Responsive Systems

Light and Human Responsive Systems in Architecture

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January 2012, Lausanne

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Thanks

I thank Jeffrey Huang, Marilyne Andersen my professors and Mandana Sarey Khanie for their great help. My special thanks to Nathaniel Zuelzke because of his generous availability during the advancement of this thesis. I also thank Prof.Boris Beaude for his invaluable advices and Dr.Milad Niqui for the great help in the editing of the work.
Unspeakable! Thanks to my parents. to little *Amélie*

"What do you want, brick?"
To express is to drive.
And when you want to give something presence,
you have to consult the nature.
And there is where Design comes in.

If you think of Brick, for instance,
and you say to Brick,
"What do you want Brick?"
Brick says to you
"I like an Arch."

And if you say to Brick
"Look, arches are expensive,
and I can use a concrete lentil over you.
What do you think of that?"
"Brick?"
Brick says:
"... I like an Arch"

Louis Kahn[1]

1 From John Lobell's "Between Silence and Light", p. 59, via Lorenz Lachauer

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0. Introduction:

Theme

This thesis studies the notion of *responsiveness* in architectural design. It tries to make a framework for understanding the act of response in architectural body. Focusing on Light as a contextual force, it studies the way light affects the built environment and architectural body, in order to introduce a light responsive system. This light responsive system will be used to design a mediatheque in the city of Geneva.

Methodology

Studying a multidisciplinary thematic between architecture and building physics this study is interested primarily to the architectural qualities of space. In parallel, it also considers the performance and comfort metrics.

Two case studies in the third chapter are based on in-situation mappings and radiation analysis. The radiation calculations are done by Diva light simulator (based on *Radiance* software). The case studies are ordered considering the scale that they study; Their outcomes are used for the same-scale factors in a light responsive system proposed in the fifth chapter.

In the chapter four the city and the program are reduced to quantitative design parameters to be used in the light responsive system.

Resume

The term responsiveness is widely used in different disciplines. In the first chapter after a survey on these usages in different contexts such as biology, social science and art, this study summarises a definition of responsiveness to found a framework for a light responsive system.

Focusing on climate responsive systems and particularly light, in the second chapter, different approaches to use light as a form-giver for architecture are introduced. This chapter is devoted to the

questions such as :What are the spatial qualities of light and how lighting concerns affect architecture and design process?

For introducing a light responsive system in the third chapter two case studies in two different scales are carried out. One studying the relation of light and the public space focusing on the urban promenades and the other one studying the relationship of interior light zones and the geometry; It searches for a lighting grammar in the interior space.

Chapter four is devoted to analysis of the contextual and organisational design problem parameters. As this study will be used later to solve a real design problem, in this chapter the objective is to propose simplified-well-behaving models of the urban context : the city of Geneva and the program: Mediatheque for the light responsive system.

Chapter five proposes the characteristics of a light responsive system, considering all the design problem parameters.

[fig.1] Next page: Justin Goodyer, Adaptive Bloom, 2010

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Responsive Systems

Responsiveness is a characteristic of dynamic systems. In a system thinking approach all the systems that are capable of changing their interior organization can stimulate a response activity.
In architecture this can happen in relation to structural organization and material characteristics (tectonic response), analysing information of the environment (smart response) or agents' rule based activity (feedback response).

1.1. Response

What is responsiveness? How can we describe this notion in architectural design?

Response derived from the Latin word *responsum* with the root *spond*,refers to “something offered in return”. This meaning of response exists in almost all the languages with its general meaning related to a volitional action. In the 20th century in order to study phenomena that could be also studied under a conception of a system that do a certain behavior, the notion of response was borrowed by diverse scientific disciplines to describe the behavior of a system in its surrounding.

The sage dictionary and thesaurus, Sequence publishing group,2010

“Response: a bodily process occurring due to the effect of some foregoing stimulus or agent”

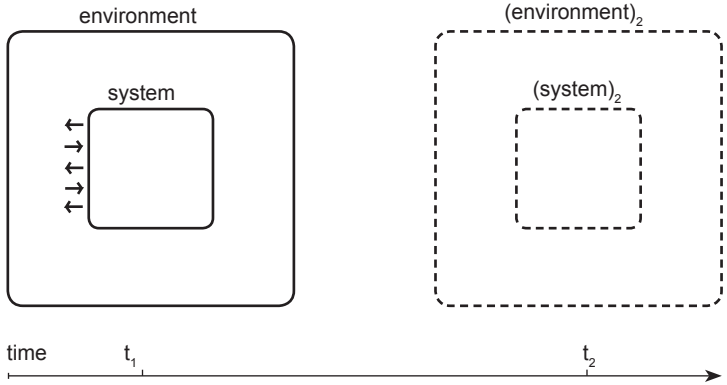
Response based on this definition is used in many disciplines such as biology, management, system sciences and electronics and all the other disciplines that study a system. What is common in all of these usages is that the term “response” is attached to a system which has a body (internal organization) and reacts to the changes in its environment.

There is a tendency among scholars to treat the built environment as a system which has a reacting body. Therefore, in the recent years, the usage of the term responsiveness has been extended to these domains. Usage of the term responsiveness in the built environment related sciences is very diverse and not concretely defined. One of the latest efforts is reflected in Patrick Schumacher‘s in “Autopoiesies of architecture”:

Schumacher, The Autopoiesies of Architecture, 2011, page 19

“...the concept of system and the concept of environment are complementary...the systems considered within the [this architectural] theory are autopoietic systems. Autopoietic systems are self referentially enclosed systems that produce all their units elements and structures within their own recursive network of reproduction...“

In this framework a desirable architecture is supposed to be a system that construct its own units based on its reproduction logics and its internal relations. In this context responsiveness is a series of acts in the interaction of system and its environment in order to reach to an equilibrium [schema.1].



[schema.1] A system changes because of change of its environment

[***response is a goal-based change in time***]

In the next section we try to categorize the concept of responsiveness in architectural design. There are two main trends in today’s literature in architecture to use the term responsiveness. One is, as we call it in this study, *a posteriori* responsiveness which considers response as a result of the built space and the other one, which we call it *systemic* responsiveness, refers to the built space reacting physically to the environment.

1.2. Responsiveness as an *a posteriori* characteristic of the space

Sue Mcglyne argues that the responsive environments are those:

Mcglyne, Responsive environments, 1985, page 9

"...with an essentially democratic setting, enriching their opportunities by maximizing the degree of choice available to them."

She counts seven guidelines that lead to an increased degree of choice in a space: 1. Permeability, 2. Variety, 3. Legibility, 4. Robustness, 5. Richness, 6. Visual appropriateness, and 7. Personalization.

She projects these factors on the urban spaces and architectural spaces. For example with permeability she means the way that the design affects the city by introducing the places where the people are or are not able to go. As another example she mentions that increasing *variety* in an urban district is to encourage the placement of the buildings with mixed usages in that district. By richness and personalization she means:

Mcglyne, Responsive environments, 1985, page 10

"Richness involves ways to increase the choice of sense experience that users can enjoy (experiences of touch, sound, light, and so forth) while personalization refers to designs that encourage people to put their own mark on the places where they live and work."

Far from criticising her theory, in her approach responsiveness is presented as an a posteriori[1] and qualitative characteristic of a space which implies that architectural body statically exists and due to this existence, it liberates potentials of space. A good example for this conception is example of a window placed in a wall; it gives a direction to the space in the room. It causes an activity to occur in the room, this activity is the act of looking through this window.

[1] A posteriori, here is used as a Kantian (Immanuel Kant) term : a property that is a result of the existence of a phenomenon.

[fig.2] Gilbert Garcin, La leçon d'optimism, 2004. The change of the architectural body liberates different types of activities. A whole on a wall can be a door,at the same time the same shape could be a chair or with a little turn it provides new spatial potentials.

[“a *posteriori” response is due to the form*]

Here, we mark this activity as the response of the design of the room. But this is not a direct response, it is causally related to the design of the room what we call architecture of the room. And the room introduces this activity for being able to happen in the room. In other words, the placement of the window on the wall of the room which leads to this act, makes the room responsive in order to liberate a possibly joyful activity in terms of use of the space.[fig.2]

In this sense, responsiveness of the space is evaluated after it is designed based on the parameters mentioned by Mcglyne. In this approach, architectural body is presupposed as a static body that releases these responsiveness not through a systematic interaction with environment but simply by its existence.

1.3. Systemic response

A second approach to responsiveness in building design borrows this notion from biology. In biology responsiveness is defined based on the notion of adaptability. According to Koshland *adaptability* is one of the seven pillars of the living systems:

Koshland, The Seven Pillars of Life Science, 2002

"Behavioural manifestations of adaptability are a development of feedback and feed forward responses at the molecular level and are responses of living systems that allow survival in quickly changing environments"

There are three main elements in this definition, response is adaptability to change and hence for survival, it is a result of changes in the system's entities (in biology: cells) and it includes feedback procedures. Each of these elements are addressing acts by the system so that we call this type of response as a systemic response [fig.3].

Contrary to the concept of posteriori responsiveness, in this approach a space is not the result of a static frozen physicality; it is the result of a sensitive body that has the ability to adapt to changes in its surroundings. So the architectural body changes and due to this change it provides new qualities in the space.

This type of responsiveness can be categorized in three main branches according to the process of providing a response:

1. The Response to the change is a result of the proper structure of the system. It is followed by the change in the physical parameters of system (location,temperature, ...). We call it the *tectonic response.*

2. The body has a perception (decision system) of environment that forces the body to respond to the changes. We call it *smart response*.

3. The system stimulates an answer by a feedback procedure.

[fig.3] Venus flytrap Plant, Provides Nitrogen from the bugs. It exposes its opened leaves to attract the bugs and in a sudden movement closes them when the bug is located in its sensitive area. The three factors of a systemic response could be observed. Behaviour for survival, the closing act is the result of the change of chemical balance in plant's sensitive area, and finally it is propagated by a feedback system in the cellular level.

[*systemic response is adaptive*]

1.3.1. Tectonic Response

The tectonic response is the direct result of the structure of the system. It means in this type of response there is not any intelligent unit that processes the preceptive informations taken from the environment and that act with a logic. What plays the role of responding to the environment is the architectural body, and its mechanical and physical characteristics. These are deterministic systems that for the constant inputs have constant outputs which are predictable. [fig.4]

Tectonic response comes directly from the physical characteristics of the system. For example when a piece of metal is exposed to the heat its temperature will increase. This can be interpreted as the response of the metal piece to the heat. This new state of the system is not goal-based or survival-based like biological system, it is not also intelligent in relation to the various system inputs.

Theo Jansen's low-tech made creatures function on the basis of tectonic response. He uses the wind force for moving wind catching wings, the wings cause a piston to roll and with the joints that he has designed for the animal's leg the piston will cause the legs to move in a repetitive manner. This rotational movement of three legs will let the toes of the creature to move using the friction. The creature imitates a walk crab. The whole process is done only through the mechanical joints and the movement is a result of the positioning of the joints and constraints in the legs. If we consider this creature like a system and the wind like the environmental force, the tectonics (internal structure) cause the system to give a response (which here is movement) to the exterior force.

In this category we can mention the tools made by human before the invention of computers. Passive systems in architecture also work with the same logic.

[fig.4] Animaris Ulmerus , a kinetik creature made by Theo Jansen Dutch artist in the beaches of Scheveningen in Netherlands.
"I've seen a lot of mechanical sculpture, and Jansen's animals are the finest I've seen by far in the low-tech clockwork mechanism category." (Carl Pisaturo, a robotic designer) "By clockwork, I mean mechanisms that they have intrinsic, not universally controllable actions, and by low-tech I mean parts more crafted than machined, and the lack of electronic or electrical systems. These are amazing creations and the simplicity of the technology and the fact that they are wind-powered only makes their poetic motions more impressive."

[tectonic response is due to the physical state of the system and is mechanical]

1.3.1.1. Tectonic Response in Architecture: Climate Response

Tectonic response is the basis of the current climatic responsive systems in architecture. Buildings are rigid bodies that function through a long period and they should response to the changing climate in different times of the year. Therefore, the tectonic response systems has been elaborated and developed to make them responsive to the climate during the whole life of the building and in different periods in the year. This response includes decisions about their materiality, spatial organization and their orientation according to the sunlight.

The tectonic climate response is dominant in vernacular architecture, where the main forces of evolution has been the climate forces.

Tectonic climate response systems are divided into active and passive with respect to their way of integration in the buildings and the response conception beyond them.

1.3.1.2 Passive systems

Passive systems are instruments that are integrated in a building in the primitive stages of design. An atrium that shapes the main spatial element of a building to gain the solar rays and provides cross ventilations functions during the whole life of a building. No control or change is needed to decrease or increase its effect on the building. It is functioning based on the position and physics as an integrated part of the building. The same holds for a Thrombe wall or a sunspace[2] that stores heat in a thermal mass (air for Thrombe wall) to use it further for ventilation or heating of the building's spaces. In a passive ventilator the pipes that transfer the air are embodied in the walls of a building. The air ventilator can be positioned on the top of the roof as an

[2] A sunspace is a glazed room that is part of or attached to a building. Sun enters through the south-facing windows and heats the room. The warm sunspace air is then circulated to the building's interior for heating.

integral part of the building. The following facts are the characteristics of the passive systems from a responsiveness concerned view:

Roulet, Claude-Alain, Santé et qualité de l'environnement intérieur, 2008, page 4

1. Passive systems are the result of the tectonics of a building.
2. They are built upon the major climatic factors in relation to the location of the building, they are not sensitive to the micro-scale changes.
3. They are an integral part of the building. Therefore, there is no human control over them.
4. They affect the spatial relationship of the spaces.

1.3.1.3. Active Systems

Active systems are attached to the building's spaces and normally use an external energy supply in order to heat, cool or light the space. Radiators and HVACs and lighting equipment are of this kind. Active instruments need energy supply and control and can be removed or changed during the building's life.

1. They need human control and maintenance
2. They can be changed or removed during the building's life
3. They use external energy supply

Active systems can be described as the tectonic response system as far as they have no critical sense about the environment and are fully controlled by human. They change their behaviour according to the data they get from the controller and they have physical strategies.
To decrease the energy consumption and the need of

[*climate passive systems target tectonics*]

control and since the environmental factors are mostly constant in a geographical location, the effort should be to integrate the responsive systems in the building on the basis of tectonic response. However for dramatic changes in the environment it is better to have backup active systems that balance the need for interior comfort.

1.3.2. Smart Response

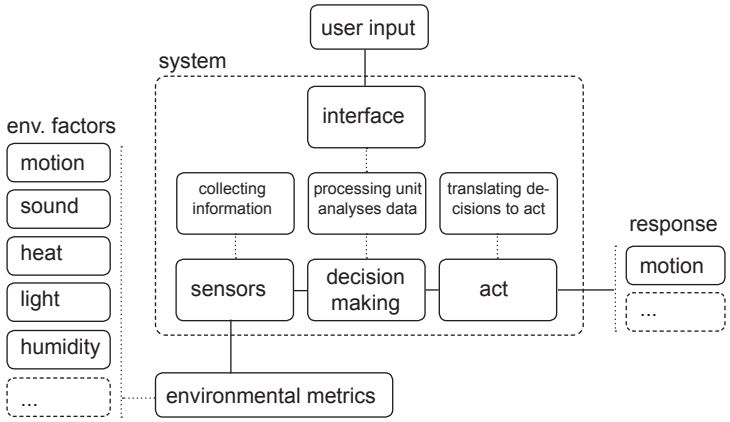
A smart response system has intelligence about its environment. For this intelligence it should have a perception. These systems collect the sensory information through an interface from human or with the sensors. This system responds to a stimuli in the environment with an analysis of the sensory information it receives. A smart system has a processing unit that makes the decision and executes the logic of the system.

The smartness of a response system can vary form a simple conditional unit that works on a yes-no logic to a complex processing unit that can have learning abilities. There is a new tendency to integrate smart object and intelligent spaces in built environment, the roots of this tendency can be seen in the modern movement in the beginning of the twentieth century.

Le Corbusier, towards a new architecture, 1923

“The house is a machine for living in”; this is an idealistic quote by Le Corbusier at the times of progression of the Modern movement in architecture in 1923. In the history this is one of the first times that someone faces the essence of architecture as a machine; as a machine that is as functional and as a car. The buildings of the Modernism era are the reproductions of this mentality with little changes in different architectural design contexts.

In the recent years with the advent of technology this trend has been reproduced in its new form. The image of machine has changed from the Modern deterministic steam engine, a mechanical machine that has no perception from environment and is there to defeat the nature’s power, to a machine that has more complexities. Machine in post-modern era has more complexities, it is not only mechanical but it has perception from the environment. It is not only deterministic, it analyses the information. Its aim is not to defeat and occupy the nature but it is inspired by nature. The smart response is about how to produce such kind of machines.



[schema.2] Elements and procedure inside a smart response system

[*smart systems use a desicion making unit*]

[Schema.2] shows the elements of a smart system, the environmental factors are all the sources of information. The processing unit has an expert system to weight the different dicisions according to the inputs. The expert system is a criteria -based decision making system that is translated to machine language (a software) and it controls the responding parts of the system, the response could be mechanical (movement of a part of system) or other type but it is directly related to the expert system. It is not deterministic.

An interface allows the user to set the parameters for the expert systems. As the expert systems and softwares are becoming more and more complex to communicate for human and needs special trainings there is tendency to facilitate the boundary between human and machine.

1.3.2.1. Human computer interaction

With integration of machines in human's life, this is not only humans that should learn the machines language, the machines should fit into the human's life. The field of Human Computer Interaction is a field to develop this idea.

Sears, Andrew. The human-computer interaction handbook, 2008

"Human computer interaction[HCI] is the study, planning and design of the interaction between people (users) and computers. Interaction between users and computers occurs at the user interface (or simply interface), which includes both software and hardware."

In HCI computer approaches to fit into human life. We can place the HCI projects under the smart response systems. There has been many projects targeting architectural space and art works, that uses HCI to response to human action in the space.

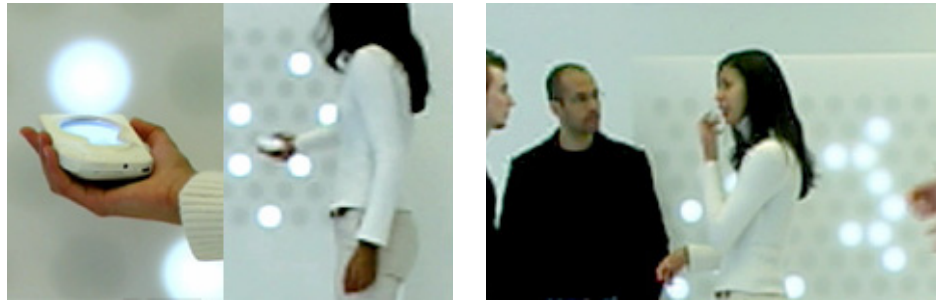
1. "The Hello Wall" [fig.7] by Ambient Agoras is a wall that uses audio sensors to catch the sounds spoken by the users in the room. It visualises the sound on a LED wall with a low resolution. The visualization is depended to the distance of the user with the wall if he is in the ambient zone the patterns are general, if he is in notification area the wall shows patterns known to the person, and in the cell zone person can interact with every single cell or a group of cells.

2. "Adaptive bloom" project [fig.1] conveys another degree of interaction, here the bloom of a series of the artificial flowers fixed on a wall is used responding to human movement in front of the wall.

3. In an artwork by Daniel Rozin, called "Mirrors Mirror" [fig.6] ,the project creates the viewers' image by directing 768 small mirror tiles in a way that reflects different portions of their image. The piece is made of 24 columns of "pixels" that form a con caved curved surface that is aimed at the viewer. The reflection of a mirror is combined with a elaborate circuit to reflect the image of the user in a distorted way.

[fig.6] The mirrors miror project, Daniel Rozin, this project shows a realtime interaction with orienting the mirrors to reflect users image. The act is a smart response.

[*HCI facilitates the interface*]



[fig.7] Hello wall project. A wall responses to the sound with different pattern in different zones of distance.

