process where initial seed cells emerge from a generative process, though he appears to maintain a strict division between the two stages.

König, "Generating Urban Structures: New Town Planning with Cellular Automata."

87 That is, those faces that share an edge with the face in question, in CA terms, the von Neuman neighborhood.

Dijkstra and Timmermans, "Towards a Multi-Agent Model for Visualizing Simulated User Behavior to Support the Assessment of Design Performance." p224

88 Batty, "A Digital Breeder for Designing Cities."

≒5.5.3 CallAdjacency

```
0   INPUTS: mf, coeff as List
    import scriptcontext as sc
    graphObj=sc.sticky['sensitivityGraphs']

    thr = graphObj[2].Container.X0
5   #LOOP THROUGH ALL FACES
    for i,fN in enumerate(mf):
      #IF FACE .lyr VALUE IS ONE
      if fN.lyr == 1 and fN.area < 9000:
        #CALCULATE EXTENSION EFFECTS IF PHASE==1
10      k= graphObj[1].Container.ValueAt(fN.ftns[fN.use])
        adjCt= fN.CalcAdjacency(coeff, k, thr)

        #IF (>3) BUILDINGS AROUND, INCREASE GR FITNESS, DECREASE .dur
        if adjCt>3:
15        fN.ftns[3]+=.5
          fN.dur-=.75

    pyMF= mf
    OUTPUTS: pyMF
```

This script calls into action the first layer behaviors, the extension of traits from one face over its adjacent.

2 This script references GraphMapper components like those in ≒4.4.1 to gradually dampen the effect of adjacency pertrubations.

11 For each face in the loop, if the fitness value has crossed the threshold to trigger the behaviors for the first layer (:08), calculate the adjacency effects, ≒5.5.4.

≒5.5.4 CalcAdjacency

```
145 #====================================================================#
      def CalcAdjacency(self, coeff, k, t):
        #COUNT ADJ BUILT .use
        adjCt=0

150     #EXTEND INFLUENCE OVER NEIGHBORING CELLS
        for ang,ndx,len,eNdx in self.fDeg:
          #qd == 1: #NORTHWARD, 2: EAST/WEST-WARD, 3: SOUTHWARD
          qd= math.ceil(math.floor(ang/45)/2)
          mf[ndx].ftns= [f+(k*z) for f,z in zip(mf[ndx].ftns, ...
155                                                 coeff[qd][self.use])]

...       #LONG, TALL EDGES ENCOURAGE MATCHING .use
          if len > 25 and hem.eOff[eNdx] == 0 and fN.use < 2:
            mf[ndx].ftns[fN.use]+= .4
          #SUPPRESS HORIZONTAL GREEN BANDS IN FAVOR OF VERTICAL ONES
160       if self.use == 3 and mf[ndx].use == 3:
            if self.ofs[0].Z == mf[ndx].ofs[0].Z:
              mf[ndx].ftns[3]+= -1
              mf[ndx].dur+= -1.5
            else:
165           mf[ndx].ftns[3]+= .4

          if self.use < 3:
            #IF CURRENT .use IS BLDG, SUPPRESS VIEW CORRIDOR OBSTRUCTIONS
            for ang,ndx,zDelt,eNdx in self.vwDeg:
170           if ang<30:
                mf[ndx].ftns= [f+(k*z) for f,z in ...
                                        zip(mf[ndx].ftns,vwAdjst[self.use])]
                #RADIUS x2
...             for ang2, ndx2, zDelt2,eNdx in mf[ndx].vwDeg:
                  if ang2 < 30:
175                 mf[ndx2].ftns=[f+(.75*k*z) for f,z in ...
                                        zip(mf[ndx2].ftns,vwAdjst[self.use])]

...           #AND REVERSE DIRECTION
              elif ang>150:
                mf[ndx].ftns=[f+(k*z) for f,z in ...
180                                     zip(mf[ndx].ftns,rvAdjst[self.use])]
                #RADIUS x2
...             for ang2, ndx2, zDelt2,eNdx in mf[ndx].vwDeg:
                  if ang2 > 150:
                    mf[ndx2].ftns=[f+(.75*k*z) for f,z in ...
                                        zip(mf[ndx2].ftns,vwAdjst[self.use])]
185         if mf[ndx].use < 3:
...           adjCt+=1

        #CHECK LAYER THRESHOLD
        if self.dur > t:
          self.lyr= 2
190     return adjCt
    #====================================================================#
```

Each face extends a set of modifications to its neighbors fitness values and checks its own *.lyr* value

153 The quadrant *qd* in which the neighboring face is located is calculated from the angle, *ang* (this is the measure in radians from north)

154 Values from Figure 5.9 (*coeff*) are selected by the current face's *.use* and the direction of the neighboring face (*qd*) and added to the adjacent face's *.ftns* values.

167 Built uses react to view corridors with a radius of two faces (:173, 181).

188 If the current face's *.use* value has persisted, the *.dur* value will raise to signal the second layer behaviors of Cluster formation, ≒5.6.1.

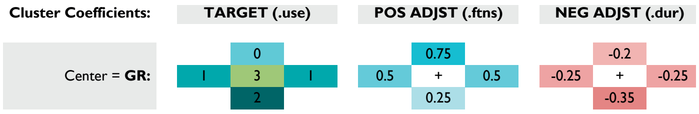


Figure 5.10
Clusters begin from a central garden space (GR=3) and search for a particular pattern of uses in their neighbors (TARGET). When a match is found a *Cluster* is instantiated. If the neighbor's *.use* value does not match, an adjustment is made to the target *.ftns* value of the neighbor (POS ADJST) and to its *.dur* value (NEG ADJST) to encourage a state change.

§5.6 Assemblage Emergence

Clustering behaviors

Finally, we introduce the final layer, which matches adjacent faces against a template to see if they follow the desired pattern of behavior. Where such *Clusters* form (≒5.6.1), they are then able to further direct their neighboring faces toward completing the set. Here we have input a target pattern with a central green space surrounded by buildings of various height, taller toward the north and terracing downward to the south (**Figure 5.10**). The *Cluster* introduces a new scalar layer of tendencies into the model.[89] Thus, while the method of influence remains incremental adjustment of the *.ftns* value (:219-220), the number of relationships that might occur between two faces multiplies. Neighboring faces may both belong to the same *Cluster*, to two different ones, or to none. A face may be added to a *Cluster* (≒5.6.2 :24), drawn away by a larger *Cluster* (≒5.6.1 :242), or two *Clusters* merged together (≒5.6.2 :29).[90] The script can extract their perimeter boundaries (≒5.6.2 :42) or links which could have design uses, such as the placement of garden walls or circulation paths..

Intensional and extensional sets

The inclusion of formal assemblages in the definition of the model raises additional questions about how such assemblages are to be defined. Badiou points out that modern set theory defines inclusion as an extensional function[91]—"that is, the result of a simple collecting together of previously existent elements, which may or may not share any unifying properties."[92] In such a case, an object can be included in a set, any set whatsoever, simply by the willful act of creating the set,[93] rather than belonging to a set because of some inherent property.[94] We should be inclined to favor the extensionally defined set then,[95] in order to preserve the distinction between the assemblage's internal definition and its external manifestation of qualities.[96] Furthermore, given that each element of the assemblage is itself an assemblage, the concept of a necessary intensionality falls apart when confronted with the complexity of an assemblage's internal multiplicity.[97] In this example, the *Clusters* are formed and unformed extensively by the script out of an intensional set, the set of all neighboring faces, in a way that sprawls and extends beyond that passive definition. In this way, set formation is a creative act that acknowledges the agency of naming that "writes a new type of reality,"[98] and better catalyzes the generative force action of the virtual.[99]

89 Cecchini and Rinaldi, "The Multi-Cellular Automaton: A Tool to Build More Sophisticated Models. A Theoretical and a Practical Implemetation."

90 In a few odd conditions it is possible for two *Clusters* to overlap one another.

91 "In an intensional set like 'the set of all red things,' 'redness' serves as the foundation of the set. Such sets require a coherent and clearly defined set of properties, and as such intensional sets are top-down affairs: system operations.

An opposite, "extensional" conception understands a set only by the collection of objects that it contains. The extensional set is fundamentally constructed from the bottom up."

Bogost, *Unit Operations*. p11

92 Hallward, *Badiou: A Subject to Truth*. p333

93 "The first advantage is the ability of the axiom system to manipulate sets without ever employing an explicit definition"

Feltham, *Alain Badiou: Live Theory*. p91

94 The intensional set, "that is, the collection of objects corresponding to a predicate or concept … presumes the logical priority of the concept over its application"

Hallward, *Badiou: A Subject to Truth*. p333

95 An example of intensional definition can be seen in morphologies based on shape-grammars.

Müller et al., "Procedural Modeling of Buildings."

96 *cf.* §2.4-2.5, especially §2.5a 'Pure Interiority'

97 The extension of an object over its neighbor, does not render the neighbor inherent to the assemblage because the relation is not contained in the subject of the assemblage.

Deleuze, *The Fold: Leibniz and the Baroque*. p111

98 Alliez, *Diagram 3000 (Words)*. p12

99 Contrasted with the intensional set whose object is the already given of the possible:

cf. §5.8 'Enacting Encounters'

≒5.6.1 ClusterFormation

```
200  #====================================================================#
     def FormCluster(self, coeff, mf, cl, n, init, i):
       #LOOP AROUND FACE
       for ang,fNbor,lng,eNdx in mf[i].fDeg:
         #IF NEIGHBOR IN SAME CLUSTER OR ACROSS ROAD, continue
205      if self.clstr >= 0 and self.clstr == mf[fNbor].clstr:
           continue
         elif m.eRd[eNdx]:
           continue

210      #OTHERWISE IF NEIHBOR IS BLDG:
         elif mf[fNbor].use >= 0 and mf[fNbor].use < 3:
           clCk= False
           qd= math.ceil(math.floor(ang/45)/2)

215        #IF USE MATCHES TARGET VALUE
           if mf[fNbor].use == coeff[0][qd]:
             clCk= True
           else:
             mf[fNbor].ftns[coeff[0][qd]]+= coeff[1][qd]
220          mf[fNbor].dur+= coeff[2][qd]

           #IF MATCHED TARGET PATTERN:
           if clCk:
             self.attch+= .1
225          mf[fNbor].attch+= .1
             #CURRENT FACE HAS NO CLUSTER; THEN CHECK IF NEIGHBOR DOES
             if self.clstr < 0:
               if mf[fNbor].clstr < 0:
                 mf[fNbor].clstr= len(cl)
230              self.clstr= len(cl)
                 cl.append(Cluster(i,fNbor,len(cl),m))
               else:
                 self.clstr= cl[mf[fNbor].clstr].ID
                 cl[mf[fNbor].clstr].AddFace(i,m)
235
             #CURRENT FACE HAS CLUSTER; THEN CHECK IF NEIGHBOR DOES
             else:
               if mf[fNbor].clstr < 0:
                 mf[fNbor].clstr= cl[self.clstr].ID
240              cl[self.clstr].AddFace(fNbor,m)
               else:
                 #IF BOTH HAVE CLUSTERS, LARGER TAKES PRECEDENCE
                 if len(cl[mf[fNbor].clstr].fNdx) > ...
...                                        len(cl[self.clstr].fNdx):
                   cl[mf[fNbor].clstr].fNdx.remove(fNbor)
245                cl[mf[fNbor].clstr].UpdateNakedEdges( ...
...                                               fNbor, hem, False)
                   cl[self.clstr].AddFace(fNbor,m)
                   mf[fNbor].clstr= cl[self.clstr].ID

250      #FOR TWO ADJACENT OPEN SPACES
         elif mf[fNbor].use == coeff[0][3]:
           if self.clstr>=0 and mf[fNbor].clstr >= 0:
             #IF BOTH ESTABLISHED IN CLUSTERS
             if len(cl[mf[fNbor].clstr].fNdx)>2 and ...
...              len(cl[self.clstr].fNdx)>len(cl[mf[fNbor].clstr].fNdx):
255            remClstr= mf[fNbor].clstr
               cl[self.clstr].AnnexCluster(cl[mf[fNbor].clstr],mf,m)
               for ndx in xrange(remClstr+1, len(cl)):
                 cl[ndx].ReIndex(mf)
               del cl[remClstr]
260
             elif len(cl[self.clstr].fNdx)>2 and ...
...              len(cl[mf[fNbor].clstr].fNdx)>len(cl[self.clstr].fNdx):
               remClstr=self.clstr
               cl[mf[fNbor].clstr].AnnexCluster(cl[self.clstr],mf,m)
               for ndx in xrange(remClstr+1, len(cl)):
265              cl[ndx].ReIndex(mf)
               del cl[remClstr]

       if self.dur > t:
         self.lyr= 1
     #====================================================================#
```

This script enacts the second layer behaviors, the formation of clusters, reinforcing groups of adjacent faces as assembled units.

205 There is not need to form a *Clusters* if the cluster already exists. *Clusters* are also interrupted if the shared edge is a road (:207).

216 The adjacent *.use* is checked against the template in the first column of (Figure 5.10), if it does not match, the adjustment values are applied to the neighbor (:219, 220).

223 If the two faces match the *Cluster* template, the face must determine whether to add itself to its neighbor's *Cluster* (:226), annexing a face into a *Cluster* (:238), or merging *Clusters* (:242).

5.6.2 Cluster class

```
0  #====================================================================#
1  class Cluster:
2     def __init__ (self, n1, n2, ct, hem):
3        self.fNdx=[]
4        self.fNdx.append(n1)
5        self.fNdx.append(n2)
6  
7        self.ID= ct
8        self.nkdEdg= []
9        self.fEdg= []
10 
11       #FOR FIRST FACE, ALL EDGES NAKED
12       eInit=hem.fIE[n1]
13       eCurr=hem.fIE[n1]
14 
15       self.nkdEdg.append(eCurr)
16       self.fEdg.append(1)
17       while hem.eNE[eCurr] != eInit:
18          eCurr= hem.eNE[eCurr]
19          self.nkdEdg.append(eCurr)
20          self.fEdg[0]+= 1
21          self.fEdg.append(0)
22          self.UpdateNakedEdges(n2,hem,True)
23 
24    def AddFace(self,ndx,hem):
25       self.fNdx.append(ndx)
26       self.fEdg.append(0)
27       self.UpdateNakedEdges(ndx,hem,True)
28 
29    def AnnexCluster(self,addCl,mf,hem):
30       for ndx in addCl.fNdx:
31          mf[ndx].clstr= self.ID
32          if ndx not in self.fNdx:
33             self.AddFace(ndx,hem)
34          else:
35             print("duplicate")
36 
37    def ReIndex(self,mf):
38       self.ID-= 1
39       for ndx in self.fNdx:
40          mf[ndx].clstr= self.ID
41 
42    def UpdateNakedEdges(self, ndx, hem, add):
43       #LOOP EDGES OF NEW FACE: ndx
44       eInit= hem.fIE[ndx]
45       eCurr= hem.fIE[ndx]
46 
47       firstLoop= True
48       while firstLoop or eCurr != eInit:
49          eChk= hem.eTE[eCurr]
50 
51          if add:
52             if eChk in self.nkdEdg:
53                #IF eTE MATCHES SOMETHING IN EDGE LIST, REMOVE
54                self.nkdEdg.remove(eChk)
55                if ndx in self.fNdx:
56                   fOrd= self.fNdx.index(hem.eIF[eChk])
57                   self.fEdg[fOrd]-=1
58             else:
59                #OTHERWISE ADD
60                self.nkdEdg.append(eCurr)
61                fOrd= self.fNdx.index(hem.eIF[eCurr])
62                self.fEdg[fOrd]+=1
63 
64          else:
65             if eCurr in self.nkdEdg:
66                #IF e MATCHES SOMETHING IN EDGE LIST, REMOVE
67                self.nkdEdg.remove(eCurr)
68                if ndx in self.fNdx:
69                   fOrd= self.fNdx.index(ndx)
70                   self.fEdg[fOrd]-= 1
71             else:
72                #IF NOT, ADD TWIN
73                self.nkdEdg.append(eChk)
74                fOrd= self.fNdx.index(hem.eIF[eChk])
75                self.fEdg[fOrd]+= 1
76 
77          firstLoop= False
78          eCurr=hem.eNE[eCurr]
79 #====================================================================#
```

The *Cluster* class has meta data to identify itself and its component faces and to effect and manage the assemblage of *Clusters*.

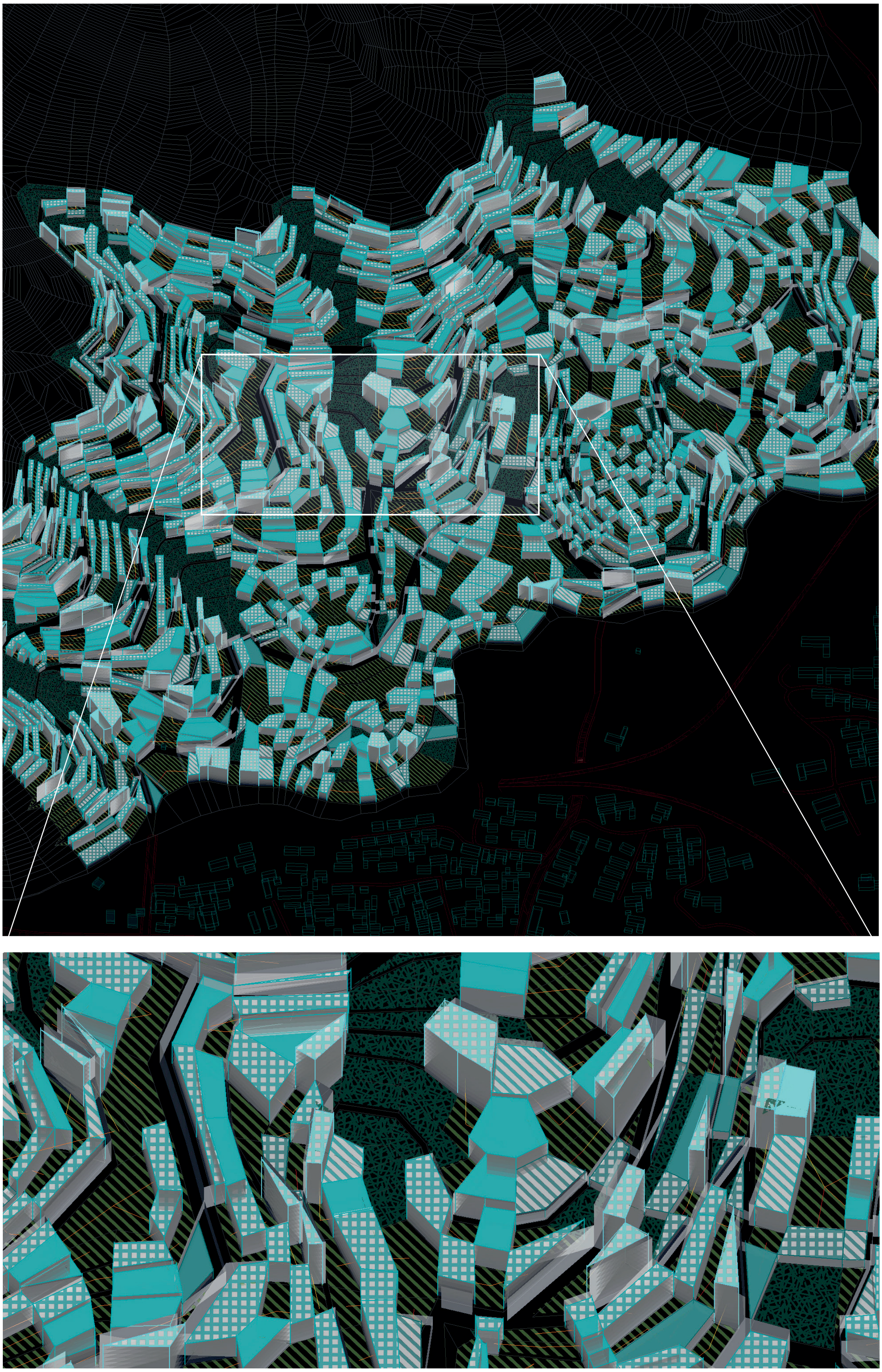
04 The face index is a property of the *Cluster* just as the *Cluster* index is a property of the face (:31)

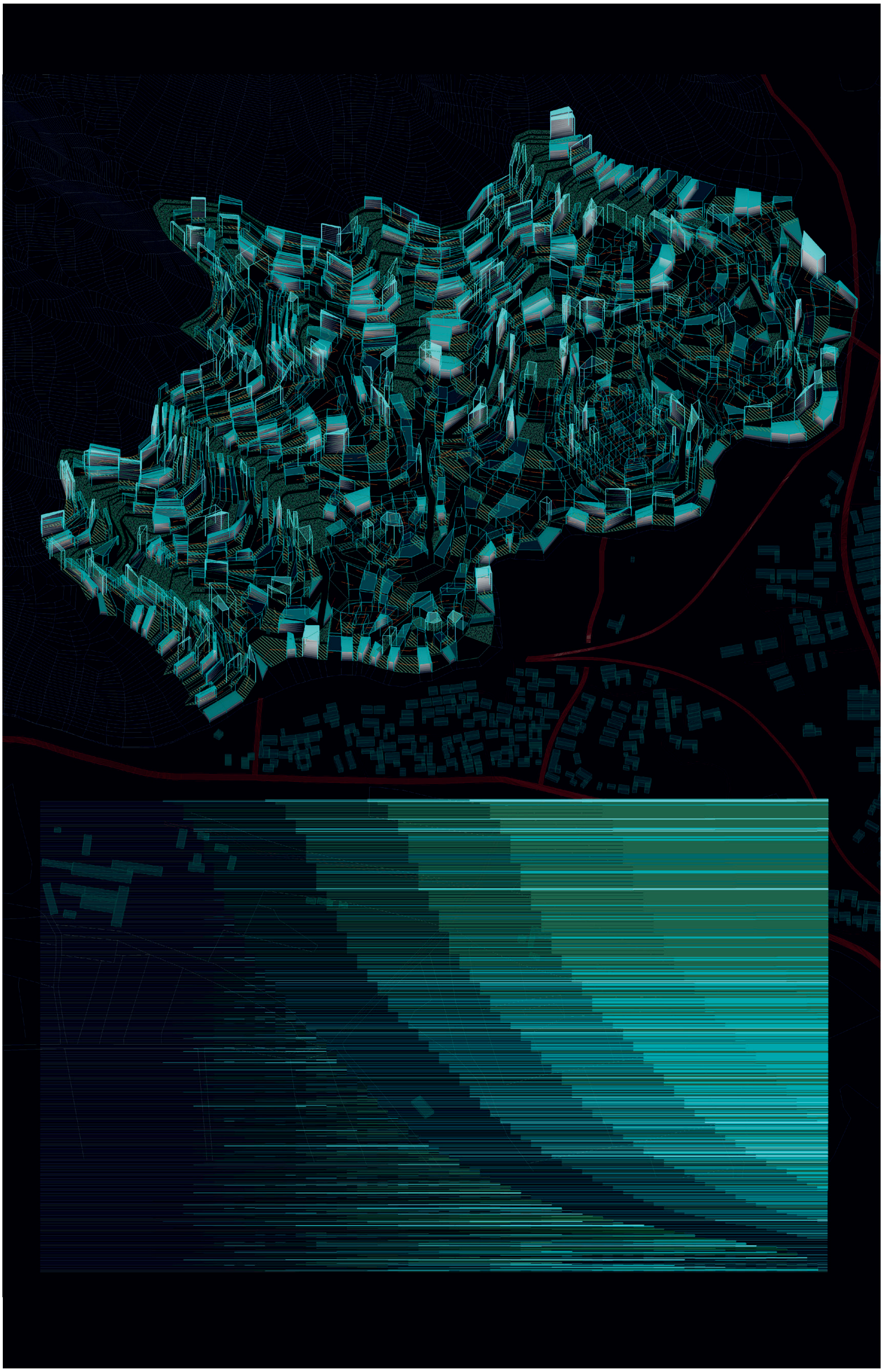
07 The *Cluster* requires an number to ID itself because as *Clusters* are formed, unformed, merged, and split, the list structure is too volatile to keep track of them.

15 The *Cluster* keeps track of its perimeter, the 'naked edges'. This can be used for visualizing *Cluster* boundaries, but also for creating garden walls or introducing paths in the site. Recording the naked edges during other transformations occurs in (:42*ff*).

Figure 5.11

Clusters forming and surface uses (rooftop and ground level) begin to be assigned at the last layer of behaviors.





§5.7 Ecology of Interaction

Observing monads

Of course, it is not only the final state that is interesting, but also the process of formation that leads there, particularly as urbanization is is not the kind of project where the time of construction and implementation can be ignored. "'Good' macroscopic form always depends on microscopic processes,"[100] however behaviors that are truly beyond observation are difficult if not impossible to control, direct, or mediate. For this reason Latour reintroduces Tarde to urge increased study of the "background of 'calculable forces'"[101] and inter-subjective decisions,[102] and the "fabric of vectors and tensors which defines the attachments of people and assets"[103] in order to erode the division between macro- and micro- actions,[104] and to erase the separation between the levels of the individual and of societies.[105] Neither individual nor assemblage is ever wholly singular, but form only as "temporary aggregates, partial stabilizers, nodes in networks,"[106] which, if they can be tracked, can inform the interpretation of results or the design decisions.

Recording temporal data

For example, Project 2 eventually converges to a stable, static solution and there is a great deal of morphological data to pore over just in this last configuration. However, as in any complex system, the difficulty of correlating this last state to the initial parameters frustrates attempts to explore alternate scenarios.[107] By recording the state values of the model as it goes from frame to frame (≒5.7.1), formatting it (≒5.7.2), and graphing the data (≒5.7.3), we can observe trends in the population of faces and compare different parameter sets asynchronously. This histomap (Figure 5.12) presents a timeline of every face's *.use* state on the x-axis, and is sorted with the faces whose state has persisted the longest toward the top. The green band at the top of this graph reveals that open green spaces tend to find their final use earlier and the blue built uses are not settled until later in the process, suggesting that a study that compared this result with models that change the proportionate adjacency or fitness adjustment values might be a revealing comparison (Figure 5.13).

100 Deleuze, *The Fold: Leibniz and the Baroque*. p88

101 Latour and Lépinay, *The Science of Passionate Interests: An Introduction to Gabriel Tarde's Economic Anthropology*. p40

102 *Ibid*. p7

103 *Ibid*. p39

104 "Micro and Macro are but two arbitrary points which hide all the work of formatting, coordination, standardization, and compatibility, and end up temporarily resolving certain conflicts through new adaptations."

Ibid. p59

105 Latour et al., "The Whole Is Always Smaller Than Its Parts: A Digital Test of Gabriel Tarde's Monads."

106 Latour and Lépinay, *The Science of Passionate Interests: An Introduction to Gabriel Tarde's Economic Anthropology*. p9

107 Patt and Huang, "Scenario Modeling for Agonistic Urban Design."

Figure 5.12

The histomap displayed in the geometry preview window below the site shows a record of every face state (*.use*) since the beginning of the simulation. Each horizontal line represents the history of one face while a vertical slice through the graph reveals the proportions between different uses across the site at a single point in time.

The lineweight increases (≒4.5.3) the longer a face state persists at a single *.use* value, which gives a density effect to the graph.

5.7.1 RecordState

```
0  INPUTS: mf as List; reset as Boolean
from collections import defaultdict; import scriptcontext as sc

histData = sc.sticky['ghDefaultDict'](defaultdict(list))
for i, fN in enumerate(mf):
5      histData.d[i].append(0)
    histData.d[i].append([])
pyHist=histData
OUTPUTS: pyHist
```

First a *defaultdict* is created to record the state of each face over time.

03 This component is not connected to the timer. it is only called at the start and saved as sticky.

05 For each face, two values are initialized, an age (=0 at the start) and a list (:06) of the state values *.use* (empty at the start).

5.7.2 HistomapData

```
0  INPUTS: mf as List; histData
from collections import defaultdict; import scriptcontext as sc
import Grasshopper as gh; from Grasshopper.Kernel.Data import GH_Path
import System

5  histoTree= gh.DataTree[System.Int32]()
age= []
for i, fN in enumerate(mf):
  if len(histData.d[i][1]) == 0:
    histData.d[i][1].append(fN.use)
10   else:
    if histData.d[i][1][-1] >= 0 and histData.d[i][1][-1] == fN.use:
      histData.d[i][0]+= 1
    else:
      histData.d[i][0]= 0
15     histData.d[i][1].append(fN.use)

  age.append((histData.d[i][0],i))

age.sort()
20 age.reverse()
for i, (val,ndx) in enumerate(age):
  histoTree.AddRange(histData.d[ndx][1], GH_Path(i))
pyHist= histData
vals= histoTree
25 ages= [val for val,ndx in age]
OUTPUTS: pyHist, vals, ages
```

While the frames are advancing, this script saves the values and creates a format for displaying the graph.

11 After the first frame has passed, the script checks how the current frame compares to the previous frame. If they match, the age increases (:12), otherwise it resets to zero (:14).

17 The *age* list is created with the age values and the index values, this is then sorted (:19) from highest to lowest (:20) and is also used to ensure that the data is output in the correct order (:22).

5.7.3 HistomapFormat

```
0  INPUTS: crv as Curve; vals as DataTree
import math; import Rhino.Geometry as rhG
import Grasshopper as gh; from Grasshopper.Kernel.Data import GH_Path

stp= crv.PointAtStart.DistanceTo(crv.PointAtEnd)/len(vals.Branch(0))
5  dir= stp*crv.TangentAtStart

dispLst=[]
colLst=[]
wtLst=[]
10 ct=0
for j,lst in enumerate(vals.Branches):
  pt= crv.PointAtStart-((1.25*ct)*rhG.Vector3d.YAxis)
  persist= 1
  fin= len(lst)
15   if lst[fin-1]>=0 and lst[fin-1]<4 and j%4==0:
    for i,use in enumerate(lst):
      dispLst.append(rhG.Line(pt,pt+dir))
      if use < 0:
        colLst.append(6)
20       else:
        colLst.append(use)
        if i > 0:
          if use == lst[i-1] and use>=0:
            persist+= .1
25           else:
            persist=1
            wtLst.append(math.floor(persist))
        pt+=dir
  ct+=1
30 ln= dispLst
col= colLst
wt= wtLst
OUTPUTS: ln, col, wt
```

The data is prepared to be drawn in the viewport as an array of Curves with lineweight and color values.

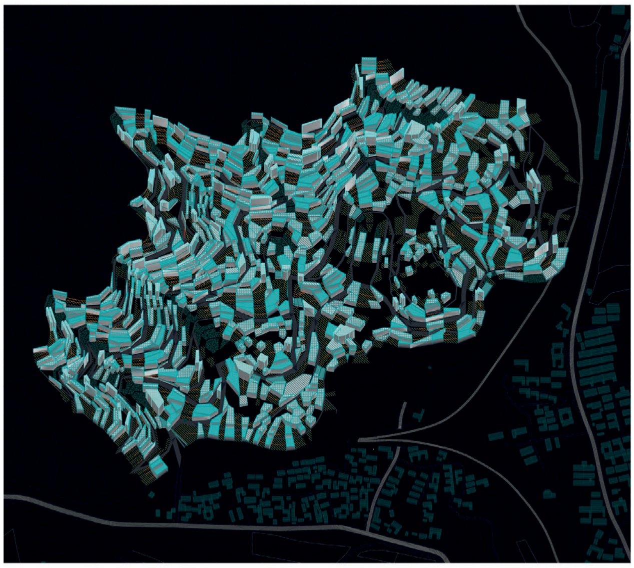
04 A base Curve is used to set the dimension, orientation (:05), and position (:12) of the graph.

21 The color is determined by the *.use* value. Here, only the integer is saved. It will later be used to select a color from a list.

27 The lineweight corresponds to the persistance of the use. The persistence increments slowly (:24) while the lineweight must always be an integer (:27).

Figure 5.13
Graphs comparing values three different simulations: the first runs only the fitness values and a simple version of adjacency behaviors; the second runs the fitness values and the adjacency behaviors shown in Figure 5.9; the third adds to that the clustering behaviors in Figure 5.10

Figure 5.14 (over)
Perspective view over the site after the model has reached a terminal state.

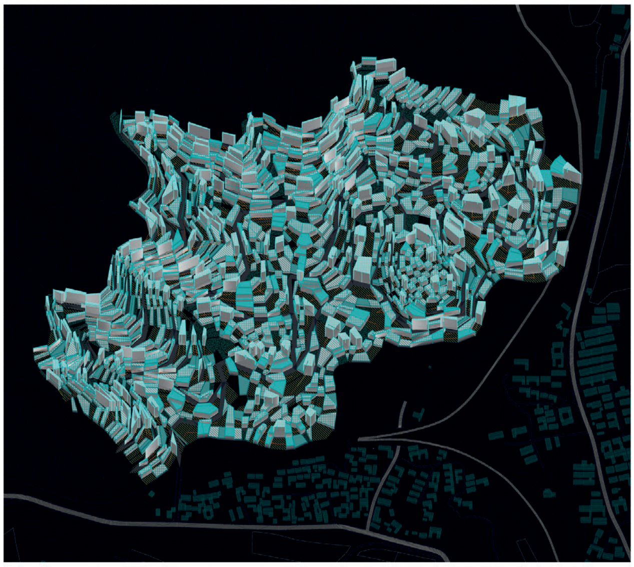


Distribution of Active Cell States
HI: 102 4.1 %
MI: 792 31.6%
LO: 130 5.2%
40.9% ∑ BUILT
GR: 997 39.8%
∅: 483 19.3%
59.1% ∑ OPEN

Total: 2504

Cluster Links from Garden to:
HI: 97
MI: 1014
LO: 136

Total: 1247

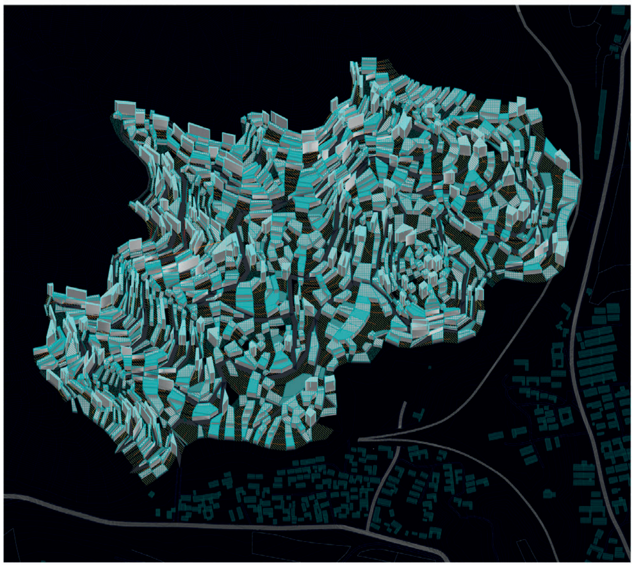


Distribution of Active Cell States
HI: 241 8.3 %
MI: 700 24.1%
LO: 400 13.8%
46.2% ∑ BUILT
GR: 837 28.9%
∅: 721 24.9%
53.8% ∑ OPEN

Total: 2899

Cluster Links from Garden to:
HI: 209
MI: 874
LO: 361

Total: 1444

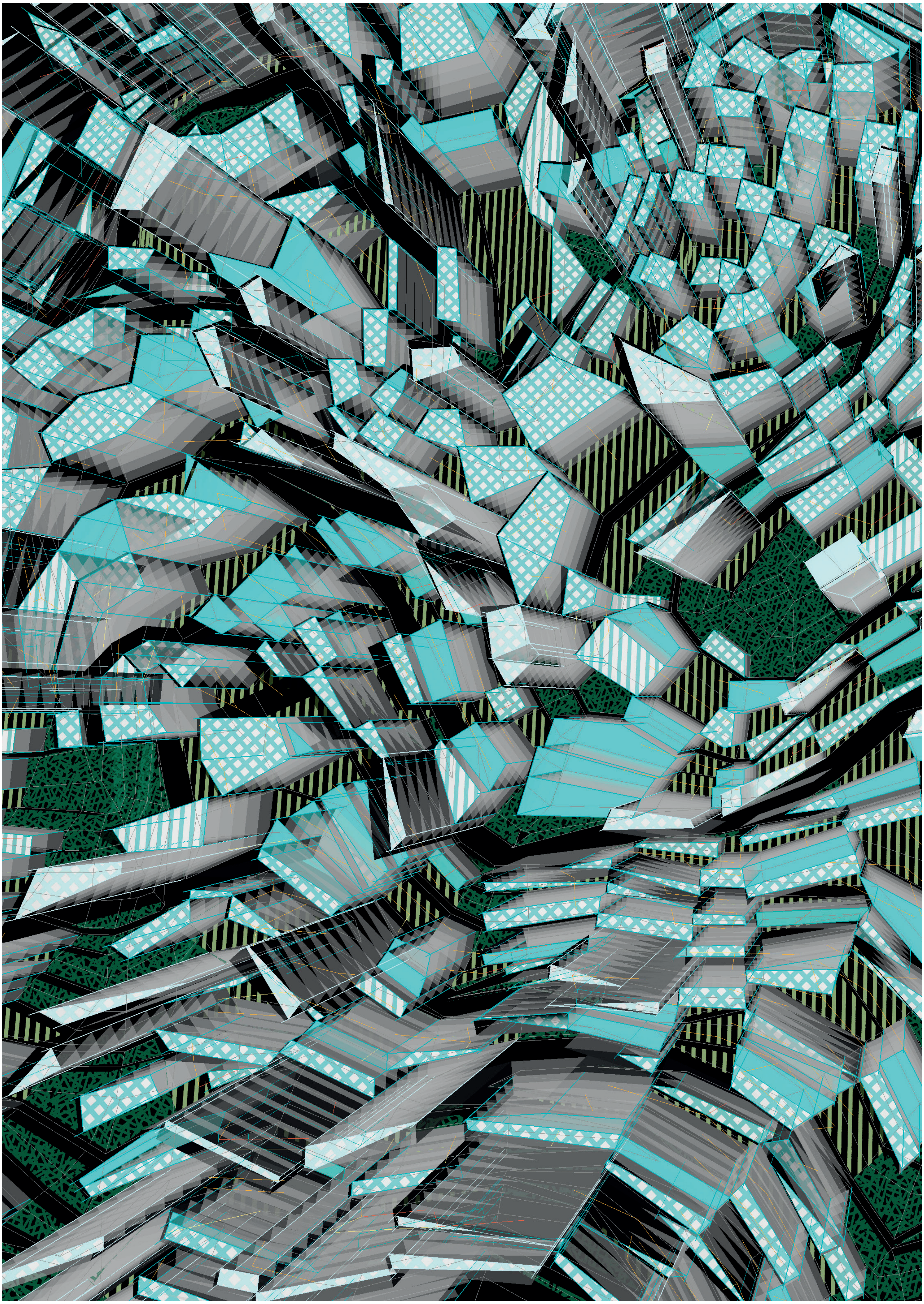


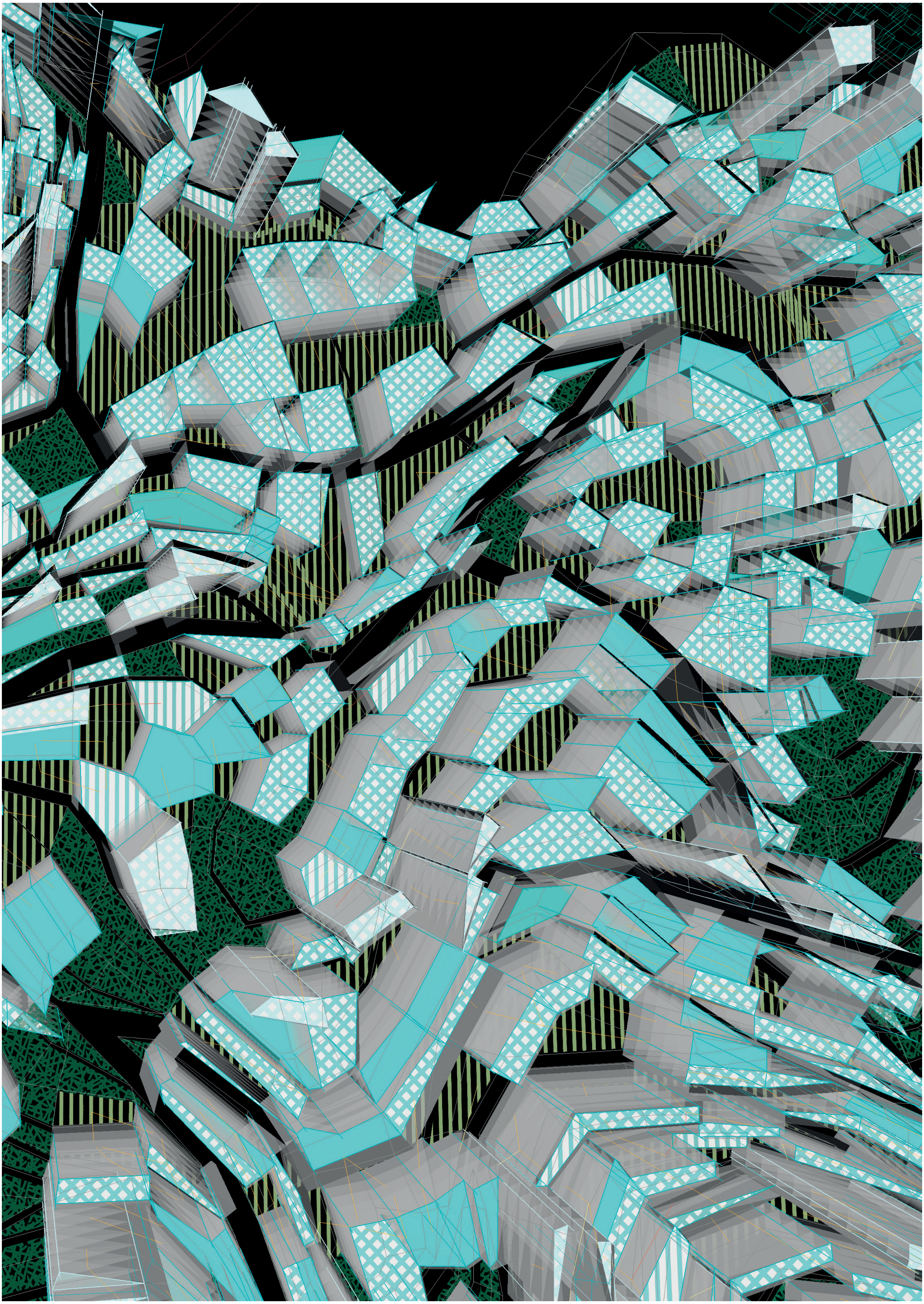
Distribution of Active Cell States
HI: 197 6.6 %
MI: 810 27.3%
LO: 339 11.4%
45.3% ∑ BUILT
GR: 991 33.4%
∅: 630 21.2%
54.6% ∑ OPEN

Total: 2967

Cluster Links from Garden to:
HI: 201
MI: 1049
LO: 336

Total: 1586





§5.8 Enacting Encounters

Virtual

In this effort we endeavor to progress from the evaluation of possible outcomes to the potential for emergent order. and even to approach an image of the virtual being of the model.[108] The application of generative behaviors to the design elements and the complex extension of their traits over on another develops the virtual being of the objects[109] by exercising the agency it has encapsulated and unfolding the individuality of these objects through their interactions.[110] This community or ecology of objects depends on the fact that objects are, on the one hand, discrete individuals, but also are continuously implicated “as a system in which all the parts simultaneously cause and affect one another.”[111] As an aggregated model of urbanism, there is a connection to Stan Allen's seminal essay on ‘field conditions’, wherein “overall shape and extent are highly fluid and less important than the internal relationships of parts, which determine the behaviour of the field”.[112] However, in his account, the field tends to become a unifying force that overwhelms the objects within it, to the extent that the field “establishes the conditions within which the material will be deployed”[113] while the material only reacts passively to “register the complexity of the given.”[114] In contrast, we would prefer to invert the proportionate influence of field and material, with more substantial entities such that each object acts as the ground for the next.[115] The formal or material properties of these objects would construct a field in a way that may not be continuous, fluid, or smoothly gradated. This parallels the earlier statement that the virtual is a dimension of the individual rather than a pre-individual plenum.[116]

Complexity of urban encounters

Moreover, the essay's characterization that field conditions “smoothly accommodated” exceptions and inconsistencies “with the overall order”[117] is at odds with an approach to urbanism that emphasizes discontinuities, ruptures, and breaks from the actual order of the city—discontinuities that the temporality of assemblages is specifically tuned to recognize.[118] The open city is not achieved through the avoidance of juxtaposition or in the correlation of differentiation,[119] but through “the capacity of events to disrupt patterns, generate new encounters with people and objects, and invent new connections and ways of inhabiting everyday urban life.”[120] The city is not a space of smooth transitions, but frequently consists of sharp demarcations even while it equivocally supports pluripotential uses.[121] The material of the city is not a self-similar passive register, but is a diverse set of assemblages and societies[122] with contradictory aims and our models should reflect that. In the next chapter we will look at how reflexivity intensifies the generative behaviors explored here into sociomaterial agency[123] and the negotiated actualization of urban assemblages.

108 "Whatever medium you are operating in, you miss the virtual unless you carry the images constructed in that medium to the point of topological transformation. If you fall short of the topological, you will still grasp the possible (the differences in content and form considered as organizable alternatives). You might even grasp the potential (the tension between materially superposed possibilities and the advent of the new). But never will you come close to the virtual."

Massumi, *Parables for the Virtual*. p134

109 "the only way an image can approach it [the virtual] alone is to twist and fold on itself, to multiply itself internally … The virtual can perhaps best be imaged by superposing these deformational moments of repetition rather than sampling differences in form and content."

Ibid. p133

110 Bryant, *The Democracy of Objects*. p104

111 *Ibid*. p108

112 Allen, "From Object to Field: Field Conditions in Architecture and Urbanism." p120

113 *Ibid*. p128

114 *Ibid*. p119

115 Trummer, "The City as an Object." p57

116 *cf.* §2.3c 'Organization and endo-relations'

117 Allen, "From Object to Field: Field Conditions in Architecture and Urbanism." p132

118 *cf.* §1.3, 1.4

119 As is advocated by Parametricist Urbanism:

Schumacher, "Parametricism: A New Global Style for Architecture and Urban Design."

120 McFarlane, "Assemblage and Critical Urbanism." p209

121 For example, the oscillation between open or built space in Project 2.

122 Latour and Lépinay, *The Science of Passionate Interests: An Introduction to Gabriel Tarde's Economic Anthropology*. p27

123 *cf.* §1.6a 'Inorganic Agency'

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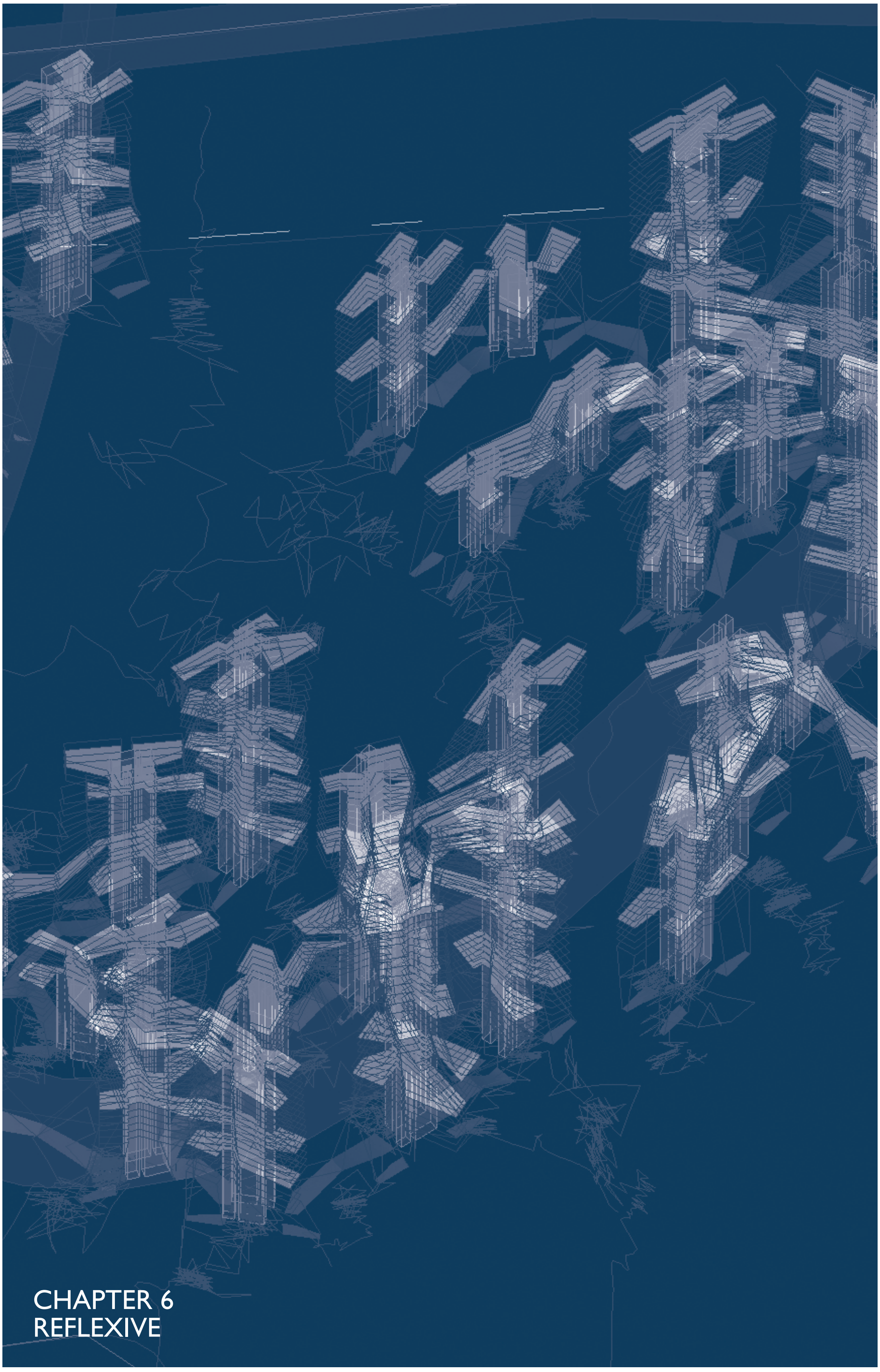


CHAPTER 6
REFLEXIVE

§6.1 Intensifiying Actualization

Actual–virtual axis

In opposition to the withdrawn virtual being of the object,[1] actualization deals with the qualities and properties that manifest externally. Left as simple expression, the generative process laid out in the previous chapter risks becoming merely an unfolding of potentials and a brief resolution of conflicting tendencies until an identity is settled on and a form produced.[2] This process would not need to invoke the virtual dimension of the object: because there is only a singular situation, the end state is never really in question of developing otherwise, so the complexity of the model is undercut.[3] The object's internal disposition only really becomes integral when changing conditions disrupt the orderly harmonization of the model and the object internalizes these perturbations. This is because the internal workings of the object determine how environment is brought in and translated into information, "any information value the perturbation takes on is constituted strictly by the distinctions belonging to the organization of the [assemblage] itself."[4] When the environment is dynamic or rapidly changing, the assemblage is characterized by "strategies of selection or continuance within an environment that they are unable to completely anticipate and which they are certainly unable to dominate or master."[5]

Intensities

In such cases, there develops a bidirectional influence between the internal and external, the virtual and actual, the encapsulated and the environment. Deleuze writes that "intensity is the determinant in the process of actualisation"[6] Intensive properties are often cursorily defined as indivisible properties,[7] though a more operative definition is that "differences in intensity, though not in quality, can drive fluxes of matter or energy."[8] because a "key concept in the definition of the intensive is productive difference."[9] For example, the difference between the desired state of an agent and its current condition drives the dynamics of a simulation until the desired condition is achieved. If, however, achieving this goal disturbs other agents there arises a new differential between the satisfaction of one agent and all the others, a condition which the various agents will attempt to equilibrate[10]—though only if the disruption of the first agent is intensively registered. In this way, intensification powers the differential engine that enacts spatio-temporal dynamism[11] and differentiation.[12] While extensive processes revealed the identities of singular objects as they related to one another discretely, intensive processes are concerned with the relations within a complex assemblage and the ways that the assemblage's entities come into convergence in an actual thing.[13] "We may expand the meaning of the term 'intensive' to include the properties of assemblages, or more exactly, of the processes which give rise to them"[14]

1 Deleuze, *Difference and Repetition*. p208

2 "The playing out of those potentials requires an unfolding in three-dimensional space and linear time—extension as actualization; actualization as expression. It is in expression that the fade-out occurs. The limits of the field of emergence are in its actual expression."
Massumi, *Parables for the Virtual*. p35

3 DeLanda, *Intensive Science and Virtual Philosophy*. p65

4 *cf.* §2.4a 'Information passes and is translated between objects'
Bryant, *The Democracy of Objects*. p141

5 "by virtue of the greater complexity that each environment possesses when compared to the complexity of systems"
Ibid. p145

6 Deleuze, *Difference and Repetition*. p245

7 DeLanda, *Intensive Science and Virtual Philosophy*. p45

8 *Ibid*. p60

9 *Ibid*. p61

10 *Ibid*. p60

11 "Spatio-temporal dynamisms, that is, morphogenetic processes exhibiting intensive properties, are processes of individuation"
Protevi, "Out of This World: Deleuze and the Philosophy of Creation."

12 *cf.* §2.2b 'Being as difference'

13 "Parts or wholes do not exist any more; they are replaced by degrees for each character."
Deleuze, *The Fold: Leibniz and the Baroque*. p47

14 DeLanda, *Intensive Science and Virtual Philosophy*. p64

Reflexivity

Therefore we can define the reflexive as the translation between virtual and actual.[15] Reflection "goes the other way from production. It is a matter of … moving from extensity through intensity to virtuality."[16] The necessity to form this loop emerges because the virtual is composed of multiplicities without qualities[17] but still "the qualities differenciated by virtue of the relations they actualise impose their own requirements, as do the extensities differenciated by virtue of the distinctive points they incarnate"[18] Intensities straddle the divide as "intensities are implicated multiplicities … which direct the course of the actualisation"[19] Protevi argues that the intensive "mediates the virtual and actual,"[20] a mediation "between unexercised power and actualized quality *within an individual.*"[21]

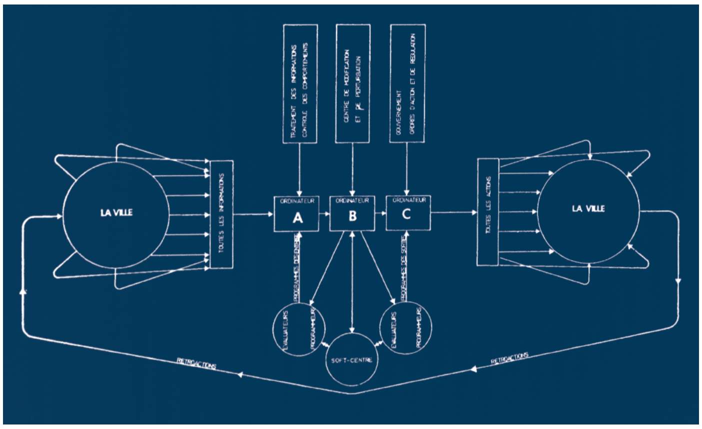
§6.2 Feedback Urbanism

Ville Cybernetique

In the realm of urban speculation, Nicholas Schöffer was an early experimenter and advocate of applying principles of cybernetics to the question of urban planning and management. Inspired by Norbert Weiner's cybernetic theories,[22] he envisioned a city integrated with three central computers "constantly receiving data, processing it, and answering its requirements with new information and directives for various urban systems and services."[23] One of these computers was responsible for "governmental mandates and regulations" but the other two handled more diffuse actions and information, with one monitoring "information and behavior" and the other "modifications and pertubations."[24] The computer system was to coordinate a self-regulation of every aspect of society from the production and availability of goods and services and affordances for leisure to the sanctioning of new social regulations to head off revolutions. Schöffer's primary attention, however, was on how these computers could influence the public life through spectacles that filled urban space. The *Ville Cybernetique* featured plazas located throughout the city, where he proposed large, frame-like towers "that supported moving sculptural elements, light projectors, and speakers,"[25] activating the city with kinetic light and sound performances as directed by the central computer. The towers were also information gathering points that would sense local activity such as sound and light levels or other urban flows,[26] and could vary their projections in response to the current conditions. In this way the regulating impulses of the city would be kept in flux, constantly adjusting itself to the conditions of the urban environment.

Participating in urbanism

Furthermore, while the projections were typically spectacles to be taken in passively, the inhabitants of the city were "sometimes actively programming them and creating new ones."[27] For Schöffer, the participation of the inhabitants was an integral aspect of the feedback mechanism. His emphasis on ambient experiences rather than more explicit messages points to the significance of the experience of space over communication as the primary motivation in the *Ville Cybernetique*: "the cybernetic city was a place in which space had been activated as a palpable substance, filled with the transmission of aesthetic and informational 'matter'. The forms of the structures mattered less than the 'psychophenomenological' effects of this ambience, which would serve to immerse the inhabitant in a vast field of perceptual space."[28] In spite of the centralized processing hub, the *Ville Cybernetique* valorized these kinds of bottom-up acts of urbanism that also characterized de Certeau's pedestrians, substituting localized actions in place of global representations.[29]



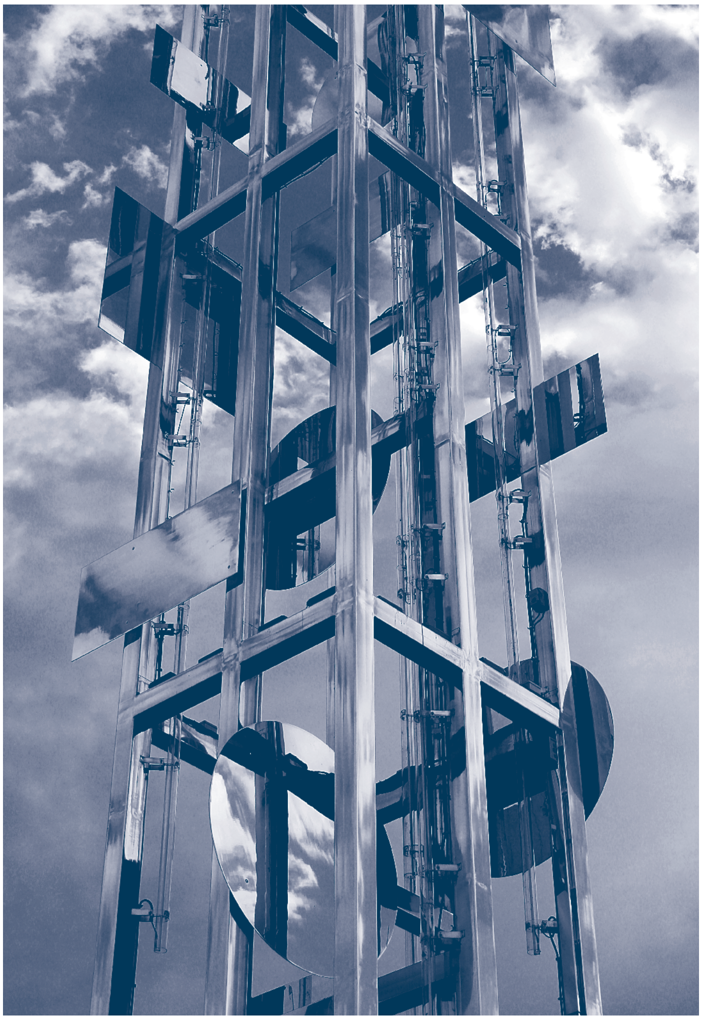


Figure 6.1;

Schema of control cener functions and regulation of the *Ville Cyberetique* detailing the three computer (*Ordinateurs A,B,C*) and the feedback loop between the computers and the city. Schöffer, *La Tour Lumière Cybernétique*. p97

Figure 6.2 :

Lyonéon: tour lumière cybernétique, Lyon, 1988
This sculpture rising 30m above the metro station and extending downward to the level of the train platforms was created by Schöffer on the model of those in the *Ville Cyberetique* and is animated in response to the activity of the metro and its surroundings.

The placard at the base of the scultpure reads in part: « *Il s'agit là de la première sculpture cybernétique monumentale de France … l'artiste, par son oeuvre rend la station interactive avec ses usagers et lui confère les qualités d'un environnement vivant.* »

15 Brian Massumi, in a suggestive paragraph, describes affect in very similar terms:

"What is being termed affect in this essay is precisely this two-sidedness, the simultaneous participation of the virtual in the actual and the actual in the virtual, as one arises from and returns to the other. Affect is this two-sidedness as seen from the side of the actual thing, as couched in its perceptions and cognitions."

Massumi, *Parables for the Virtual*. p35

16 Protevi, "Water."

17 Bryant, *The Democracy of Objects*. p109

18 Deleuze, *Difference and Repetition*. p245

19 *Ibid*. p244

20 Protevi also argues that "we should consider the intensive as an independent ontological register" in part because the intensive disappears in the individualization process[20b] but I do not think this is necessary in our case where the virtual is always already individual.