1.3.2.2. Internet of the things

The idea of smart systems is not limited to restrictions of physical world. In benefit of a platform that the smart objects can run on, it is possible to construct a network which has a distributed memory. The idea of networking smart objects is coined by the term *Internet of the things.*It is a paradigm that searches for the same concept of internet for physical objects. The idea is that if we make all the entities of the world identifiable and attach them to a network of information we can release many reticular benefices. We can have track of all the entities and access and use and address them through a universal network. Use evaluative methods to valorise them and have a elaborated maintenance and control system.

Ubiquitous computing is the development of this idea practically in everyday life. The concept is based on:

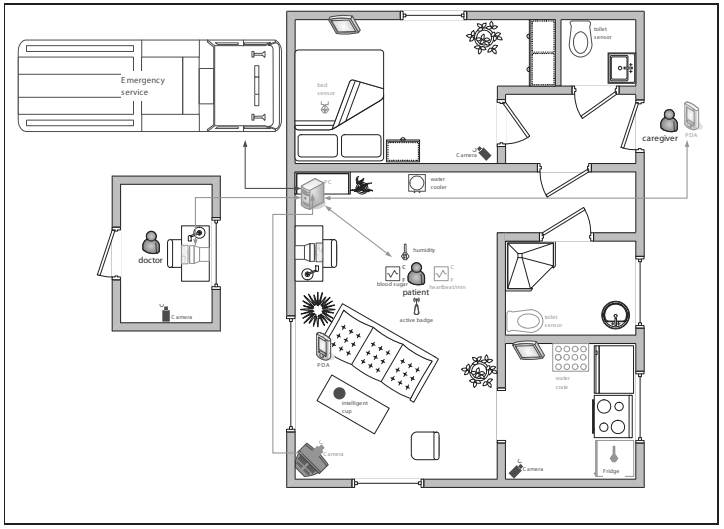
“Machines that fit the human environment instead of forcing humans to enter theirs.”

Weiser Mark, The coming age of calm technology, 1996

In Mark Weiser (the inventor of the term ubiquitous computing) view, Three scales of ubiquitous systems could be imaginable. HCI facilities exist in 3 scales that human might interact in day life. A dimensional categorization to cover all the happenings that are occur in the scale of performance of the fingers, the hands or and the body is proposed by him:

1. Smart pads: wearable (centimetre) devices
2. Smart tabs: hand-held (decimetre) devices
3. Smart boards: panel sized(meter) interactive devices

When the ubiquitous computing devices are making networks and they interact with larger scales, where human is placed in rooms and the other architectural spaces the notion of *Ambient Intelligence* (AmI) is introduced. AmI is referring to an electronic environment that can interact with its user with the HCI facilities. It gets the sensory information it uses it to evaluate the architectural space or user’s condition then make decisions to adapt the architectural body or inform actors to do certain actions.



[fig.8] BelAmI assisted home, Prante, R. Stenzel,” the availability of services in AmI systems is not static. Physically or logically appearing nodes carrying services have to be dynamically integrated. Context-awareness is a major feature of AmI applications. It basically involves context acquisition, interpretation, specification, and persistence”

[*AmI changes the conception of a house*]

In [fig.8] we see an study to illustrate how a person can be connected to a doctor and caregiver and emergency service at the same time, through distributed sensory facilities. The track of users health (sugar rage, heartbeat,...) would be examined real-time and if it approaches the unhealthy level the network would be informed.

The AmI infrastructure however is not far to reach with the current technology would have certain difficulties to integrate in the cities challenging the level of privacy, control and maintenance.

invention of machine
•5 k - 3 k BC

primitive interface
• 600 BC

deterministic machine
•1700s

invention ofsmart machine
•1950s

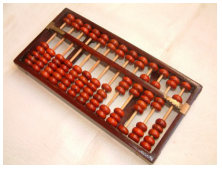
new interface
•1968

artificial living system
•1990s

smart machine
• 2007

prallel smartness
• conception

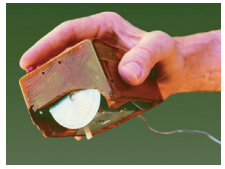
[fig.9] A hammer, a primitive tool: the functionality is integrated in its construction



[fig.10] An abacus for calculating: a physical interface, response is the ability of the user to interpret the physical state

[fig.11] An orrery from eighteenth century, to show the position of planets in the solar system. A pure deterministic machine, response is defined by its structure and order.

[fig.12] Shannon's ultimate machine, one of the first smart responsive machines with no expert system, constant response



[fig.13] The first computer mouse, a big step to develop interface with computers.

[fig.14] A computer virus, change of the code of a program, it is a smart response system that can grow and replicate in relevant environment, sample of a artificial living system

[fig.15] Smart phone, the functionality is integrated within the platform it is working on. A smart response machine. Use of the distributed facilities.

[fig.16] Conception of a smart cup. An image to show how smart object might look. The tech layer would be a second layer added to their classic image.

[*evolution of machines and interfaces*]

[fig.17] Sea creatures, Photograph by Adrian Donoghue, A mob of athletes entering the see forming patterns of queue and movement

1.3.3. Feedback response

Feedback systems are systems that their response in time *t+1* is a result of their response at the time *t*. There are two types of positive and negative feedbacks that trigger a behaviour in the system. In the feedback system the feedback parameter conduct the system to reach to an equilibrium.

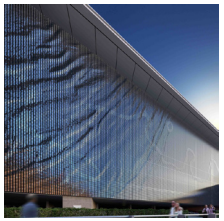
Normally, feedback systems are composed of a community of actors (living or nonliving) actors that have certain physical characters and interaction logic. We call the logic that actors or agents work upon as the rules. These rules in the agent scale result in a social intelligent behaviour which is called swarm.

For example in an ant society each male ant uses the pheromone smell to follow a track that leads to a food source. It also marks the ground with a pheromone that is distributed from its body. Initially the worker ants go out of the store to have a random walk for searching a food source. As soon as one finds a food source it takes back to the store and enhance his pheromone mark in his track. The other ants will use the same pheromone track to reach to the food source so the pheromone mark is intensified, this positive feedback continues until the food source is finished.

Social swarms comes from the micro rules respected by the agents in the system (society in case of living agents). This not only happens in a living system, but can happen in a totally deterministic system, such as shaping the sand dunes or the hills and rivers. If we look at nature most of the shapes and patterns are due to the feedback and feed forward forces in the level of action of the agents.

Feedback process also exists in human society, formation of queue and crowds and tracking patterns are due to the humans intrinsic acts and decisions. In [fig.15] we see people following each in a triathlon match make a pattern, the average distance of the actors, their time of action and the whole queue formation follows the patterns.

[swarm comes out of rules among actors]



[fig.18] Ned Kahn, facade for a parking in Winthertour. The small movable panels are deplaced by the force of wind showing movement patterns

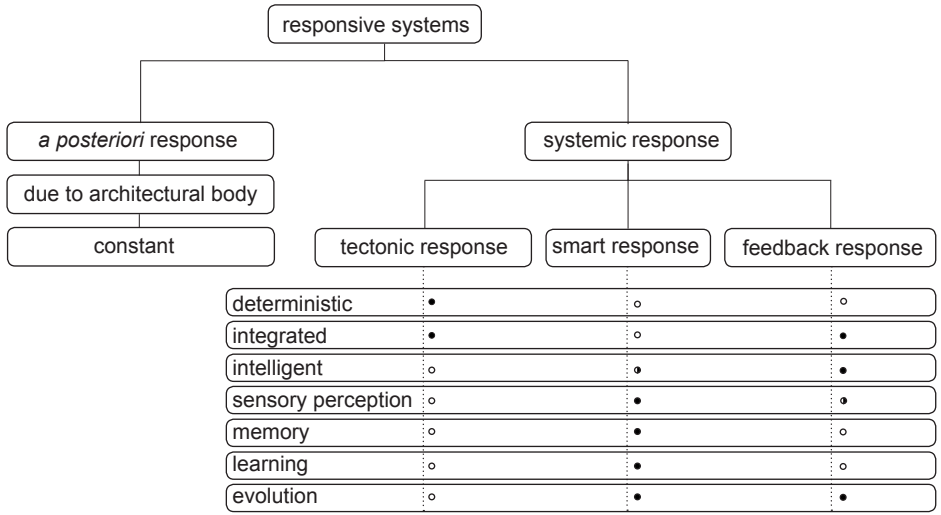
1.4. Summery

Systemic response leads to change in the internal organization of the system to adapt to the external stimuli. This can be a result of the physical properties and the structural organization of the system, a result of the intelligence of the system, or in the third hand the result of the rules affecting the interaction of the agents in a feedback system. [Schema.3] compares different kinds of response system trying to show their different characteristics.

Responsiveness in architectural space in the current state is mainly restricted to tectonic response. It is because of the rigidity and staticness that the architectural elements carry. The structure of a building could hardly be subject to a change, so that all the conception of response should be integrated in the architectural body. Tectonic response is deterministic what is close to tectonics of architecture. While architecture is using low tech materials and structure tectonic response would stay the major response system that affects spatial qualities.

The integration of smart response systems into architectural space is not a far idea. Architecture 2.0 is a field to work on possible spaces that change their interior metrcis according to th information they gain from the users. This conception need a change in the infrastructure of cities and architecture and requires integration of the smart systems inside the building elements. This conception can dramatically change the usability of the buildings and life how ever it might less have influence on the physicality of the buildings.

The feedback response is a notion harder to be utilised in actual architectural bodies. It is because of the current state of tectonics and materiality of the built environment. Built environment is not composed of dynamic agents. This notion stays further for a period that architecture could be able to approach organic structures like trees. Architecture should be composed of structural and specialized cells that act in micro scale and change the qualities in the macro scale.



[schema.3] Comparison of different response systems

[*actual architecture searchs for tectonic response*]

For the near future this notion could be applied in the elements of architecture that could be reduced to small acting elements like facades cells. For instance in [fig.18] in Ned Kahn's work we see feedback patterns because of the direct touch of the wind waves on the facade which has solely a visual effect. This project shows that for using feedback response in the architectural spaces a series of micro structures contacting each other is needed.

1.5. Conclusion

With actual state of architecture and in the scope of the interest of this thesis proposition for a climate (particularly light) and human response system in architecture could be attained by choosing a tectonic response.

Using the tectonic response means to see all the possible situation of the building during its life and designing it at a certain time to respond to all these possible situations. While the building is not dynamic and can not change its respond it should have a good average respond to all these changing situations. By choosing tectonic response approach building is seen as a deterministic tool. It would have predictable and none intelligent behaviour over the constant inputs. this is a turn to the idea of *house is a machine for living*.

Tectonic response is integrated in the form. It means the response of light and human behaviour should be previewed and integrated before the building is formed. One strategy is to define the form of the building by mapping of factors in consideration during the life of the building, and propose a form that has the best performance during the change of these factors. It means the building should have an average good response for changing different environmental factors.

1.5.1. light response

There are two important factors for this project, light and human behaviour. Environmental information about the light for a defined location in the city are two types according to their longevity:

1. Major constant parameters such as radiation angel and amount of radiation, duration of radiation in each day. The shadow-making and reflection of the adjacent buildings

2. Minor local and temporary changes, such as changes in solar radiation for cloudy days.

The first type of light statistics would be the main basis for this project because the minor local change cannot be overseen in the constant tectonics level. The response system in search should be tectonic (passively) responsive to the changes in the climatic factors. And It should be integrated into the building concept in order to function without human's control and maintenance.

1.5.2. Human response

The main challenge would be to affect the human response factor on the building's formation, this challenge is because that a part of the human behaviour information in the building is not constant and predictable, how ever the behaviour in the urban space tends to be more regulated and is possible to be mapped and then integrated into architectural decisions.

In this thesis we will focus on light those types of human behaviour information that could be mapped in the city space and could affect the spatial formation of architecture.

In next chapter we will look more in depth into the light characteristics and metric. doing two study of the relations of light and space and human behaviour we try to propose a light and human tectonic response system.

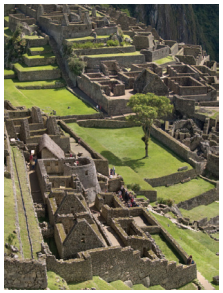
[***tectonic response is based on constant forces***]

[fig.1] Next page: Running, jumping, standing still, photograph by Adrian Donoghue.

2

Light and Space
Light as a formgiver for architecture

Light has been acting as a formgiver to architecture during the past. This has affected the orientation and development of the cities and the buildings. It has lead to creation of elements to provide better lighting.
In todays practice, day lighting stays one of the important factors of interior comfort. An elaborated system of metrics is developed and are used in design process, however the question of how to influence the lighting metrics in initial stages of designs stays open and is related to the experience of architects.



[fig.2] Intihuatana, the temple of the sun dedicated to the god of sun. In the holy district of the city of Machu Picchu

2.1. Light as a Formgiver: Spiritual

The physics of light was not known before the twentieth century however it used to play an important factor in human beliefs. Light was a holy element in the middle eastern religions. In Mithraism an Indo-Aryan belief sun is the second divine force of the world which was worshiped by mankind. The beliefs in Light has gone further than spiritual forces there are the examples that light played as a factor to affect the town planing and the architecture of the city. For instance in ancient Egypt, the Pharaonic city of Lunu, referred to by the Greeks as Heliopolis or 'the city of the sun, ' represented the geographical centre of the sun cult.

Located on the east bank of the Nile in Thebes, Egypt, Karnak is known as the solstice solar temple. Many of its features were built along an east–west axis that acknowledged the movement of the sun and a north–south line that mirrored ancient Egypt's geographic shape and the course of the Nile. In addition, Karnak had special alignments that corresponded to the summer and winter solstices. The winter solstice sunrise appears in the east in the archway of the axis of Karnak celebrating the sun god Ra through its majestic pillars.

Boubekri, M., Day lighting , Architecture and Health, 2008, page 15

Machu Picchu [fig.3] a pre Colombian 15th century city in Peru at 2430 m above sea level has its walls primarily facing east and south to capture and store the heat. Because wood and combustible fuels were difficult to obtain at high altitudes, they were replaced by passive solar heating. Located in the sacred and primary zone of the city of Machu Picchu, the Temple of the Sun [fig.2], known as the Intihuatana, was dedicated to the most revered and greatest deity, the sun god.

In this era the influence of light on the human life and production stays under a sense of spiritualty. And light itself has a sacred image. The interesting fact is that this sometimes this spiritual drive leads to a functional benefice of light or a an aesthetical quality.

[fig.3] Machu Picchu, building's walls are oriented to east and south to capture and store the heat

[light as a divine force affect the built environment]

[fig.4] Next page: the master plan for the radiant city

2.2. Light as a Formgiver: Functional

In the modern times light, along with its desacrification, plays a functional role in architecture. In this epoque light is important functionally for two aspects comfort and aesthetics. Comfort is the necessity of sufficient light for the activities done in the interior space. Aesthetics is the usage of light as an ambiance maker to releasse an spatial quality.

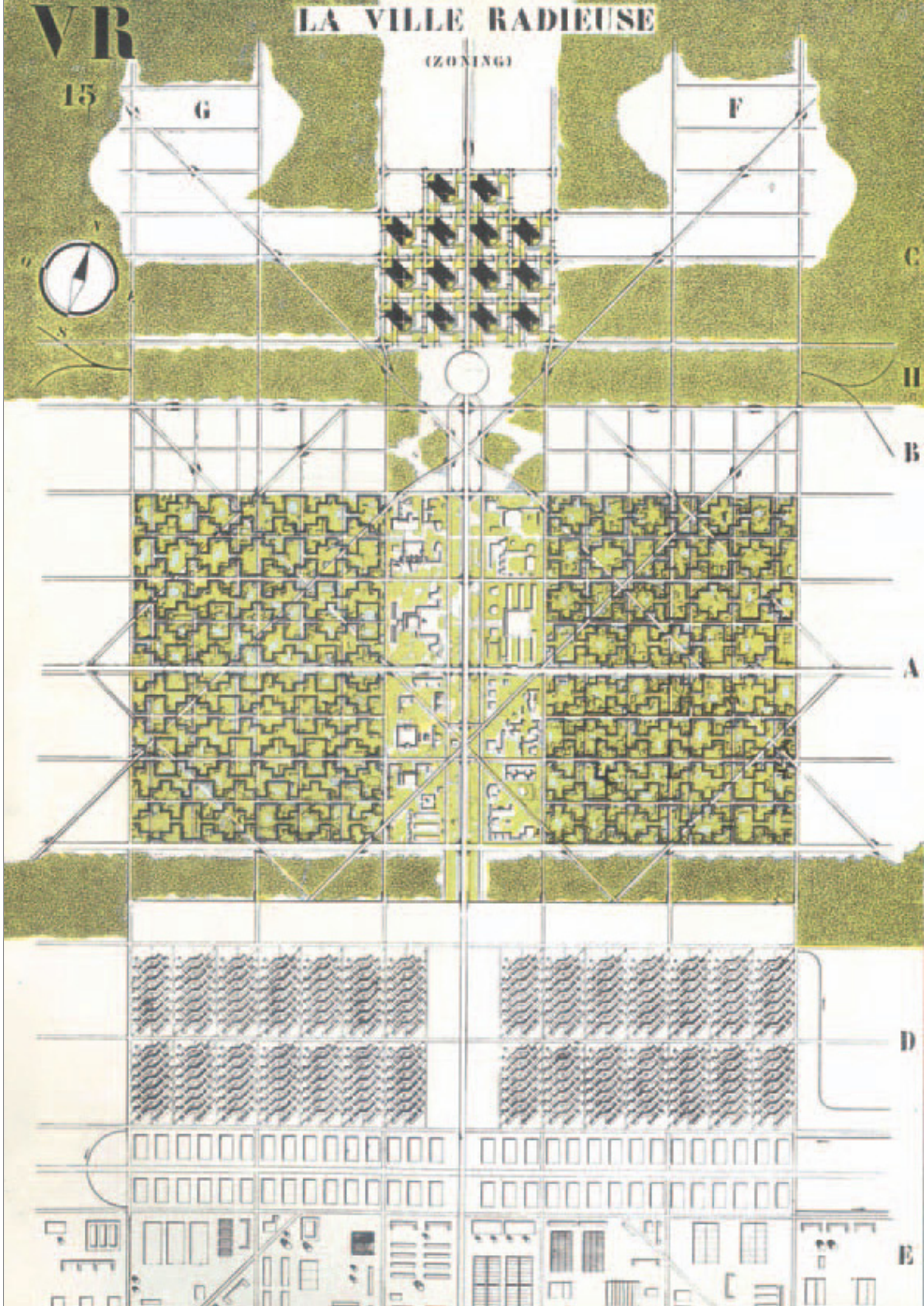
[the return of light and green to the modern city]

The natural light with fresh air and greenery is one of the main issues in urban theories of early 20th century namely, works of Ebenezer Howard: *Garden city* and Le Corbusier: *La Ville Radieuse*.

Master plan of La Ville Radieuse [fig.3] proposed on 1922. is a utopian city for a population of three million that would increase the urban capacity and at the same time improve the urban environment and the efficiency of the city. It is divided into functional zones: twenty four glass towers in the centre [fig.4] would form the commercial district, separated from the industrial and residential districts by expansive green belts with immeuble-villas with access to green space and sunlight.

Sunlight is the major factor to form the spaces of this city, the distribution and shape and distance of the skyscrapers , exposure on their facade .

[fig.5] The radiant city, Le Corbusier,1922



2.3. Spatial Qualities of Light

Far from the functional approach to provide a relevant lighting, light can have several and special spatial qualities which enhance the architectural value of the space. Here we try to highlight some of these qualities in different examples.

2.3.1. Temporality

Voila, Bill, Catherine's Room, 2001

Natural light shows the pass of the time in the space. The installation of Bill Viola [fig.8] shows a room with different lighting in different times of the day. We see how the natural light gives the sense of the season and the day time inside the space, natural light can decorate the space to trigger certain moods and activities.

Natural light, lets an space be seen in different moments. On the contrary, the artificial light which is constant and purposefully planned, decorates an space symbolically and augment the fantasy inside the space.