Protevi, "Out of This World: Deleuze and the Philosophy of Creation."

20b: DeLanda, *Intensive Science and Virtual Philosophy*. p59

21 Bryant, *The Democracy of Objects*. p97

22 Darò, "Nicolas Schöffer and the Cybernetic City." p5

23 Busbea, *Topologies: The Urban Utopia in France, 1968-1970*. p54

24 My translation, the original reads:

« *gouvernement ordres d'action et de regulation* », « *traitement des informations controle des comportements* », « *centre de modification et de perturbations* »

Schöffer, *La Tour Lumière Cybernétique*. p97

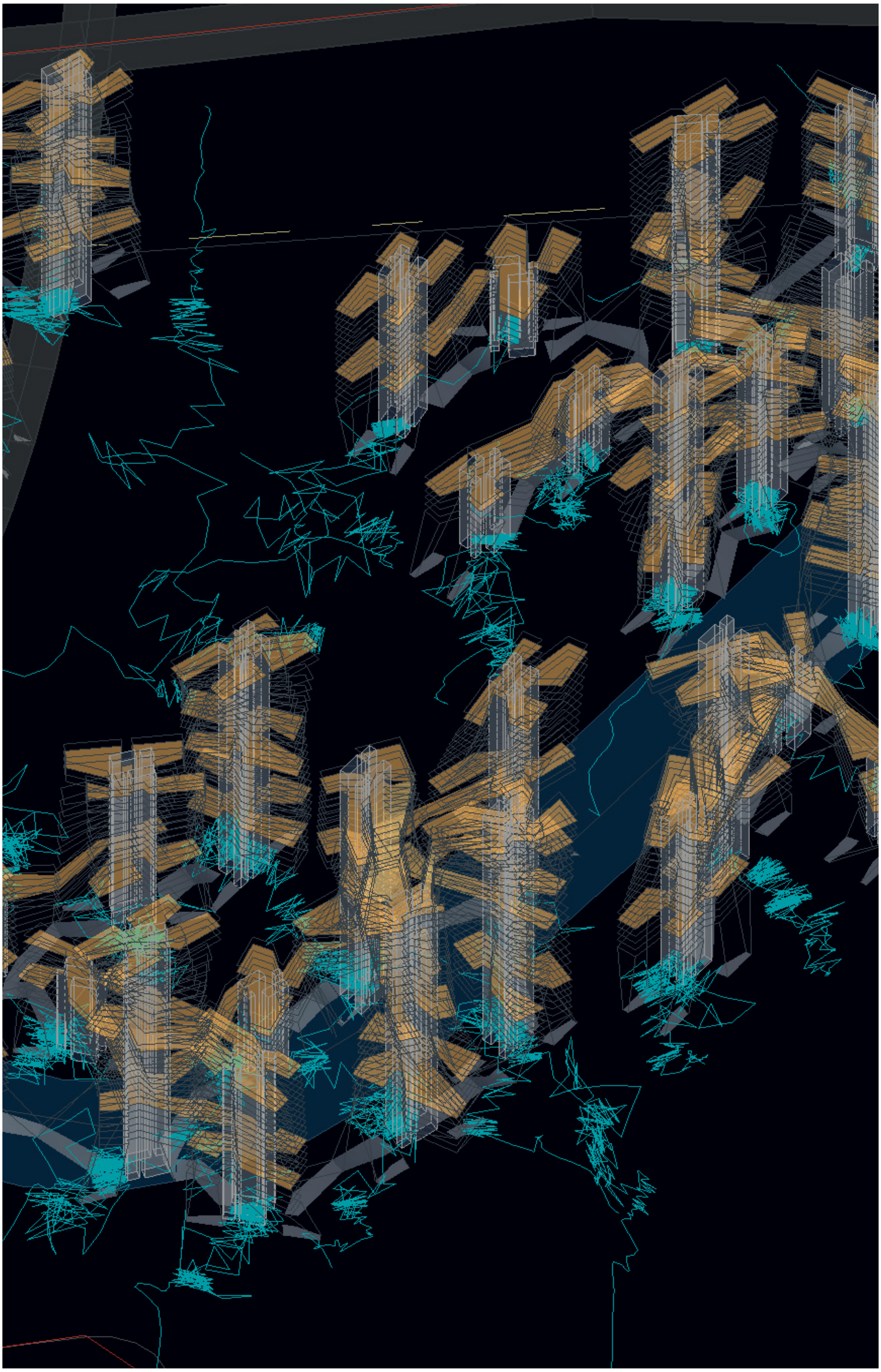
25 Busbea, *Topologies: The Urban Utopia in France, 1968-1970*. p51

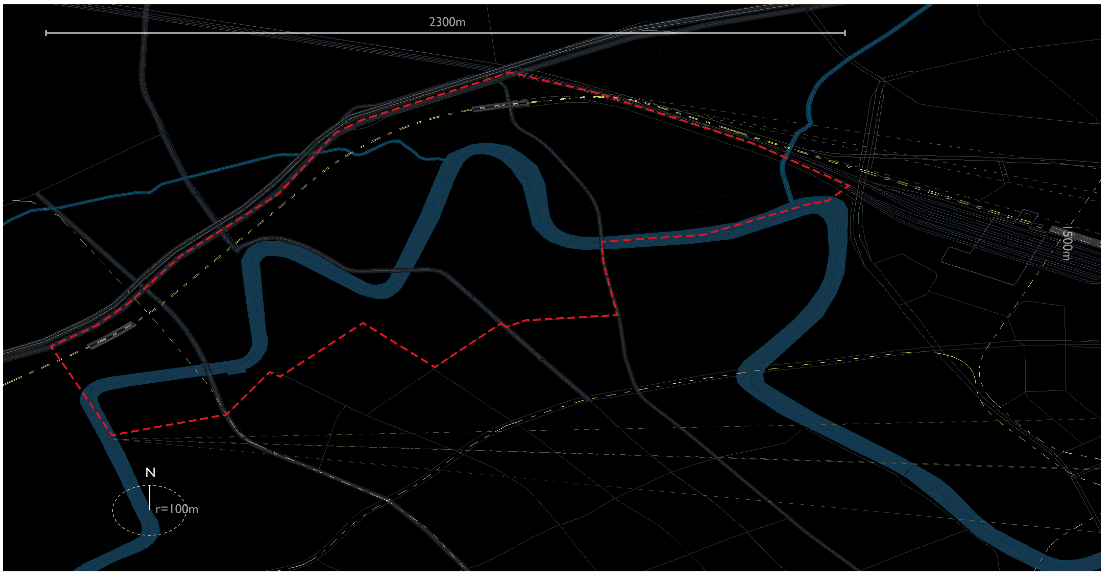
26 For example, the tower constructed in Lyon (Figure 6.2) reacts to the coming and going of the metro trains below it.

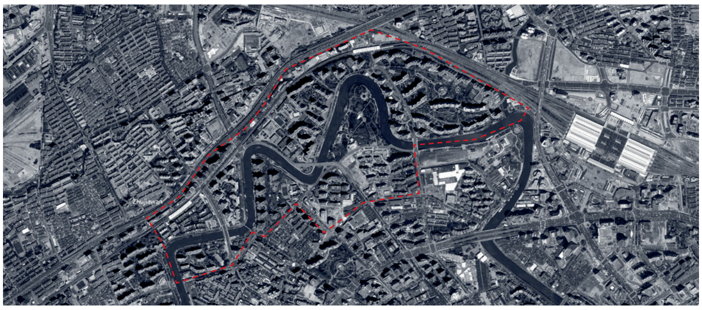
27 Busbea, Topologies: T*he Urban Utopia in France, 1968-1970*. p54

28 *Ibid*. p55

29 *cf.* §1.4c 'Enaction and Agency'







Project 3: Buildings (Shanghai)

The site in Shanghai is a large area of 143ha spanning both banks of the Wusong River. It includes the Zhongtan and Zhenping metro stations on the #4 and #2 lines of the subway and the elevated track of the #3 line, which passes along the north edge of the site.[30] Directly to the east is the Shanghai Railway Station. This site is currently occupied by high-rise apartment towers densely packed in a semi-gated neighborhood and modeled on typical floor-plan types that are repeated with minimal variation.

This project proposes an alternate plan that activates the buildings themselves in the determination of siting and formal variation. Each building is conceived as an individual agent seeking a desirable location and adjusting its position, and its formal and geometrical properties in negotiation with the other agents. Of particular interest is the motivation of masterplanning decisions by architectural details—both technical limits of building systems and design logics—that demonstrate the freedom of cross-scalar influence[31] in early stages of the design process.[32]

30 Site data collected from openstreetmap.org. Importing geometry from an .osm file is described in Appendix.6.2.

31 *cf.* §1.3a 'Against scalar hierarchies'

32 Zuelzke, Patt, and Huang, "Computation as an Ideological Practice."

Figure 6.3
Detail of Project 3: tower elements adjusting location and position relative to one another.

Figure 6.4
Site condition and boundary, lines pointing to the east converge at Pudong

Figure 6.5
Orthophoto of Shanghai from Bing Maps

§6.3 Mobile Agents

Tropism and stigmergy

Chapter 5 introduced agent-based models[33] with an emphasis on the encapsulation of operational behaviors and data within object classes that activated themselves as opposed to having an external functional control. Mobile agents introduce additional requirements such as determining their position within their environment, sensing their changing surroundings, or communicating with other agents in dynamic, unstructured interactions. In the simplest model, agents decide their movements based on a tropistic response[34] to some property of the environment that varies in density or distribution. Tropism is "a compulsive movement,"[35] a strict rule of cause-and-effect. Yet when subjected to a changing gradient of external stimuli, the agent does not follow a single-minded goal but is continuously redirected, tracing out nonlinear paths through the environment.[36] A purely tropistic agent operates indexically, making legible the field of forces that it reacts to. A slightly more complex agent model is one that is able to act on, add to, or modify the environment either to reinforce its decisions or to communicate indirectly with other agents. A common reference for such agents is found in the stigmergic behavior of insect colonies that build up pheromone trails over well-traveled routes.[37] The stigmergic process displays a positive feedback loop that reinforces behaviors over time.

Determinant and emergent planning

In a more controlled setting, this offers the attractive combination of combining given conditions of a global environmental with a responsive augmentation of that environment.[38] In the context of masterplanning, it is easy to imagine general data, such as overall density plots constituting one facet of an environmental dataset within which individual massing volumes could emerge. In ≒**6.3.1**, a simple mobile agent is defined that moves over the site through a combination of its own momentum and external forces (:**64**)[39] which are modulated by a site-derived coefficient(:**58**). The agent's position is mapped to a grid of 50×50m cells that have been projected density values assigned to them from a color-coded image (**Figure 6.6**).[40] The higher the correspondence between the agent's height value and the desired density the lower the coefficient (:**56**), suppressing the movement vector and keeping the agent in place. In contrast, a low correlation will magnify the movement vector, moving the agent to a new location more quickly. During the searching process, the agents also subtly modifying the density diagram (:**73*ff***), reinforcing their position and, over time, increasing the chance of gathering similar agents near them.

33 Or approximations thereof.

34 Wooldridge, *An Introduction to Multiagent Systems*. p33

35 Verstegen, *Tropisms: Metaphoric Animatino and Architecture*. p9

36 As previously mentioned this is an effect of localizing the diagram but now the impact of spatial diffusion is multiplied by each incremental step in time.

37 Bonabeau, Theraulaz, and Dorigo, *Swarm Intelligence: From Natural to Artificial Systems*. p26*ff*

38 Wooldridge describes an example that demonstrates how controlled stigmergic signals can communicate more specific instructions even without direct contact.

Wooldridge, *An Introduction to Multiagent Systems*. p92-94

39 The external forces are a combination of resistance from site boundaries and the attraction or repulsion of nearby agents.

40 Importing pixel data from a bitmap image is covered in Appendix **6**.

≒6.3.1 BaseAgent

```
15 #======================================================================#
16 class BaseAgent:
17    def __init__(self,pt,i,j):
18       #LOCATION AND ORIENTATION
19       self.ndx= (i,j)
20       self.xyz= pt
21       self.trace= rhG.Polyline()
22       self.trace.Add(self.xyz)
23       self.pln= rhG.Plane(pt, -rhG.Vector3d.YAxis, rhG.Vector3d.ZAxis)
24       self.plnX= rhG.Vector3d(self.pln.XAxis)
25 
26       #ACTIVE STATUS
27       self.state= True
28 
29       #INITIAL HEADING AND EXTERNAL FORCES
30       tVal= rvr.ClosestPoint(pt)[1]
31       rvrPt= rvr.PointAt(tVal)
32       self.vec= rhG.Vector3d(rvrPt-pt)
33       self.vec*= 4/self.vec.Length
34       self.force= rhG.Vector3d(0,0,0)
35 
36       #LINKS TO OTHERS
37       self.lnk= []
38       self.lnkData= []
39       self.lnks= [False,False,False,False]
40 
41       #LEFT/RIGHT 'ANTENNAE'
42       self.pts= []
43       self.pts.append(self.pln.PointAt(0,0,-10))
44       self.pts.append(self.pln.PointAt(0,0,10))
45 
46       #FLOORPLATE GEOMETRY?
47       self.plt= False
48 
49 #======================================================================#
50    def Move(self, grd, crnr, ht, ct):
51       grdX= self.ndx[0]
52       grdY= self.ndx[1]
53       #TIME BASED COEFFICIENTS
54       dmpn= GaussFnct(ct, 1.25, 0, 100, .1)
55 
56       tmpVec= (.75*self.vec)+(.5*self.force)
57       #HIGHER (R/G/B) VALUES WILL LESSEN MOVEMENT
58       attrK= ((125-grd[grdX][grdY][0].attr[ht])/250)+1
59       #CHECK AGAINST EXTREME MOVEMENTS
60       if ((tmpVec*attrK)*dmp).Length>10:
61          dmpn=10/(((tmpVec*attrK)*dmp).Length)
62 
63       #MOVE POINT
64       self.xyz+= (tmpVec*attrK)*dmp
65       #RESET MOMENTUM VECTOR AND EXTERNAL FORCES
66       tmpVec= (.5*self.vec) + (.25*self.force)
67       self.vec= tmpVec
68       self.force= rhG.Vector3d(0,0,0)
69 
70       #RECORD TRACE
71       self.trace.Add(self.xyz)
72 
73       #ADJUST DENSITY ATTRACTION VALUES
74       for i in xrange(1,4):
75          if i == ht:
76             if grd[grdX][grdY][0].attr[i] < 253:
77                grd[grdX][grdY][0].attr[i]+= 2
78             else:
79                for j in xrange(1,4):
80                   if grd[grdX][grdY][0].attr[(i+j) %4] > 1:
81                      grd[grdX][grdY][0].attr[(i+j) %4]+= -1
82          else:
83             if grd[grdX][grdY][0].attr[i] > 1:
84                grd[grdX][grdY][0].attr[i]+= -.5
85 #======================================================================#
```

A simple mobile agent, this will be the base of the tower (≒6.4.1) and the main force of movement.

19 The agent is located by a grid cell to make position and adjacency comparisons more efficient.

21 A polyline of the sequential positions (:22) traces the path that the *BaseAgent* has taken (:71).

27 *BaseAgents* can be frozen in place by setting their state to *False*.

32 The agent's *.vec* value is similar to momentum, it records the direction of the last movement.

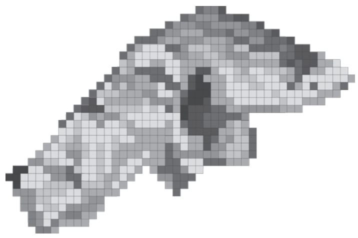
34 The *.force* vector gathers up all the external forces pushing the agent in other directions.

37 Links form when an agent is the realm of influence of another.

41 Since the floorplate of the tower will be rather large relative to the distance between agents, it's helpful to have points for comparison offset from the agent's central point to formulate more accurate distance nad angle measurements.

56 The movement of the agent will be a combination of its momentum (*.vec*) and external forces (*.force*).

64 The base grid (:50, 51) is coordinated to an image density map (Figure 6.6, below) that moderates (via the coefficient *attrK*) the magnitude of the movement vector. As the agent crosses the site it also leaves an impact on this data (:73).



66 A fraction of that movement vector is saved as the *.vec* value for the next frame, and the *.force* vector is reset to zero (:68).

6.4.1 TowerSkeleton

```
140  #====================================================================#
     class TowerSkeleton
       def __init__ (self,pt,i,j,n,ht):
         self.ord= n
         self.ht= ht
145      self.ct= 0

         #AXIS OF LINKED LEVELS (BaseAgent + LevelAgents)
         self.ax= []
         self.ax.append(BaseAgent(pt,i,j))
150      self.ax.append(LvlAgent(self.ax[0], r.randint(10,12)*4, ht >= 1))
         self.ax.append(lvlAgent(self.ax[0], r.randint(20,23)*4, ht >= 2))
         self.ax.append(lvlAgent(self.ax[0], r.randint(30,34)*4, ht >= 3))

     #====================================================================#
155    def DragAxis(self,grd,acc):
         dmpn=.2
         #DRAG FORCE FROM BELOW (HORIZONTAL)
         for i in xrange(1,4):
           tmpVec= rhG.Vector3d(self.ax[i-1].xyz-self.ax[i].xyz)
160        tmpVec.Z= 0
           tmpVec*= dmpn

           #ADD FORCE FROM ABOVE TO tmpVec (EXCEPT AT TOP POINT)
           if i < 3: tmpVec+= dmpn*self.ax[i+1].force
165        #ADD tmpVec TO LEVEL FORCES
           self.ax[i].force+= tmpVec

         for i in xrange(0,4):
           if i > 0:
170          tempVec= (.75*self.ax[i].vec) + (.5*self.ax[i].force)
             if tempVec.Length>4: tempVec*= 3/tempVec.Length

             self.ax[i].xyz+= tempVec
             self.ax[i].vec= .25*self.ax[i].force
175          self.ax[i].force= rhG.Vector3d(0,0,0)

           currX= (self.ax[i].plnX)*.5
           #TOP POINT FACTORS IN VIEW ANGLE
           if i == 3:
180          currX+= (grd[grdX][grdY][0].pdng/ ...
                                   grd[grdX][grdY][0].pdng.Length)*.2
             ang= rhG.Vect=or3d.VectorAngle(currX, self.ax[i-1].pln.XAxis)
             if ang > math.pi/2: currX*= -1
               self.ax[i].pln= rhG.Plane(self.ax[i].xyz, currX, ...
185                                rhG.Vector3d.ZAxis)

             else:
               if self.ax[i+1].state:
                 currX+= self.ax[i+1].pln.XAxis*.2
190            if i > 0:
                 currX+= self.ax[i-1].pln.XAxis*.35
                 ang=rhG.Vector3d.VectorAngle(currX, ...
...                                self.ax[i-1].pln.XAxis)
                 if ang > math.pi/2: currX*= -1

195            if currX.Length > 1: currX.Unitize
                 self.ax[i].pln= rhG.Plane(self.ax[i].xyz, ...
...                        self.ax[i].pln.XAxis+currX, rhG.Vector3d.ZAxis)

             self.ax[i].pts[0]= self.ax[i].pln.PointAt(0,0,-5)
             self.ax[i].pts[1]= self.ax[i].pln.PointAt(0,0,5)
200  #====================================================================#
```

Each building is itself an assemblage of multiple agents, bundled together in a single class.

144 The *.ht* value determines the height in number of key floorplates as *LvlAgents*.

148 These levels are saved in a list as an central axis, *.ax*.

157 Each level exerts a horizontal (:160) force on the ones above (:164) and below it.

```
    #=====================================================================#
205 def UpdateNdx(self,crnr,dict,grd):
        #FIND POSITION IN GRID
        grdX= int(math.floor((self.ax[0].xyz.X-crnr.X)/50))
        grdY= int(math.floor((self.ax[0].xyz.Y-crnr.Y)/50))
        #CLIP TO LIMITS
210     if grdX<0 or grdX>45 or grdY<0 or grdY>29:
            self.ax[0].vec*= -1
            grdX= min(max(0,grdX),45)
            grdY= min(max(0,grdY),29)

215     #CHECK IF INDEX HAS CHANGED
        if grdX != self.ax[0].ndx[0] or grdY != self.ax[0].ndx[1]:
            dict[self.ax[0].ndx[0]][self.ax[0].ndx[1]].remove(self)
            dict[grdX][grdY].append(self)

220         self.ax[0].ndx= (grdX,grdY)

    #=====================================================================#
    def Move(self, crnr, dict, grd):
            self.ct+=1
225         #MOVE BASEAGENT .ax[0]
            self.ax[0].Move(grd,crnr,self.ht,self.ct)

            #UPDATE UPPER POINTS
            self.DragAxis(grd,accl)
230
            #AFTER MOVING .bspt, UPDATE .ndx
            self.UpdateNdx(crnr,dict, grd)
    #=====================================================================#
```

205 After the *baseAgent* moves, the tower's position within the grid has to be checked.

226 The *TowerSkeleton* object initieates the *baseAgent* movement (≒6.31, :50), then calls the *DragAxis* function (:229), and updates the index (:232)

§6.4 Multi-scalar and bidirectional influence

Internal complication

In addition to the interplay between top-down and bottom-up, the reflexive also oscillates between the singular and the plural, and between the interior and the exterior depending on whether we count the assemblage as a multiple of many parts, as an individual monad, or as a component in an assemblage that annexes it.[41] Because the assemblage does not erase the individuality of its component elements,[42] we should expect a heterogeneous mixture of impulses, trajectories, and motivations within an assemblage. Complex agents will often find themselves caught between contradictory tendencies, to say nothing of multi-agent systems.

In this project, each building is modeled by a series of agents (≒6.4.1) linked together at intervals of about 10 storeys (:149-152) in a vetical axis. Each makes connections with other agents at the same level that impart horizontal and rotational forces on the tower up and down the axis (:159, 164, 189, 191). The inevitable conflicts are resolved through iterative, non-binding actions that express the goals of the individual agents while maintaining the intensive and topological relationships within the tower assemblage. The *TowerSkeleton* cluster itself is minimally defined. Most of the action has been moved into subcomponents—the *BaseAgent* or *LevelAgent* classes—as have most of the metadata variables.[43] While *.DragAxis* (:155) preserves a proximity and orientation affinity between layers, *.UpdateNdx* (:205) is restricted to maintaining a position in the *defaultDict* datastructure that reflects the location of the tower for easier recall while *.Move* (:236) and *.AdjAgents* (≒6.4.2) are simply coordinated prompts to component actions.

41 *cf.* Figure 0.1

42 *cf.* §1.3b 'The elements of urbansim'

43 This recalls Bruno Latour's digital monad *cf.* §5.1b 'Means of interaction'

44 Lee and Jacoby, "Typological Urbanism and the Idea of the City."

45 Trummer, "Associative Design: From Type to Population." p182

Type and populations

It is possible to pursue this approach further and to further to delineate the architectural object into a multiplicity of parts. This emphasizes the formation of architecture as a procedural event that also informs the urban configuration, and opposes a typological ideal or forces a reconsideration of typology that does not stand apart as a preexisting ideal.[44] "These changes are no longer defined by the identity or essence of an object, but rather would allow us to understand the object as possible forms of appearances through the interaction of the population of its parts"[45] Deleuze describes such aggregates as an "area that can be called mixed, or rather, intermediary, between statistical collections and individual distributions … still more interindividual and interactive than it is collective,"[46] emphasizing that the identity of the assemblage does not dictate the configuration of the assemblage.[47] Rather,"it is the real in matter, the thing, that has inner characters whose determination enters each time into a series of magnitudes converging toward a limit, the relation between these limits being that of a new type"[48] Here the idea of a type is replaced by a contingent definition. The assemblage does not conform to some law, but a type is simply the result as a statistical description[49]—each time and for each case a new 'type' is formed.[50] The replacement of definitions with limit conditions[51] enables a shift from given forms to open-ended becoming.

In the same way that assemblage urbanism was given to emphasize the agency of the socio-material of the city, population thinking also emphasizes the agency of the associative material of the design model. In the associative model "each of the architectural primitives defines the metrical constraint components of an architectural object."[52] The challenge, then, is to preserve the individual agency of the components and not to fall back into a predefined type. Parametric modeling supports a classical interpretation of typology (the necessity of explicit formalization in some ways predisposes it to such an interpretation) just as readily as it constitutes a challenge to such thinking. In this project, we extend the configurational intelligence into smaller and smaller parts of the design, first with key floorplates that structure the overall shape of the tower and react to the presence of neighboring towers, and then again into individual units (Figure 6.4.1). Units are flexible within their own limits and limits relative to the floorplates, while floorplates are limited by the building's surroundings and vertical cores. The tower converges to a final form through the feedback that occurs between all of these individuals equally, not bounded by scalar categories, resulting in a widening of the gap between the scale of architectural objects and the scale of its potential theater of effects.

46 Deleuze, *The Fold: Leibniz and the Baroque*. p115

47 "This area of interindividual, interactive clustering is quite agitated, because it is an area of temporary appurtenances or of provisional possessions … everywhere there are places available for mutations, explosions, abrupt associations and dissociations, or reconcatenations."

Ibid. p115

48 *Ibid*. p47

49 Because the limits cannot be known from a single case, the conditions that thoroughly describe an assemblage have to converge from a large sample that covers "the latitude of their variation and the relation of their limits"

Ibid. p47

DeLanda, *A New Philosophy of Society: Assemblage Theory and Social Complexity*. p21

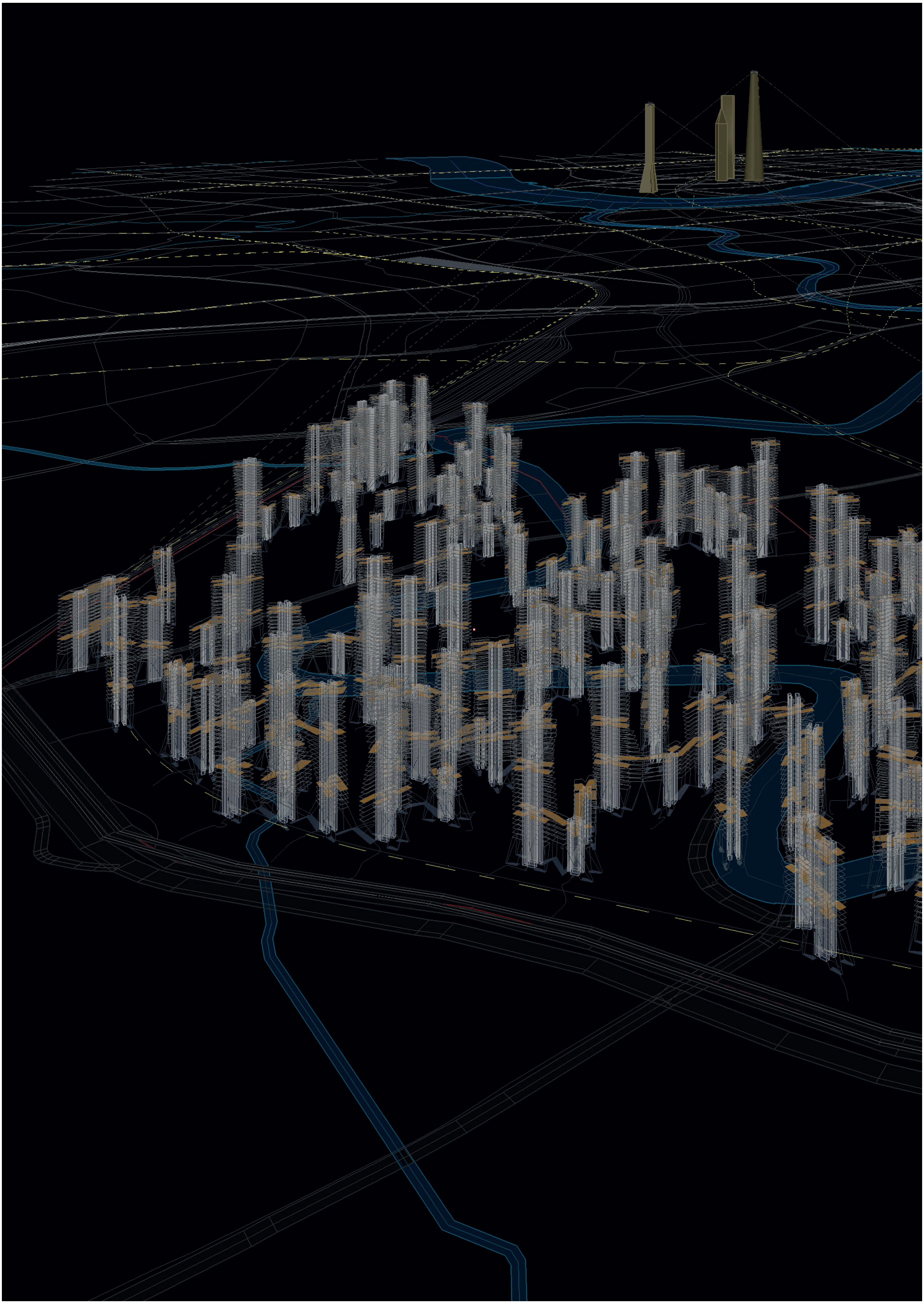
50 "Principles as such will be put to a reflective use. A case being given, we shall invent its principle."

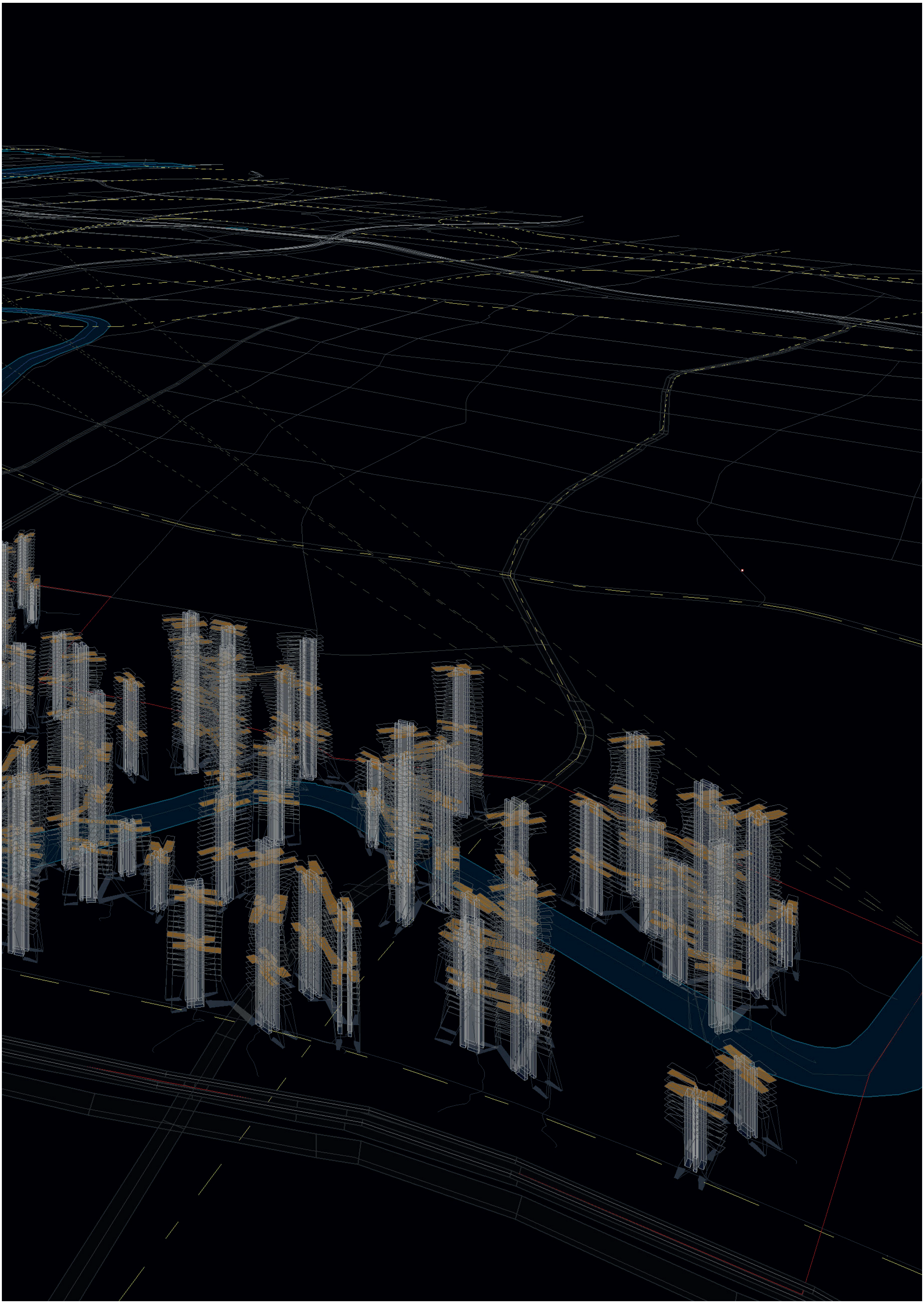
Deleuze, *The Fold: Leibniz and the Baroque*. p67

51 Deleuze connects definables with extensities, magnitudes (Figure 0.1), and similitude.

Ibid. p46, 57

52 Trummer, "Associative Design: From Type to Population." p182





§6.5 Architecture as Effectual Urban Input

Architecture as urban effector

For Schöffer, the particular form of the *Ville Cybernetiqe*, plays a very minor role, even less developed than in Yona Friedman's *Ville Spatiale*, "rather, he focuses on the city's complex system of functions and topologies, so that the whole remains at a very abstract level in terms of its design and planning."[53] Schöffer's ambitions are really to extend the means of information feedback, while the architectural objects in the city surface are simply "a way to literally cover the surfaces of the city and fill its spaces with a structured grammatical system of patterns and ambient effects."[54] The conception of architecture as a mediating link between intent and spatial effect,[55] as well as the role of architecture to facilitate further creative acts of urbanism,[56] are both aspects of that we would like to advocate as features of reflexivity that draw attention to the active role architecture has shaping urban organization and not merely responding to the urban plan.

Collective form

However, this leaves out a significant and necessary element, which is the influence of architecture as an actual object and material presence in the city. The importance of the formal details of architecture is too often omitted from discussions of urbanism as though their significance was limited to the sphere of immediate experience or an indifferent symbolic function.[57] In a lecture from 1965, Fumihiko Maki drew a distinction between mega-structures and group-form,[58] two approaches to open-ended and temporal processes of collective forms. Mega-structures were those constructed of primarily independent systems that were bound together within a frame.[59] While the expression of a physical, infrastructural frame would come to be a stylistically dominant feature of the mega-structure,[60] Maki's early definition accurately describes the *Ville Cybernetique*, whose tower array constitutes a conceptual and experiential framework that bundles together Schöffer's five topological systems.[61] Group-form, in contrast, "evolves from a system of generative elements in space,"[62] where the units actively give shape to a mutable overall form.[63] The formal details are significant, even operative, in the formation of collectives. "Forms in group-form have their own built-in link, whether expressed or latent, so that they may grow in a system. They define basic environmental space which also partakes of the quality of systemic linkage."[64] In this way, each element is reciprocally linked in a feedback relationship with the larger pattern[65] as well as the local environmental conditions.[66]

Increasingly, the acceleration of large-scale urbanization in Asia points to the need to formulate a new relationship between architecture and urbanism.[67] In the case of urban developments that are built immediately rather than incrementally, there is a unique opportunity for hybrid or unprecedented typologies that exceed the received forms of urban architecture.[68] Nor is this only a negative case, an acquiescence to a narrow range wherein the architect's influence can be exercised,[69] but rather an exemplary case that points to a new general link between architecture and urbanism, one that can be exported from the large-scale development to other implementations.[70] I would like to argue that, in fact, the potentiality of architecture as a reflexive urban interface, underscores urban architectural pursuits in general.[71]

§6.6 Reflexive Model Tendencies

Differentiation engines

With regard to computational modeling, reflexivity prioritizes pluralistic models that develop through iterative differentiation.[72] This development could be called 'agonistic' to the extent that it stages agents with conflicting motivations but shared common ground in an environment that does not resolve the conflict but works through solutions that construct a consensus without removing the intensive differences that set agents against one another.[73] With enough active variables in the model, the process begins to exhibits nonlinear complexity. Still, the actualized results are not completely divergent, but will begin to fall into recurring states. Any given outcome "can be activated in a variety of different ways, actualizing objects in a variety of different ways at the level of local manifestations."[74] These attractor states can only be

53 Schöffer's designs for various buildings within the city are composed in an style of *architecture parlante* that appears to disregard the cybernetic network entirely. Darò argues that the metaphoric expressionism of these buildings is at least consistent with the scientific metaphor that Schöffer employs at the expense of "application and its material constitution."

Darò, "Nicolas Schöffer and the Cybernetic City." p9, 11

54 Busbea, *Topologies: The Urban Utopia in France, 1968-1970*. p178-179

55 *Ibid*. p180

56 « *Le rôle de l'artiste n'est plus de creér un oeuvre, mais de creér la création*. »

Schöffer, *La Ville Cybernétique*. p5

57 Jencks, *The Iconic Building*.

58 Maki, *Investigations in Collective Form*. p4

59 *Ibid*. p8, 12

60 Banham cites Ralph Wilcoxon's four point definition of megastructures, two of which insist on a prominent structural frame. Banham's definition is looser, but he dismisses attempts to retroactively deem the medieval urban matrix of Urbino equivalent to the frame.

Banham, *Megastructure: Urban Futures of the Recen Past*. p8, 76

61 In fact, Banham does mention Schöffer among the "Beginners and Begetters" of megastructuralism.

Ibid. p57

The five topologies are: time (rhythms), light, sound, climate, and space.

Schöffer, *La Ville Cybernétique*. pXX

62 Maki, *Investigations in Collective Form*. p14

63 *cf.* §5.8 'Enacting Encounters' for a parallel with 'field conditions'.

"a unit can be added without changing the basic structure of the village. The depth and frontage of the unit, or the size … may differ from unit to unit."

Ibid. p18

64 *Ibid*. p19

65 *Ibid*. p19

66 "It may be easy for someone to invent a geometric form and call it group-form because such forms have characteristics of being multiplied in a sequential manner. This is, however, meaningless, unless the form derives from environmental needs"

Ibid. p21

67 Keeton, *Rising in the East: Contemporary New Towns in Asia*. p23*ff*, esp.31-33

68 "The split between architecture and urbanism that was collaged and amalgamated by the skyscraper was newly rebuilt within a larger superseding process, which uses the skyscraper as a means … If the skyscraper apparently obliterated urban traditions in order to develop itself as an anti-urban tradition, the overskyscraper uses its typology as an organizational primitive and as a thematic platform, from where to engineer new and empowered forms of discipline."

Najle, "The Overskyscraper: Ubiquitous Tower Collectives."

69 "we may conclude that architects can only intervene urbanistically in an increasingly remedial manner and that one effeective instrument for this is the large building program that may be rendered as a megaform"

Frampton, *Megaform as Urban Landscape*. p39-40

Note that Frampton differentiates his use of 'megaform' from the megastructure through the relative continuity of the megaform, its topographic orientation, and its civic setting in the megalopolitan landscape, though he acknowledges that the two terms are not necessarily exclusive.

Ibid. p16

70 In more limited cases, the anticipatory potential "for linking newly established parts with parts not yet conceived" is particularly present.

Maki, *Investigations in Collective Form*. p35

71 *cf.* §9.2 'The Urban Generic'

72 An assembly process may be said to be characterized by intensive properties when it articulates heterogeneous elements as such … a process is intensive if it relates difference to difference … but also endow the process with the capacity of divergent evolution, that is, the capacity to further differentiate differences."

DeLanda, *Intensive Science and Virtual Philosophy*. p64

73 Mouffe, "Deliberative Democracy or Agonistic Pluralism." p15

74 Bryant, *The Democracy of Objects*. P114

cf. §1.5b 'Manuel DeLanda' on redundant causality described after comparing a number of simulations to one another through statistical measures, that is, these categories are populations that emerge from the model rather than being preexisting templates or types.[75]

Risk of Equilibrium

Of course the notion of patterns of attractors implies that the model tends toward a state of equilibrium at which point the passage of time becomes immaterial.[76] Counteracting the tendency toward stasis requires that "appropriately large differences in intensity need to be maintained by external constraints and not allowed to get canceled or be made too small."[77] The key point here is not simply the disruption of static states with additional energy or displacement but the preservation of intensities. After all, Schöffer himself considered the disruptions that issued from the central computer of the *Ville Cybernetique* to tend not toward eccentricity but "towards efficiency, by modifying a situation in such a way as to maintain a supple balance between its components."[78] The next chapter will describe the movement following intension to the entropic function as a means of countering inflexible, teleological models.[79]

75 DeLanda, *Intensive Science and Virtual Philosophy*. p47-50

76 "Cybernetics is the science of the materialism—or the materialization—of time."

Kwinter, "The Genealogy of Models: The Hammer and the Song." p60

77 DeLanda, *Intensive Science and Virtual Philosophy*. p66

78 « *vers l'efficacite par la modification opportune d'une situation, en vue du maintien d'un equilibre souple entre ses composantes* »

Schöffer, *La Nouvelle Charte de La Ville*. p105

79 Verebes, *Masterplanning the Adaptive City*. p93

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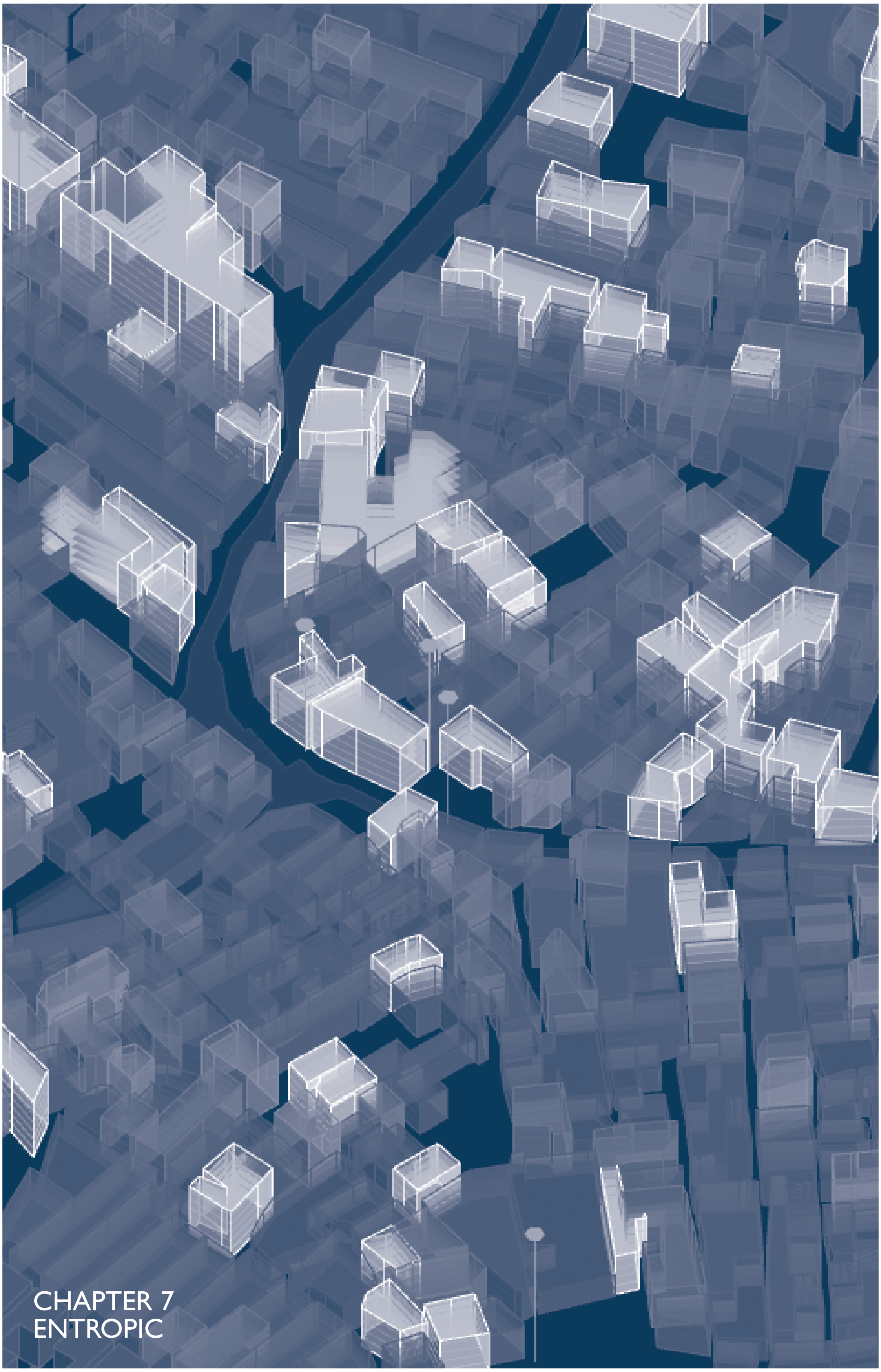


CHAPTER 7
ENTROPIC

§7.1 Resisting Terminality

Nondeterministic models

Current masterplanning practices, display an "overreliance on narrow, singular, inflexible pictures of the future,"[1] whether through two-dimensional plans or in rendered images. Even when designated for phased implementation, these plans project themselves years into the future, attempting to offer concrete targets for the future of the city.[2] Unfortunately, because of the complexity of the city and the impossibility of producing a truly complete model, these targets will often never be achieved. This is true even of plans that employ dynamic or procedural modeling in their formulation.[3] This chapter seeks to put forward the possibility of a method of urban design that is projective, but not teleological, one that remains open-ended and enacted in time through selective introduction of entropy into the model. This entropy could come in the form of updates to the model that allow unforeseen changes in the city to be incorporated (effectively resetting the given conditions), or as a programmed process of forgetting[4] that would disrupt configurations that have reached static equilibrium. In addition to providing more responsivity to real contingencies,[5] this would also shift the emphasis of urban design toward more strategic goals like encapsulating responses as unit operations[6] and how actions might be assembled together in networks across the city.[7]

Generator

One project that explicitly embraced this idea was Cedric Price's *Generator*. Unlike the other projects referenced in this text, the various studies for *Generator* never approached the urban or masterplanning scale, however it was designed with that potential in mind[8] and its use and ultimate form was left to the whims of the occupants.[9] Originally worked out through menus and physical games, the project was redeveloped by John and Julia Frazer as an intelligent computational system composed of programs to "manage the rules for *Generator*'s layout and the use of its parts,"[10] to engage with the users, prompting changes, and "allowing users to prototype and visualize the outcomes"[11] through physical models and computer plots. A final program, a boredom function[12] was added to correct for inaction by the users or a history of monotonous uses. Thus while the program could "learn from the alterations made to its own organization and coach itself to make better suggestions,"[13] it was also capable of challenging its users' directions[14] even when reconfiguration required unlearning all the patterns it had developed. Molly Wright Steenson argues that Price's attraction to organizational tools such as computer programming was not motivated by harnessing methods of control, like it was for Schöffer, but "as a means to destructure the experience of the architectural project"[15] in service of flexibility and indeterminacy. Following this, Price viewed the structural function of the cubes themselves as less important than the circulation network of paths and catwalks that constituted a 'free-space' "not intended to make a straightforward directive information flow; it represents possibilities and distribution, or different flows over time."[16]

1 Verebes, *Masterplanning the Adaptive City.* p93

2 On predictions of the future:

Patt, "The Collective Image: Form, Figure, and the Future."

3 For example ZHA's *Kartel-Pendik masterplan* or GroundLab's *Deep Ground* plan for Longgang

Bullivant, *Masterplanning Futures.* p22, 252-258

4 *cf.* §8.2

5 "The cycle of decay can become a linking force in our cities. If recognized, it provides an opportunity to replace old structures in an old environment with new structures still in an old environment."

Maki, *Investigations in Collective Form.* p34

6 *cf.* §3.4 'Unit Operations'

7 *cf.* §1.7 'Responsivity, Assemblage Urbanism, and Engagement with the City'

8 Price describes the project as "a forest facility for between one and one thousand visitors." though it was never explored in more than 150 room-sized cubes.

Price, *Cedric Price: Works II Architectural Association.* p97

9 The project materially consisted of 12'×12' timber-framed cubes (some of which were serviced), infill panels, catwalks, and screens which could be arranged by a mobile crane and positioned on a gridded matrix of concrete and steel pads.

Ibid. p92-97

10 All physical parts were to be fitted with sensors and logic circuits so that their use and position could be tracked and the computer could maintain a model of the existing configuration.

Steenson, "Architectures of Information: Christopher Alexander, Cedric Price, and Nicholas Negroponte & MIT's Architecture Machine Group." p149

In fact, "one of the initial reasons why computers were required was to assist in handling the overlapping parameters involved in the Generator's performance"

Furtado, "Cedric Price's Generator and the Frazers' Systems Research." p58

11 Steenson, "Architectures of Information: Christopher Alexander, Cedric Price, and Nicholas Negroponte & MIT's Architecture Machine Group." p149

12 *Ibid.* p150

13 Frazer, *An Evolutionary Architecture: Themes VII.* p41

14 "boredom would have to be the character of the shift in agency"

Steenson, "Architectures of Information: Christopher Alexander, Cedric Price, and Nicholas Negroponte & MIT's Architecture Machine Group." p150

15 *Ibid.* p123

16 *Ibid.* p147

17 *Ibid.* p146

18 Price, *Cedric Price: Works II Architectural Association.* p90

19 In fact this constitutes our primary point of departure from Badiou.

Badiou, *Being and Event.*

§7.2 Informal Structures

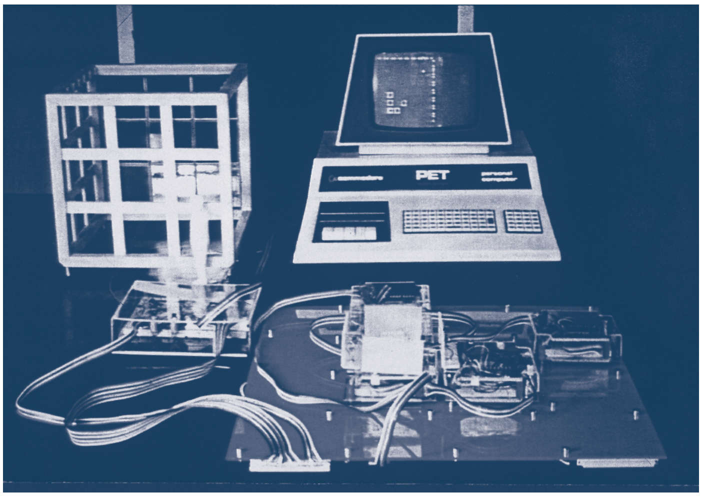
Novel through network excess

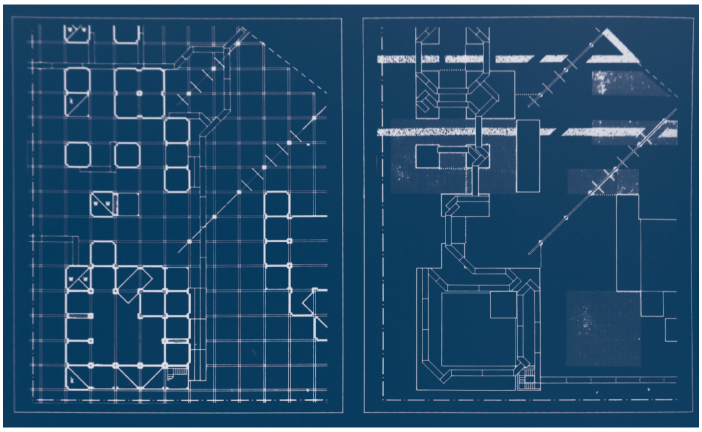
Price envisioned these paths "as a puzzle or a maze"[17] that could only be understood by walking through it and experiencing the connections or disconnections that were produced. Such experiences would then prompt the visitors to envision changes and to imagine the complex differently. This reflected his belief that "uncommitted or free-space must be seen not merely as the canvas for a new piece of architecture but as a continuing resource."[18] Philosophical accounts of how new forms come into being tend to favor a negative cause that derives from a void or lack in the current situation,[19] however this position "is thoroughly informed by implicit structuralist assumptions."[20] Bryant suggests instead to locate the novel in the excess latent within the network, looking at the existing system not as a deterministic structure but as the dynamic formation of "ever shifting elements in networks or assemblages. In fact, it is already misleading to speak of networks or assemblages as this implies fixed and static beings. Rather, we should speak of assembling and networking, where elements brought together evoke action in one another, producing unforeseeable results and configurations."[21] Understanding and responding to such an environment calls for an immanent[22] process of making sense of these processes, "a superior empiricism, a practice of cartography, capable of tracing networks and assemblages, or ever shifting relations among actors."[23] In order to engage in this sort of mapping, it is important to avoid totalizing and aloof images[24] that would detach from "a more procedural sequence of intermittent coupling."[25]

Urban morphology

Historically, the dominant practices of urban morphology[26] have been concerned with defining morphological regions through identification of historical forms of development (that is, with similar relationships between ground plan, built fabric, and land use)[27] and identification of typological processes.[28] Although addressed to the processes of city formation, the dynamism of urban morphogenesis is stunted by placing it within a catalog of fixed types. A trend toward techniques that could enable a more procedural cartography of the city can be discerned in some of the newer methods of urban morphology that merge the analytical power of computational processing with the metrical precision of GIS software[29] and typically combine topological network analysis with metrical and spatial data.[30] While still frequently employed for quite traditional mapping purposes, in the best cases these maps approach what Kwinter called "*procedural maps …* protocols or formulas for negotiating local situations and their fluctuating conditions."[31] An adoption of these methods by designers suggests the potential for many new metrics to be developed (since the design process opens direct access to morphological data that are not available to the researcher looking backward in time) as well as an activated concern for projecting alternative futures[32] within particular, concrete urban assemblages.[33]

The most well-defined and wide-spread of these new practices is the 'space syntax' approach, which developed from morphological studies of architecture into a series of "consistent techniques for the representation and analysis of spatial patterns,"[34] particularly those that characterize "the cognitive dimension of architectural and urban space."[35] A unique aspect of space syntax is the reconstruction of the urban network "illustrating street segments as nodes and junctions as edges, known as the dual representation,"[36] which better corresponds to the subjective, experiential position of space syntax, but which creates formal difficulties in correlating the results with other models.[37] In our opinion, the attachment of space syntax's analytic categories to vaguely defined cognitive categories also introduces problematic epistemological issues between analysis and interpretation.[38] Alternatively, one can apply an analysis of the urban network that uses the primal graph (representing streets with segments and intersections with nodes[39]), which implies a less subjective and more materialist focus.





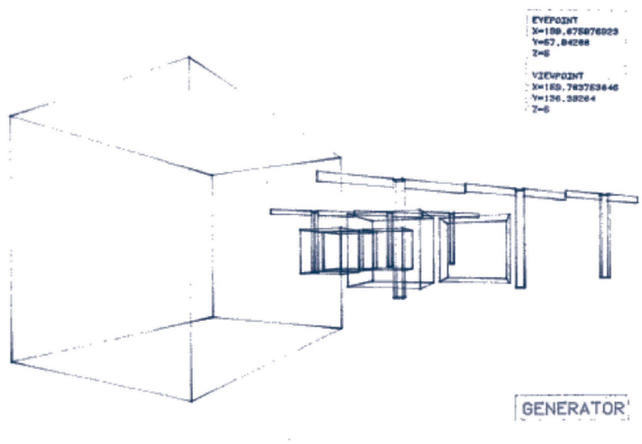


Figure 7.1;
Tangible interface for *Generator*. 1978-80

Riley, *The Changing of the Avant-Garde: Visionary Architectural Drawings from the Howard Gilman Collection*. p185

Figure 7,2;
Detail of ground floor and roof plans with walkways.

Price, *Cedric Price: Works II Architectural Association*. p92

Figure 7.3
Computer generated perspectives created by John Frazer, 1979

Riley, *The Changing of the Avant-Garde: Visionary Architectural Drawings from the Howard Gilman Collection*. p187

20 Bryant, "Towards a Critique of the Politics of the Void: Notes Towards a Politics of Assemblages." p4

21 *Ibid*. p9

22 "it is the insertion of the dimension of time into the field that establishes a relation of continuity between subject and object, figure and ground, observer and event."

Kwinter, *Architectures of Time: Toward a Theory of Event in Modernist Culture*. p98

23 Bryant, "Towards a Critique of the Politics of the Void: Notes Towards a Politics of Assemblages." p14

24 de Certeau, *The Practice of Everyday Life*. p92-93

25 Kwinter, *Architectures of Time: Toward a Theory of Event in Modernist Culture*. p80

26 The main schools of urban morphology follow Conzen, primarily in the realm of urban geography, or Caniggia, who takes a more architectural approach. Integrated or comparative studies are increasingly popular.

Sima and Zhang, "Comparative Precedents on the Study of Urban Morphology."

27 "For M.R.G. Conzen the climax of the exploration of the physical development of an urban area was the division of that area into morphological reagions … an area that has a unity in respect of its form that distinguishes from surrounding areas."

Whitehand, "British Urban Morphology: The Conzenian Tradition." p106

28 "The typological process is a succession of types in the same cultural area – diachronic changes – or in several cultural areas in the same space of time – synchronic changes … For Caniggia and Maffei, the type is a cultural entity rooted in, and specific to, the local process of cultural development."

Oliveira, Monteiro, and Partanen, "A Comparative Study of Urban Form." p80

29 Jiang, "Extending Space Syntax towards an Alternative Model of Space within GIS."

30 Marcus, Westin, and Liebst, "Network Buzz: Conception and Geometry of Networks in Geography, Architecture, and Sociology."

31 Kwinter, *Architectures of Time: Toward a Theory of Event in Modernist Culture*. p98

For example, Eric Fischer's map of bus movement during the Occupy Oakland protests, compiled and uploaded the same day.

Fischer, "AC Transit Bus Service so Far Today."

32 "it is a process of assembling possibilities out of actualities. Design connects us with vision, image and imagination; it produces hope and is productive of desire."

Dovey, "Uprooting Critical Urbanism." p350

33 "politics must be seen as a response to a particular problem inhabiting an assemblage and not as an eternal and unchanging set of questions"

Bryant, "Towards a Critique of the Politics of the Void: Notes Towards a Politics of Assemblages." p12

34 HIllier and Hanson, "The Reasoning Art: Or, The Need for an Analytical Theory of Architecture." p1

35 Marcus, Westin, and Liebst, "Network Buzz: Conception and Geometry of Networks in Geography, Architecture, and Sociology." p68:6

36 Sevtsuk and Mekonnen, "Urban Network Analysis: A New Toolbox for ArcGIS." p289

Figure 7.4
Site geometry with buildings colored by height (low buildings are darker) and the canal network visible

Figure 7.5
The site converted to a half-edge mesh. Metadata taken directly from the image file in Figure 7.4 is saved to the faces' methods and output color from Grasshoppper for visual confirmation.

Graph agents

One criticism of street network graphs is that one segment may actually have many different qualities over its length, limiting the resolution of an analysis that uses street segments and resulting in a granularity that varies unevenly depending on the network morphology. Sevtsuk addresses this concern by adding building entrances to the network as terminal points that branch off from the street segments, enabling the use of building data such as floor height, use, or occupant load to add weighted values to the urban analysis.[40] In this project, we address this concern by adding additional segments at the location of the party walls that separate buildings or at locations where the street width changes significantly (Figure 7.5). This gives a much finer (and relatively even) resolution and renders the building volumes a more integral part of the network itself.[41]

The additional benefit of using the primal graph is that it is compatible with the half-edge mesh datastructure that we introduced in ≒5.4.1. We will now add a dynamic component to this framework in the form of agents capable of movement through the network and capable of altering its topology. These agents are constructed in a similar manner as the mobile agents in ≒6.3.1 but instead of an xyz position and free trajectory vectors, they will be located at vertex points of the mesh (:30, 33) and take their direction from the incident mesh edges (:29, 32). Movement of the agents can be initially defined as a random walk—or, in this case a weighted randomization that factors in the width of the path (:33, 40)—and then grow more motivated as a record of information is added to and collected from the environment.

37 "axial line computation is ambiguous from a computational point of view … A second practical problem with the axial line computation relies [sic] in the fact that axial lines do not exist in reality, that is they are not explicitly represented within the GIS database."

Jiang, "Extending Space Syntax towards an Alternative Model of Space within GIS." p6-7

38 Against the confusion of the irreality of constructed models for natural processs, *cf.* §4.9 'Concept of Model.'

The cognitive dimension of Space Syntax also leads to an inert 'universal subject' and the bizarre defense of determinism below, which we would counter as in §4.3a 'Prepositional mode of being.'

"To argue in principle against any kind of architectural determinism, that is, any kind of positive or negative effects of architecture, leads to the odd proposition that it does not matter at all how environments are designed, since they are behaviourally neutral."