In this installation we can also observe that the same space with the same dimensions release different sensations under different types of lighting. Candle light gives an spiritual character to the space while the pointed and directional light diffused from desk lamp increase the formality of space and make it seem like and office. Spatial quality of space can be dramatically touched by different lighting in the space.

2.3.2. Monumentality

In Euro Sarinan's monument at MIT chapel [fig.9], What gives existence to the monument is playing with the reflections of light on the surfaces. This effect is due to the lighting of differently positioned surfaces which leads us to see a gradient in the black background. Without proper lighting this gradient would not exist and the monument will disappear and somehow it loses its physicality. So that here light is a tool to release a quality that represents a volume.
Light In this monument is constant. What is changing is the positioning of the reflective objects. And this harmonious rotation produces the effect of gradient.

2.3.3. Nomadic

In Tadao ando's church [fig.10] the intention is to highlight the shape of a symbolic object (a cross) in the space. It is not only direct representation of the symbol but also a delicate mean to light the space. The light here sculpts the empty space. The cross doesn't exist by itself but this is the empty space that gives a presence to the cross with the natural light.

2.3.4. Thickness

In Le Cobusier's Ronchamp, the light accentuates the thickness, the contrast between mass and voids is accentuated with the enter of the light in the interior space.

Far from the physical approach light can goes further in releasing spatial qualities. The effort to parameters the light and setting standard lighting regulations can help to increase the comfort and the usability of the space but releasing additional spatial qualities is rather an aesthetical process which stays in the hands of architects experience.

• ornament

[fig.6] Gothic church ornamentation, aesthetical and representational

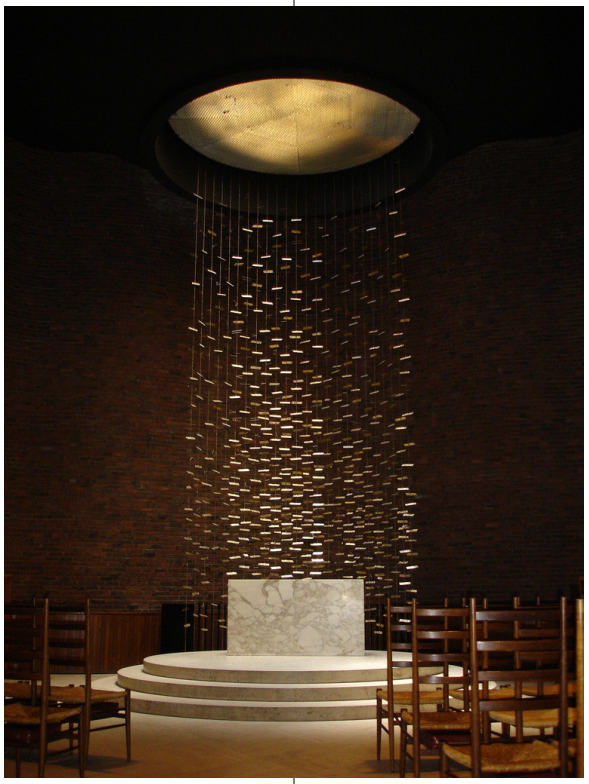
• centrality

[fig.7] Pantheon, the light of the top of the dome illuminates the space and defines a centrality.

• temporality

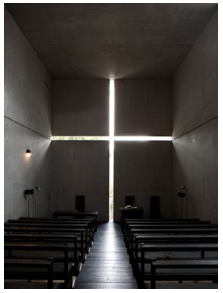
[fig.8] Catherine rooms, Bill Viola installation, five spaces in 5 times with different types of lighting decorate the rooms differently and increases a sense of temporality

• monumental



[fig.9] The monument of light, Euro Sarinen, the opacity is made by turning the position of the reflecting small pieces of metal

• nomadic



[fig.10] Church of light, Tadao Ando, representing symbolic shape of a cross

• translucent

[fig.11] Maisson de verre, Piere Chareu, one of the first usages of translucent light in interior space in the modern era, the diffusion of light through the parcels of the window elevates the quality of interior space.

• thikness

[fig.12] Ronchamp,Le Corbusier, light accentuates the thickness of the wall

[*spatial qualities of light*]

2.4. Physics of Light

Light is an electromagnetic wave that is perceptible by human's eye's retina. Light is known by the frequency of the alternating electromagnetic fields. The Visible light has wavelength from 380 manometers to 740 manometers.[fig.5] This range is a tiny part of the whole electromagnetic waves. Other electromagnetic waves have a wide range of usage such as radio telecommunication, cooking, heating the spaces and night vision.

The factors that create the interior light ambiance are distribution and quantity of illumination, glare, light direction, light colour and colour rendering. Here we discuss the factors that could give a clue to design a light-human response engine.

Hausladen, Gerhard, Climate Design, solutions for buildings, 2005

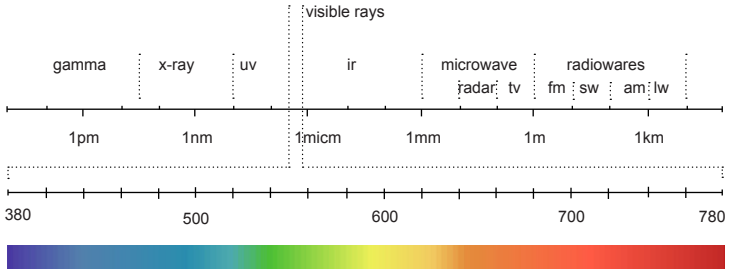
Luminous Flux: Luminous flux is the amount of light radiated by a light source.(unit: lumen)

Illuminance: Illuminance is the amount of luminous flux fallen on a surface. (unit: lumen/m2 or lux) . The regulation set certain limits for level of illuminance, for instance:
Filing rooms 200 lx,Circulation zones 200 lx
Workplaces 500 lx, Technical drawing room 750 lx

Luminance: Luminance is the amount of the light propagated of the surface. It is therefore related to the reflectance of a surface and is the main factor for the impression of brightness of an object.

Glare: Glare is caused by elevated brightness in the viewing field it can cause discomfort or disability glare.

Reflectance: A coefficient related to the material that indicates the percentage of the light that the material reflects. There are some limits in regulation for selection of the materials in interior space. Reflectance for some materials are:
Aluminium 80-85, rough concrete 20-30
Stainless steel: 50-60, Granite: 20-25



[fig.13] The proportion of visible wave to other electromagnetic waves

[*visibility is a result of a set of light metrics*]

2.5. Light and Users

Lighting metrics, not independently can define the relevant quality of lighting in the space. For example the illumination level is only one of the many factors that determine how well we see in the space. What we sense as brightness is connected to the illuminance level and the ambient contrast at the same time. It is possible that an environment with a higher illuminance and less ambient contrast seem to be less bright in the eyes of the user.

Hausladen, Gerhard , Climate Design, solutions for buildings, 2005

Each viewer and each space have specific information needs, and each object and task have specific requisites. The sense of visibility for a certain user is related to focus, distraction, and the context he is looking at. Increasing visibility by brute strength (illumination) rather than room dimensions is wasteful and may produce bad side effects such as glare.

Lam, William, Sunlighting as formgiver for architecture, 1985

In summery we should say that it is possible to set up metrics for defining the minimums of sufficient lighting but the final quality of experience stays related to the user and what he does.

2.6. Daylighting Factor

The sensations that accompany good lighting include excitement, alertness, and dominance. In contrast, poor lighting results in dullness, boredom, and submissiveness. These affective states in turn increase the quality of the social behavioural response of the occupants of the room and the decision making in a workplace environment. These investigation motivates to influence the lighting levels as an important factor in building design, so that there should be metrics related to architectural spaces to foresee the effects of decisions about the space geometry on the final lighting quality.

For measuring the lighting situation in relation to architecture of the interior space there are certain metrics defined by the lighting institutions (such as IESNA[1]) .One of the metrics that is widely used is *Day lighting factor* (DF). DF is the ratio of the illumination of the interior to the illumination of the exterior. Majority of standard codes propose a DF factor of minimum 5% for the spaces supposed to be lighted with natural light during the day and 2% for those spaces that are supposed to be lighted with the help of the artificial lighting fixtures during the day.

Reinhart, A rules of thumb-based design sequence for diffuse daylight, 2009

DF could be estimated based on the rules of thumbs. The most current rule of thumb to predict the day lighting factor of an interior space is the Lynes Formula proposed on 1979 [formula.1] which proposes the DF as a function of the glazing surface, overall interior surface, the sky angle, the glazing transmittance, and the average reflectance of the interior materials. According to an study done by Reinhart (2009) the Lynes formula shows a reliable correlation with the experimental measurements of DF, however there are substantial simplifications in this formula:

$$DF = \frac{A_{glazing}\,\tau_{vis}\,\theta}{A_{total} 2(1 - R_{mean})}$$

[formula.1] A on top is the area of glazing, τ is the transmittance of the glazing, theta is the sky angle and the mean R is the weighed average of the reflectance of the interior material

1. The DF which is calculated by Lynes's formula is considered for the spaces lighted under the only the overcast sky which is not the permanent condition.

1 Illuminance Engineering Society of North America

2. The effect of local climatic condition doesn't show up in the Lynes such as geometrical longitude and latitude.

Climate-based daylight modelling(CBDM) methods are those try to avoid these simplifications. CBDMs are based on sky and sun light and annual radiation data sets related to the geographical location of the study. These data are hourly information taken from climate stations located in each city. A set of simulation softwares are produced based on CBDM to calculate lighting metrics more precise and visualize them such as Radiance, Diva and Light Solve .

For making decision concerning light metrics these simulations help simulating space in its actual state. In next section we see what are the decisions in design process that can be affected by lighting metrics. This help us to go further for proposition of our light responsive system.

[daylighting factor is an approximative formula for measuring interior light comfort level]

2.8. Light Related Decisions in Design Process

In order to design a light responsive engine, we first take a look at what are the factors that are involved in decision making of the architects in their design process.

Decisions that affects the quality of light in the spaces are distributed along the whole process of design they are diverse according to the level of design and the scale of design [schema.1]. Advancing in the process of design, the decisions are more detailed and targeting small scales.

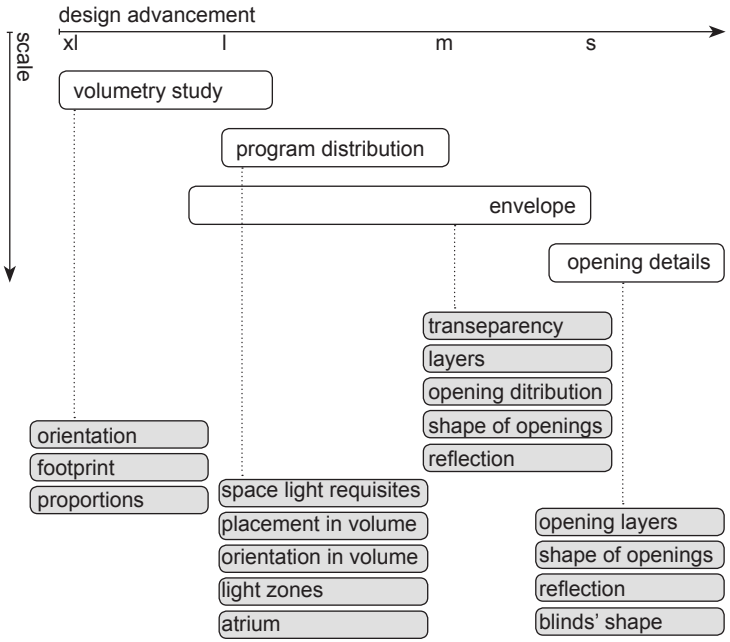
In volumetry study, decisions about the placement, orientation and proportion of the facades are very crucial. This studies is aimed to avoid the building to be placed in over shadowed spaces specially when it is located in a dense and high-rise neighbourhood.

While deciding about the program distribution choices about the locating the spaces and shaping different zones become important. In this level each space's lighting requisites should be measured. For example in a hospital the support and service spaces don't require natural lighting how ever the patient rooms need a relevant level of lighting preferably direct. Lighting conception of building, such as major lighting zones in the building normally would be decided in this phase. Placement of an atrium and the light collectors.

In envelope design, transparency and shading and filtering layers are the major concerns. Envelope is the element that controls the level and quality of light entering the interior space.

Finally in opening design the division of the openings would control the flow of light and its directness. Blinds are the elements that would give user the ability to change the interior lighting quality.

These comprehensive procedure of decision making affects the exposed area to light, flux and diffusion of the light



[schema.1] Decisions related to lighting in the design process

[*light-concerned decisions affect form in different scales*]

inside the space. Heading for including decisions in a light response system in next chapter we will go through each steps according to the [schema.1] to find out design initiatives in each scale.

According to this design decisions could study light and its affect on built environment in four different scales:
extra large concerning light and urban space, large concerning light and the building mass, medium concerning light and the interior space and small concerning light and skin.

2.7. Summary

A scientific approach to understand the physics and the behaviour of the light in the space is very important to provide relevant level of comfort in the space for the users. However, light should not be simplified in physical models without considering all the diverse poetic meanings it has for human. As we went through some temporal, nomadic, symbolic, etc ,these factors that light adds to the architectural space do significantly change the value of the space.

Studying light with reductionistic approaches might not reveal all the reality about the spatial qualities of the light. Not always decomposing light into its elements and try then to integrate a light theory could describe holistic events. The positive fact about architectural mapping is we study light but its effect on the space and we try to project a grammar on the behaviour of light.

In the scope of interest of this thesis, natural light is studied by its spatial effects on the space and on human. Spatial effects here is what natural light cause like defining territories, divisions and sequences in the space. The spatial grammar of light is something directly related to architectural mass because every nuance on the quality of the light in the space is due to the shadow making of a physical object.

This approach might not be in the axial focus of scientists in general however it could be parallel working in the same direction of their objectives for increasing the interior comfort.

[spatial effects of light could be discovered through architectural mappings]

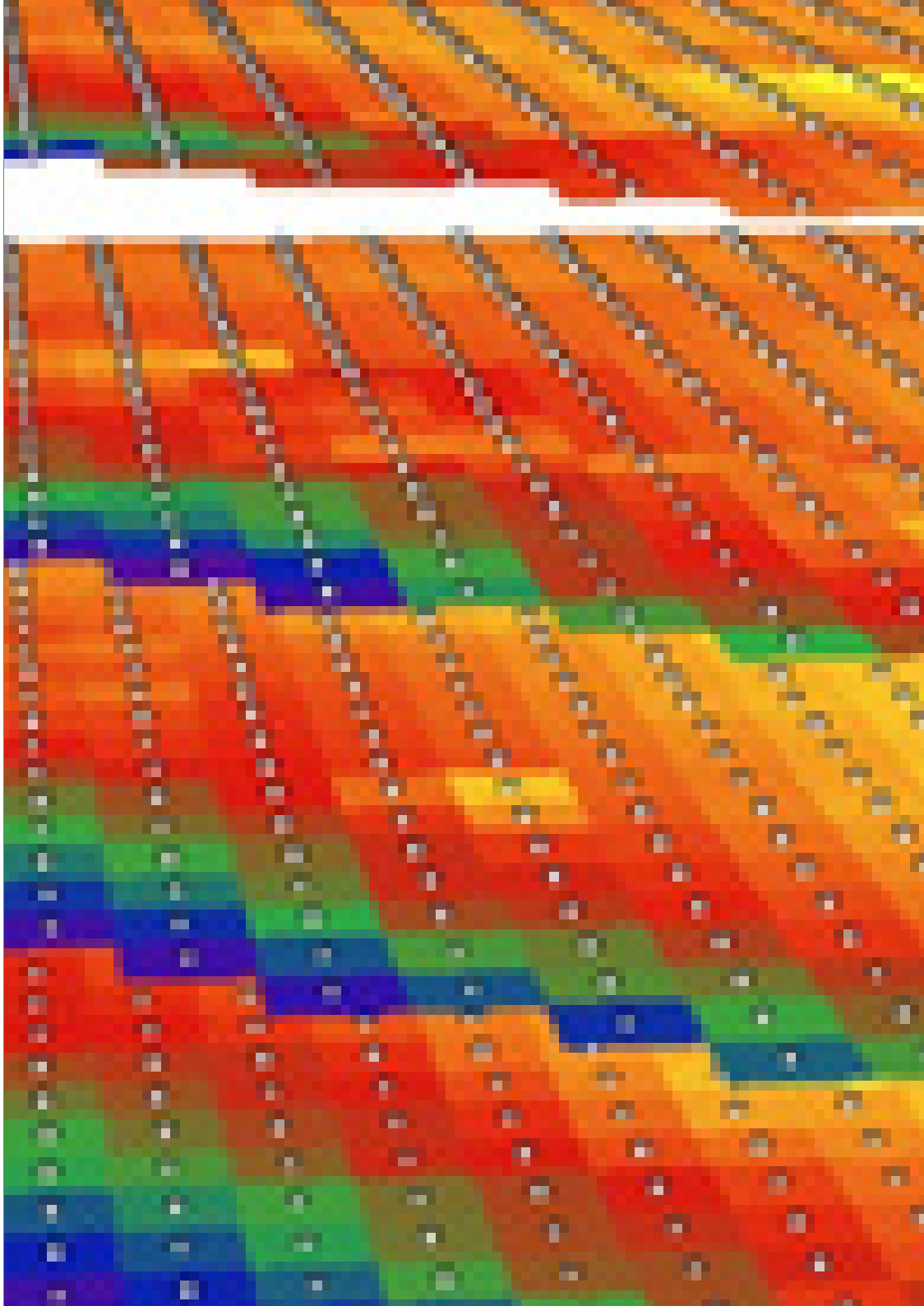
[fig.1] Next page: calculation of the radiation for points on level surfaces in the space, with Diva a light simulator plugin for Rhino

3

Light Mapping

Case Studies on Light in Urban and Interior Space

Light's effect on the built environment is related to the scale we are studying it. In the large scale, for example a public space light marks large territories while in the interior space light creates small scale light zones. Two case studies based on radiation mapping in this section surveys the effects of light in two scales, urban scale and interior scale.



3.1. Light Mapping Method

Radiation of the light on a piece of surface on the earth is not constant. It is related to the position of the sun, degree of the solar rays, the shadow-making obstacles around the surface and the climatic conditions.

In [fig.2] we see shadow-making obstacles have a changing area of shadow on a surface according to the time in the year (Longer in winter and vice versa in summer). If we superpose the effect of all the shadows caused by the neighbouring buildings during the year[1], we reach to a map called *radiation map* of the surface, which shows that amount of radiation that each point of a surface take during one year.[2]

This map is based on the solar radiation data for the selected geographical location. This map shows the cumulative radiation during the whole year. It is unique according to the geometry of the space.

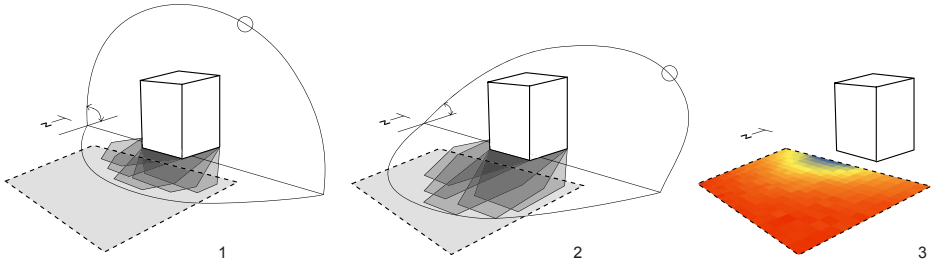
If we provide the radiation maps on the different surfaces with the different heights in a site we reach to a three dimensional scalar field that assigns the radiation value of each point to the position of that point in the space[fig.3]. We call this field as *radiation field(*)*.

×A scalar field assigns a value to each point of the space. Many physical properties form a scalar field such as temperature.

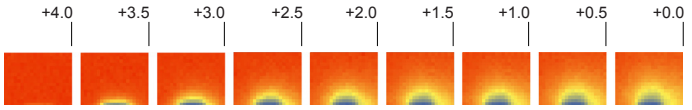
The three dimensional radiation field for a given architectural context represents different zones that can be a base for decision making in the large scale. It can be a source for decision in problems in urban master planing or building's volumetric study.

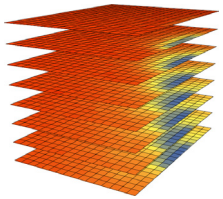
In an X-Large case study coming in the next section, we use 2 dimensional radiation map as a basis for doing urban mappings. We will use this map for observations on human behavior according to light maps. Later we use it in a system for land occupation initiatives and interventions in the urban public space based on the case study.

1 This model is simplified, we do not consider the climate change through different years. It means the calculations is based on radiation data during one year.
2 The method for calculating radiation of the points in a radiation map is described in Appendix 1



[fig.2] 1) summer 2) winter 3) the annual radiation map





[fig.3]Three dimensional light as an scalar radiation field

[mapping the light in the space indicates the existing immaterial territories]

3.2. X-Large Scale: Light and Urban Space

Role of the light in the urban scale is rather different than other large scale factors such as view, urban zones, transportation network, etc. For a site, most of the large scale urban factors are directly related to its position relative to the morphology of the city, however speaking about light only the shadow making masses around the site will affect the light gain for the site. In other words, light is a ubiquitous and constant urban force. Other than very large geographical changes light is only depended to the major climate condition which is related to the general geographical situation of the city.

Light in urban space is mixed with the urban tissue, the shadow making of building masses is the only factor that defines the radiation gain. As we saw in previous section in the light mapping method, radiation field for a chosen site is a unique result of the site's tissue.

Light and its interaction with the building mass produces immaterial territories in the urban space. Now the question is how these territories change the public space qualities and the experience in the urban space? Does this really have effects on the the users' pathway selection or purpose and longevity of urban promenades?

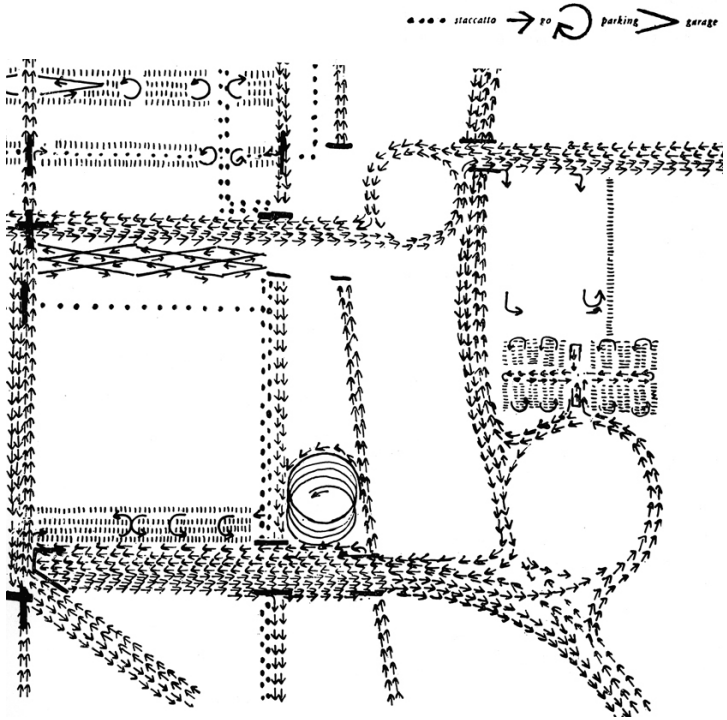
The answer to the above questions will reveal a reality about an existing field (force) in the urban scale. This field has many beneficial aspects, it can be used for decision makings about interventions or activity zones in the open space. It also can be used as a reliable base for being used in an engine valorizing the placement and orientation of the building blocks.

[fig.4] is a map of the transportation factors produced by Kahn to study Philadelphia's city centre. The series of arrows in this map, as he calls "*go*" in the legend, are indications of the *potential of movement* in each point. It means, where we see an arrow it shows where in which direction

the car can go and where there is no arrow there is not the potential of the movement. The arrow is not an existing materiality(car); it is a description what a car will do if it is placed in this point. This indication is close to the way physicists introduce the notion of electromagnetic fields in Physics. An electromagnetic field exists but it is shown when an electric charge is placed in the space.

The case study in the next section superposes the movement of the users and the radiation field to see what is the interaction of these two fields, how they affect each other and what is their effects on human's movements and decisions?

[*what is the interaction of radiation field and the urban flows?*]



[fig.4] Louis Kahn, A study for Philadelphia city centre, ideogram to study the movement of busses, trolleys and cars, 1963

3.3. Case Study : Mapping Light and Flow in the Public Space

In this case study we generate two dimensional light field for three selected public spaces in Geneva while mapping user activity in the sames spaces. The aim of this mapping study is primarily to observe the effect of light field on urban promenades; in parallel we look for indicating light sequences in public space. This will be done by superposing light field and activity maps on the city map.

3.3.1. Definitions

Light Field 
Light field is the annual solar radiation for points calculated on the basis of aggregation of the instantaneous radiations for each sensor point(described in the [appendix.1]).

Promenade 
The activity under observation are short normal urban promenades less than 0.5 kilometres with a purpose of going to work, shopping or traversing a park. It is on foot.

Light Zone
Parts of promenade with significantly different radiation level.

Light Sequence
The sequences of light zones that are experienced during a promenade.

3.3.2. Parameters

Flow 
Flow is a vector showing the average movement of a sample person in the urban space. In this mapping flow has a direction shown by an arrow and a velocity shown by the length of the arrow, bigger length for slower movements and vice versa. The flow vector is not for a single person. Refering to the map done by Kahn in previous section it is the description of the space in that certain point.

Wait 
It is staying in the urban space for different purposes in the intervals less than 2 minutes. For instance the activity during a wait event can be talking on the phone, making a choice, or short time sittings. The purpose of waiting can vary. Long waits such as eating, taking coffee or any other waits are not considered in this study.

Staccato 
It is the moment of attention to the other urban events, the augmented and conscious thinking about behaving in the space which can be due to the desicion to change the path or stop for a little moment.

Bifurcation of the Path 
It is a point at a promenade that a person should take a decision for choosing a passway, there are two types of the bifurcation points:
1. When two identical pass exists for one purpose
2. When the passes are not identical and the destination changes according to the choice
In this study we do not discriminate among different types of bifurcation, all type of bifurcations are considered equal.

Urban Barrier: 
Urban barriers are all nonmoving bodies in urban space that are bigger than human body. These include buildings, bridges that restrict human movement in one direction. Trees are not included.

3.3.3. Experiment

The flow mappings are based on in-situation observations during one day, morning and afternoon (Tuesday 13.12.2011) a average sunny day without rain and heavy wind. The flow map is produced by recording presence of flows and users in random time intervals during 3 hours for each sequence. Selected promenades are result of the recording of one sample user’s activity.

[fig.5] Next page: map of the city of Geneva. Next page bottom: three selected open spaces.

3.3.4. Selected Public Spaces:

Study is done in the city of Geneva. Three urban public spaces are selected which make a sequence from the central station to the Plainpalais connected with a strong circulation axis including two tramways and one bus line. This axis is one of the main connections of the north-Rhone Geneva to south-Rhone Geneva.

Main aspects for selection was distance to the centre and owning a special spatial quality. The Cornavin station square is a circulation area. The Saint Jean park has a character as a local park located in the middle of transportation axis. And PlainPalais is a giant urban void which is not proportional to the city, considering a normal sized public space.

Sequence 1: Cornavin a Circulation Area

The main city distribution node from the station. It is the point of singularity of the city transportation grid, the tramway network and bus lines. Considering users, it is the space of confrontation of very diverse types of users, the first-time visiting passengers and local population.

Sequence 2: Saint Jean Park a Local Park

The public space is exposed to the south, it is among two big urban edges, the railway and Rhone river. This blockage makes the public space to work as a local park and the district's respiration space. It is less dense and crowded and the urban promenades are not purposed for serious day job.

Sequence 3: Plainpalais an Urban Void

Lopez, Carlos, La ville aménage le Plainpalais pour la 2014, 2010

A giant urban void existing from the middle ages and have its current form 1662 after removal of the fortification of the city. It measures over 75,000 m².
The public space is over-scaled,so that not many purposeful promenades are taken through the space. Other than the edges people penetrate the square because of its space.

Study space 2: Parc de Saint Jean

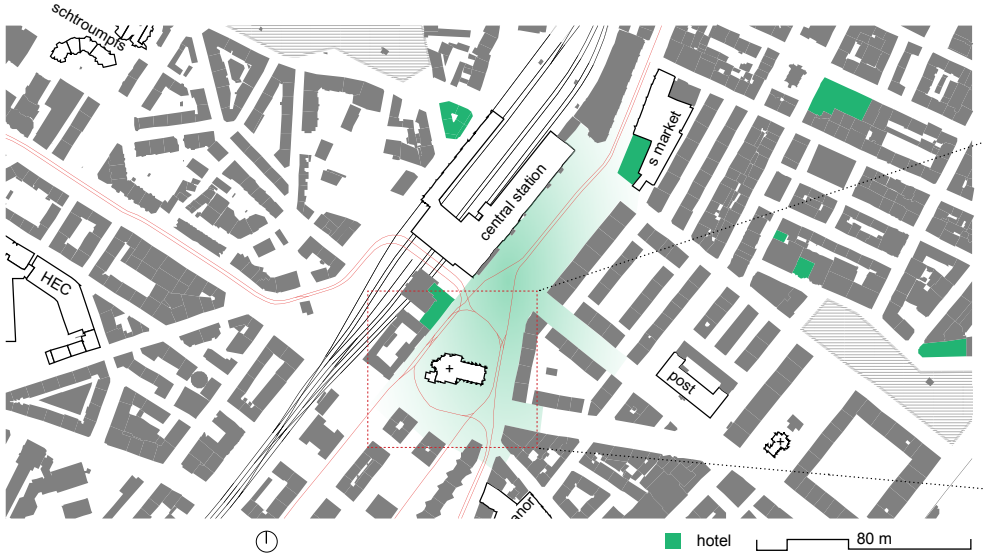
Major specifications:
- Between two edges: railway and the river
- Local park
- Low activity

Study space 3: Plainpalais

Major specifications:
- Giant urban void
- Over-scaled
- Surrounded by cultural spaces

Study space 1: Gare Cornavin

Major specifications:
- Surrounded by small scaled-retails and hotels
- High occupancy and activity
- One sided edge : railway



[fig.6] Above: Cornavin station

[fig.7] Next page: mapping analysis for Cornavin station, church side

3.3.5.1. Sequence 1 - Church side

Statistics

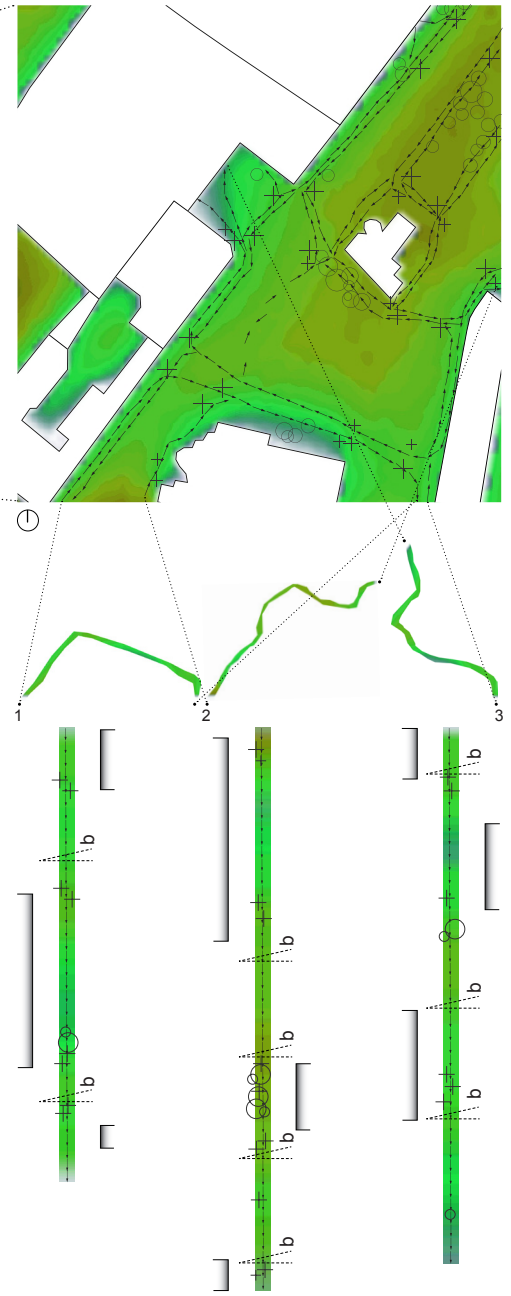
For three selected promenades the average light zone change is 5.33 times per promenade. According to the average distance which is 163 m. It has a high rate of light zone change.

Territories

There are two major waiting territory one close to the church site which is in a shadowed light zone, the other one is in the conjunction of different passes in the centre of the square.

Observations

1. Urban promenades are rather short and goal-oriented
2. High level of light zone change
3. Functional promenades, no extended promenade
4. High rate of staccato because of high crossing of the vehicle roots. It shows a low assurance in the public space.

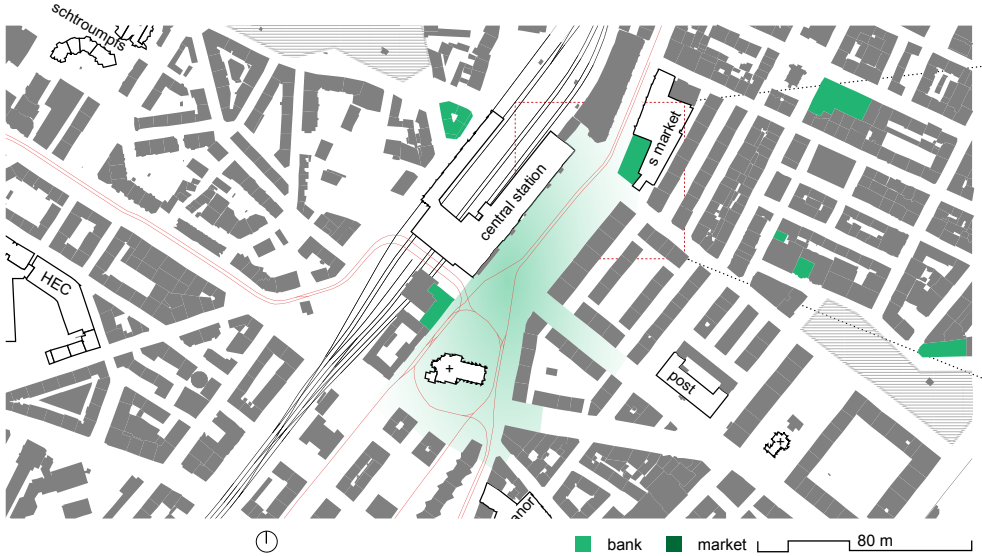


Light map
Flow
Wait
Staccato
Bifurcate
Barrier

1. Church traverse:
distance : 150 m
passing 4 light zones, 4 staccato, 2 bifurcations

2. Church to shopping area:
distance 174 m
passing 6 light zones, 6 staccato, 4 bifurcations

3. To bus station:
distance 166 m
passing 6 light zones, 3 staccato, 3 bifurcations



[fig.8] Above: Cornavin station

[fig.9] Next page: mapping analysis for Cornavin station, north side

3.3.5.2. Sequence 1 - North side

Statistics

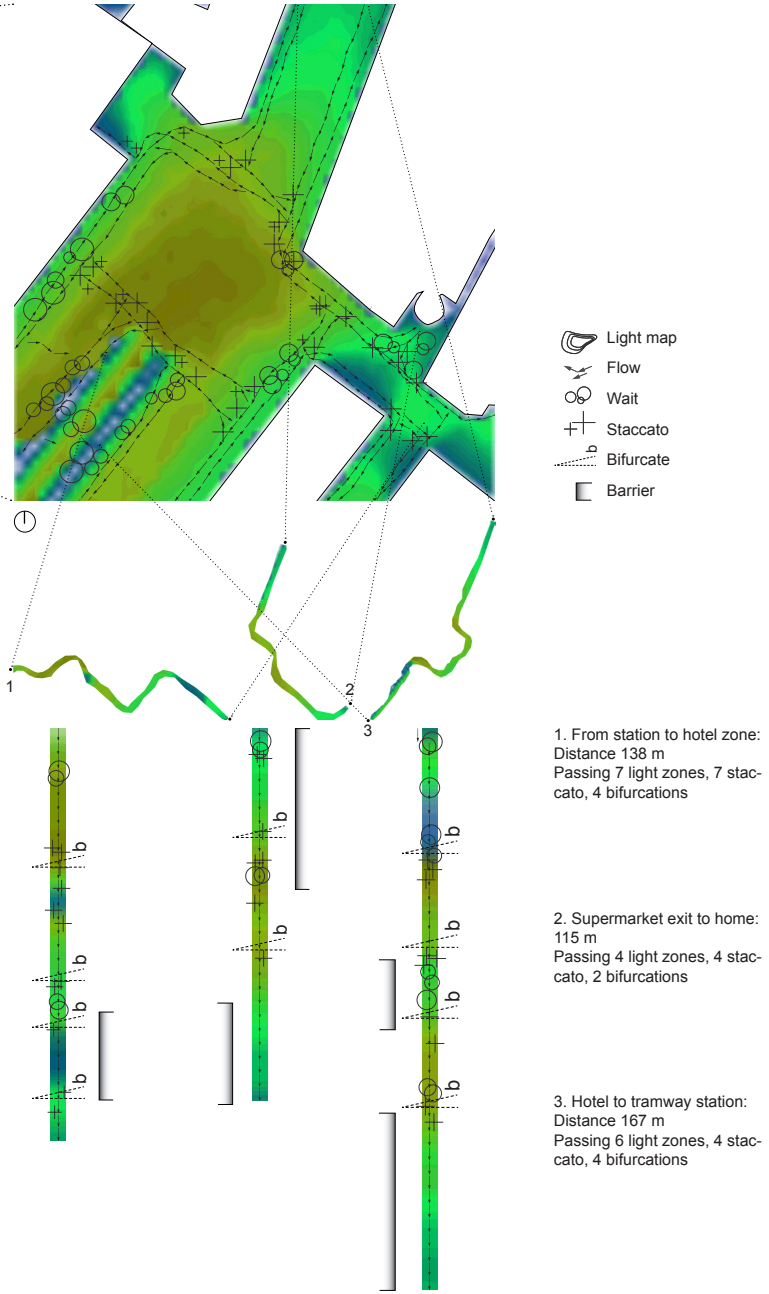
For three selected promenades the average light zone change is 5.66 times per promenade. Average distance for the promenades is 140 m which shows a very high rate for changes of light zones.

Territories

Waiting territories are placed near tramway station and the junctions. High radiation gain surface is not accessible for the walking users.