HIllier, *Space Is the Machine: A Configurational Theory of Architecture.* p139

39 Porta, "The Network Analysis of Urban Streets: A Primal Approach."

40 Sevtsuk and Mekonnen, "Urban Network Analysis: A New Toolbox for ArcGIS." p290

41 *cf.* §7.4 'Nonlinear Dynamics'

≒7.2.1 GraphAgent

```
10  class graphAgent:
      def __init__(self,ndx,m):
        self.vtx= ndx
        self.prev= ndx
        self.eCurr= m.eTE[m.vIE[ndx]]
15      self.age=0
        self.trace=rhG.Polyline()
        self.trace.Add(m.v[self.vtx])
        self.dpthLst={}
        self.ntwrkLngth=0
20      self.dpthRto=(-10,-10)
        self.pth=[]

      def step(self,m,edgData,Rndm,boolCalc):
        zeroCt=[]
25
        eInit= m.vIE[self.vtx]
        #COMPILE LIST OF INCIDENT EDGES
        eLst= []
        eTest= eInit
30      mult=int(math.ceil(edgData[eTest].wdth))
        if eTest != m.eTE[self.eCurr]:
          eLst.extend([eTest] * min(mult,5) )
        if mult == 0: zeroCt.append(eTest)

35      while m.eNE[m.eTE[eTest]] != eInit:
          eTest= m.eNE[m.eTE[eTest]]
          mult=int(math.ceil(edgData[eTest].wdth-.01))
          if eTest != m.eTE[self.eCurr]:
            eLst.extend([eTest] * min(mult,5 ))
40        if mult == 0: zeroCt.append(eTest)

        #RANDOMLY CHOOSE NEXT EDGE
        if eLst:
          nxt= int(math.floor(Rndm*len(eLst)))
45        self.eCurr= eLst[nxt]
          self.vtx= m.eOV[m.eTE[eLst[nxt]]]
        else:
          self.eCurr= m.eTE[self.eCurr]
          self.vtx= m.eOV[m.eTE[self.eCurr]]
50      self.trace.Add(m.v[self.vtx])

        if len(self.trace)>12: self.trace.RemoveAt(0)

        #ADD UP TRAFFIC, DEMAND
55      edgData[self.eCurr].traffic+= 1
        edgData[m.eTE[self.eCurr]].traffic+= 1
        self.age+= 1 + (edgData[self.eCurr].traffic/5)

        totalWdth= edgData[self.eCurr].wdth + ...
...                 edgData[m.eTE[self.eCurr]].wdth
60      edgData[self.eCurr].dmnd= edgData[self.eCurr].traffic / ...
...                                   (1+totalWidth*2)
        edgData[m.eTE[self.eCurr]].dmnd= edgData[self.eCurr].dmnd

        #CALCULATE THE LOCAL DEPTH MAP
        if len(zeroCt)>=0 and boolCalc:
65        CalcDepthList(edgData)
        else:
          self.pth.append(m.e[self.eCurr])
```

This agent class' mobility is defined by the edges of a mesh. Its methods allow it analyze, mape, and operate on the topology of the mesh.

12 The location and direction (:14) of the agent are defined relative to the mesh by index values.

18 Initializes a dictionary for *.dpthLst* for local network analysis.

27 List of possible trajectory headings (edges that radiate from the current vertex, *.vtx*). are included in the list a number of times based on a multiple of their width value (:33).

38 During each step, the agent loops through the various edges radiating from the current vertex, skipping over the direction just traveled (:35, 31).

44 The direction for movement is selecteed at random from the list of edges (weighted by width) unless the list is empty (:47). which would mean a dead end and requires the agent to turn round (:48).

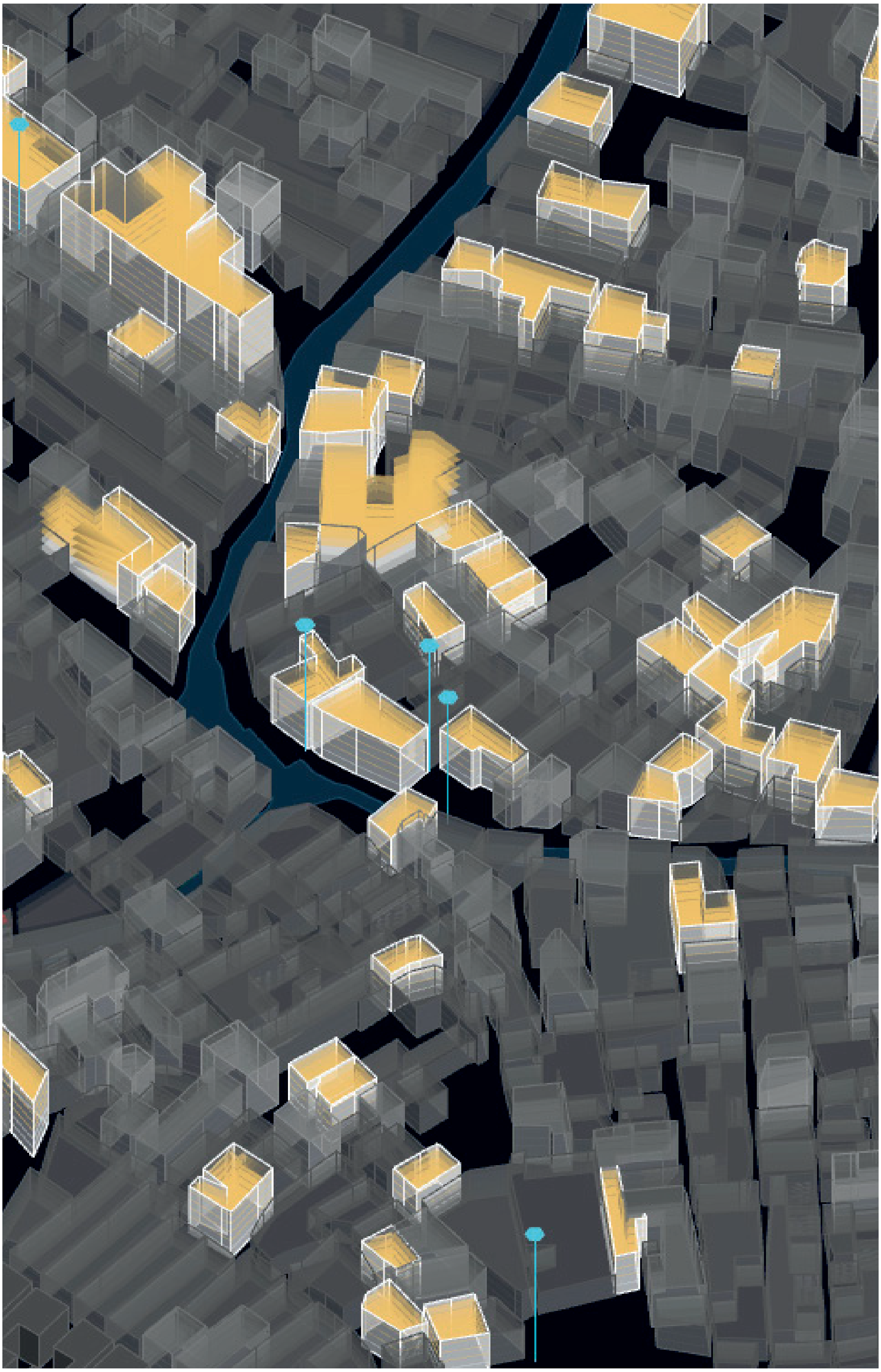
52 The agent's *.trace* is a list of the last twelve locations. This is tracked mostly for visualization purposes.

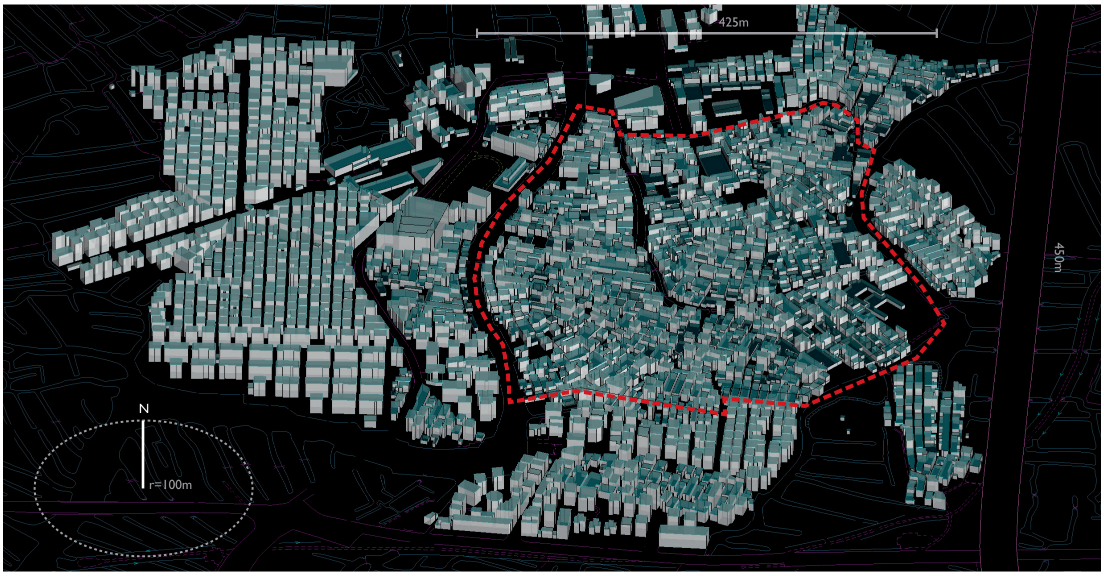
55 Increase the *.traffic* values of the edge and is twin-edge (:56).

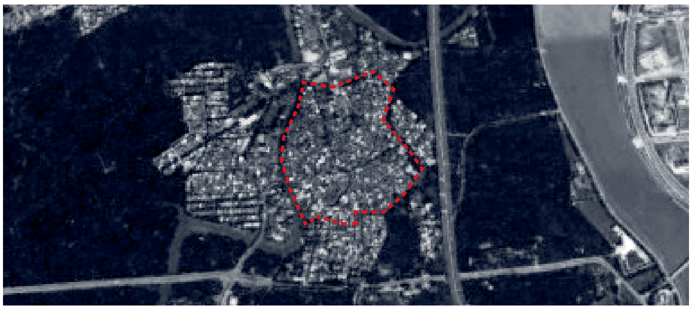
57 Agents are aged based on the aggregate traffic at their location and disactivated after the *.age* passes a certain threshold. This prevents them getting stuck in loops and producing unbalanced results.

60 Traffic values are passed on to the network edges through a propety, *.dmnd* as a factor or the edge's width.

64 *zeroCt* records the indices of incident edges that are impassable and have a width of zero, i.e. party walls or blocked paths (:33, 40). When the current intersection has such a segment, the agent will run the local network analysis *CalcDepthList*, ≒7.4.1. This analysis is only run on even frames (given by *boolCalc*) because adjacent frames returned quite similar results. On odd frames the shortcut path is extended by one segment for continuity in the visualization (:67).







The village-in-the-city[42] phenomenon in Chinese cities, which has resulted from rigid restrictions on migrant mobility[43] and lack of effective urban planning restrictions in what are legally considered rural lands,[44] has been well documented. However the majority of research focuses on those villages-in-the-city most embedded in the urban fabric.[45] The villages of Haizhu island in Guangzhou are unique in that they are still surrounded by agricultural (and park) land, the Wanmu Orchard,[46] despite occupying a geographically central position within Guangzhou. This fact isolates them somewhat from the pressures of urbanization and renders them more autonomous units than their counterparts.

This project is sited within Xiahzhoucun, one of the larger villages in Haizhu, located on the banks of a forked canal that connects the irrigation network of the orchard to the Zhujiang River. Unlike many villages-in-the-city, the population growth of Xiaozhoucun is not predominantly driven by migrant workers, but by students who attend school in the nearby University Town and artists associated with the Guangzhou Academy of Fine Arts[47] drawn to the quietness and tranquility of the village.[48] This project focuses on the network of public space (in a 15ha area at the center of the village[49]) as dynamic material for enacting situated, loosely coordinated, incremental renovation and densification.[50]

42 城中村: 'chengzhongcun,' also sometimes called 'urban village.'

Chung, "Building an Image of Villages-in-the-City: A Clarification of China's Distinct Urban Spaces."

43 Mullan, Grosjean, and Kontoleon, "Land Tenure Arrangements and Rural–Urban Migration in China."

44 Wang, Wang, and Wu, "Urbanization and Informal Development in China: Urban Villages in Shenzhen."

45 Zacharias, Hu, and Huang, "Morphology and Spatial Dynamics of Urban Villages in Guangzhou's CBD."

46 "Yingzhou Ecological Park, located in Xiaozhou Village in southeast of Haizhu District, together with the neighbouring Wanmu Orchard, form the largest agro-ecological park in Guangzhou … Wanmu Orchard is a large green land rarely seen in large-scale cities in China."

Guangzhou Municipality, "Wanmu Orchard & Yingzhou Ecological Park."

Figure 7.6
Detail of Project 4: Building volumes

Figure 7.7
Site condition and boundary

Figure 7.8
Orthophoto of Haizhu Island from Harvard GSD studio 'Green-Heart Urbanism' (STU 160500) instructors: Kongjian Yu, Stephen Ervin, Adrian Blackwell.

http://isites.harvard.edu/icb/icb.do?keyword=k92118

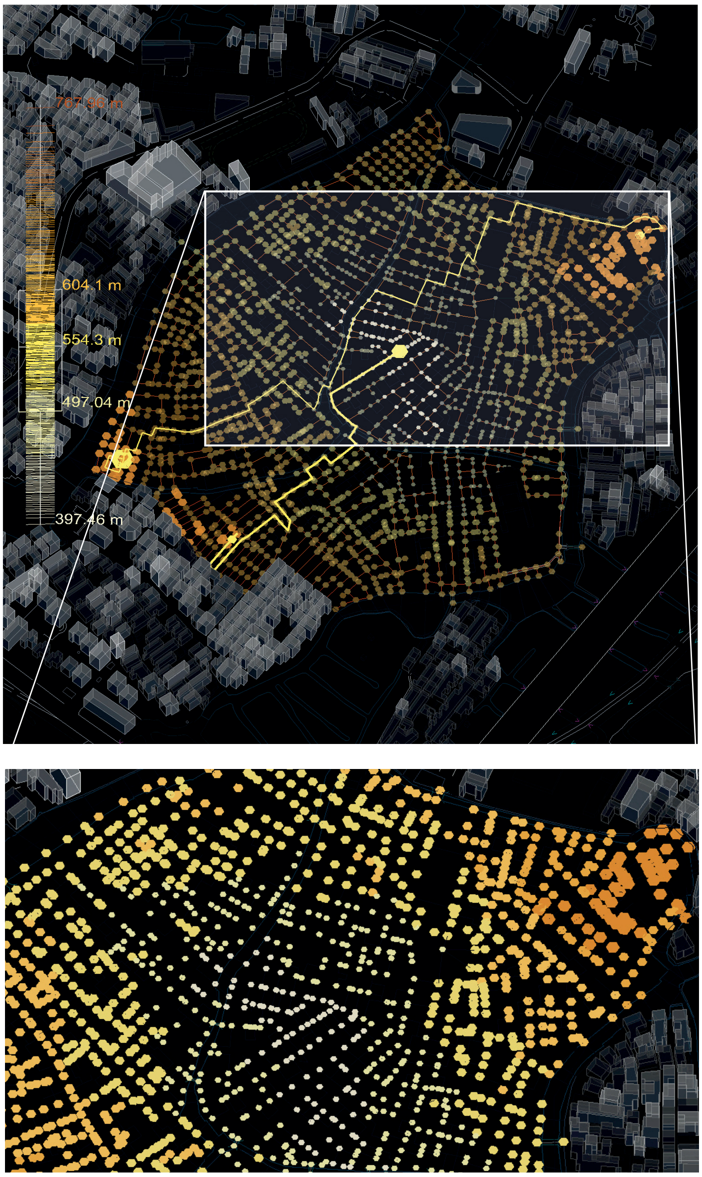
§7.3 Graph Functions

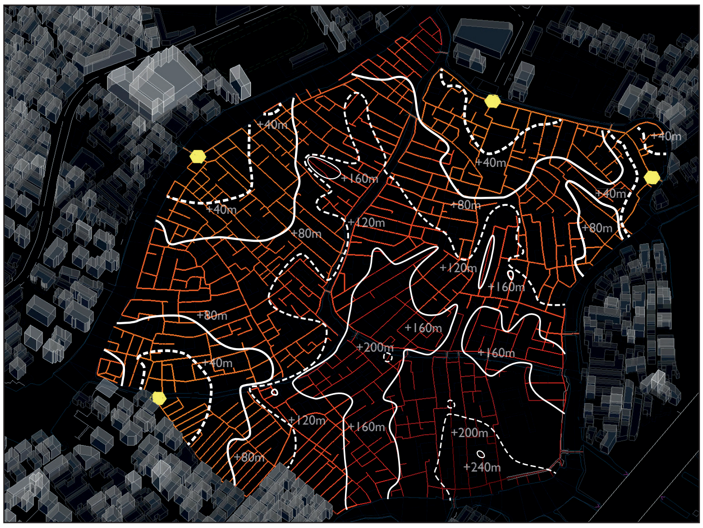
Network depth and properties

Before initializing the agents, it will be helpful to analyze the existing urban fabric in its current condition. Whereas the previous examples have used the half-edge mesh structure solely as a means of data organization and recall, here the properties of the mesh network are of direct interest. We will first look at properties of the street connections (as edges), then the intersections (as nodes), and finally the plots (as faces).

In constructing these analyses, there is a great deal of research to draw upon from the field of graph theory that seeks to explain properties of a network based on its morphological properties. From each node, the minimum distance required to reach the most distant node in the network is referrred to as the eccentricity at that node.[51] The largest eccentricity is called the diameter of the graph and the smallest, the radius. In ≒7.3.1 we set up a script that calculates eccentricity of a given node by recursively (:21) tracing along the path network until the shortest distance to each path has been calculated, using a depth-first search.[52] By iterating this analysis over the entire network, we can calculate the diameter and radius and identify central and peripheral vertices by comparing the distribution of ecccentricity over the graph (Figure 7.9b). These metrics on their own may not tell us much about the structure,[53] however they can give some suggestions about the urban network when plotted alongside the graph geometry (Figure 7.9a). For example, the path of the radius is a winding route that occasionally turns back on itself, highlighting detours or blocked connections, while the diameter alternates between stair-stepping and continuous spines (these are usually following geographic boundaries such as the river edges), illustrating that the meshwork has aspects of both a grid and a ladder structure.[54] Similarly, the central and peripheral nodes are not arrayed radially but along the diagonal that stretches from the southeast to the northwest. Interestingly, two of the main entrances (Figure 7.10) are among the most peripheral points.

Beyond these graph-specific properties, we must also remember that the urban network is insistently place-based, adding an additional spatial dimension of fixed distances and locations. Thus where graph analysis may be interested in the simple depth, urban network analysis can extend that anlysis by considering not just the number of links, but also the physical length of the segments and a comparison of the embedded graph space to continuous global space (Figure 7.12).





47 Qian, He, and Liu, "Aestheticisation, Rent-Seeking, and Rural Gentrification Amidst China's Rapid Urbanisation: The Case of Xiaozhou Village, Guanghou."

Andersson, "Migrant Positioning: In Transforming Urban Ambiene, Urban Villages and the City, Guangzhou, China." p230-233

48 Qian, Qian, and Zhu, "Subjectivity, Modernity, and the Politics of Difference in a Periurban Village in China: Towards a Progressive Sense of Place?"

49 Xiaozhoucun site data courtesy of Lu Xiaoxuan.

50 This text provides an useful guide to the political and financial issues involved with village-in-the-city redevelopment plans. (though it should not be understood as a guide to this project).

Lin and De Meulder, "A Conceptual Framework for the Strategic Urban Project Approach for the Sustainable Redevelopment of 'Villages in the City' in Guangzhou."

51 Weisstein, "Graph Eccentricity."

Harary, *Graph Theory*. p14, 35

52 Even, *Graph Algorithms*. p46

53 In addition to these rough indications, these values can serve as benchmarks to compare the modified network against.

cf. Note 72, §4.4c 'Metabolism and Catastrophe'

Calculating these values over the entire network is slow and not efficient to try during the dynamic operation.

54 Pope, *Ladders*.

Figure 7.9
Plotting the radius (397.46m) and diameter (767.96m) of the graph in the heavy yellow lines. Additionally, each vertex is labeled with a hexagon whose size and color is defined by the value of the vertex's eccentricity. The 10% most peripheral and 10% most central nodes are highlighted with more opacity.

The zoom-in displays the eccentricites without the other data overlaid.

Figure 7.10
A level structure map of the distance to each segment of the circulation network from the four primary entrances to the village in network lengths. Edges are colored based on their distance to the nearest of the four entrances. Isocurves have been drawn over the map afterwards in the style of Friedman's *Flatwriter* to emphasize the irregularity of the urban network.

≒7.3.1 DepthMap

```
0  INPUTS: hem, mEdge as List, stNdx, lim
   import Rhino.Geometry as rhG

   def TracePaths(vNdx,vOrig,m,mE,dist,dLst):
     eInit= m.vIE[vNdx]
5    eTest= eInit

     while True:
       if mE[eTest].wdth> 0.01:
         #ADD DISTANCE TO EDGE MIDPOINT, COMPARE TO EXSITING VALUE
10       lng= mE[eTest].lngth
         if dist+(lng/2) < dLst[eTest][0]:
           #WRITE TO distOut 0: GEODESIC DISTANCE, 1: EUCLIDEAN DISTANCE
           eDist= m.v[vOrig].DistanceTo(m.e[eTest].PointAt(.5))
           dLst[eTest]= (dist+(lng/2), eDist)
15         dLst[m.eTE[eTest]]= (dist+(lng/2), eDist)

           if m.eNE[eTest] == m.eTE[eTest]:
             continue
           else:
20           vNxt= m.eOV[m.eNE[eTest]]
             TracePaths(vNxt,vOrig, m, mE,dist+(lng),dLst)

         #GET NEXT EDGE AT INTERSECTION
         eTest= m.eNE[m.eTE[eTest]]
25       if eTest == eInit: break
   #====================================================================#

   #MAIN CODDE. INITIALIZE OUTPUT LISTS
   ctOut=[]
30 distOut=[]
   ntwrkSum=[]
   rtoLst=[]
   edgOut=[]
   #FILL LIST WITH DEFAULT VALUE == LIMIT
35 for i, pt in enumerate(stNdx):
     distOut.append([])
     distOut[i].extend ([(lim*1.2,lim*1.2)] * len(hem.e) )

     TracePaths(pt, pt, hem, mEdge, 0, distOut[i])
40
     lngSum= 0
     rto= 0
     ct= 0
     for j,val in enumerate(distOut[i]):
45     if j%2 == 0 and val[0] < lim and val[1] > 0:
         #distOut CONTAINS 0: GEODESIC DISTANCE, 1: EUCLIDEAN DISTANCE
         rto+= val[0]/val[1]
         ct+=1
         lngSum+=mEdge[j].lngth
50
     rtoLst.append(rto/ct)
     ntwrkSum.append(lngSum)
     ctOut.append(ct)

55 dpthLst=[]
   distList=[]
   for j, val in enumerate (distOut[0]):
     #COUNT STREET SEGMENT JUST ONCE (PER EDGE, NOT HALF-EDGE)
     if j%2 == 0:
60     valCk=[]
       for iLst in distOut:
         valCk.append(iLst[j][0])
       newVal=valCk.index(min(valCk))
       if distOut[newVal][j][0] < lim:
65       distLst.append(distOut[newVal][j][0]/distOut[newVal][j][1])
         dpthList.append(distOut[newVal][j][0])
         edgOut.append(hem.e[j])
       else:
         distLst.append(-lim *2)
70       dpthList.append(-lim *2)
         edgOut.append(hem.e[j])
   gD= dpthList
   eD= distLst
   pR= rtoLst
75 nt= ntwrkSum
   ecc= max(distList)
   eNdx= distList.index(ecc)
   e=edgOut
   OUTPUTS: gD, eD, pR, nt, ecc, eNdx, e
```

The script measures the distance from given vertex points to every point in the graph (or up to a given limit).

07 The recursion of this subroutine (:21) follows the next edge (`.eNE`) in the HEM datastructure until it encounters an already measured lower value or a dead end. The `while` loop ensures that the subroutine picks up where it left off with other branches at the given intersection (:24).

08 Check that the edge has a width greater than zero (i.e. is currently a path).

11 Check that the edge has a width greater than zero (i.e. is currently a path)

15 Write a tuple of the geodesic and Euclidian distances to the ouput list.

17 Exit `while` loop if a dead end is reached.

36 For each edge, a default value greater than the limit is added to the distance list. These values are replaced whenever a lower measured value is found.

38 Call the recursive function `TracePaths`.

40 The remainder of the code processes the distance values assigned to each segment into intividual metric values, such as the proportional ratio between the geodesic and Euclidean distances (:49), the total length of the network reachable within the limit (:50), and the number of segments reached(:51).

44 Only every other value (`j%2`) is used because segments are not directed and thus half-edges and their twins will always have the same values. Also in (:57).

49 When all the fitness adjustments have been added up they are added to the *FaceAgent*'s *.ftns* values.

62 At each segment, find the lowest value of all the distances measured from the various starting points.

≒7.3.2 TracebackShortestPath

```
0  INPUTS: hem, gD as List, stNdx, eNdx
1  import Rhino.Geometry as rhG; import math
2
3  def EdgesOut(m,eCurr,eOrig, d, lst):
4     eNxt= m.eNE[eCurr]
5     if eNxt == m.eTE[eOrig]:
6        return
7     else:
8        if d[int(math.floor(eNxt/2))]>-10:
9           lst.append( (d[int(math.floor(eNxt/2))], eNxt) )
10       else:
11          lst.append( (10000, eNxt))
12       EdgesOut(m, m.eTE[eNxt], eOrig, d, lst)
13    return(lst)
14 #=====================================================================#
15
16 def TrackBack(m,eCurr,d,lst):
17    lstOut=[]
18    EdgesOut(m,eCurr,eCurr,d,lstOut)
19    if len(lstOut)>0:
20       eNxt= min(lstOut)[1]
21       if m.eOV[eNxt] == stNdx or m.eOV[m.eTE[eNxt]] == stNdx:
22          lst.append(m.e[eNxt])
23          return
24       else:
25          lst.append(m.e[eNxt])
26          TrackBack(m,eNxt,d,lst)
27 #=====================================================================#
28
29 #MAIN CODDE. INITIALIZE LISTS
30 edgLst=[]
31 lstEven=[]
32 lstOdd=[]
33 EdgesOut(hem, (eNdx*2), (eNdx*2), gD, lstEven)
34 EdgesOut(hem, (eNdx*2)+1, (eNdx*2)+1, gD, lstOdd)
35
36 #COMPARE VALUE IN EITHER DIRECTION, CHOOSE WHICH HALF-EDGE TO FOLLOW
37 if lstEven and lstOdd:
38    if min(lstEven) < min(lstOdd):
39       edgLst.append(hem.e[eNdx*2])
40       TrackBack(hem, eNdx*2,gD,edgLst)
41    else:
42       edgLst.append(hem.e[(eNdx*2)+1])
43       TrackBack(hem, (eNdx*2)+1,gD,edgLst)
44 elif lstEven:
45      edgLst.append(hem.e[eNdx*2])
46      TrackBack(hem, eNdx*2,gD,edgLst)
47 else:
48      edgLst.append(hem.e[(eNdx*2)+1])
49      TrackBack(hem, (eNdx*2)+1,gD,edgLst)
50 e= edgLst
51 OUTPUTS: e
```

This script uses the geodesic distance values computed in ≒7.3.1 and traces back from any given ending segment to the starting point following the lowest values. This will only work with a single starting point.

3 The `EdgesOut` subroutine runs recursively to loop through all the edges radiating outward from an intersection given an incoming half-edge.

9 Return the list of indices and the geodesic distances associated with them in a tuple so that they lowest value can be determined.

16 The `TrackBack` subroutine calls `EdgesOut`, saving the edge with the lowest value and calling itself recursively (:26) if it has not yet reached the start point (:21).

33 To begin the code, run the `EdgesOut` subroutine on either side of the given edge and proceed in the direction with the lower value (:38, :41) or in the direction that is continuous if the other does not continue (:44, :47).