Observations

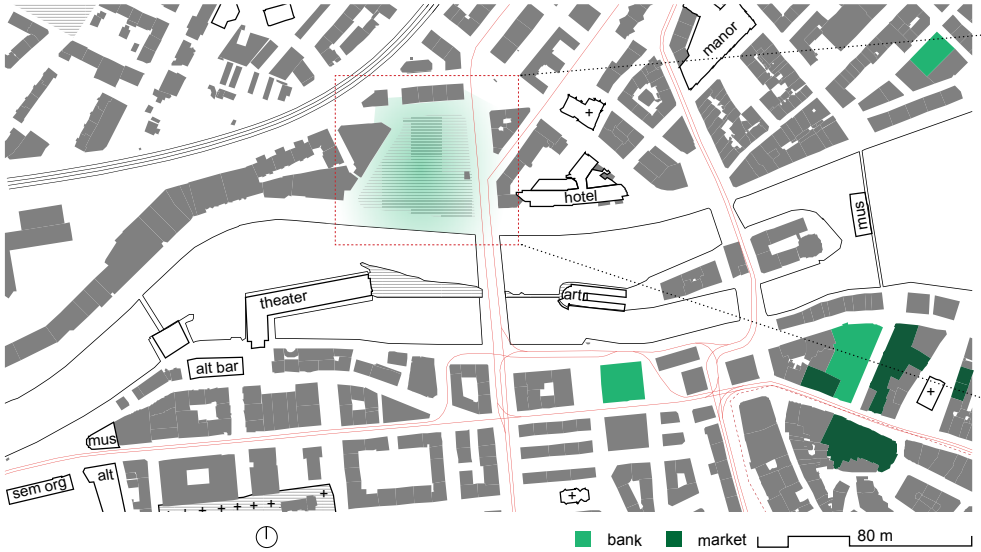
1. Urban promenades are rather short and goal-oriented
2. High level of light zone change
3. Short shopping promenades
4. Priority is not to traverse the square in bifurcation situations



1. From station to hotel zone:
Distance 138 m
Passing 7 light zones, 7 staccato, 4 bifurcations

2. Supermarket exit to home:
115 m
Passing 4 light zones, 4 staccato, 2 bifurcations

3. Hotel to tramway station:
Distance 167 m
Passing 6 light zones, 4 staccato, 4 bifurcations



[fig.10] Above: Saint Jean park

[fig.11] Next page: mapping analysis for Saint Jean park, north side

3.3.6.1. Sequence 2 - North side

Statistics

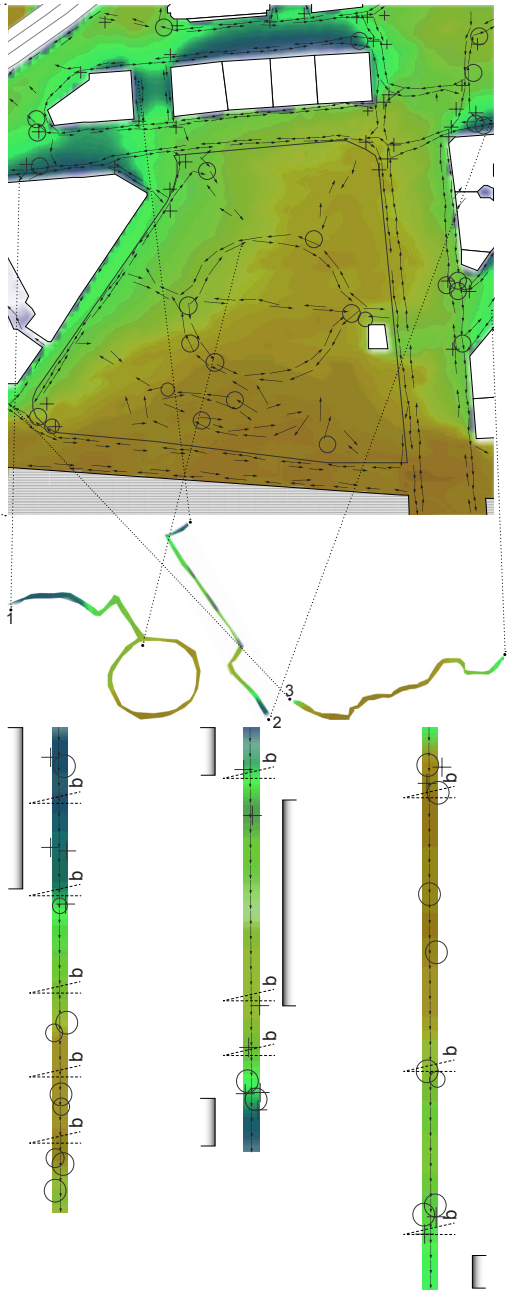
For three selected promenades the average light zone change is 4.33 times per promenade. Average distance for the promenades is 191 m which shows a low rate of light zone change.

Territories

Waiting territories are placed in the park and turning points. River edge has high radiation gain which is rather constant, no diverse quality.

Observations

1. Long promenades mainly for entertaining purposes
2. Low level of light zone change
3. Park promenades are rather popular
4. Park traverse is also rather popular

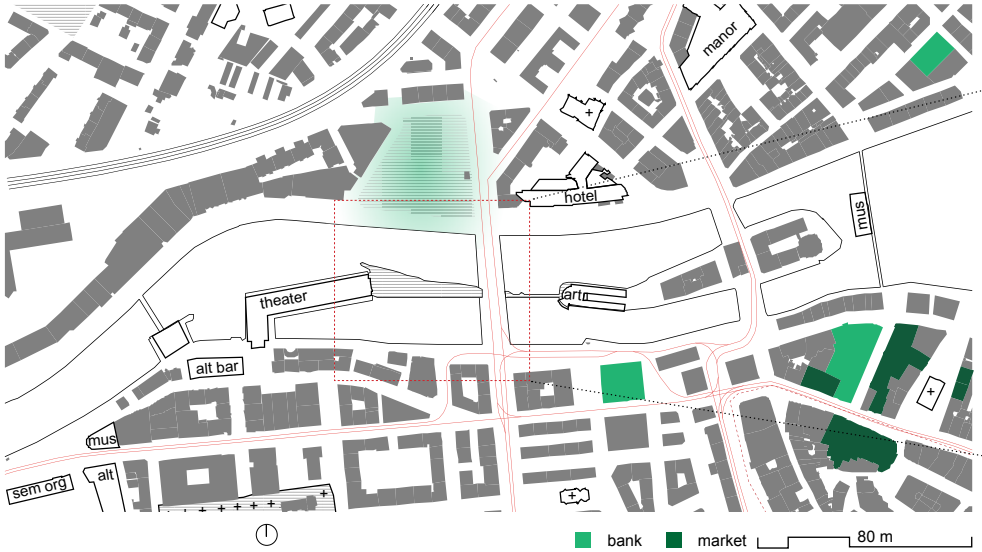


Light map
Flow
Wait
Staccato
Bifurcate
Barrier

1. Block traverse to park :
Distance: 203 m
Passing 5 light zones, 3 staccato, 5 bifurcations

2. Bus station to home:
Distance: 156 m
Passing 5 light zones, 4 staccato, 3 bifurcations

3. From school park traverse:
Distance: 214 m
Passing 3 light zones, 3 staccato, 3 bifurcations



[fig.12] Above: Saint Jean park

[fig.13] Next page: mapping analysis for Saint Jean park, south side

3.3.6.2. Sequence 1 - South side

Statistics

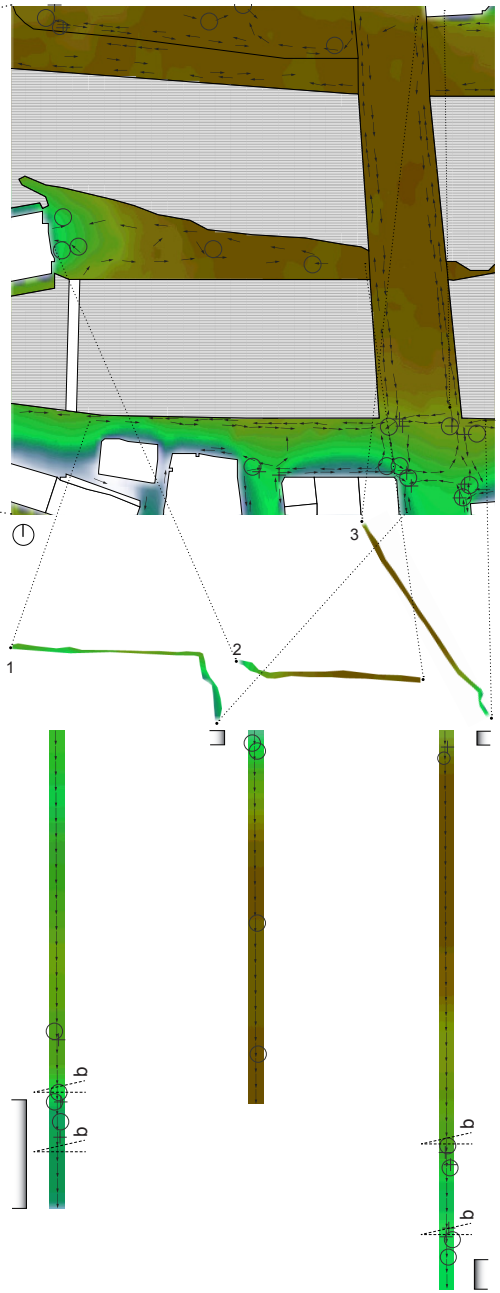
For three selected promenades the average light zone change is 2.66 times per promenade. Average distance for the promenades is 124 m which shows a low rate of light zone change.

Territories

Waiting territories are located at the turning points. Island promenade is staccato-free.

Observations

1. Urban promenades are not well defined
2. Low level of light zone change
4. Bridge traverse lacks diverse quality



Light map
Flow
Wait
Staccato
Bifurcate
Barrier

1. Park to shop:
Distance: 119 m
Passing 3 light zones, 2 staccato, 2 bifurcations

2. Island promenade
Distance: 110 m
passing 2 light zones, 0 staccato, 0 bifurcations

3. Bridge traverse
Distance: 143 m
Passing 3 light zones, 3 staccato, 2 bifurcations

[fig.14] Above: Plainpalais

[fig.15] Next page: mapping analysis for Plainpalais, north side

3.3.7.1. Sequence 1 - North side

Statistics

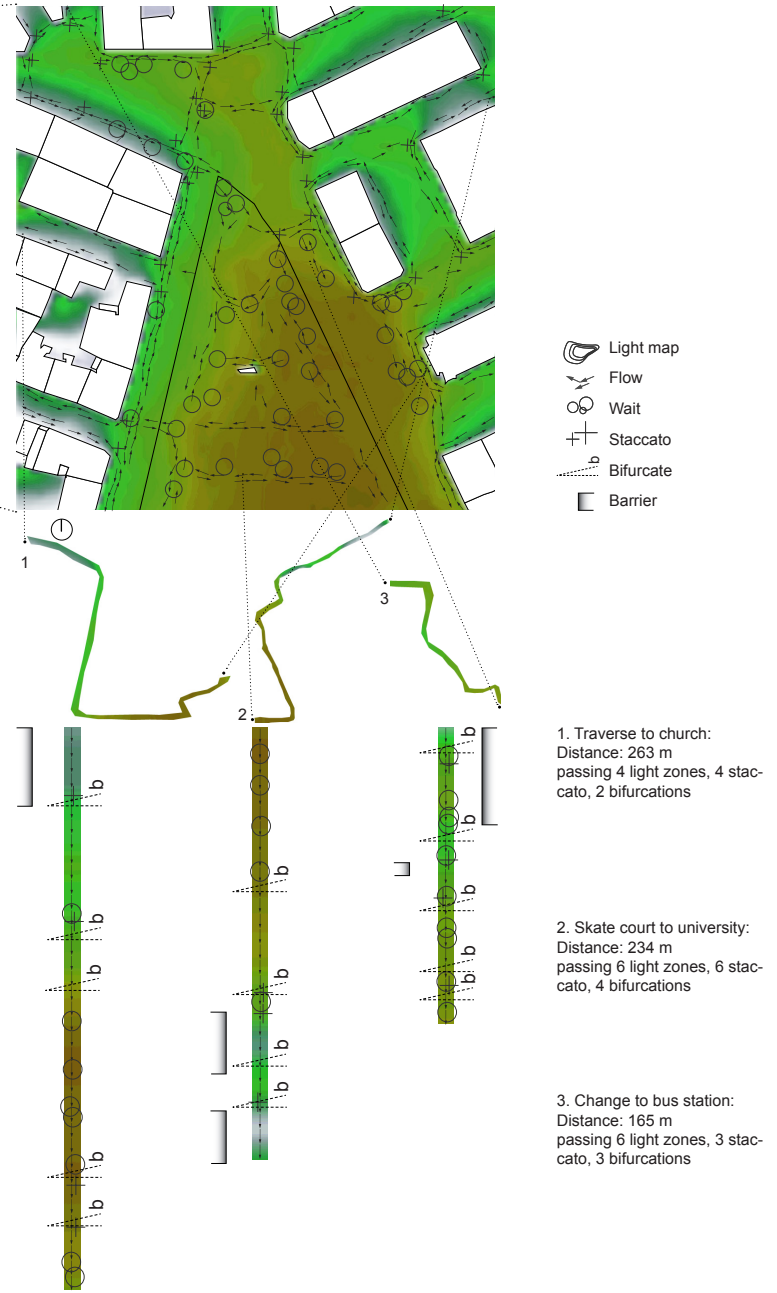
For three selected promenades the average light zone change is 5.66 times per promenade. Average distance for the promenades is 220 m which shows a normal rate of light zone change.

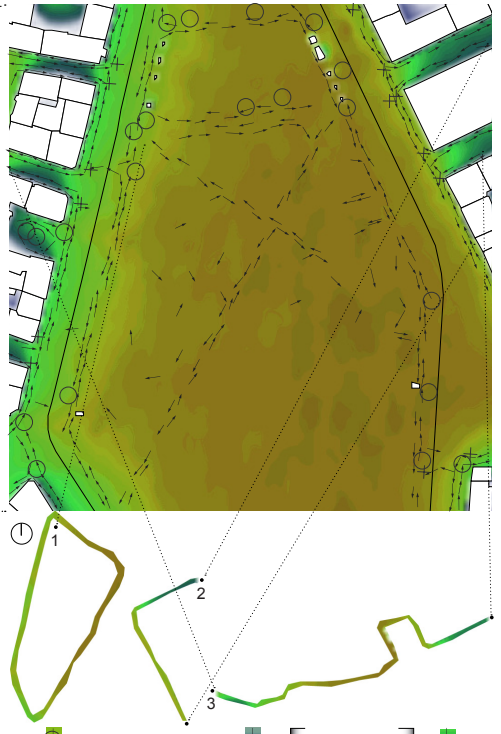
Territories

Waiting territories are placed in the Plainpalais itself and in big pedestrian walks around.

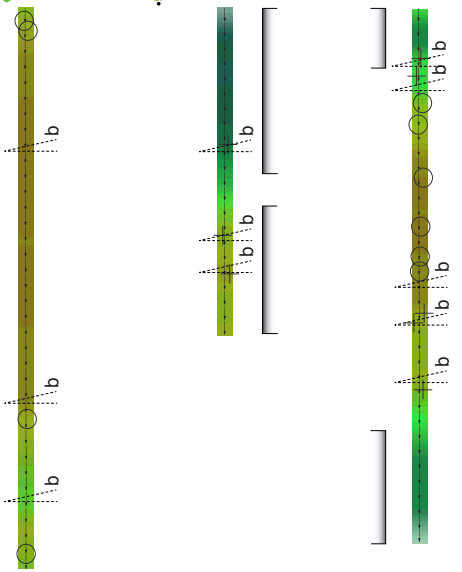
Observations

1. Urban promenades are long and aimed for changing transport mean
2. High radiation level in Plainpalais. It is not used largely
3. Park promenade are popular
4. Park traverse is not very popular because of the distance





Light map
Flow
Wait
Staccato
Bifurcate
Barrier



1. Plainpalais promenade:
Distance: 311 m
passing 4 light zones, 4 staccato, 2 bifurcations

2. Pass to tramway station:
Distance: 175 m
passing 6 light zones, 6 staccato, 4 bifurcations

3. Plainpalais traverse:
Distance: 276 m
passing 6 light zones, 3 staccato, 3 bifurcations

[fig.16] Above: Plainpalais

[fig.17] Next page: mapping analysis for Plainpalais, south side

3.3.7.2. Sequence 1 - South side

Statistics

For three selected promenades the average light zone change is 5.66 times per promenade. Average distance for the promenades is 254 m which shows a normal rate of light zone change.

Territories

Waiting territories are placed in Plainpalais Square with less distance from the siding streets (less depth).

Observations

1. Urban promenades are very long and purposed for entertaining activities. Circular promenades are possible
2. Low level of light zone change especially in Plainpalais
3. Long promenades are more possible to occur
4. Plainpalais traverse is not at all popular

3.3.8. Discussions

3.3.8.1. Overall Hypothesises

Below there is a list of hypothesises based on flow and light mappings. These results should be considered as being recorded of urban activities in one whole day and should be reinforced by further long period mappings and observations. The error can be reduced by random and several sampling in different climatic situations.

1. Wait events with high probability happen in the low radiation gain light zones.

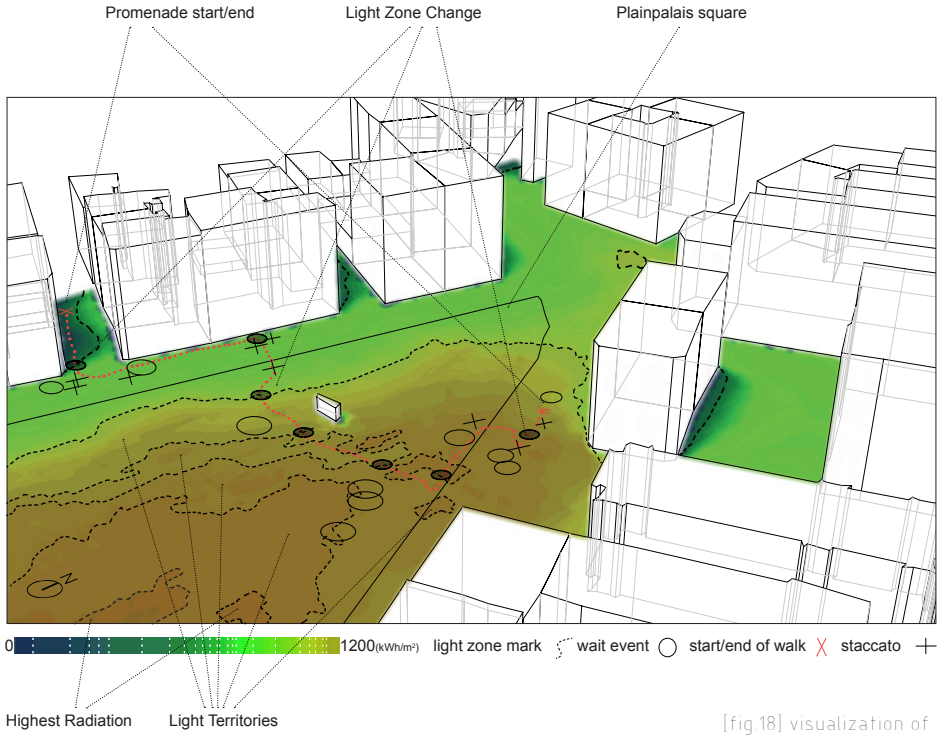
2. The bifurcation point map and light zone change are highly correlated. A high number of bifurcations superpose the places where there is a change in the light zone.

3. The bifurcation is more to be often occurred when users are going from a low radiation gain zone to a zone with higher radiation gain. The same bifurcation is less probable to occur going to the zones with less radiation. The effect of season on this hypothesis should be considered. It is predicted that, increase of urban flows in hotter days of the year, when the intention is to go to the less radiated zones, will affect the bifurcation pattern.

4. Long promenades with less changes in the light zones are showed to be less popular than long promenades with more change in the light zones.

3.3.8.2. Lighting Territories

Lighting territories are defined based on the *Uni-level-radiation* points in the urban space [fig18]. These territories may vary according to the urban morphology. They could be continuous or discrete based on the size and the height of the shadow making elements (buildings, canopies, etc.). They can be central or directional. The lighting sequence is created through passing through the lighting territories.



[fig.18] visualization of a Plainpalais traverse promenade to get to the bus stop. Passing through the lighting zones

3.3.8.3. Light Zone Change Distance

Referring to the [table.1] An average of 4.8 times *light zone change* for an average of 182 m long promenades shows one change in almost every 38 m. We name this factor which is defined as the ratio of average promenade distance to average light zone change as "*average light zone change distance (alzcd)".* According to [table.2] alzcd factor for three urban spaces (s1,s2,s3) are 28.7 m, 45 m ,44.5 m .

Cornavin square has the shortest alzcd. This can be justified by the high rate of bifurcations in the promenades in this square. Another reason can be the average block size which is rather smaller in Cornavin according to the two other spaces. Another reason is the promenade purposes.

[table.2] Average light zone change distance(alzcd) for the three studied urban spaces

	Cornavin	Saint Jean park	Plainpalais
Average promenade distance	151.7 m	157.5 m	237.3 m
Average Light zone change	5.5	3.5	5.3
Average light zone change distance	27.6 m	45 m	44.5 m

The promenades in Cornavin are very fast-paced and have transporting purposes.

Alzcd factors seems to be a relevant factor to be studied in different urban spaces. It is the unique result of the morphology and the physics of the urban space and it is meaningful in terms of representing the lighting diversity of the space. In addition it is a good tool to study the urban promenades.

This index is a function of the size and height of the buildings, purpose of presence of the people in the urban space and the interference with the transportation roots.

The high alzcd factor for Plainpalais could interpreted that this space has a less diverse spatial quality and it is not functioning as an active urban circulation space.

P-Space	Peromenade	Length	Light Zone	Staccato	Wait
S1 - Church	1. Church traverse	150	4	4	2
	2. Church to shopping area	174	6	6	4
	3. To bus station	166	6	3	3
S1 - North	1. From station to hotel zone	138	7	7	4
	2. Supermarket exit to home	115	4	4	2
	3. Hotel to tramway station	167	6	4	4
S2 - North	1. Block traverse to park	203	5	3	5
	2. Bus station to home	156	5	4	3
	3. From school park traverse	214	3	3	3
S2 - South	1. Park to shop	119	3	2	2
	2. Island promenade	110	2	0	0
	3. Bridge traverse	143	3	3	2
S3 - North	1. Traverse to church	263	4	4	2
	2. Skate court to university	234	6	6	4
	3. Change to bus station	165	6	3	3
S3 - South	1. Plainpalais promenade	311	4	4	2
	2. Pass to tramway station	175	6	6	4
	3. Plainpalais traverse	276	6	3	3
		182.17	4.78	3.83	2.89
			38.13	47.52	63.06

[table.1] Parameters' comparison for the sample promenades. Shows an average of 4.8 times of light zone change for an average of 182 meter-long promenades.

[average *light zone change distance is an indicator for lighting diversity of the urban space*]

[fig.19] Next page: Comparative graphs of light radiation change in relation to the distance passed in a promenade.

3.3.8.4. Light Sequence Graph

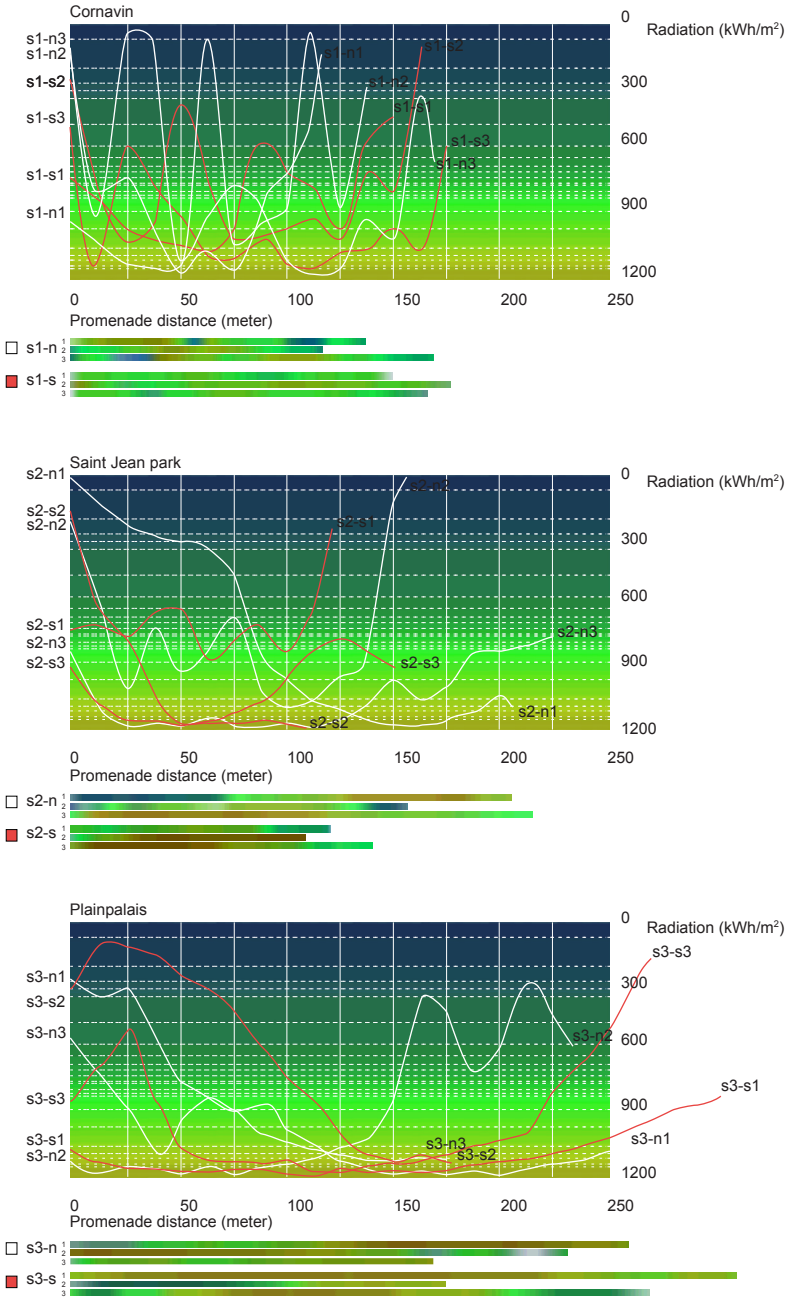
A good measure to compare the light zone radiation change in a promenade and the amount of its change is to map the promenades on a graph of distance and radiation. This graph as we call it the *light sequence graph* expresses the amount and the rate of the radiation change in each point of the promenade.

The x axis component is the distance passed on the promenade and the y axis component which is also represented by the background color shows the radiation level. The derivatives of the graph shows the *rate of radiation change* and the second derivative shows the rate of the rate of the light radiation change.

In comparing the next page graphs we observe: the high rate of radiation change in Cornavin station(s1), while in Saint Jean park (s2) and Plainpalais(s3) the changes are more moderate. High alternating rate of the graph of s1 also justifies the short alzcd factor that we talked about in previous section. It could be observed that in s3 the promenades in a long part pass through the high radiation level zones. The other observation is that promenades in the middle radiation zone levels (500-1000 kWh/m^2) are more alternating than promenades that are situated in the high radiation zones. In addition, promenades in the low radiation zones do not occur very much.

[light sequence graph represents the diversity and richness of urban promenades]

S1-n1 promenade which has a high alternating graph is related to the flow from the train station to the hotel area in the north side of Cornavin square. It could be said that this promenade which is very rich in light zone change happens for the new visitors to the city. Therefore, it is very probable that this rate of light zone change make visitors first impression of the city very special.



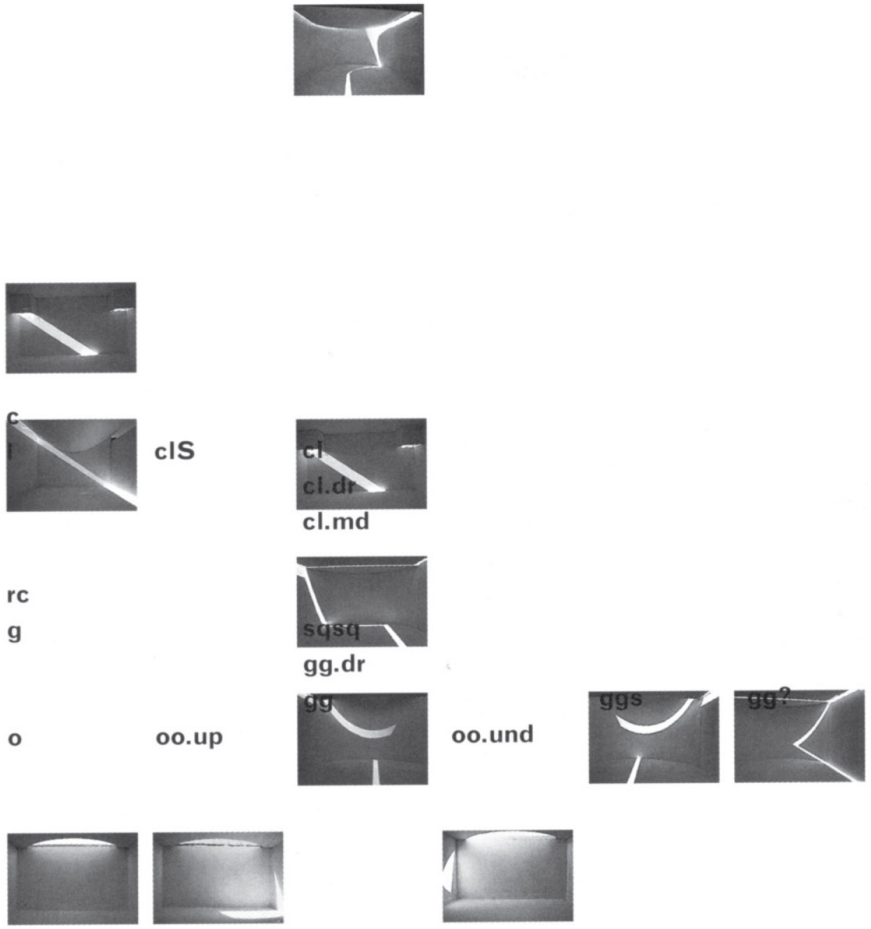
3.4. Medium Scale - Light and Interior space

Questions like: what are the relations of geometry and the lighting in the interior space? How light affects the zones of the interior space?, are discussed in the second case study.

Considering the building geometry, natural light in the interior space is distributed according to two major geometrical elements: the openings and the shadow-makers. It passes through the openings and it is reflected bouncing the bodies located in the interior (walls). Doing experiment with a simple geometry we will study what are the effects of the different formation of openings and interior walls on the lighting qualities of the geometry. Then we try to see how we can define a *lighting grammar* unique to this geometry. We will then go further to see if we can assign a lighting grammar to each generative geometry.

[fig.20] Steven Holl's lighting project

The study is mainly inspired by the Steven Holl's lighting project in which he studies different light making openings. He tries to take out different categories of light footprint such as curved, pointed and linear on a sample space based on changing the different openings exposed to light. This study is interesting because it aims for finding a language for interior lighting; The fact that openings could be generators of interior lighting in a way that the light propagates additional values and territories in the space and act not only as an illuminator.



[*light in the interior space distributes according to the openings and the divisions*]

3.5. Case study : Light and Interior Space

In this case study, the relation between light and geometry is studied.

3.5.1. Definitions:

Light Footprint: 

Light footprint is volume representing a certain level of radiation in the radiation map of a geometry calculated in its 3d volume. While radiation map is unique for a defined geometry, it can be translated into different light footprints according to the change in the radiation level.

Unit Generator: 

Unit generator is the basic unit that make it possible to have variations in a geometry. In a unit generator the change in the number and place of the openings and the interior divisions makes different variations. It generates a family of geometries with a variety of the openings and the divisions.

Geometry: 

Each possible geometry in the unit generator family which is defined by 2 parameters: openings and divisions.

Geometry Set: 

It is the family of geometries that are produced with a unique geometry unit.

3.5.2. Parameters

Division Index:

It shows the number and the place of the divisions in a geometry. We name the division index for a geometry by d(x,y) where x is the number of hidden panels and y is the total number of the panels. For example for the [fig.21] sample x is between 0 and 4 and y is 4.

Opening Index:

It shows the number and the place of the openings in a geometry. This index is composed of two elements one shows the openings in the ceiling and the other shows openings in facade. The vertical opening index is written such as v(x,y) where x is the number of openings and y is the total number of possible openings. This index is followed by a sub-set out of this set: s1,s2,e1,e2,w1,w2,n1,n2 ; Named after the beginning of south, east, west, and north, in counter clockwise direction. This part of the index shows which panels are exactly the openings. For vertical or horizontal openings a “v” ,or an “h” is added to the division index: ov(x,y) , oh(x,y).

Radiation Limit:

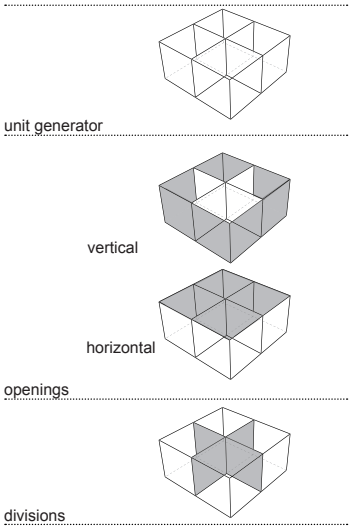
Radiation limit is the level of radiation that produces the light footprint. It is a number between 0 and 2000 kwh/m^2. The space which takes less radiation than this radiation limit and the area that takes more radiation than this radiation level would be separated and form the light footprint.

[fig.21] Next two pages: footprint for a sample geometry

3.5.3. Sample Geometry

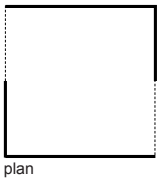
In next two page [fig.21] the light footprint for a geometry of a cubic unit generator, is represented. The indexes for the sample geometry are ov(2,4) {s1, n2} oh(0,4) and d(0,4) which means two opposite panel in north and south are hidden, and the vertical openings are places in these two panels in north and south.

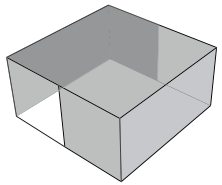
For a 110 kwh/m^2 the footprint is a continuous volume, and nearly symmetric because of the existing symmetry in the geometry. There is a certain radiation limit in which the light footprint starts to separate into two pieces. This radiation level is the radiation level that defines three zones in the interior space. We call this radiation level as the *critical radiation limit* because at this level segmentation of the space changes.

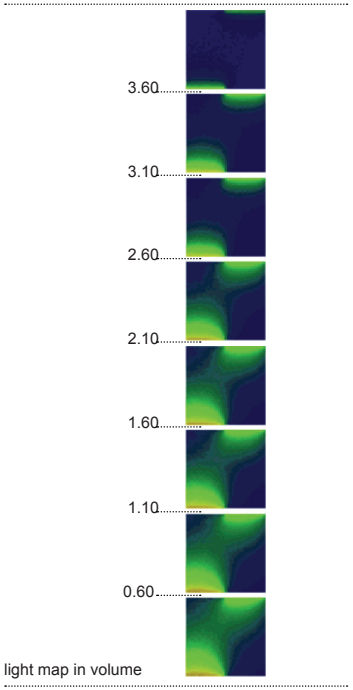


sample geometry

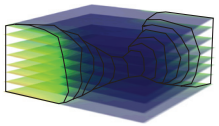
ov(2,4) {s1, n2}
oh(0,4)
d(0,4)

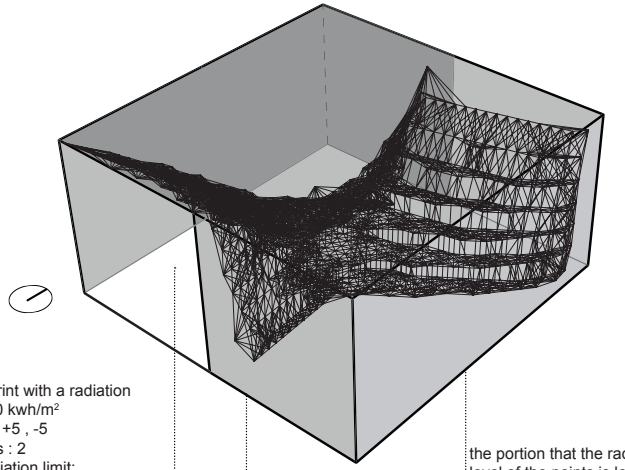






light map resolution:
altitude: 0.50 unit
pixels: 0.25 unit
radiation limit: 110 kwh/m²





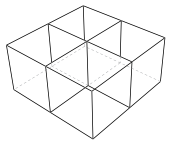
light footprint with a radiation
limit of 110 kwh/m²
tolerance: +5 , -5
light zones : 2
critical radiation limit:
57 kwh/m²

the portion that the radiation level of the points is less than the radiation limit

the mesh created form the points that their radiation is at radiation limit level (light footprint)

the portion of the space that the radiation level of the points are higher than the radiation limit

[light footprint releases the zones]



[fig.22] The cubic unit generator

3.5.3 Lighting Grammar

In the [fig.23] a geometry set on the cubic unit generator [fig.22] is indicated. The constant parameter is the division index which is one oh(1,4) and the vertical openings ov(4,4). The different geometries show the variety produced by the change of one division and 1,2 or 3 horizontal openings: *oh(1,4), oh(2,4), oh(3,4)*. Therefore, in the image we observe the diversity of 2d radiation map according to the change of one division panel and the horizontal openings.

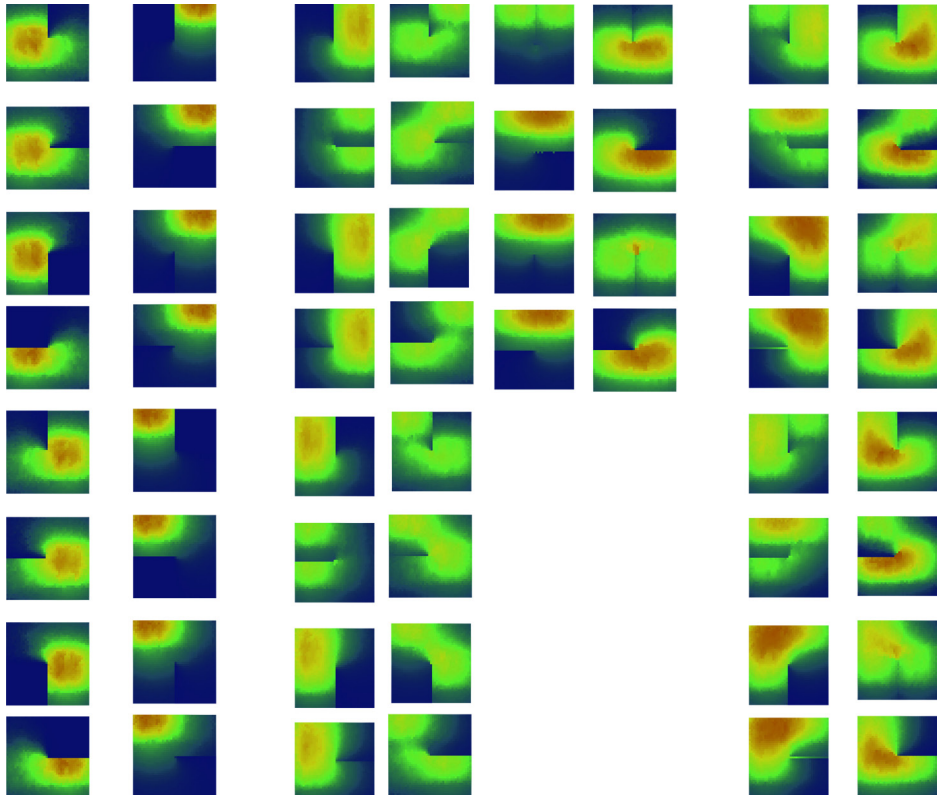
[fig.23] Next page: The different 2d footprints of a geometry set based on a cubic unit generator [fig.22]

In this observation we can recognize certain similarities in 2d foot prints. This could be an interesting source to study what is the similarities of the geometries producing these footprints. Is there a rule that bounds certain variations together?

3.5.4. Discussion

The generator unit can be changed and for any new generator unit we can find a new language. The fact that the 2d footprints have similarities in some cases can be a tool to study how we can take out a lighting grammar out of these similarities. We can name the similar geometries and define how they can join together and shape the combined geometries. Combinations (just like words and sentences) could be imagined that are produced through putting together the relevant geometries. The integration of all these rules gives us a geometry that can work as interior light quality generator. This grammar is a unique to each geometry unit that we take. Studies on, if the lighting grammar of different geometry units have something in common carries out the more complex properties of the lighting unit. It is imaginable that it can reveal rules about the potential of the geometries. In other words this method is the study of shape through its effect on the space(which is light).