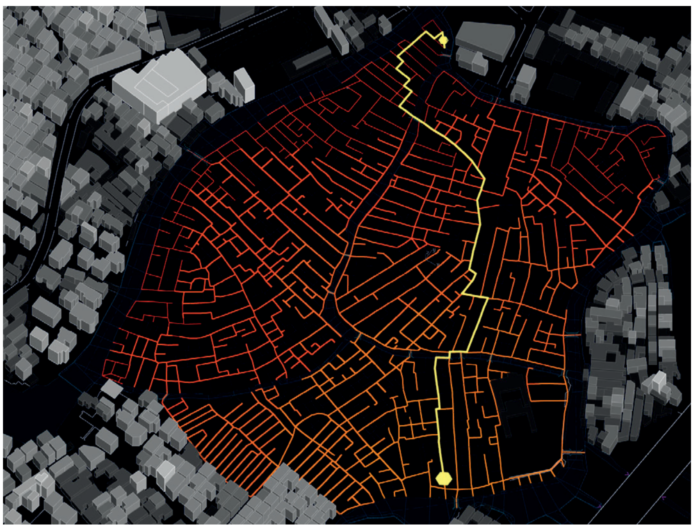
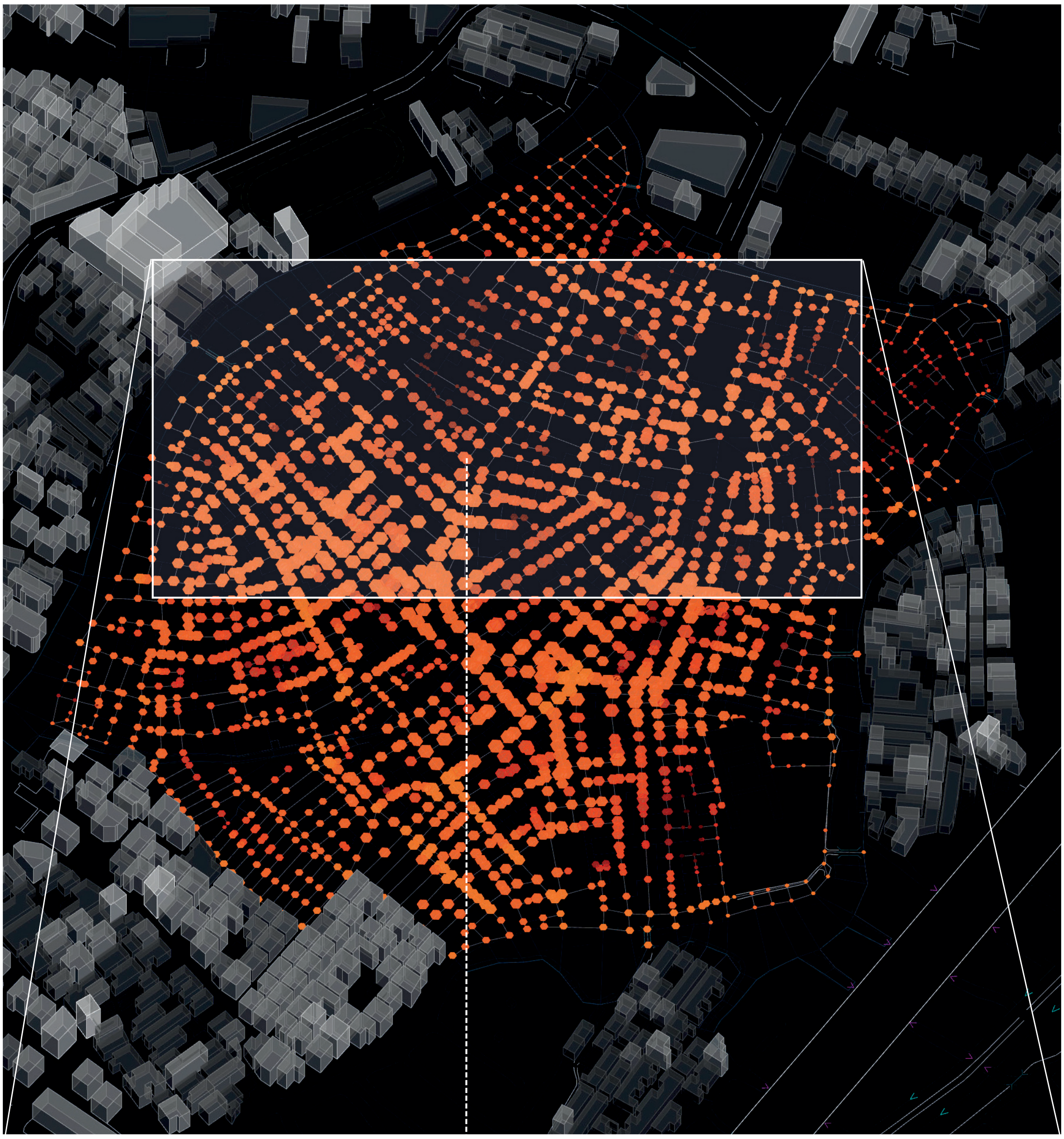
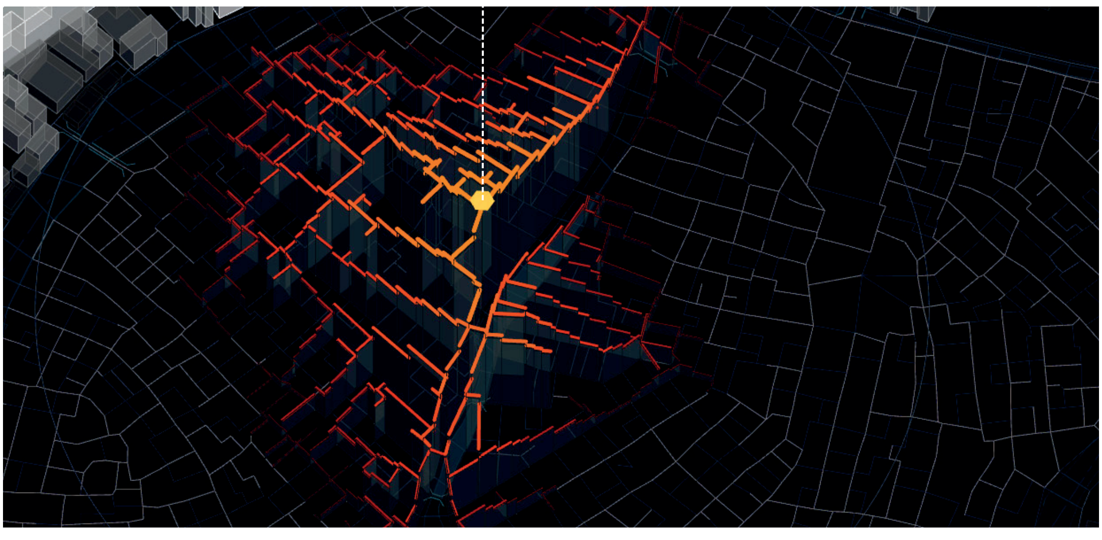


Figure 7.11
An analysis of the network depth from node #1900, and the trackback of longest path across the network using the scripts on these pages. This contributes one datapoint (of 2035) to Figure 7.9.





Nodal properties

Similarly, the physical nature of urban networks affect which properties of the network nodes are interesting. In certain cases, mapping the angle of intersetions can reveal intersections or blocks of regularity, as can the plotting the degree of the nodes.[55] Unlike social networks, urban networks are rarely scale-free networks,[56] but have a relatively normal distribution of low-degree intersections (**Figure 7.13**). While certain central hubs may seem to dominate urban space, this is typically a result of use—for example, carrying disproportionate traffic—rather than the number of physical connections. Urban networks are not as discrete as,are social networks, and actually emphasize the continuity from one link to another.[57] For this reason, among others, the project will use dynamic, mobile agents as the basis of an analysis that accumulates over time.

Urban networks as design foundation

Much of the attractive urban quality of the village of Xiaozhoucun derives from the experience of walking rhough the warren-like alleys of the village and the small pockets of open space, especially along the river. In this project, the existing urban fabric will be preserved to the greatest extent possible while rehabilitating the building stock through selectve rebuilding. As mentioned earlier (**Figures 1.1-1.4**), there is a rich, dynamic pulse to the villae that is driven by a material cycle of demolition and rebuilding. As opposed to the current methods of clearing and rebuilding tabula rasa or updating superficial stylistic features[58] this project proposes a framework for planning the redevelopment of informal urbanism temporally and punctually, from within. The plan will not be defined, nor will it have a targeted end product, but will remain open to continually changing in response to collected information. For this project, that information will be generated by a swarm of

Figure 7.12
This map compares the connectivity of the circulation network. The radius of the hexagon at each node is determined by the size of the network that can be reached within a 150m walk. The color reflects a ratio between the distance required to walk to each of those points and the Euclidean distance measured directly.

The zoom-in shows one such local network with a maximum depth of 150m and the effect that discontinuites (like the canal) have on accessibility.

Figure 7.13
The node degree represented with larger and brighter spots for higher degrees. The distribution is roughly normal.

55 This has not seemed beneficial here because the production of the mesh has taken some liberties with intersections and segment orientation in order to produce more regular polygons.

For an example of this kind of an analysis on a nearby urban village see:

Patt, "The Public Realm of the Urban Village: A Visual Interrogation of Longtancun, Guangzhou."

56 Small, "Scale-Free Network."

57 Another way to say this would be that an edge can link together more than node as in a hypergraph.

58 Patt, "The Self-Othering Event of Architecture: Mutable Objects rather than Identical Qualities."

mobile agents and we will search for opportunities to increase the overall connectivity of the circulation network, to open up additional small pockets of public space, and to increase the built density when existing buildings fall into obsolescence.

§7.4 Nonlinear Dynamics

Agents and embedded mapping

In making the transition from deterministic to open-ended masterplanning, we will adapt our static, global analyses into dynamic, embedded procedural maps.[59] Rather than trying to characterize features of the urban network, such as clusters, bottlenecks, or betweenness based on morphological patterns, we are using a small swarm of mobile agents.[60] Random walks on a network, and particularly random walks by multi-agent systems have been shown to be an effective way of determining clustering patterns in networks.[61] The first metric we will use is simply the record of the agents' movement history, recorded as an incremental value stored in each edge that increases every time an agent passes over that edge (≒7.2.1, :55). As the agents are instantiated at public spaces throughout the village, those areas that are conveniently connected to these public spaces will record high traffic[62] and modifications can be made that reinforce their status as places of public gathering. Other segments that will record high traffic values are dead-ends and cul-de-sacs (i.e. small clusters that are not well integrated in the network) where agents will get trapped for multiple frames.[63] These are equally important to address because they are points where the typical connectivity is disrupted and small changes to the network can have more intense impact.[64] During their random walk, the graph agents are also executing local analyses of the graph proximties (≒7.4.1). These functions operate like the global analysis shown in Figure 7.11, except that the scope of exploration is capped at a lower limit, 75 meters. In this case, however, the agent's are not interested in calculating specific properties of the local network, but of finding opportunities for modifying it. Thus, they process the depth map twice (≒7.4.1, :73, Figure 7.14b): first as usual, restricted to the circulation network; and then again including the edges that denote party walls or untraversable edges.[65] By comparing the two sets, the agents can determine more interesting data than simply the eccentricity of their surroundings. They identify instead, the location which exhibits the greatest expansion of distance in the current network state compared to a potentially open network (≒7.4.1, :88). The more efficient path is traced (≒7.4.1, :100), and the closed segments that it crosses are recorded with an incremental value representing shortcut potential. The traffic and shortcut values are merged into a single number that can be displayed on the network while the model is running (Figure 7.14a).

Duration and persistance

Meanwhile, data about the existing buildings have been imported through a bitmap image,[66] and each face has been assigned a value that defines its persistence, a value that incrementally decreases each frame. Presently, the value is created as a factor of of the building height, but this value would also allow differentiation of buildings by ownership, physical condition, age, construction type, or some top-down redevelopment plan. The face's persistence value is compared to the pressures exerted on it by the demand from its perimeter edges and enters contention for replacement when the pressure exceeds persistence (Figure 7.15).[67] When a building is selected for redevelopment, the edges that triggered the event are widened, any adjacent edges that had high shortcut potential are considered a part of the circulation network proper, and the plot is rebuilt with the appropriate setbacks and additional height as appropriate. If a setback is deep enough, that spot will be added to the list of public spaces that can instantiate a new agent. Existing agents are cleared away, and the cycle repeats, now operating on a different ground condition.

Metabolism and Catastrophe

Fumihiko Maki wrote that urban metabolism "gives morphological demonstration of the ever-changing and diverse character of city life,"[68] specifically referencing a cycle of decay that allowed old structures to be replaced with new ones within an old environment. For assemblage urbanists, metabolism is a lens that brings into focus sociomaterial interactions: revealing "process geographies and wherever they lead."[69] In this chapter we would like to bring these two perspectives, retaining both the significance of the evolving form of the city as well as maintining a social role for material to play in the development process. In this sense, the recycling of brick that occurs in Haizhu villages (Figures 1.1-1.5) is not simply a curiosity, but a parameter of the village form. Properly approached, even the material properties of standardised construction can be incorporated into the project metabolically—that is, not as a criteria that requires a certain plan, but as a filter that helps regulate or distribute particular processes. For example, the dimensions required for an elevator can be used in conjunction with the process outlined above to determine the height of new construction: plots that are sizable enough, or can pair with an adjacent plot, are able to build higher than those that must be reliant on staircases alone. This filter would encourage assemblages or group form, without necessitating an erasure of the older context.[70]

Typically, the dynamics of social space are not characterized by a smoothly continuous change, but by sudden changes and mutations in character. In dynamics, such bifurcations in the trajectory of a system are termed catastrophe events.[71] Catastrophes plunge the system out of equilibrium disproportionately to the change of parameters that triggered them. Generator's boredom routine instigated a catastrophe, all the learned patterns of occupation were thrown out, with the hope of catalysing a reaction that would drive it into a new set of order. The opening up of shortcuts into a dense urban fabric may also spark a catastrophe that diverts users, uses, and materials into new actions and new forms of organization.[72] The increased entropy of a dynamical system out of equilibrium disrupts settled identities and leaves it susceptible to influence by incidental perturbations.[73] While even the more tightly controlled masterplans are always succeptible to catastrophes from outside, thus far they have not risen to the challenge of working with and through castastrophe.[74]

59 "The event belongs to a complex and abstract realm of space-time; so must the cartographic techniques that sketch out its lines."

Kwinter, *Architectures of Time: Toward a Theory of Event in Modernist Culture*.

60 The number is variable, but here we used up to 40 at a time. This number was decided by the size of the network, the number of starting poins and the computational load.

61 Harel and Koren, "On Clustering Using Random Walks."

Alamgir and von Luxburg, "Multi-Agent Random Walks for Local Clustering on Graphs."

62 We would caution that agents should not be taken as modeling pedestrian traffic. Agent movement could, in theory, be modeled on pedestrian habits, but in fact, we are more interested in the agents as a formal process for revealing network structure than as a reproduction of subjective movement, not least because it allows for 'artificial' or inventive manipulation of the analysis methods.

cf. §4.9d 'An inventive praxis'

63 The agents are 'aged' proportionate to the traffic that hey traverse and removed when this age grows too high, this prevents an agent from becoming permanently trapped in one area and throwing the development of the network out of balance (≒7.2.1, :57).

64 This recalls Granovetter's insight that "whatever is to be diffused can … traverse a greater social distance … when passed through weak ties rather than strong."

Granovetter, "The Strength of Weak Ties." p1366

65 *cf.* §7.2c 'Graph Agents'

66 cf. ≒Appendix 6.2

67 This is done every fifth frame, to allow a number of candidates to accumulate.

68 Maki, *Investigations in Collective Form*. p34

69 McFarlane, "Metabolic Inequalities in Mumbai." p500

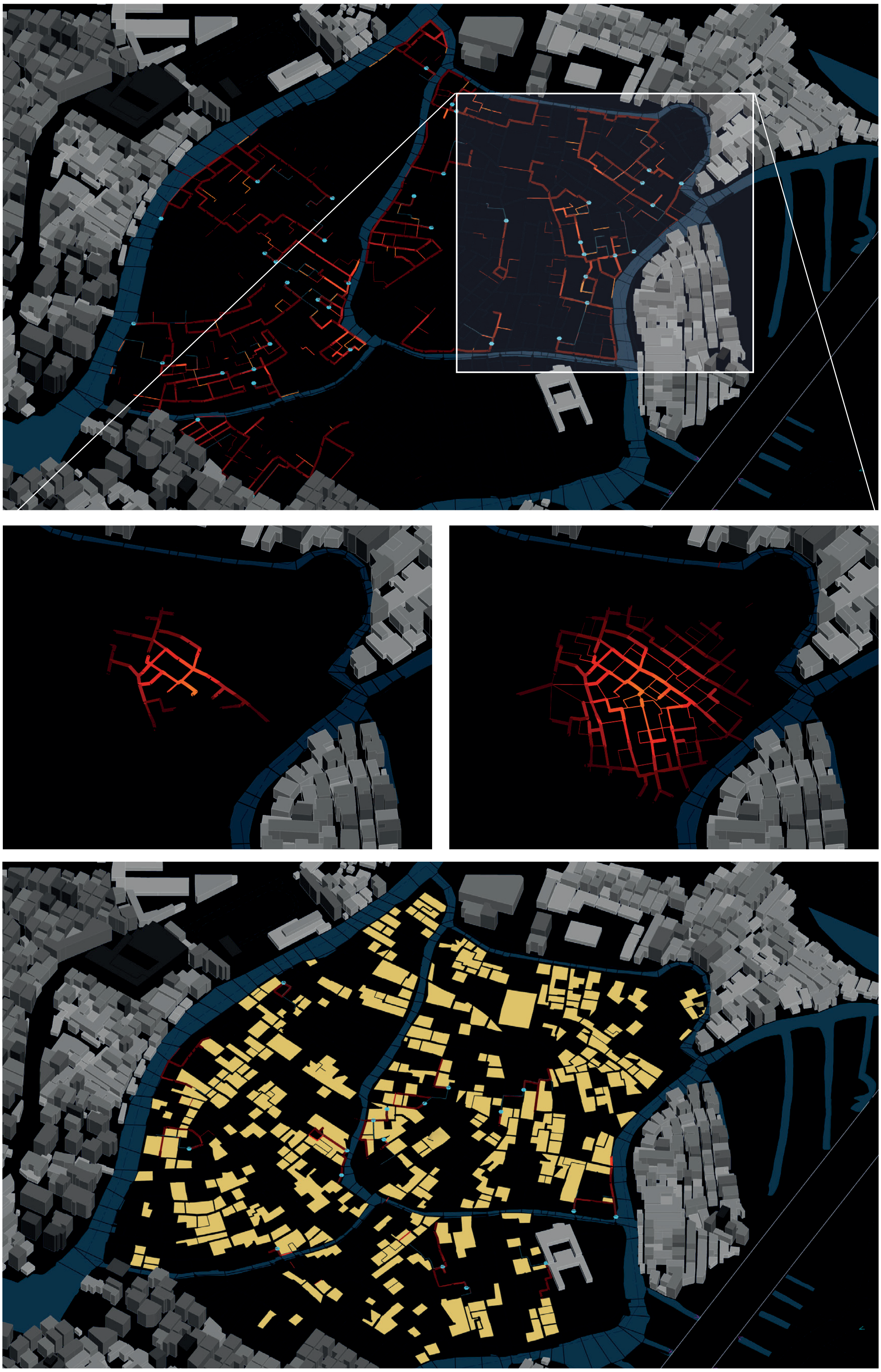
70 Both this and the tracking of recyclable material are procedures that I expect to incorporate into this model soon.

71 Verstegen, *Tropisms: Metaphoric Animation and Architecture*. p60

72 After running the simulation for 2050 frames, 97 parcels (from 1158: 8.38%) had been selected for reconstruction, with 58 new paths opened up (from 1369 possibles, 4.23%). The total length of these paths was only 376m, but their opening decreased the average eccentricity by 26.4% or 150m, including 40 values that decreased by over 300m.

73 Kwinter, *Far From Equilibrium: Essays on Technology and Design Culture*. p16

74 Hao, Sliuzas, and Geertman, "Race Against Planning: Unplanned Urban Spaces in Shenzhen."



≒7.4.1 CalcDepthList

```
70    def CalcDepthList(edgData):
        lim= 75
        self.dpthLst.clear()
        self.CircDepthNetwork(self.vtx, m, edgData,lim,0)
        self.FullDepthNetwork(self.vtx, m, edgData,lim,0)
75
        self.ntwrkLngth=0
        self.dpthRto= (0,0)
        #dpthLst == TUPLE:(FULL NET DIST, CIRC NET DIST, EUCLIDEAN DIST)
        for key,val in self.dpthLst.items():
80        if k%2 == 0 and val[1] < lim and val[2] > 0:
            self.ntwrkLngth+= edgData[key].lngth
            self.dpthRto= (self.dpthRto[0] + (val[1]/val[2]), ...
...                        self.dpthRto[1]+1)

        #FIND BIGGEST DISCREPANCY
85      nullVal= math.ceil((lim-vals[1])/lim)
        deltLst= [ ((vals[1]-vals[0]) * nullVal,key) ...
...       for key,vals in self.dpthLst.items() ]
        deltLst.sorted()
        endSeg= int(2*math.floor(deltLst[-1][1]/2))

90      #INITIALIZE TRACKBACK
        evenLst= []
        oddLst= []
        pthLst= []
        self.VetexEdges(m, endSeg, endSeg, evenLst)
95      self.VetexEdges(m, endSeg+1, endSeg+1,oddLst)

        if evenLst and oddLst:
          if min(evenLst) < min(oddLst):
            pthLst.append(m.e[endSeg])
100         self.TrackBack(m,endSeg,pthLst,edgData)
          else:
            pthLst.append(m.e[endSeg+1])
            self.TrackBack(m,endSeg+1,pthLst,edgData)
        elif evenLst:
105       pthLst.append(m.e[endSeg])
          self.TrackBack(m,endSeg,pthLst,edgData)
        else:
          pthLst.append(m.e[endSeg+1])
          self.TrackBack(m,endSeg+1,pthLst,edgData)
```

≒7.4.2 VertexEdges

```
      def VetexEdges(self,m,eCurr,eOrig,lst):
        eNxt= m.eNE[eCurr]

        if eNxt== m.eTE[eOrig]:
115       return
        else:
          if int(math.floor(eNxt)) in self.dpthLst:
            lst.append( (self.dpthLst[int(eNxt)][0], eNxt) )
            self.vtxEdges(m, m.eTE[eNxt], eOrig, lst)
120     return(lst)
```

The function is located in the *GraphAgent* class (≒7.2.1), and is called from within the *.step()* function to produce an embedded analysis of the agent's locale.

73 The primary analysis carried out is the calculation of depth maps (as in ≒7.3.1, with minor alterations to adjust for the dict datastructure used here) for the area immediately surrounding the agent (geodesic distance is capped by the *lim*) variable (:71). This operation is done twice: first with the circulation network as before, and a second time (:74) only making use of all edges—even those with a *.width* of zero. The purpose is to identify gross inefficiencies in the circulation network (:87)

79 *.dpthRto* is a *dict* (≒7.2.1, :18).

81 The total length of the network currently reachable within *lim* is summed (note that this is non-directional, only one of the half-edge/twin-edge pair is counted (:80)).

82 *.dpthRto* is the averaged ratio of the distance to each point in the local network divided by the direct, Euclidean distance, high values signal inefficiency.

86 *deltLst* finds the difference between the distance deetermined by the two depth maps to each point in the circulation network (results that were not reached by *CircDepthNetwork* are zeroed-out by *nullVal* (:85)). The difference value is paired with the edge's index so that the largest value can easily be located with the *.sorted()* function (:86).

94 The targeted point is located at the middle of the edge at *endSeg* (:88), it may have been approached from either end, so we test both this edge and its twin-edge (:95) to find the path of lowest value (:97-109). The function *.VertexEdges()* is a simple recusive loop that returns all the edges radiating out from a vertex (:111).

100 The function *.TrackBack* is again similar to ≒7.3.2, *TrackBackShortestPath*, with the exception of using the *FullDepthNetwork* values, so not limited to circulation-width edges. This traces the fastest shortcut back from the target point to the agent in *pthLst*. It also increments the *.dmnd* value (≒7.2.1, :60) of the zero-width edges to prompt the widening of the edge into a circulation path if the adjacent faces are reconstructed.

118 This function uses the depth values from *FullDepthNetwork* and so includes zero-width edges.

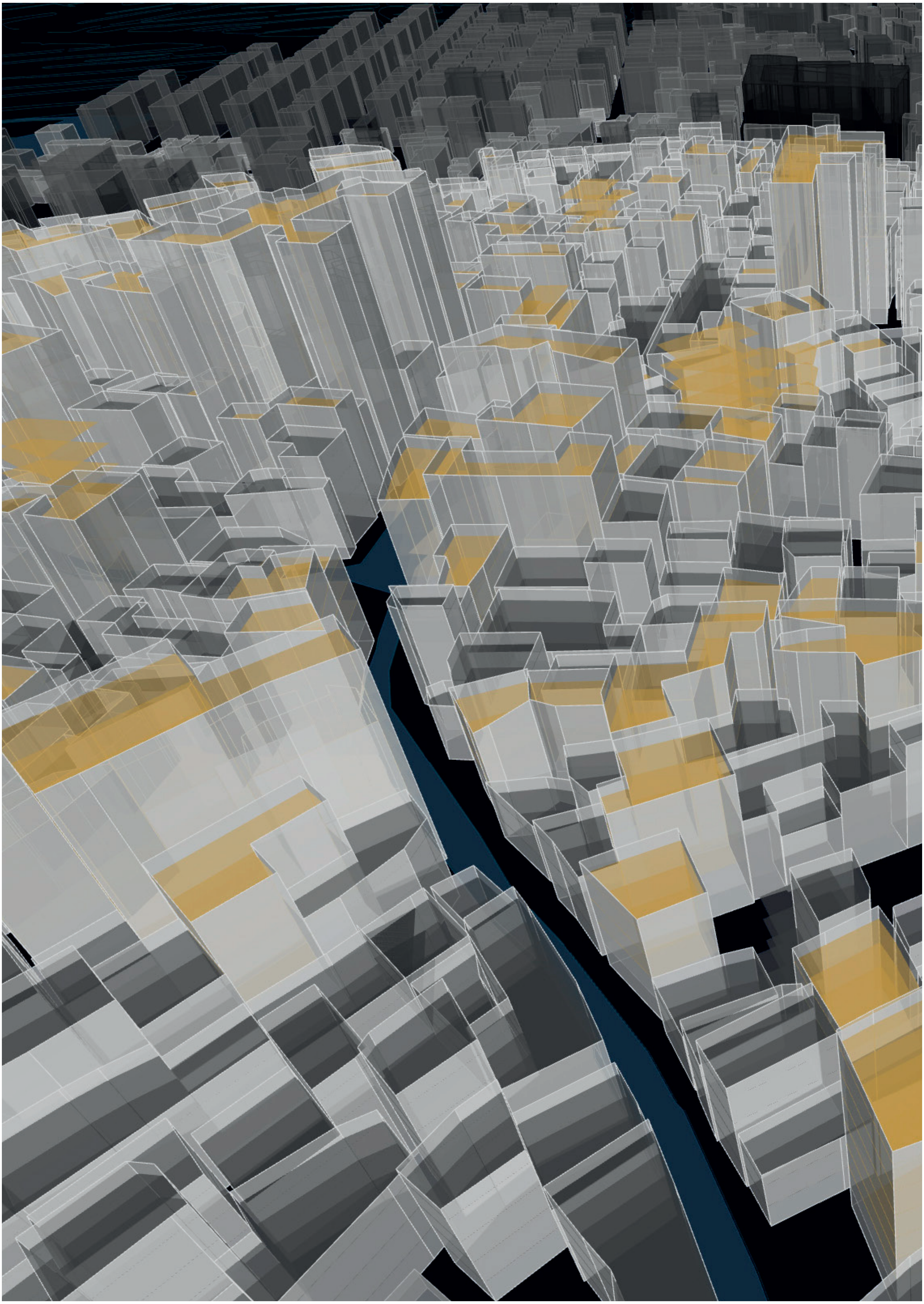
Figure 7.14

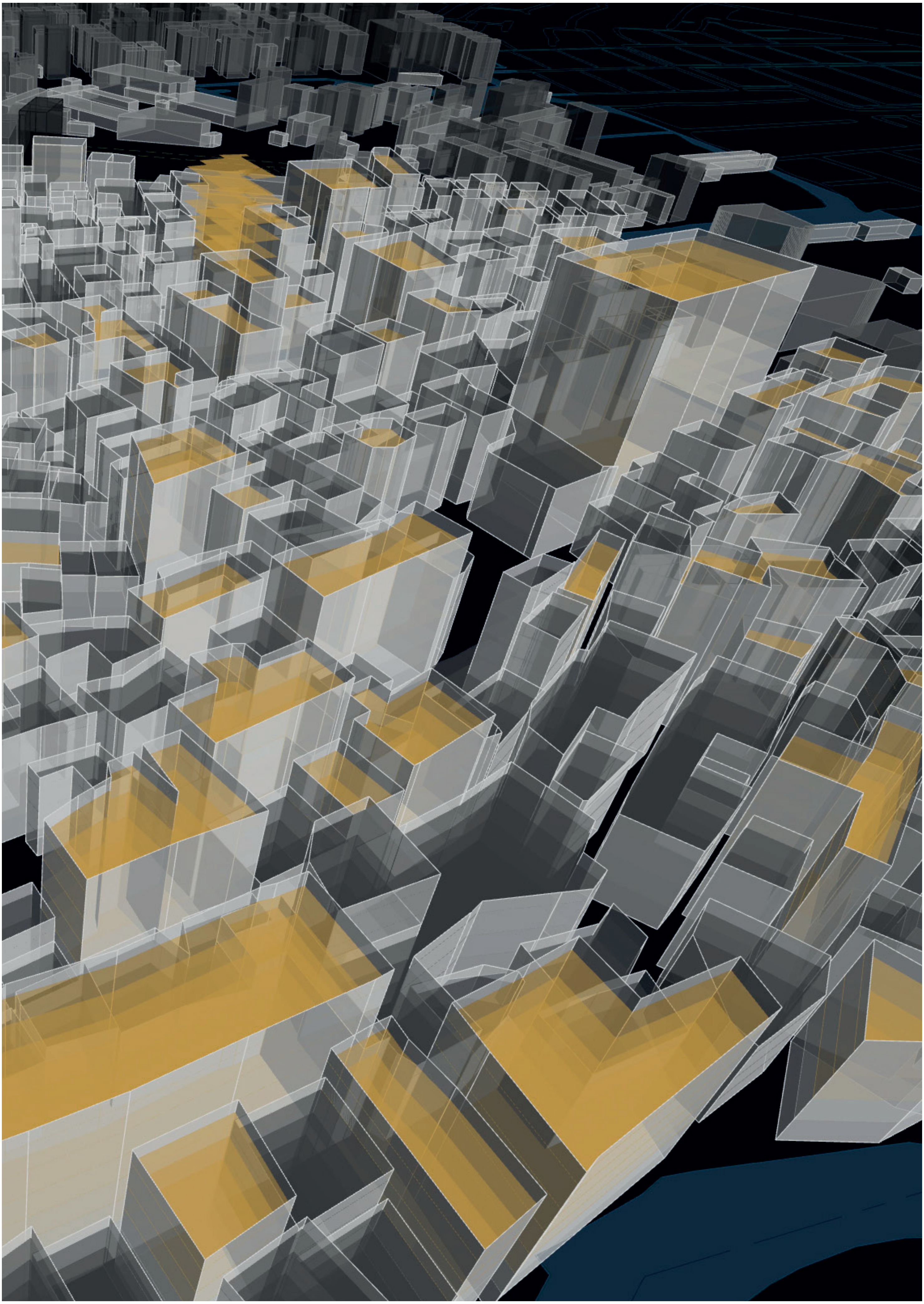
A path property, *.dmnd*, is displayed on the urban network with increasingly bright color as the aggregate value increases. This property is a factor of the traffic history of the agents and the potential shortcuts (a very light blue polyline) found through the graph's non-circulation edges (:100) after about 50 frames, before the first face has been selected for replacement.

Zoom-in illustrates the network depth analyses calculated by one agent at this frame. At left the results of *CircDepthNetwork*, at right, *FullDepthNetwork* (:73).

Figure 7.15

Selected faces after about 5000 frames. Approximately 30% of the village area has been marked for replacement at this point.





§7.5 Contingent Identity

Disassembling

Thus entropoy is invoked here not as a gradual evening out of energy or a dissolution of order, but in the sense of a process that emphasizes the actions of making and unmaking rather than ultimate state of the finished work,[75] in the same way that it was adopted within 'process art.'[76] Entropy is also interesting because it "contradicts the usual notion of a mechanistic world view"[77] through its irreversability. In an entropic system, serial repetition does not produce identical replication, but is each time acting in a contex that has been incrementally differentiated.[78] Because entropy tends toward disorder, this should not be interpreted as a teleological drive, but as potentially leading to a catastrophe event.[79]

The reason that we can avoid an eventual static equilibrium is that we do not define the city or the plan as a closed system[80] but as one with a constant injection of energy from without. In the model, the agency of the diagram is added to the model at each cycle to both disassemble existing order while also creating new, imminant organizations.[81] The diagram acts to entropically to remove structure, but also negentropically by inserting new forms: "it makes history by unmaking its past realities and significations, constituting so many cutting edges of emergence or of creationism, of unexpected conjunctions, of improbable continua."[82] Furthermore, this model permits the introduction of other external events—the uncoordinated and naturally occuring development of the village—without them disrupting or derailing the usefulness of the model.