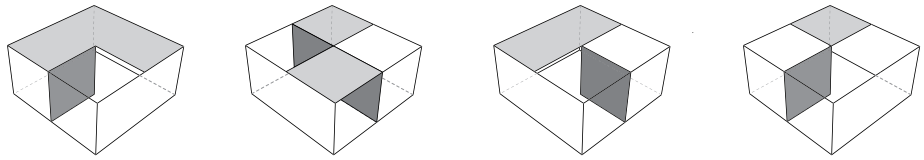
Certainly, the notion of lighting grammar should be polished to port its appropriate meaning.



ov (4,4) constant
oh (3,4)
d (1,4)
three horizontal opening

ov (4,4) constant
oh (2,4)
d (1,4)
two horizontal opening

ov (4,4) constant
oh (1,4)
d (1,4)
one horizontal opening



[*geometry set*]

[fig.1] Oblique projection map of Geneva, Jean Blaeu, 1641

4

Design Problem Parameters

City: Geneva, Program: Mediatheque

After focusing on the light in this section we survey the non environmental parameters that affect the intended design problem. This parameters are: the city and the program . We try to give a well-behaving model of these parameters to be used in a light responsive system.
Geneva, at the corner of Leman lake, benefits an exceptional locality; centrality in Europe and locating on the edge of France and Switzerland, parallel to the existence of international organizations gives an special character to Geneva as a design context.

[fig.2] Next page: Plan of the city of Geneva in Europe, Switzerland and the canton

[fig.3] Next two pages: aerial photo of Geneva at Rhone meeting Leman lake

4.1. City: Geneva

In this section we study the city parameters that we can use for the light responsive design engine. We observe the city with the scope of interest of this thesis. Locality, Rhone, politics and identity are the for topics of discussion. At the end a simplified model of the city important factors for design engine would be proposed.

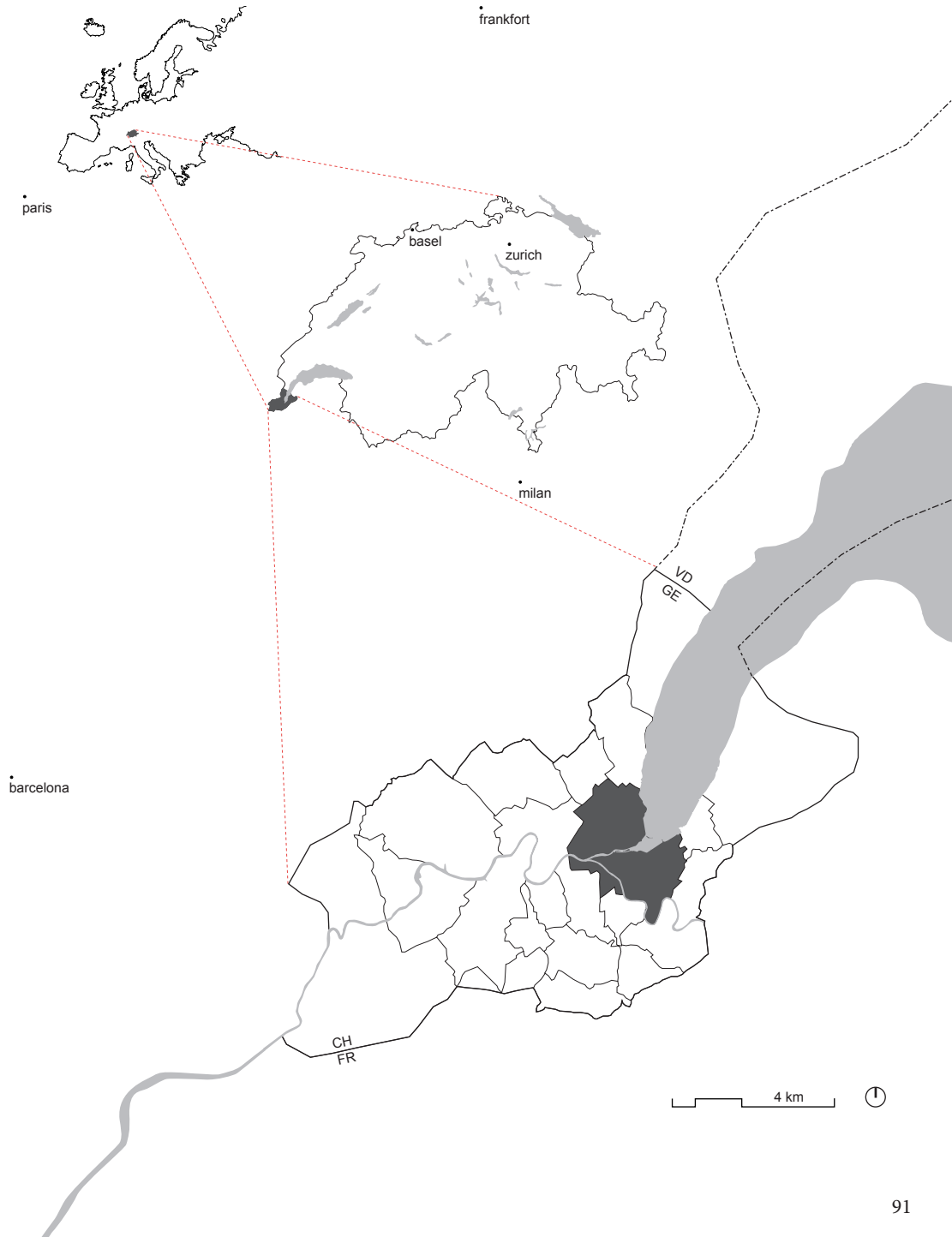
4.1.1 An International Metropole

City of Geneva is located geographically among the large European metro poles, Paris, zurich, Milan and Frankfort. Geneva is the centre of Franc-valdo-Genevois urban area (from 2010 this region is comparatively studied with other EU urban areas) which is composed of canton of Geneva, district of Nyon (in Vaud Canton) and some parts of Ain and Haute-Savoie departments in France. This area is inhibiting 890,000 inhabitants. It is ranked the 79th most populated urban area among 319 urban areas in Europe.

Comité régional Franco-Genevois, Observtoir statistique transfrontalier, 2010

According to EU urban area categorizations Fraco-valdo-Genevois urban area is placed in the third category (population from 500,000 to 1 million) of large urban areas in the EU along with Leipzig, Nantes and Venise. Comparing to the other cities with the same demographic scale city of Geneva has more iconic value and importance in the world because of mainly its location and hosting many international organizations such as United Nations. This pushes the city forward to search for an international identity rather than being solely European, Francophone or Swiss.

[city of Geneva needs to fit its international reputation, considering its architectural image]




COMPTOIR GENEVOIS IMMOBILIER

[fig.4] Next page: the master plan of Geneva in 1935

4.1.2. Rhone and The Lake

Rhone river is one of the main causes of formation of Geneva as a border town controlling the passage of *Helvetti* tribes through Rhone. The functionality of Rhone has changed during the time. Rhone on the contrary to the Rhine river which is an industrial river and has penetrated to the centre of Europe has a less transportational role in the region.

The central Geneva is stretched in both north south part of Rhone. The actual Role of the Rhone in the city and the lake is very complex. It is a big urban edge, dividing the city, while being itself a centre of interest for many activities. The promenade along the Mont Blanch bridge on Rhone looking to the Lake is the most populated touristic part of the city.

However, this city landscape role and acting as an urban cooling tool doesn't stay constant along the Rhone in the city, we see when it approaches the other big city edges like the railway, the districts which are located in between lack certain means of accessibility.

The other major factor in Geneva's environment is the Leman lake, in large scale the lake has affected the city morphology [fig.4]. It causes a type of zoning which means that the districts adjacent to the lake are mostly the service districts providing hotel and restauration and commerce facilities.

4.1.3. The United Nation City

Geneva is a city under the shadow of politics, because of the presence of the UN in the city, there is a service system developed to support the VIP visitors. This has affected majority of the districts among station, lakeand the UN palace in the northern Geneva.

[***Rhone, Lake and rail way are the backbones of the city***]

[fig.5] Image: TSR tower in Geneva, dl-architects, End of construction 2010

4.1.4. Identity

Geneva's contemporary image is a rather a conservative image comparting to the other cities in Switzerland and Eroupe. Exmining the recent projects done in the recent years in Geneva a great interest to build less radical and more fundamental projects rather than trying to experience pioneer designs, is seen. The description for TSR tower, the tallest structure in the city (with 17 floors) built on 2010, represents this issue very well, :

Description by Devanthéry & Lamunière architectes, dl-a.ch

"Elle est un emblème hiératique, un peu froid et relativement opaque[ ]...Poétiser la forme... c'est passer d'un volume verticalisé par l'inox à un volume pixelisé par l'inox; c'est passer d'un volume sans image à un volume d'images; c'est passer d'un volume silencieux à un volume murmurant; c'est passer à un volume gai. "

The coldness which is described here and the fact that city avoids planting skyscrapers and urban icons is a tendency that has passed to some extent by the neighbouring same scale cities like Lausanne (Rolex Learning Centre) and Bern (Paul Klee museum).

4.1.5. Summary : City Parameters

Here we will introduce the potential quantified parameters that can be taken from the study that we did on the city of Geneva. These parameters should be able to be measured into quantities and geometries to be able to be used in a light responsive engine.

Firstly we choose geometrical factors that are taken from the existing city morphology such as city grids and circulation network. We discussed that the main major backbones of the city are the lake,the river and the railway. These are the forces that have affected the city formation [fig.4]. Therefor we take these three factors as the main geometrical city inputs of the light response system. Here we list these factors and predict how we can use them as formalized elements.

1. The Leman lake
Leman lake topologically is a distributed surface forcing the blocks to have a good view to its area. View factor will be the main factor concerning the affects of the lake. It is potentially a distributed *view attractor*.

2. The Rhone river
The Rhone river is a longitudinal linear element that is not only important because of its view it has a cooling effect for the close building blocks, so the exposed side to river not only is important because of the it gets, it can be playing a role by making the air circulation flows and cooling the blocks.

3. The railway
The railway is a rigid edge that could not be penetrated by pedestrians. It has two main affects, it blocks the circulations to the site, and in the other hand it is source of noise. So that if we simulate the sound in the proposed light response engine it should act as a linear repulsion force.

These parameters are based on geometries that can be interpreted to the context forces and interact with the building.

There are also qualitative parameters such as concerns of being iconic for the city and promoting contemporary image of the city. These parameters are delicately related to the strategies that we choose about our geometrical elements. However they can affect the building also in its details. As we saw in [fig.5] the iconic speciality is summarised in a pixelated facade that communicates a kind of dynamic image for the TSR tower in high contrast with the existing architecture in the city.

In summary the parameters concerning image and iconic aspect that can not be quantified show their affect on facade and detail design, for instance the strategy that will be used for facade modules or panelization algorithm.

[lake, river and the railway are interpreted to the context forces affecting building formation]

[fig.6] Next page:
Like This, Interactive object by Maroi Klingemann, 2011

"we will not define a thing by its form, nor by its organs and functions, nor as a substance or a subject. Borrowing terms from the Middle Ages, or from geography, we will define it by longitude and latitude. A body can be anything: it can be an animal, a body of sounds, a mind or an idea; it can be a linguistic corpus, a social body, a ***collectivity.****"*

Gilles Deleuze, 1970

4.2. Program: Mediatheque

In this section we discuss what are the effects of program (in this project a mediatheque) on a responsive system. As in the design problem we have decided to make a mediatheque after a brief discussion on what is the role of new media in the contemporary city we will introduce the challenges that we face while defining a contemporary mediatheque. At the end the model which can be used in a responsive system is proposed.

4.2.1. New Media

Media is a tool, natural (such as language) or technical (such as Television), for transferring information between two parts (message) or among a society of people(information). It covers a large range of communication tools and affects society and individuals in different layers. Because of the contact with the people, media in its social form is extensively involved in the social life.

Conventional types of media such as television , radio and newspaper are mostly confined to national boundaries, language boundaries or special societies with special interests (same religion, language, nationality). Internet on the other hand as a platform for media provides contact with all groups of people. It is a liberal platform not confined to special audience.

Internet has changed the way that individuals communicate with the society, this change is not only about the power and liberty of the individuals, but also is about the type of connection and zone of influence of individuals. One type of the actors on the internet that help these change are the social network websites. The Social networks such as Google+, Facebook and Twitter are the new types of Media to diffuse information by individuals. They are extended tools to spread, evaluate and order information among people.

On the internet (a giant platform that is stored on the numerous servers across the world) many media diffusion methods are emerged. Blogs as the personal publisher services, video sharing sites as self operating personal broadcasting channels and social networks as a kind of personal news publishers let individuals diffuse information. These new actors have proven that internet is not just like another media type; it is a platform that changes depth and speed of information flow.

For conventional tools of diffusing information like newspapers and books, the media and the medium are present at the time of transferring the information. In other words there is a direct physical contact between human and the object which carries information. But internet is an existent with no physicality. The informations on the internet are stored as translation of bits of 0 1 on servers. Even, if we consider these servers as the physical body of the internet, users, while interacting, don't have any direct and physical contact with this body.

With this approach to the new media the concept of mediatheque should be re-investigated. What is the role of a mediatheque if the type of media is going to change? For going deeper in this question we should study what is the architecture of internet and the qualities of media diffused on it.

[***human's interaction with the new media is not any more through the physicality of the medium***]

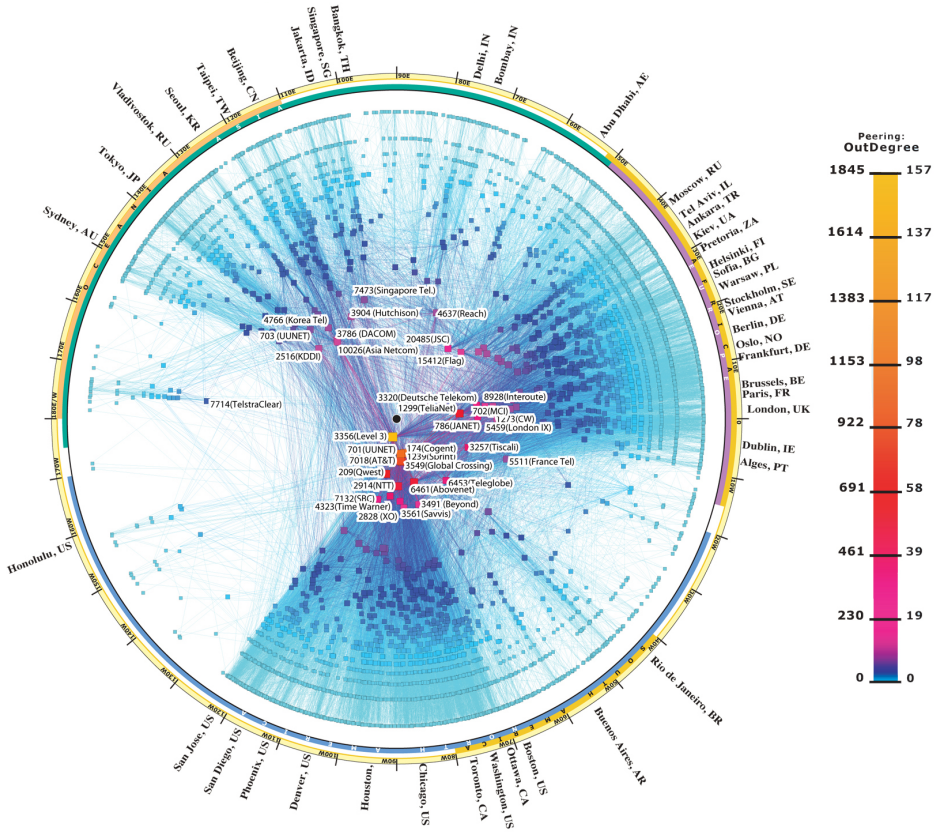
4.2.2. Internet and Reticularity

Internet is an existent that is not embodied in its physical body. It is a distributed network of the computers that its main functionality comes from the reticular logic that connects these computers. The fact that every two computer can be connected through internet and each computer can itself become a part of the network, shows that the body of internet is not constant, it changes according to the number of connecting computers and furthermore according to what the users do on the internet. So that, we can say internet is better represented by its reticularity rather than its physicality.

[fig.7] is a project to represent internet's reticularity in an snapshot of transferring data through the data centres in the different cities. If we compare this image to a world map, we see that the relational position of the cities is not like their relational position on the earth. There are actually cities that are sharing more information with each other while the others are not involving and may not even exist, so that we can say these cities are virtually more connected and they are closer in a reticular sense to each other. Actually the notion of distance would be re defined.

This reticulrity that has changed the territorial distances, has also defined the ways to access internet. Internet has generated the necessity of devices such as smart phones and tablets. All these triggers the question of: what is the internet's influence on built environment,and more precise on mediatheque? A mediatheque is a physical space that serves to media public. The new media needs its own type of space for being accessed, for protection and for archive.

To see what is a relevant space that can provide access to internet we study the differences of the characteristics of the information produced on the internet in comparison to the conventional media. We see these differences in terms of information's accessibility, value, physicality and half life.



[fig.7] "What does internet look like?" is a project to represent the reticularity of internet. It is the state of the data transfer among the internet hubs in a certain period(January 2008). The rectangles show the data hubs lined up with the cities they are located in. Closer to the centre are hubs with more traffic. Cities are sorted according to their geographical longitude on the periphery of the circle. The legend shows a traffic index in colour, CAIDA, 2008

[new spaces(interfaces) to serve new media]

4.2.2.1. Accessibility

Information on the internet is stored on the servers. It is only accessible through interfaces connected to the internet. Because there is not any physical limit, users has access to all the existing information online, unless there are limited because of privacy. So accessibility on the internet is unlimited.

Historically, the problem of accessibility was a challenge to diffuse the information. Territorial infrastructures based in the cities were used to distribute the information. For example we survey the accessibility criteria about newspaper:

Newspaper is a soft object that contains the news of a locality. A territorial network composed of publishers, distributors and the places for sale is required to provide the people's access to this media. The same is with the books, a system of libraries across the countries are needed to provide it for the users. In summary, internet provides accessibility to a large amount of information without concerns for the constraints of locality, time and physicality.

4.2.2.2. Value

Relationship between physicality of an object and its value is rather complex. Does a piece of information on a computer server has a value? Does an e-book has the same value of a real book? What is certain is that the presence of the object itself, the history of it, in other words the memory of the thing that has touched the real world is a part of the value of an object. If we remove the physicality what would replace the value of a thing?

4.2.2.3. Physicality

Internet will change the necessity of information-container-objects (such as book, newspaper, CDs, etc.). It is predictable that in this case the interface becomes important instead of the object and takes its place.

4.2.2.4. Half life

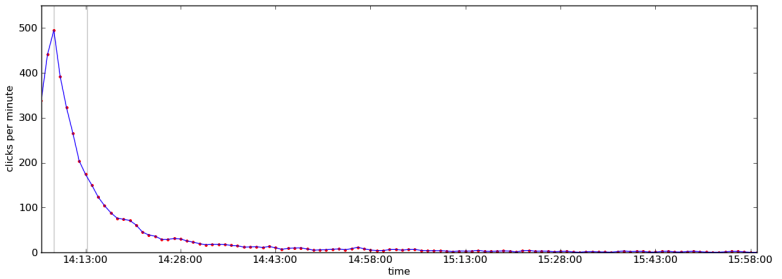
Life of a newspaper is one day. There is a balancing force between the need for archiving the medium and its life. More a piece of object is taking up a place with temporary information more it is likely to have a shorter life.

Life of a piece of information on the internet is free of its content durability. Life for a piece of information on internet is defined by its *half life*. Half life is how much time does the information take half of its attention by online community compared to the attention it takes during its life (counted by visits, clicks,etc).