Pluripotential

Rather, this variability is assumed as a natural behavior for the model, which anticipates the complete mutability of the individual entities. Alliez writes that the diagram is a "surface of experimentation … flush with the real that writes a new type of reality, carried into the very fabric of the most concrete of assemblages by the joint deterritorialization of expression and content."[83] Stripping away the intensities of the assemblage, this forces the object back into confrontation with its informal substance and the possiblity of new forms (Figure 0.1). For this reason, the informality of the village-in-the-city is a productive testing ground where the identities assigned by building and land-use codes are either absent or only apply ironically[84] allowing material traits to draw out new alternate potentials.[85] The next section will expand on how this surface of experimentation works through material enaction to supercede simple description.

75 Arheim points out that entropy cannot be measured in an instantaeous state. "The particular nature of any one such state does not matter. Its structural uniqueness, orderliness or disorderliness does not count, and its entropy cannot be measured. What does matter is the totality of these innumerable complexions, adding up to a global macrostate… only by adding up a sufficient number of momentary complexions over a sufficient length of time can we tell something about the macroscopic state."

Arnheim, *Entropy and Art: An Essay on Disorder and Order*. p17

76 Lee, *Object to Be Destroyed: The Work of Gordon Matta-Clark*. p39

77 Smithson, "Entropy Made Visible: Interview with Alison Sky (1973)." p301

78 Deleuze, *Difference and Repetition*. p2

79 As in Smithson's 'Partially Buried Woodshed' (1970).

Lee, *Object to Be Destroyed: The Work of Gordon Matta-Clark*. p46

80 As it was in Chapter 5

81 "the diagram and abstract machine have lines of flight that are primary, which are not phenomena of resistance or ccounterattack in an assemblage, but cutting edges of creation and deterritorialization."

Deleuze and Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia*. p585

as quoted (and translated) in

Alliez, *Diagram 3000 (Words)*. p11

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CHAPTER 8
INAESTHETICS

§8.1 Urban Inaesthetics

The city thinks itself

Badiou introduces inaesthetics as an alternative to historical modes of thinking[1] where the relationship of philosophy to art is such that philosophy does not dictate an aesthetic agenda, but reflects on the revelations of art and "maintaining that art is itself a producer of truths, makes no claim to turn art into an object for philosophy. Against aesthetic speculation, inaesthetics describes the strictly intraphilosophical effects produced by the independent existence of some works of art"[2] Key to this relationship is a position that art is itself a unique form of thought and that it is irreducible to other forms of thinking (including philosophy).[3] He elaborates that individual works of art constitute a "local instance" or "differential point"[4] of an artistic configuration "which is a generic multiple, possesses neither a proper name nor a proper contour, not even a possible totalization in terms of a single predicate. It cannot be exhausted, only imperfectly described."[5] In this light, inaesthetics offer a productive analogue to the relationship between the city and architecture. The city, as we know can never be contained by the theory that reflects on it; it proceeds through a momentum and metabolism proper to itself.[6] At the same time, works of architecture swarm around, assembling the city, not by any single plan but participating in the prefiguring of the city through "inventive inquiry into the configuration."[7] Even large masterplans can only be implemented as discrete elements of the city, the whole can be approached "only by the chance of their successive occurrences."[8]

§8.2 The Open City

The heterogeneity of the urban

At the same time, we must be careful not to accept this formulation uncritically. One particular problematic point of divergence is that the city cannot be defined so narrowly as Badiou defines artistic configurations—selectively assembled out of material that is all of a kind[9]—but must acknowledge (at least temporarily[10]) all of the objects that inhabit in, interface with, or pass through itself.[11] The city is continuously changing its alignment, being made and unmade[12] in ways that exceed the variation that Badiou's configurations undergo.[13]

1 Didactic, romantic, and classical are the three historical aesthetic schemata to which Badiou contrasts inaesthetics. In the text they are represented by the philosophies of Plato, Heidegger, and Aristotle, respectively.

Badiou, *Handbook of Inaesthetics*. p5, 7

2 *Ibid.* p0

3 "'Immanence' refers to the following question: Is truth really internal to the artistic effect of works of art? Or is the artwork instead nothing but the instrument of an external truth? 'Singularity' points us to another question: Does the truth testified by art belong to it absolutely? Or can this truth circulate among other registers of work-producing thought …

We will therefore affirm this simultaneity … Art is rigorously coextensive with the truths that it generates … These truths are given nowhere else than in art."

Ibid. p9

4 *Ibid.* p12

5 *Ibid.* p12

6 "we must above all not conclude that it is philosophy's task to think art. Instead, a configuration thinks itself in the works that compose it."

Ibid. p14

7 *Ibid.* p14

8 "which therefore thinks the thought that the configuration will have been"

Ibid. p12

9 "This procedure is composed of nothing but works."

Ibid. p12

10 *cf.* §2.4b 'Exo-relations form new assemblages'

11 "What Leibniz calls metamorphosis or metaschematism not only involves the initial property of bodies—in other words, their capacity to envelop infinitely and, up to a certain point, develop their specific parts—but also the second property, the fluxion that causes parts endlessly to leave their specified aggregate in order to enter into entirely different aggregates that are differently specified."

Deleuze, *The Fold: Leibniz and the Baroque*. p115

12 *cf.* §1.2 'The dynamic city'

13 Strictly speaking, these configurations are "intrinsically infinite" truths, and thus not truly variable. However, as their description is always imperfect (*cf.* note 5, above), the description and understanding of what these configurations '*will have been*' can and does change as new works emerge. This is covered under the concept of 'forcing,' *cf.* §9.1b 'Relating the generic to formalization'

Badiou, *Handbook of Inaesthetics*. p14

The multiplicity of architecture

Nor can the parallel between architecture and art be made so simply. For Badiou, the work of art is essentially finite, it is self-defined by its own finitude.[14] We have already argued, however, that architecture "is incapable of being restricted to a single domain"[15] but is always an object acting in a multiplicity of associations and that it should be understood as an interface[16] that extends out beyond its limits. Michael Guggenheim does an excellent job of showing how a building is often simultaneously a work of art, a dwelling, a technical system, or any other number of uses;[17] "the manifold interfaces simply allow too many starting points for different uses by different people at the same time."[18] This is not simply a property of buildings as such, but is also intrinsically linked to how buildings are necessarily situated in their environment, and their disposition within the urban assemblage.[19] The meaning and definition of architecture changes from moment to moment depending on the networks that engage it or the material assemblages to which it is enlisted. Being finite neither in time nor in space, evading principles of autonomous completion, architecture cannot be made equivalent to art in this comparison.[20] We will say then that architecture does not define the urban nor does it exist as finite inquiries into the urban condition, but instead that "it is the sign of the possibility" of an urbanism.[21]

§8.3 Material Enaction

Enaction supersedes the script

What does inaesthetics have to say about architecture, then? In fact, Badiou writes at length about the possibility of aesthetic media dedicated not to the singularity of art, but that remain open to the infinite; a condition he uses to illustrate the native act of thinking that occurs within media.[22] The deferral, or refusal, of the limits of finitude points "toward thought as event, but before this thought has received a name"[23] The event is in the act of being worked out, not predetermined, though neither is it entirely indeterminate.[24] Rather, architecture acts as a ground that organizes an undecided event, setting up the next steps, without impinging in the least on what they may be.[25]

We have touched on this topic already, but Badiou elaborates on its mechanics. Firstly, there is a complication of the internal potential state that prevents a simple, direct realization by requiring a continual adjustment to the situation.[26] This occurs when the contingencies of the city interact with the diagram of architecture. Architecture in its enaction supersedes its own diagram, replacing a scripted definition with something more improvisational.[27] "What one sees is at no point the realization of a preexisting knowledge, even though knowledge is, through and through, its matter or support."[28] Badiou characterizes this as an act of forgetting, which we can also compare to the caesura of self-othering that takes place in information exchange or recall.[29] When Badiou writes that this pre-existing quality yields to emergence[30] he is reiterating that to remain as a mode of thinking means to maintain a state of unfixed uncertainty despite actively pressing forward.[31] A work of art is a presentation, or even a representation, of "the persuasive procedure of its own finitude,"[32] but architecture manifests as "a false totality. It does not possess the closed duration of a spectacle, but is instead the permanent showing of an event in its flight, caught in the undecided."[33] All of this adds up to the banishment of a panoptic view of urbanism, of plans that could stand outside of time, "what there are instead are disparate truths, an aleatory multiple of events of thought"[34] that must be played out as a temporal process, embedded in a particular urban space.[35]

14 "art is the creation of an intrinsically finite multiple, a multiple that exposes its own organization in and by the finite framing of its presentation and that turns this border into the stakes of its existence."

Ibid. p11

15 *cf.* §2.5c 'Objectile'

16 *cf.* §4.10b 'Architecture as urban interface'

17 "Whereas an artwork is the product of the system of art, and without the functional system of art the artwork would often not even exist, this cannot be said of buildings. They are first of all buildings and can be made into objects of art or science, but never exclusively. Even those buildings that are monofunctional building types … are not controlled by these functional systems."

Guggenheim, "Building Memory: Architecture, Networks and Users." p46 (also p48)

18 Guggenheim uses the description 'quasi-technology': "objects that are sometimes real technologies, functioning as black boxes, but at other times they lose this quality. They are turned from technologies, in the sense of blackboxed procedures, into 'mere' masses of materials. They become materialized as I would like to call it. To materialize in this sense means that an object is freed from its actor-network and reduced to its material qualities." Thereby enabling undirected or opportunistic uses.

Guggenheim, "Mutable Immobiles: Change of Use of Buildings as a Problem of Quasi-Technologies." p7

19 Guggenheim, "Building Memory: Architecture, Networks and Users." p47

20 "A work of art is essentially finite. It is trebly finite. First of all, it exposes itself as finite objectivity in space and/or in time. Second, it is always regulated by a Greek principle of completion: It moves within the fulfillment of its own limit. It signals its display of all the perfection of which it is capable. Finally, and most importantly, it sets itself up as an inquiry into the question of its own finality. It is the persuasive procedure of its own finitude."

Badiou, *Handbook of Inaesthetics*. p10-11

21 The full quotation reads, "Dance is not an art, because it is the sign of the possibility of art as inscribed in the body."

Ibid. p69

22 In the text, Badiou singles out dance as an exemplary practice. For more on the connection between architecture and dance see my forthcoming essay.[22b]

Ibid. Chapter 6, 'Dance as a metaphor for thought' p56*ff*

22b: Patt, "Performance Review: In Praise of the Possibility of Architecture."

23 Badiou, *Handbook of Inaesthetics*. p61

24 "the spatialization of imminence would thus be the metaphor for what every thinking grounds and organizes."

Ibid. p62

25 *cf.* §4.3a 'Prepositional mode of being,' especially note 26

26 In fact, this addresses one of Badiou's disputes with Deleuze, *vis-à-vis* chance and the "eternal Return." We will avoid this debate, but point instead to the explication of "virtual proper being" in §2.3c 'Organization and endo-relations'

Badiou, *Deleuze: The Clamor of Being*. p75

27 Patt, "Performance Review: In Praise of the Possibility of Architecture."

28 Badiou, *Handbook of Inaesthetics*. p66

29 *cf.* §2.4a 'Information passes and is translated between objects,' especially notes 50, 51

30 "knowledge (which is technical, immense, and painfully acquired) is traversed, as null, by the pure emergence of … gesture"

Badiou, *Handbook of Inaesthetics*. p66

31 "Every genuine instance of thinking is subtracted from the knowledge in which it is constituted."

Ibid. p66

32 *Ibid*. p11

33 *Ibid*. p67-68

34 *Ibid*. p70

35 "thought is not effectuated anywhere else than where it is given—thought is effective *in situ*"

Ibid. p58

§8.4 Lines of Flight

Content and action

Thus the concept of forgetting as de-differentiation plays an important role in preserving the multiplicity inherent in urban design and in re-orienting urban design from the production of a plan to an environment for continual production and reconfiguration;[36] an environment that would formulate the contested status of urbanism's own inherent complexity as a condition to be extended rather than resolved.[37] Just as the material enactment of the city overrides the motive force behind it, the production of urban designs should also avoid the direct execution of their underlying support data, instead striving to make productive use the slippages and discontinuity of information by leveraging urbanism's discrete constellations,[38] instrumentalizing emergence and erasure to evolve relevance of definition and diagrams of design. In contrast to those who argue that the assemblage of urban systems from architecture "can be most adequately grasped if it is analyzed as an … autopoetic system of communications"[39] we would argue that to the extent that architecture is concerned with communication, it does so "not as carriers of something Other," semiotic content, for example, "but as forces-signs of deterritorialization and of reterritorialization."[40] The parametricist position seeks to maintain the singularity of architecture—"as a *sui generis* system"[41]—but gives up its immanence by locating the content entirely in external meanings and abstractions.[42] Ultimately, this also removes architecture from the generation or transformation of ideas, offering instead "nothing but the consequence of playing out an act of naming."[43] Inaesthetics demonstrates an alternative axis between content and action that invests the reality of material assemblages with an agency to extend and support the potentiality of new organizations that exceed strict, technocratic definitions and reimagine the city otherwise than it is.[44]

36 *cf.* §7.1 'Resisting terminality'

37 *cf.* §6.7a 'Differentiation engines'

38 Patt, "Taipei 2.0.2: Computation and the Urban Generic."

39 Schumacher, *The Autopoiesis of Architecture: A New Framework for Architecture, Volume 1*. p1

40 Alliez, *Diagram 3000 [Words]*. p12-13

41 Schumacher, *The Autopoiesis of Architecture: A New Framework for Architecture, Volume 1*. p1

42 Singular but not immanent corresponds with Badiou's 'didactic' schema: "in didacticism, the relation is certainly singular (only art can exhibit a truth in the form of semblance), but not at all immanent, because the position of truth is ultimately extrinsic.."

Badiou, *Handbook of Inaesthetics*. p9

This affiliation with didacticism is fully borne out in Schumacher's text as well: "The societal function of architecture is to order/adapt society via the continuous provision and innovation of the built environment as a system of frames"

Schumacher, *The Autopoiesis of Architecture: A New Framework for Architecture, Volume 1*. p364

43 Badiou, *Handbook of Inaesthetics*. p63

44 "The interaction of assemblages, in contrast, is a symbiosis defined … by the lines of flight that run through them, where 'line of flight' names the possibility of creating something new … it rejects the necessary causal relationship between content and action … assemblage thinking places a particular emphasis on the process of reassembling, that is, by emphasising how urbanism might be produced otherwise, assemblage thinking asks us to consider how an alternative world might be assembled."

McFarlane, "Assemblage and Critical Urbanism." p211

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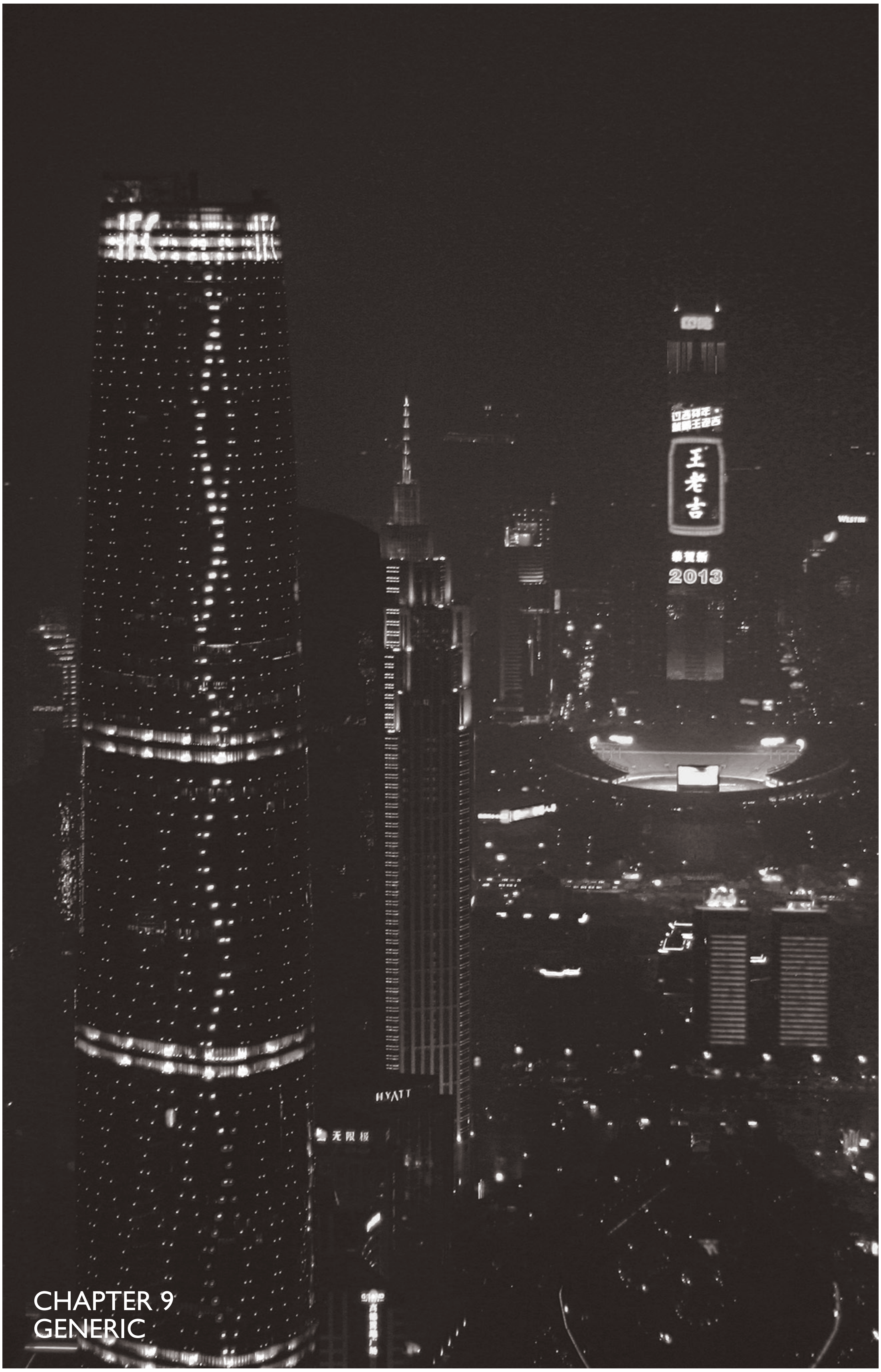

CHAPTER 9
GENERIC

§9.1 The Generic Multiple

Accounting for novelty

The capacity for transformation is surely one of the most essential points of a theory of contemporary urbanism. For a thorough, formal model this requirement is made more difficult by the fact that a true change cannot be given in advance by the initial state of the urban situation.[1] Modeling an urban situation (whether computationally or mentally) requires constructing some sort of formal definition or representation of the specific conditions,[2] whereas true change must exceed this formalization not by negating it but by instantiating a generic alternative. Such an alternative is called a 'generic' multiplicity because, in contrast to the specific form of the known model, this part cannot initially be described in full by the model. It is "something lying beneath, or something at work in the situation, something that remains to be discovered through a constructive practice. In short, there is unknown consistency, there is a way of doing things … that remains foreign"[3] to the logic of the model. The generic leverages its own indiscernibility to bridge the gap between presentation and the vast number of possible forms of representation.[4] Badiou goes through a lengthy explication of how the generic multiplicity is defined in set theory in order to prove the rigorous possibility of the logical operations that have to occur[5] and the correspondence of the mathematical proofs to his own ontology.[6]

Relating the generic to formalization

It is unnecessary to recount these details here, instead we want to highlight the usefulness of the generic as a conceptual tool. In the same way that the construction of assemblages benefited from an external definition,[7] we do not need to completely know or understand the generic muliplicity. Knowing for certain only that it cannot be entirely defined by the previous situation,[8] we can include it in the current situation extensionally[9] and investigate the consequences under a projective hypothesis of what the generic might entail.[10] This leads to "a praxis consisting of a series of enquiries into the situation … to work out how to transform the situation in line with what is revealed by the event's belonging to the situation."[11] Such inquiries can be used[12] to reveal the contour of the generic subset.[13] The process of inquiry, which Badiou (following Cohen) calls 'forcing', is an anticipatory modeling[14] that incrementally reveals aspects of the generic and ultimately "renders the indiscernible immanent."[15]

1 "The fact that the procedure is generic entails the noncoincidence of this part with anything classified by an encyclopaedic determinant. Consequently, this part is unnameable by the resources of the language of the situation alone. It is subtracted from any knowledge"

cf. §8.3a 'Material enaction' especially note 31

Badiou, *Being and Event*. p338

2 "The orientation of constructivist thought … is the one which naturally prevails in established situations because it measures being to language such as it is."

Ibid. p328

3 Feltham, *Alain Badiou: Live Theory*. p108

4 In this passage the generic is contrasted with the constructivist position: "The constructivist orientation of thought proceeds by restricting the multiples admitted at the level of representation to those multiples that correspond to a strictly defined formula," and while this might hold true in the early set theory of Frege, it does not characterize Leibniz's ontology (as we have employed it in chapter 2), which is equally permissive about the production of new multiples.[4b]

Feltham, *Alain Badiou: Live Theory*. p95-96

4b: "The Baroque solution is the following: we shall multiply principles … and in this way we will change their use. We will not have to ask what available object corresponds to a given luminous principle, but what hidden principle reponds to whatever object is given, that is to say, to this or that "perplexing case." Principles as such will be put to a reflective use. A case being given, we shall invent its principle."

Deleuze, *The Fold: Leibniz and the Baroque*. p67

5 "to assert the existence of a generic multiple is to assert that a procedure can hold together in the absence of objective and known guarantees."

Feltham, *Alain Badiou: Live Theory*. p110

Badiou details this process in:

Badiou, *Being and Event*. Meditation 33, p355*ff*

6 "yet philosophy itself does not make up a generic procedure. Its particular function is to arrange multiples for a random encounter with such a procedure."

Ibid. p341

cf. §8.1 'Urban Inaesthetics'

7 *cf.* §5.6b 'Intensional and extensional sets'

8 "In set theory, one can have 'models' of set theory which are interpretations that flesh out the bare bones of sets and elements by giving values to the variables … The model itself, as a structured multiplicity, can be treated itself as a set. Cohen takes as his starting point what he terms a 'ground model' of set theory. Badiou takes this model as the schema of a historical situation. Each subset of this model satisfies a property which can be expressed in the language used in the model. That is, every multiple found in the model can be discerned using the tools of language. A generic set, on the other hand, is a subset that is 'new' insofar as it cannot be discerned by that language. For every property that one formulates, even the most general … the generic set has at least one element which does not share that property."

Badiou, *Infinite Thought: Truth and the Return to Philosophy*. Introduction by Feltham and Clemens, p29-30

§9.2 The Urban Generic

Locating the generic

The generic dimension of urbanism will therefore be located within architecture,[16] which provides the kind of infinite multiplicity required[17] and is also capable, when introduced into an existing urban situation, of provoking a reconfiguration of the urban order.[18] While other subsets of urbanism—programmatic organizations, functional systems, infrastructures, policy and regulatory dictates—have the capacity to effect this realignment, none belong to or participate in the urban as insistently as architecture.[19] The generic subset "is a multiple that intersects—contains some elements of—every domination. The generic multiple thus contains at least one element corresponding to every property whatsoever; it contains a little bit of everything."[20] In this sense, although architecture is uniquely suited to the role of urbanism's generic multiplicity, we cannot indiscriminately confer the category of generic on any and all architecture. Only architecture that operates as an interface to the city,[21] cutting across every category[22] can occupy this role. What we have argued here is that it must be an active participant in the processes of the urban ecology (as an integrator of different systems and flows; as a reconfigurable environment; as a model that adapts to multiple locations through out the city; as a material support for diverse urban practices; etc…) because the generic is never simply given, but always assembled or "gathered together."[23]

Procedural engagement also allows architecture to continuously prompt new inquiries into the changing potential of the urban situation. Because "a concrete situation is an interplay of different situations in the ontological sense of the term,"[24] there may be multiple ways of conceiving the generic extension within one or many different assemblages.[25] As mentioned above,[26] the indeterminacy of the generic subset allows this redundancy to exist while the generic remains undecided.[27] This also prevents the role of architecture from becoming a deterministic influence on the city.[28] The urban situation is always developing, never complete, even if it lies dormant for a prolonged duration.

Mutual contingence of architecture and urbanism

All this having been said, care must be taken not to reduce the relationship between architecture and urbanism to a simple part-to-whole relationship, the two are inextricably and mutually contingent. While the urban precedes the architecture that develops it—urbanism is virtually first—it is not given material definition until the architecture enacts it—architecture is actually first. This is an identical relationship to the one between the monad and the environment and the same relation of bidirectional feedback applies here.[29] Thus, we should also be wary of drawing too firm a divide between the two, urban assemblages—neighborhoods, quarters, ensembles, masterplans, communities—exist on the same plane in our flat ontology[30] and are subject to the same oscillation between their components and their environments.[31]

§9.3 Conclusion

Summary of the thesis

Through the course of this text I have continuously endeavored to draw a line between a series of texts and sources (that may have appeared disparate at first) and to synthesize them into a single body of thought. My goal has been twofold: first, to define a contemporary theory of urbanism that is active, agile, and responsive; and second, to delineate a project for design that preserves the radical openness of urbanity in contrast to the often closed tendencies of masterplanning. Inspired by the concept of the Generic as described in this chapter—an untotalizable multiplicity, one that cannot be defined or known in advance, that exceeds any given formal system—I have sought to detail how such a concept would appear as an approach to these questions around urbanism.

My hypothesis has been that these two positions could be brought together by framing them in terms of themes that are shared by both urban processes and procedural modeling. The Interactive theme described the application of procedurality and the ways that it shapes an epistemological understanding of the situation

9 "To show that a generic set actually exists, Cohen develops a procedure whereby one adds it to the existing ground model as a type of supplement, thereby forming a new set. Within this new set, the generic multiple will exist at the level of belonging, or in meta-ontological terms, presentation. The new supplemented set provides the ontological schema of a historical situation which has undergone wholesale change."

Ibid. Introduction by Feltham and Clemens, p30

10 Badiou calls this "the 'generic extension' and it results from the initial situation being supplemented by its own generic subset as one of its elements … [it] produces an anticipatory knowledge of the new situation, a knowledge that is under condition"

Feltham, *Alain Badiou: Live Theory*. p111

11 Badiou, *Infinite Thought: Truth and the Return to Philosophy*. Introduction by Feltham and Clemens, p28

12 In Badiou's account "the subject falls outside the purview of ontology. Thus in Badiou's terms, ontology cannot think the being of the subject, but it can think its operation, which is forcing." The object-oriented ontology we have put forward, does not advance the same privileged position of the subject, but this point can be compared, with some substitution, to the point that local manifestations of the monad are acts and not definitive states and that the 'point of view' of a monad is a preceding condition that the monad comes to apprehend.

cf. §2.5a 'Pure interiority' and §2.6c 'Construction' especially note 98

Ibid. p111

13 *Ibid*. p64, 65

14 *cf.* §4.9d 'An inventive praxis'

15 Badiou, *Being and Event*. p342

16 'Architecture' being interpreted broadly to include landscape design and open public spaces, not only buildings.

17 *cf.* §8.2b 'The multiplicity of architecture'

18 "a suitably subtractive or generic art, which is always an effort to devise new kinds of form at the very edge of what the situation considers monstrous or devoid of form."

Badiou and Hallward, "Beyond Formalisation: An Interview." p113

19 *cf.* §1.1 'Challenges and Shortcomings of Critical Urban Theory'

20 Feltham, *Alain Badiou: Live Theory*. p108-109

21 *cf.* §4.10b 'Architecture as urban interface'

22 Feltham, *Alain Badiou: Live Theory*. p109

23 *Ibid*. p108

24 Badiou, *Infinite Thought: Truth and the Return to Philosophy*. p174

25 *cf.* §2.6b 'Incompossibility'

26 *cf.* §9.1, note 4

27 *cf.* §1.5b 'Manuel DeLanda' on redundant causality

28 "there is thus an unassignable gap between presentation and representation: there are incalculably more ways of representing presented multiples than there are such multiples," the spanning of this gap is never unilaterally completed, this is why architecture is only the sign of the possibility of architecture (*cf.* §8.2b 'The multiplicity of architecture')

Feltham, *Alain Badiou: Live Theory*. p95-96

29 *cf.* §2.6 'Environment'

30 *cf.* §1.5b 'Manuel DeLanda'

This is another point of agreement between set theory and assemblage theory:

"the axiom of union states that one can form a consistent set out of all of the elements of the elements of an initial set. Thus there is no distinction in ZFC set theory between elements and sets; each element can be treated as a set and decomposed into its elements and so on." (Badiou calls this operation the 'count-as-one'.)

Feltham, *Alain Badiou: Live Theory*. p92

31 *cf.* §2.6c 'Construction' especially note 99

and includes the problematic concerns and possible reactions of a model. Ontological questions were addressed by the Generative, particularly the definition of objects along monadological lines: the internalization of virtual identities and extension of traits across the environment. The Reflexive function guided the actualization of intensifying urban dynamics into assemblages that self-organize in a network of heterogeneous agency. Finally, Entropic behaviors immanent to real assemblages worked to unform assemblages. Though they frustrate the attempt of the theorist to provide concrete identities, they enact a necessary process of continual regrounding to prevent terminal stasis. The selection of these four themes is not meant to dictate the absolute terms of urbanism or urban design, however I believe that they do form a complete schema whose coherence and level of integration truly constitute a total theory of urbanism. This theory is certainly not complete, in particular, the design examples are probably too elementary to thoroughly explore the analogues between (computational) model and the city—an especially interesting field of research, I think.[32] Much is being done to produce urban simulations that reproduce empirically measured phenomena, but much more needs to be done to explore the realm of the productive irreality and alterity that models can offer to the designer and to the city-dweller.[33]

Ultimately, the generic itself gives the model for research: a series of inquiries that "cuts through and intersects with each category,"[34] little by little drawing out the contour of a new future, unknowable but approached at each moment with new anticipation.

32 "Modelling alone that renders … ontology 'concrete' by producing new knowledge of what is concrete in a particular domain … modelling itself, through its procedures of assigning specific semantic values to elements of a syntax, produces consistent procedures of change … this knowledge is valuable since it can pass, via philosophy's encounter with generic procedures, into other practices."

Feltham, *Alain Badiou: Live Theory*. p133-134

33 Modeling that "attempts to enlarge its boundaries and disrupt any supposed completion" that "de-totalizes it and extends it"

Ibid. p132

34 *Ibid*. p109

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≒Appendix.4.1 ReadCSV

```
0   INPUTS: pth, fN as Str
    import os.path

    #==========================IMPORT FROM CSV============================#
    def ImportFitnessCoeff(p,f):
5      openFile= p + "\\" + f
       if os.path.isfile(openFile):
         print ("File Exists.")
         fileData= file(openFile).readlines()

10       v= []
         for i, line in enumerate(fileData):
           cells= line.split(',')
           #ADD NEW LINE
           v.append([])
15
           #READ LINES WITH NUMERIC VALUES
           try:
             float(cells[2])
             for j in xrange(2,7):
20             v[-1].append(float(cells[j]))
           except ValueError:
             continue

         #FITNESS COEFFICIENTS
25       slopeAdjst= [v[2],v[3],v[4]]
         solAdjst= [v[6],v[7],v[8]]
         elevAdjst= [v[10],v[11],v[12]]
         runoffAdjst= v[14]
         smallAdjst= v[16]
30       largeAdjst= v[17]
         rdAdjst= [v[19],v[20], v[21]]
         attrAdjst= [v[23],v[24],v[25],v[26]]

         return [slopeAdjst, solAdjst, elevAdjst,
35              runoffAdjst, smallAdjst, largeAdjst,
                rdAdjst, attrAdjst]
       else:
         print("File Does Not Exist")

40  #================================MAIN=================================#

    k= ImportFitnessCoeff(pth,fN)
    OUTPUTS: k
```

The script reads values from a *.csv* file and formats them as a list of lists to be used as coefficients in assigning fitness values to a landscape.

05 Concatenate the folder path *p* and the filename *f*.

06 Check that this file exists.

08 *.readlines()* loads the entire document into memory, on larger files this could be dangerous and using the iterative *.readline()* could be preferable (*cf.* ≒A.6.2). It could also be substituted here, since we only examine one line at a time (:11), but it is possible we may want to compare values from different lines at some point.

12 Dividing the *.csv* using a comma delineator returns a list of the cell values.

17 We attempt to cast the third value of the line to a float to check if it is numeric. Comparing to the spreadsheet (Figure A.4.1) if there is not a numeric value, the line is either the header or a blank space.

19 If a data line, save the five values into the last list.

24 At the end of the loop, all values have been saved, with empty lists in the place of non-data lines. In the following, we reassign the relevant lines to new variables to increase readability in the code.

34 The coefficients are then returned to the main body of the cody formatted and ordered.

Sheet1

Fitness Coefficients:	**HI**	**MI**	**LO**	**GR**	**∅**
Slope **<15°**	0.15	0.25	0.1	0.2	-0.2
Slope **<30°**	0	0.1	-0.1	0.35	0
Slope **<90°**	0.25	0	-0.3	0.5	0.6
Solar Incidence **<30°**	0.15	0.25	0.1	0.2	-0.2
Solar Incidence **<60°**	0	0.1	-0.1	0.35	0
Solar Incidence **<90°**	-0.2	0	-0.3	0.2	0.3
Elevation **<105m**	0	0	0.2	0.2	0
Elevation **<135m**	0	0.4	0.1	0.25	0
Elevation **<160m**	0.2	0.1	0	0.3	0
Excessive **Runoff**	-1	-0.75	-0.5	-0.25	1
Very Small Parcels	-1	-0.75	-0.25	-0.5	0.75
Very Large Parcels	-0.75	-0.5	-0.1	0.2	0.15
Road Adjacent: **0 Edges**	0	0.1	0	0.3	0
Road Adjacent: **1 Edge**	0.3	-0.1	0.1	0.2	0
Road Adjacent: **2 Edges**	-0.2	-0.1	0	0	0.3
Density Attr: **Very Near**	1.5	1	0	0	0
Density Attr: **Near**	1	0.5	0	0	0
Openness Attr: **Very Near**	-0.5	0	0.5	1.5	2
Openness Attr: **Near**	-0.25	0	0.25	0.75	1

Figure A.4.1
The formatted spreadsheet to be read (*cf.* §5.5 'Extension').

Appendix.6.1 SampleBitmap

```
0  INPUTS: fPth, fNm, cntr as List, crnr, refresh
1  import scriptcontext
2  import Grasshopper as gh
3  import System.Drawing as sysDraw
4  
5  attrLst=[]
6  
7  #=====================================================================#
8  f= fPth+ "\\" + fNm
9  btmp= sysDraw.Bitmap(f)
10 attrSampler = gh.Kernel.GH_MemoryBitmap(btmp)
11 
12 for pt in cntr:
13    pixX= pt.X-crnr.X
14    pixY= -(pt.Y-crnr.Y)
15    col= sysDraw.Color()
16 
17    if attrSampler.Sample(pixX,pixY,col)[0]:
18       if attrSampler.A(pixX,pixY) == 0:
19          attrLst.append(False)
20       else:
21          attrLst.append(edgSampler.Colour(pixX, pixY)
22 
23 if attrSampler:
24    attrSampler.Release(False)
25 
26 #=====================================================================#
27 
28 px= attrLst
29 OUTPUTS: px
```

The script retrieves the pixel data of an image file (*.bmp, .gif, exif, .jpg, .png, .tif*) that maps values onto a plan of the site using a grid of reference points in the 3d model as sampling locations within the image.

Reference (including other methods): *http://www.grasshopper3d.com/forum/topics/dynamic-input-for-image*

08 Concatenate the folder path and the image name to create the file location as a string.

10 *GH_MemoryBitmap()* is the most straightforward means of reading image data in Grasshopper. For other methods see the reference note above.

14 The images used have been scaled so that one pixel is equal to 1 meter, so the only conversion necessary is to subtract the coordinates of the upper-left corner from the sample points.

15 Image coordinates start with y==0 at the top row and increase as the rows count down, inverse of the geomety's coordinate system.

17 The *.Sample()* method returns a boolean and a color. Here, check that the operation was successful by reading the boolean returned.

18 In the definition, the reference images are *.png* files with a transparent background, where only the site bounds are opaque. This line checks whether the alpha channel of the current pixel is transparent, meaning it is not located within the bounds of the site.

21 The *.Colour()* method can also be used to replace a pixel value by giving a color input as a third input value.

24 Always release the *MemoryBitmap* or the file will remain locked. Change the boolean field to *True* if changes were made that you want to be saved.

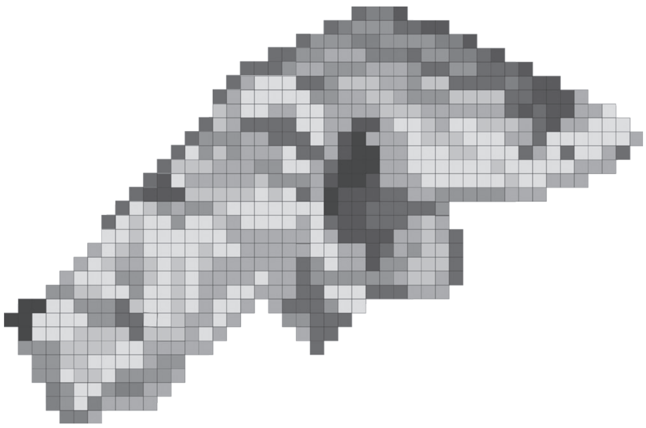


Figure A.6.1
The image map of the site coded with user-defined attraction values (*cf.* §6.3 'Mobile Agents').

≒Appendix.6.2 OSMpoints

```
0    INPUTS: fFldr, fNom, LngLat, rhPos as UVInterval, brckt as UVInterval
     import scriptcontext; from collections import defaultdict;
     import System.IO as io
     import math
     import Rhino.Geometry as rhG
5    import sys

     OSMpath= fFldr + "\\" + fNom
     sortNode= []
     vRng= LngLat.V[1]-LngLat.V[0]
10   yRng= rhPos.V[1]-rhPos.V[0]
     mercProjScale= yRng/vRng
     mapVar= (LngLat.U[0],LngLat.V[0], rhPos.U[0],rhPos.V[0], mercProjScale)

     sortWay=scriptcontext.sticky['ghDefaultDict'](defaultdict(list))
...  plOut=[]
15
     def PlotLngLatOnXY(lng,lat,map):
       xVal= map[2]+ (( (lng-map[0]) * map[4] ) * ...
           ( math.cos(math.radians(lat)) ) )
       yVal= map[3]+ ( (lat-map[1]) * map[4] )
20
       pt=rhG.Point3d(xVal,yVal,0)
       return pt


25   #================================MAIN=================================#
     #CHECK THAT FILE EXISTS
     if not io.File.Exists(OSMpath):
       print("File DNE")

30   else:
       lineCt= 0
       fOSM= open(OSMpath, "r")
       lineStr= fOSM.readline()

35     while lineStr:
         lineSpl= lineStr.split('"')

         if lineSpl[0] == " <node id=":
           inclPt= True
40
           #CHECK FOR NODE COORDINATES [NDX=ndx1, LAT=ndx15, LNG=ndx17]
           ndxVal=int(lineSpl[1])
           latVal=float(lineSpl[15])
           lngVal= float(lineSpl[17])
45
           #IF BRACKET VALUE EXISTS CHECK IF INSIDE
           if brckt:
             if abs(brckt.U1-brckt.U0) > 0 and abs(brckt.V1-brckt.V0) > 0:
               if lngVal < brckt.U0 or lngVal > brckt.U1 or ...
50                      latVal < brckt.V0 or latVal > brckt.V1:
...              inclPt= False

           if inclPt:
             sortNode.append( (ndxVal, ...
                              PlotLngLatOnXY(lngVal, latVal, mapVar) ) )
55
         elif lineSpl[0] == " <way id=":
           break

         lineStr= fOSM.readline()
60       lineCt+= 1

       ptID= [val[0] for val in sortNode]
       pt= [val[1] for val in sortNode]
```

The script reads an *.osm* file from OpenStreetMap and creates points for each "node." Then polylines are created from the "way" data and saved with their tags in a *defaultdict*, so that they can be selected or sorted through this metadata.

Note that the .osm formatting changes from time to time and the precise data position or identification may need to be adjusted.

16 This function maps the longitude and latitude values to a rectangular plot.

32 The file is opened in read-only mode with the *"r"* tag.

33 *.readline()* returns the first line of the file and iterates to the next line everytime thereafter.

35 *lineStr* will only be empty at the end of the file or if the file is completely empty.

36 Use quote delimiter to separate values.

38 Check the first value in the line for the tag that identifies a new point location.

42 Only three values are of interest for the node: its index number, and its latitude (:43) and longitude (:44).

47 An optional *UVInterval* input, *brckt*, can be input to limit nodes to only those within a certain boundary.

53 The index value of the node and a *Point3d* are saved as a tuple in list to be sorted. This will help with recall later.

56 If the line begins with the tag that identifies a new way, the *while* loop is broken and the *while* loop exited.

62 The node index values and point locations (:63) are converted to lists with list comprehenesions.

```
65      idTemp= 0
        wayBool= False

        #MAKE WAYS
        while lineStr:
70          lineSpl= lineStr.split('"')

            #BEGIN WAY
            if lineSpl[0] == " <way id=":
                idTemp= int(lineSpl[1])
75              wayBool= True
                pL= rhG.Polyline()
                keyList= []
                valList= []

80          #WAY IS ALREADY BEGUN
            if wayBool:
                #END WAY
                if lineSpl[0][2] == "/":
                    if len(pL) > 1:
85                      sortWay.d[idTemp].append(pL)
                        sortWay.d[idTemp].append(keyList)
                        sortWay.d[idTemp].append(valList)

                        plOut.append(pL)
90                      wayBool= False

                #WAY DATA
                else:
                    #ADD NODE TO WAY
95                  if lineSpl[0] == "  <nd ref=":
                        idCk= int(lineSpl[1])
                        try:
                            ndxGet= ptID.index(idCk)
                            pL.Add(pt[ndxGet])
100                     except:
                            error= True

                    #ADD TAG TO WAY
                    else:
105                     keyList.append(lineSpl[1])
                        valList.append(lineSpl[3])

            #RELATIONS BEGIN
            if lineSpl[0] == " <relation id=":
110             print (lineCt)
                break

            lineStr= fOSM.readline()
            lineCt+= 1
115
    fOSM.close()

    pth= OSMpath
    crv= plOut
120 pyWay= sortWay
    OUTPUTS: pth, ptID, pt, crv,pyWay
```

69 A new loop to iterate through all the way data.

73 Check the first value in the line for the tag that identifies a new way. Save the index number (:74), flip the boolean value (:75), and initiate a polyline (:76), and lists for metadata (:77,78)

81 If a way has been started, check for the tag that closes the way (:83). Otherwise, add the node to the polyline (:95ff) or add metadata to the lists (:105ff).

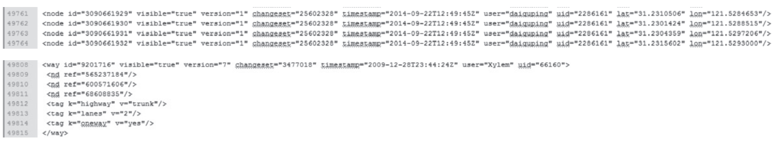
85 The completed polyline is added to a *defaultdict* along with its keys and values. These will be searchable in another script to select ways by their type.

101 This is a dummy action in the case that the node selected does not appear in *ptID*.

109 Check the first value in the line for the tag that identifies a new relationship. Exit the loop when this occurs.

21 The *.Colour()* method can also be used to replace a pixel value by giving a color input as a third input value.

24 Always release the *MemoryBitmap* or the file will remain locked. Change the boolean field to *True* if changes were made that you want to be saved.



```
49761 <node id="3090661929" visible="true" version="1" changeset="25602328" timestamp="2014-09-22T12:49:45Z" user="daiquping" uid="2286161" lat="31.2310506" lon="121.5284653"/>
49762 <node id="3090661930" visible="true" version="1" changeset="25602328" timestamp="2014-09-22T12:49:45Z" user="daiquping" uid="2286161" lat="31.2301424" lon="121.5288515"/>
49763 <node id="3090661931" visible="true" version="1" changeset="25602328" timestamp="2014-09-22T12:49:45Z" user="daiquping" uid="2286161" lat="31.2304359" lon="121.5297206"/>
49764 <node id="3090661932" visible="true" version="1" changeset="25602328" timestamp="2014-09-22T12:49:45Z" user="daiquping" uid="2286161" lat="31.2315602" lon="121.5293000"/>

49808 <way id="9201716" visible="true" version="7" changeset="3477018" timestamp="2009-12-28T23:44:24Z" user="Xylem" uid="66160">
49809  <nd ref="565237184"/>
49810  <nd ref="600571606"/>
49811  <nd ref="68608835"/>
49812  <tag k="highway" v="trunk"/>
49813  <tag k="lanes" v="2"/>
49814  <tag k="oneway" v="yes"/>
49815 </way>
```

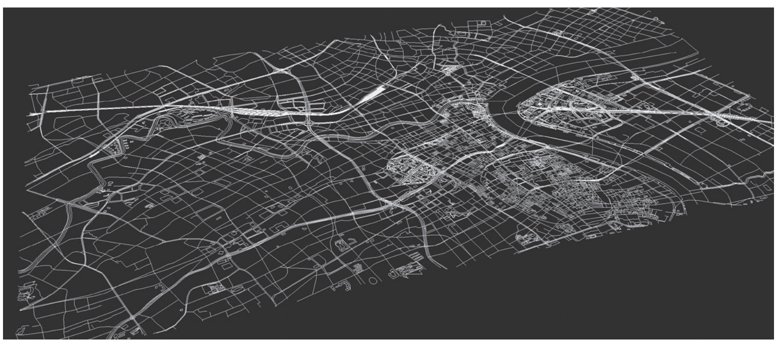


Figure A.6.2
Nodes and ways as they are represented in the .osm file.

Figure A.6.3
Ways as they appear in the geometry preview.

Curriculum Vitae

EDUCATION

2016 **Doctor ès Sciences (Ph.D.)**
École Polytechnique Fédérale de Lausanne
'Assemblage Form: An ontology of the urban generic with regard to architecture, computation, and design'
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2009 **Master of Architecture (MArch I AP)**
Harvard Graduate School of Design
'Taipei 2.0.2: Computation and the urban generic'
Digital Design Award, 2009

2006 **Bachelor of Science in Architectural Studies (BSAS)**
University of Wisconsin–Milwaukee SARUP
Magna cum laude
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2014 **Singapore University of Technology and Design**
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Fall 2014
'Core Studio I'

2009-13 **École Polytechnique Fédérale de Lausanne**
« Assistant Scientifique » / « Assistant Doctorant »

Masters Design Studios:

Fall 2012 and Spring 2013
'Morphogenesis: Parametric Typologies.'

Spring 2012
'Morphogenesis: Growth Typologies.'

Fall 2011
'Organicités: Food Urbanism Lausanne.'

Fall 2010 and Spring 2011
'Organicités: Ras-al-Khaimah Ecological Campus.'

Spring 2010
'Organicités: Tectonic Differentiation.'

Fall 2009
'Organicités: (Un)Natural Selection.'

Masters theses supervised as « Maître »:

2013-14
Christina Haas, « La mer d'Aral, d'une zone sinistrée à un parc du patrimoine. »
Charles Sarasin, « Méta-hutong: une couture entre quartiers traditionnels.' »
Alexandre Sadeghi, « Anamnesis. Plan urbain évolutif.' »

2012-13
Anne-Catherine Gay, « Integrative Network. Ecoles techniques et parcs urbains pour l'intégration des "barrios" et de ses jeunes dans Caracas. »
Johann Watzke, « Hybridation d'infrastructure et d'architecture dans un quartier de Lausanne en pleine mutation. »

2010-11
Andrea Pellacani, « La mort dans la vi(ll)e: Création d'un complexe funéraire au sein de Sara D. Roosevelt Park. »

Undergraduate Design Seminar:

May 2010
'HOME 2.0: Parametric Quality.'

2012 **Universität für Angewandte Kunst, Wien**
Workshop Instructor

Design and Fabrication Workshop:

February 2012
'IoA Spring Challenge.'

2007-09 Harvard Graduate School of Design
Teaching Assistant

Design Studio and Seminar TA:

Spring 2009
'Verticalism.' critics Iñaki Abalos and Daniel Lopez-Perez.

Fall 2008
'Overskyscraper: Ubiquitous Tower Collectives.' critic: Ciro Najle.

Spring 2008
'Monococques, Component Design.' critic: Winka Dubbeldam.

Fall 2007 and Spring 2007
'Algorithmic Architecture' and 'Digital Media.' critic: Kostas Terzidis.

Digital Media Workshop Instructor:

Spring 2008-Spring 2009
Rhino3d, Rhino VBscript, Grasshopper3d
MELscript for Maya

Spring 2009
Workshop for 'Mat Ecologies.' critic: Chris Reed
Workshop for 'Fourth Semester Core Studio.' critic: John Hong

CAD/CAM Technician:

2008-09
6-axis robotic waterjet and milling machines

PUBLICATIONS

Research Articles as Primary Author:

2016 "Performance Review: In Praise of the Possibility of Architecture."
Trevor Patt. in *Architecture is All Over.* Esther Choi and Marrikka Trotter, eds. Work Books, Actar. 2016 (*forthcoming.*).

2015 "Generative Masterplanning Inspired by Cellular Automata with Context-specific Tessellations"
Trevor Patt. in *Real Time: Extending the Reach of Computation.* Bob Martens, Gabriel Wurzer, Thoms Grasl, Wolfgang E. Lorenz, Richard Shaffranek, eds. 2015.

2015 "Visualizing Data: Qinglonghuzhen, Peri-Urban Beijing."
Trevor Patt. in 'Visual(izing) Data.' 2015. Retrieved from http://contour.epfl.ch/visualizing-data/

2014 "The Public Realm of the Urban Village: A Visual Interrogation of Longtancun, Guangzhou."
Trevor Patt. in *e-publicspace.net* 2014.

2014 "Scenario Modeling for Agonistic Urban Design."
Trevor Patt, Jeffrey Huang. in *Symposium on Simulation for Architecture & Urban Design.* Simulation Series v46n7. David Jason Gerber and
Sonny Astani, eds. SimAUD. 2014.

2013 "The Surface of Borromini."
Trevor Patt. in *Clog: Unpublished.* Kyle May, Julia van den Hout, Jacob Reidel, Archie Lee Coates IV, and
Jeff Franklin, eds. 2013.

2013 "Food Urbanism Modeling."
Trevor Patt. in *ACADIA 2013: Adaptive Architecture.* Philip Beesley, Omar Khan, Michael Stacey, eds. Acadia and Riverside Architectural, Cambridge, ON. 2013.

2012 "Computation as an Ideological Practice."
Nathaniel Zuelzke, Trevor Patt, Jeffrey Huang. in *ACSA 100th Annual Meeting: Digital Aptitudes + Other Openings.* Marc Goulthorpe and
Amy Murphy, eds. ACSA, 2012.

2011 "Taipei 2.0.2: Computation and the Urban Generic."
Trevor Patt. in *Highrise Shuffle: 4th International Alvar Aalto Meeting on Modern Architecture.* Antti Ahlava and Esa Laaksonen, eds. Alvar Aalto Academy, 2011.

2010 "The Collective Image: Form, Figure, and the Future."
Trevor Patt. in *Architecture at the Edge of Everything Else.* Esther Choi and Marrikka Trotter, eds. Work Books, MIT Press. 2010.

2008 "Surfacing Stone: Digital Stereotomy and Material Effect."
Trevor Patt. in 'Trays: GSD online journal.' Qilian Riano, ed. 2008.

2007 *Skycar City*.
Winy Maas and Grace La eds. Actar. 2007.

Research Articles as Secondary Author:

2015 "Code and its Image: The Functions of Text and Visualization in a Code-Based Design Studio."
Mark Meagher, Jeffrey Huang, Nathaniel Zuelzke, Trevor Patt, Guillaume Labelle, Julien Nembrini, Simon Potier, Thomas Favre-Bulle. in *Digital Creativity*. v26n2, 2015.

2013 "Artificial Morphogenesis: The Guangzhou Tower Delta Studio."
Jeffrey Huang, Trevor Patt, and Peter Ortner, in 'Foreign Designers Venture into China.' *Landscape Architecture Frontiers*. v1n5, October. 2013,

2013 "Architecture Challenge 2012."
Andrei Gheorghe, Bence Pap, Trevor Patt, Irina Bogdan, Clemens Preisinger, and Moritz Heimrath. in *Encoding Architecture 2013*. CMU, Pittsburgh, 2013.

2012 "Architecture Spring Challenge."
Andrei Gheorghe, Bence Pap, Trevor Patt, Irina Bogdan, Clemens Preisinger, and Moritz Heimrath. in *ACADIA 2012: Synthetic Digital Ecologies*. Acadia , San Francisco, 2012.

Non-Authored Publications Featuring Design Work / Media Exposure

2015 "Growth Typologies, Localities and Defamiliarisation: Experiments with Artificial Urbanism in Sichuan, Guangzhou and Beijing."
in 'Mass-Customized Cities,' *AD: Architectural Design*, v85n6. 2015.

2013 "Topographie des Senses."
in 'Pabellones experimentales, EPFL Lausanne' in *AV Proyectos*. n057, 2013.

2010 "Chinatown Storefront Library."
in *GSD Platform 3*. Emily Waugh, ed. Actar, 2010.

2010 "Chinatown Storefront Library."
in *DO! Design Opportunity*. Quardean Lewis-Allen and Shelby Elizabeth Doyle, eds. SOCA GSD. 2010

2010 "New Stone Shells: Design and Robotic Fabrication."
Martin Bechthold. in *Proceedings of the IASS, Symposium 2009*. Valencia. Alberto Domingo and Carlos Lazaro eds. 2010.

2010 "SkyCar City: Metropolis 2.0."
in 'Post Oil City.' *ARCH+* 196/197. Sabine Kraft, Nikolaus Kuhnert, Günther Uhlig eds. February. p98-102. 2010.

2009 "Taipei 2.0.2: Computation and the Urban Generic."
in *GSD Platform 2*. Felipe Correa, ed. Actar. 2009.

2009 "Lending a Library."
Joan Wickersham. in *Architecture Boston*. v14n4 Winter. 2009.

2009 "Argos Tower."
in *A View on Harvard GSD*. Tank Books. 2009.

2009 "More Bang for the Buck."
Martin Bechthold. in 'Nonstandard Structures.' *GAM – Graz Architecture Magazine*. v06. Urs Hirschberg, Daniel Gethmann, Ingrid Böck, Harals Kloft eds. 2009.

2010 "The Return of the Future: A Second Go at Robotic Construction."
Martin Bechthold. in 'The New Structuralism.' *AD: Architectural Design*. v80.n4, Helen Castle ed. Wiley. 2010.

2008 "Surfacing Stone: Digital Explorations in Masonry Curtain Wall Design."
in *GSD 08 Platform*. Lluis Ortega, ed. Actar. 2008.

PRESENTATIONS AND LECTURES

2015 “City and Model: Commingling of Formal and Informal Urban Agency”
Symposium speaker: ‘Agency/Agents of Urbanism Colloquium,’ Edinburgh School of Architecture, Edinburgh. 1 June, 2015.

2015 “The self-othering event of object qualities and architecture as a mutable interface.”
Symposium speaker: ‘Architecture of Alterity Symposium,’ Edinburgh School of Architecture, Edinburgh. 27 May, 2015.

2014 “Notes on Assemblage Form.”
Invited lecture: ‘SUTD PhD. Small Talks,’ Singapore University of Technology and Design, Singapore. 10 December, 2014.

2014 “Scenario Modeling for Agonistic Urban Design.”
Conference presentation: ‘Symposium on Simulation for Architecture & Urban Design.’ Tampa. 13-16 April, 2014.

2012 “Negotiation between aesthetics and execution in architecture.”
Invited lecture with Nathaniel Zuelzke: ‘Creative Mornings, Geneva.’ 15 June, 2012

2012 “Computation as an Ideological Practice.”
Paper presentation with Nathaniel Zuelzke: ‘ACSA 100th Annual Meeting: Digital Aptitudes + Other Openings.’ Boston. 2 March, 2012.

2011 “Procedures: Designing from the bottom up.”
Invited lecture: the Gerald D. Hines College of Architecture, University of Houston. 9 September, 2011.

2011 “Taipei 2.0.2: Computation and the Urban Generic.”
Paper presentation: ‘IAAMMA 4.’ Jyväskylä, Finland. August 27-28, 2011.

2011 “Closing Performance: In Praise of the Possibility of Architecture.”
Symposium speaker: ‘Architecture is All Over.’ organized by Work Books with UT, OCAD, TIFF; Toronto, Canada. 11-12 February, 2011.

2008 “Directing Instruments: Digital Stereotomy and Material Effects.”
Invited lecture: ‘Craft and Computation Series.’ University of Wisconsin-Milwaukee. 3 October., 2008.

AWARDS AND RESEARCH GRANTS

2011-14 “Food Urbanism Initiative”
Awarded by Swiss National Science Foundation (NFS/SNF). National Research Programme 65, ‘New Urban Quality’. 2010.
3-year cooperative grant, project lead: Craig Verzone.
interdisciplinary team members: Verzone Woods Architects, EPFL Media×Design Lab, ETHZ Agri-food & Agri-environmental Economics Group, Agroscope ProfiCrops

2009 “Digital Design Award”
Awarded by Harvard Graduate School of Design.

EXHIBITIONS

Curated:

2015 "Land-/Sea-Scape"
Organized and designed at Galerie Antenne, Lausanne. 27 June, 2015.

Included in:

2016 "Tell me about a Rhino command: architectural history through change logs"
Curated by Matthew Allen. Gund Gallery, Cambridge, MA. April 2016 (*scheduled*).

2013-14 "Totally Lost"
Curated by Spaci Indecisi. Ex Deposito ATR, Largo Savonarola, Forlí, IT. ; Luxembourg. 4-16 June, 2013. 11 June-11 July, 2014.

2012 "Cosandey Pavilions"
Curated by EPFL. Foyer SG, EPFL, Lausanne. October-November, 2012.

2012 "AAG Video Panorama"
Curated by Advances in Architectural Geometry and Aurélien Lemonier. Centre Pompidou, Paris. 27-30 September, 2012.

2010 "HOME 2.0"
Curated by Swissnex China. Swiss Pavilion at Shanghai World Expo 2010, Shanghai. 20 June-1 July, 2010.

2010 "Post-Oil-City – The History of the Future of the City"
2010
Curated by Anh-Linh Ngo. ifa-Galleries, Stuttgart and Berlin; Semperdepot, Wien; et al. 2010ff.

2010 "Emerging Professionals"
Curated by AIAS. American Center for Architecture, Washington D.C. 2010.

2010 "Futures in the Present"
Curated by Mohsen Mostafavi. Massachusetts Hall, Cambridge, MA. 2010.

2009 "GSD Platform 2"
Curated by Felipe Correa. Gund Gallery, Cambridge, MA. 2009.

2009 "BEYOND MEDIA Festival"
Florence. 2009.

2008 "(Im)material Processes"
Curated by Neil Leach. Architecture Beijing Biennale 2008. Beijing. 2008.

2008 "Venice Biennale"
Arsenale. Venice. 2008.

2007 "Studioworks"
Gund Gallery, Cambridge, MA. 2007.

PROFESSIONAL EMPLOYMENT

2012- Ahtehha
Principal: SUTD DManD Laboratory, sg50 Innovation Landscape with Immanuel Koh, et al.

2009-15 Convergeo
Designer: Pavillons Cosandey, Rolex Experience, Rolex Flagship

2009 New World Design
Intern Architect: Nassiriyah Truck Stop

2006-09 Freelance Design/Computation Consultant

MOS
2008-09
Computational Designer: Necklace Dome, Desert Islands #2, Museum Boijman, Warsaw

Preston Scott Cohen Inc.
2008
Scripting Consultant: Tel Aviv Museum of Art

SEED Magazine
2008
Visualization Consultant: 2008 WEF

MVRDV
2006
Visualization Consultant: Istanbul Waterfront

2007 SsD Architects
Intern Architect: Hidden Fortune House

2006-07 La Dallman Architects
Intern Architect: Levy House, Discovery World

NON-PROFIT WORK

2009 Chinatown Storefront Library
Design and Fabrication: with Department of Micro-Urbanism, Boston Street Lab, Harvard Community Service Fellows

EDITORIAL POSITIONS

2016- Frontiers Journal
Associate Editor, Digital Architecture (Specialty section in Digital Humanities)


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