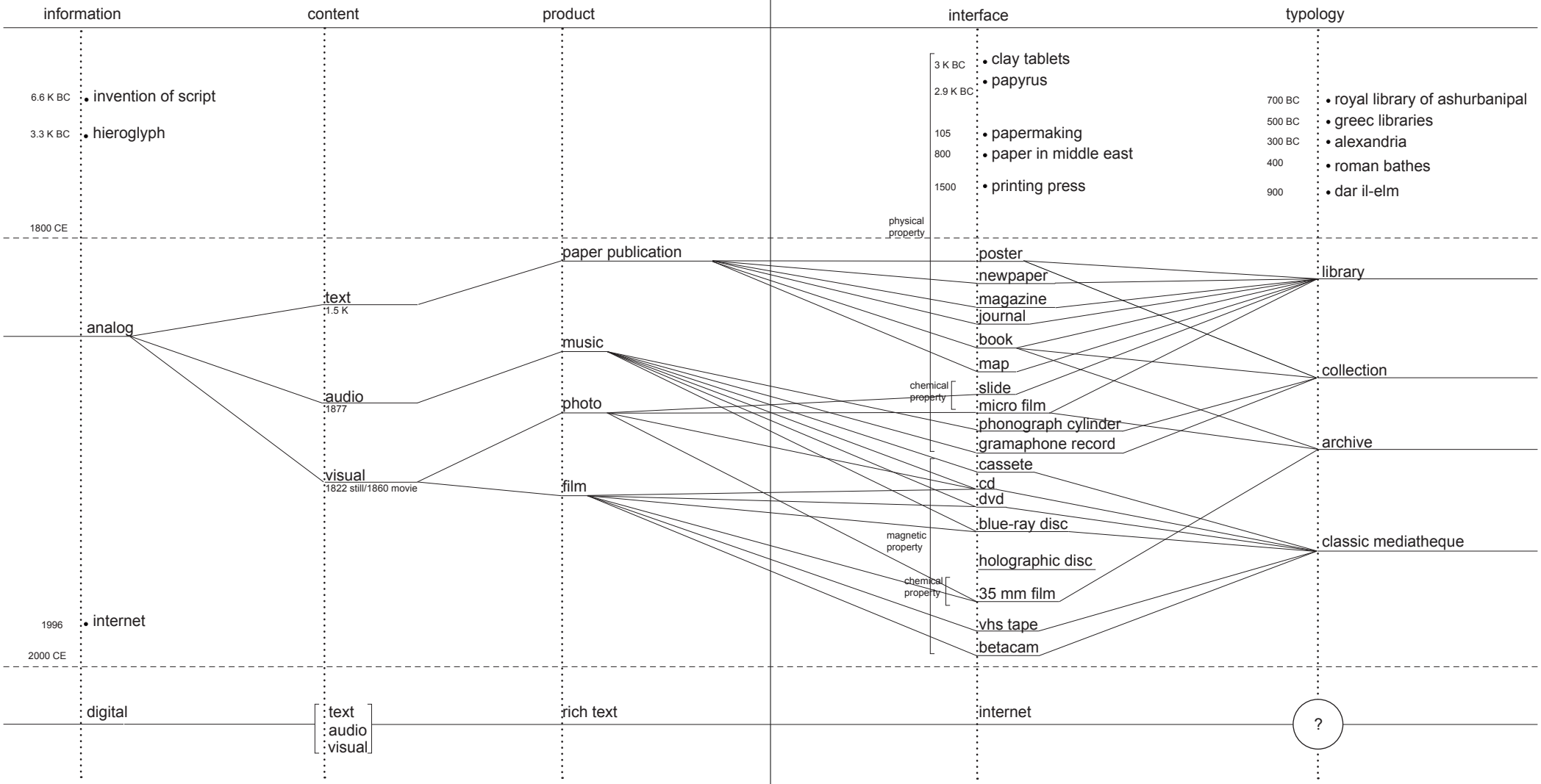
[fig.9] shows half life of a link posted on twitter (about an earthquake) is less than 5 minutes. It means in 5 minutes it has taken all the visits that it will take during its life. This shows that when the internet removes the necessity of physical medium it can reach to incomparable rate of diffusion and life for the information.

4.2.2.5. Summery

In summery, these changes are introducing a new type of transfer of information which needs its relevant territorial spaces and strategies to access it and archive it. New mediatheque can not be a collection of books, CDs and DVDs to provide public access to them; new mediatheque should search a definition of space for treating the new media.[schema.1] in next page ask the same question with a chronological approach.



[fig.8] Number of visits of a link about "East coast's earthquake in US" posted by washington post on twitter. its half-life is 5 minutes, http://blog.bitly.com


information
content
product
interface
typology
6.6 K BC
• invention of script
3.3 K BC
• hieroglyph
1800 CE
1996
• internet
2000 CE
digital
analog
text
1.5 K
audio
1877
visual
1822 still/1860 movie
text
audio
visual
paper publication
music
photo
film
rich text
3 K BC
• clay tablets
2.9 K BC
• papyrus
105
• papermaking
800
• paper in middle east
1500
• printing press
physical property
chemical property
magnetic property
chemical property
poster
newpaper
magazine
journal
book
map
slide
micro film
phonograph cylinder
gramaphone record
cassete
cd
dvd
blue-ray disc
holographic disc
35 mm film
vhs tape
betacam
internet
700 BC
• royal library of ashurbanipal
500 BC
• greec libraries
300 BC
• alexandria
400
• roman bathes
900
• dar il-elm
library
collection
archive
classic mediatheque
?

[fig.10] Sendai mediatheque, Toyo Ito

4.2.3. Mediatheque Typology

Mediatheque is a term coined in the 1980s when the mediums such as cassettes, vhs tapes came into mass production. In this period the necessity of a public place apart from the central library to provide access to these objects for public came into question. Therefore, initial mediatheques were places with the same functionality of a library but providing audio visual material, sometimes they were a part of the central a library.

This typology started to replicate in 90s in cities specially in France where the big cities started to found a central mediatheque. The most famous building of this period which was planed as a museum but later called a mediatheque is Sendai mediatheque by Toyo Ito [fig.10]. Planned to be a museum but later discussed to integrate a part of the existing library of the city and then it became a mediatheque.

With disappearance of medium's object mediatheques are going under a big change considering their definition. Not only mediatheques but also the libraries are facing a big change. A library has been historically a place to gather the published books inside a central space. Library was a space to archive and provide access to the books. Libraries nowadays are going to be more information-based rather than being object-based. While books can be accessed on the internet and be read on the tablets without any need to the book itself, libraries are changing their identity. They are going to be more an access point and be a kind of learning centre.

ULTRA SOCIAL

Help children,
separate your Waste,
buy organic:
collect points.

Donate online,
add a Comment,
save friends:
collect points.

Sit back,
consume,
be affected:
collect points.

Correct.
Nice.
Beautiful.

ULTRA SOCIAL

[fig.11] Slogan for the UAMO FESTIVAL, 2011

4.2.4. A Territorial Web Browser

What is the characteristics of a new mediatheque? New media is not storing any object, so that there is not any need of containers and centralised buildings to provide a physical access to books, CDs, etc. As we saw in the visualisation of internet reticularity in [fig.7] the store and the interfaces shouldn't necessary be located in the geographical location.

The physicality in a mediatheque is reduced to its minimum, we can say a mediatheque is just a centralised interface to borrows the internet. In other words, it can be compared to a is a physical/territorial internet browser. The main question is why do we need centralised public buildings like physical internet browsers while we can browse internet on our smart-phone?

In order to define a new mediatheque, we should focus on the collective experiences that is the benefit of a public building.[fig.11] shows the slogan for the UAMO festival an event based on media and urbanism and art. What is interesting is this slogan is that the concept of collectively is the main tendency in all the mentioned aspects of this slogan. A new mediatheque can also aim mainstream ideals. While the forces that shape the development are the ideals of the mainstream.

A mediatheque can also have two other functional and social aims:

1. As a public typology it can provide access for people without knowledge of using new technologies. Not educated, and old people.

2. Information on internet is very vast and confusing in a sense a mediatheque can valorize and order the information through the interface it provides for the users.

[mediatheques are no longer object-based spaces; they are information-based territorial web browsers]

4.2.5 Architecture of Internet

Our methodology to define the mediatheque parameters is inspired by territorial elements that are introducing by same concept on the internet. There are many words used on the internet referring to architectural object such as “wall”, “forum”, “home”-page. These words make sense in the online context so that we are interested to search for the roots in common that they have with their real world equals. This can help finding a basis for mediatheque parameters.

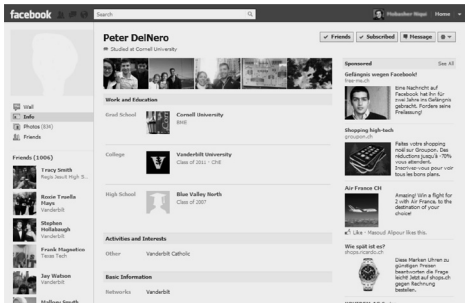
Facebook wall, home-page, forum, dashboard, etc.; The tendency to use these architectural elements shows that internet has an identical spatiality.

Classic spatiality is studied with Cartesian concept of space, it is described with absolute coordination system, it has 3 dimensions and every object occupies a certain position in the space. This spatiality can describe very well the physics of the real world. In parallel there is a relational concept of the space introduced by Leibniz. It challenges the idea of absoluteness proposing that the space is more relational than absolute. His consideration of space is a system that objects occupy a position according to the other objects rather than according to an origin.

In this sense when we come to the question of “Internet” as a “place” we could say internet has a kind of relational spatiality close to Leibniz’s concept because it provides a system of objects that are positioning in relation to each other. There is no centre and there is no standard metric to measure it.

4.2.6. The Wall

What does Facebook wall have in common comparing to a real wall? Facebook wall is the main representative element of a users usual events. A Facebook wall is not only an announcement board that everybody has the access to change it but it is a built virtual representative barrier between individual and the public. It doesn’t have a structural



[fig.12 & 13] Gilbert Garcin, photo called “Communicating”, in the right image of a formal image of a wall of the Facebook. The question is what is the common roots of a physical wall and a wall in the virtual space? Does it give a clue to us to design a virtual wall in the physical space?

aspects, however in the spatiality of the Facebook account it is a central element. It defines a boundary, and is in a sense a territory marker. If we consider individual and public territories on the web like physical spaces, the wall is a spatial separator between interior and exterior. Its marks the limit of private and public territory. In [fig.12 & 13] we see a Facebook wall could be compared to a barrier between individual and what public receives from an individual.

In conclusion, in the internet space an architectural elements such as wall keeps most of their characteristics while loosing their materiality. Now the question is: could this process be reversed while conceptualizing a mediatheque. Are there reticular elements (such as link, blog and feed) that can be materialized and translated into spaces to be used in a mediatheque?

[***Facebook wall is a representative barrier marking the wall between the territory of individual and the public***]

4.2.7. Summary : Mediatheque Parameters

Following the discussion we have done about the new physical interpretation of reticular elements such as (link, feed, tweet). As these elements are produced to borrows a large data base, if we plan to make a physical web browser as a mediatheque we should define the architectural equivalents of these elements. And these elements will shape up the programmatic definition of the mediathque.

1. Browser Interface
It is a surface in the real space possible to reshape to a cabin which is the interface for human to access to the Internet and the mediathque's data base.

2. Tags
Tags are classification switches for different interface surface. They help surfaces with the same thematic gather in the same space.

3. Links
Links are the circulation units. They provide the functionality of going from browsing one surface to the other one.

4. Feeds
Feeds are the spaces in which the surfaces with similar tags gather together. As there might be surfaces with several tag the feeds.

These elements are placing as architectural elements working on an infrastructure which is the mediatheque's overall area. Their distribution in the space is related to the inter actions that they have among them.

[*a territorial web browser can be formalized by translating the web-space elements into architectural units*]

4.3. Design Problem Summary

Intervention Zone

The site is chosen among two urban edges and a busy transportation axis to challenge the complexities of different forces. It is located among the Rhone river, the railway and a strong circulation axis between the Cornavin station and Plainpalais on the lake side. In [fig.14] we see the potential intervention area.

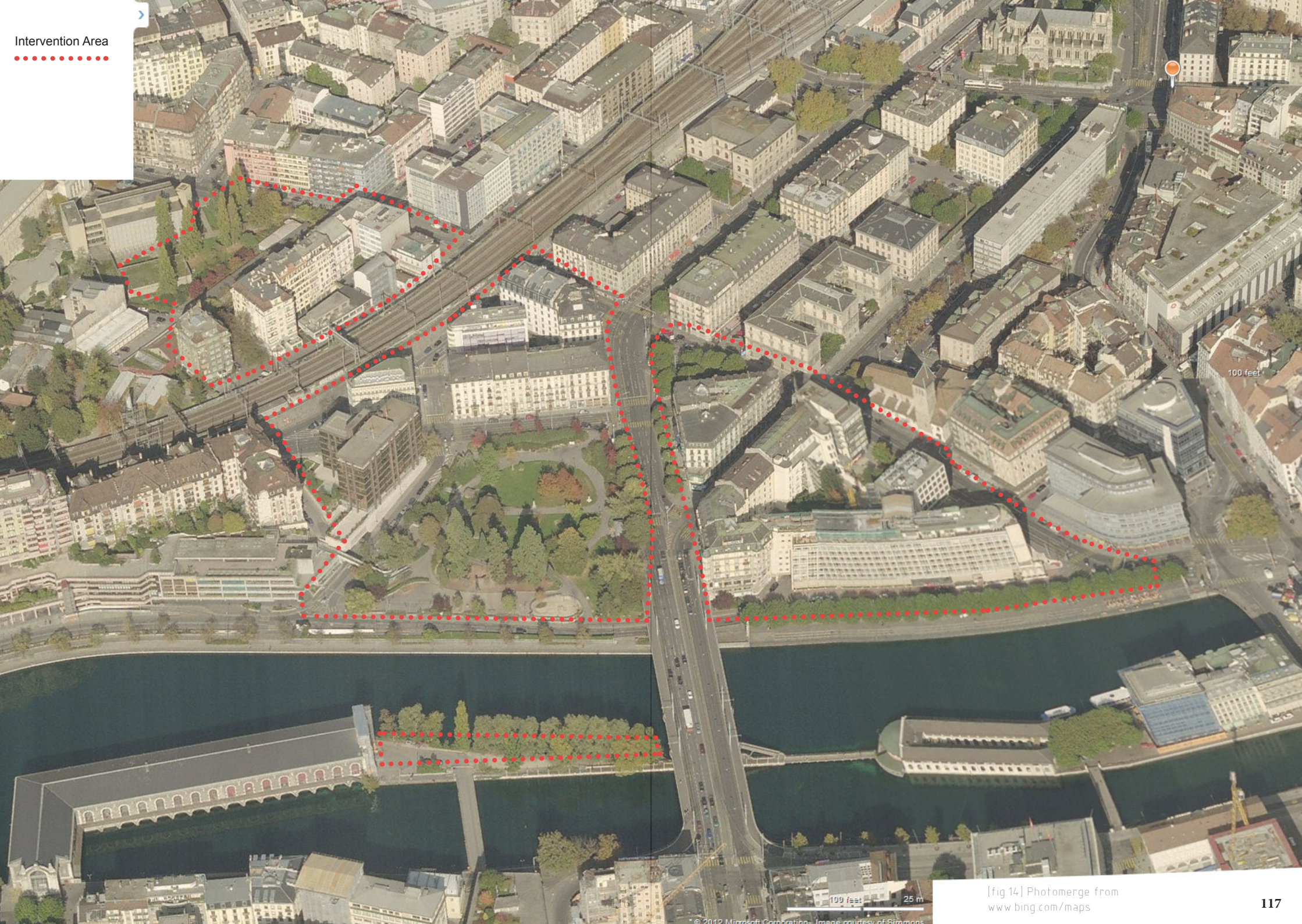
City Parameters

Geometrical:
1. Lake
2. River
3. Railway

Qualitative:
1. Facade modules
2. Panelization method

Mediatheque Parameters

1. Browser interface
2. Tags
3. Feeds
4. Links



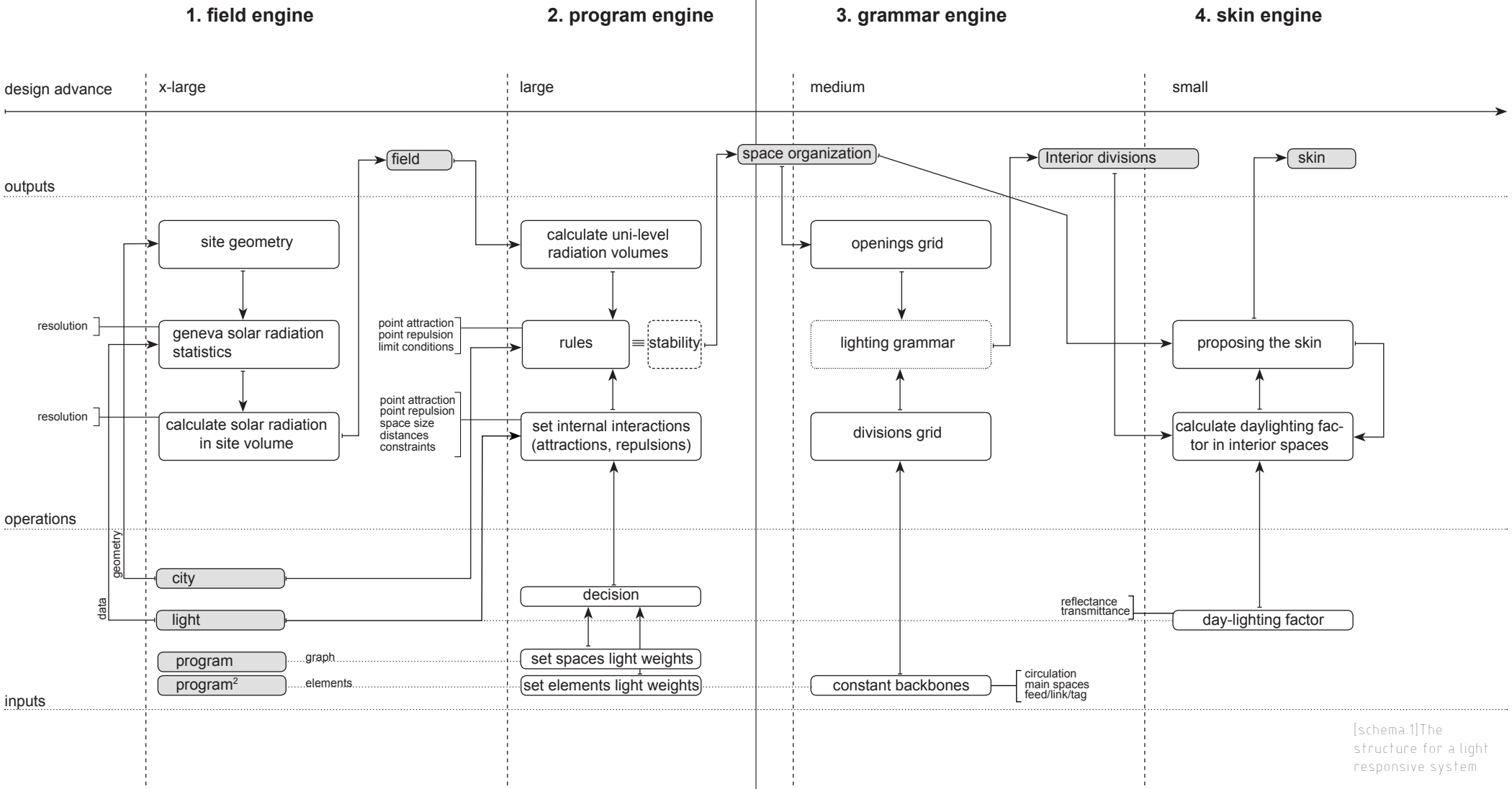
[fig.14] Photomerge from www.bing.com/maps

[fig.1] Next page: Frank Gehry, New york times building proposal, New York City, 2005

5

A Light Response System

A tectonic response engine orders, valorizes or optimizes a design criteria in the *design solution space*. The design criteria is defined by setting interactions and giving weight to the input parameters. The procedures is that the engine provides a set of possible designs based on input parameters. To propose a light tectonic response system we break the engine to 4 sub engines based on the scale that responds to the design criteria in different levels.



[schema 1] The structure for a light responsive system

[*the response system's structure*]

5.1. Field Engine

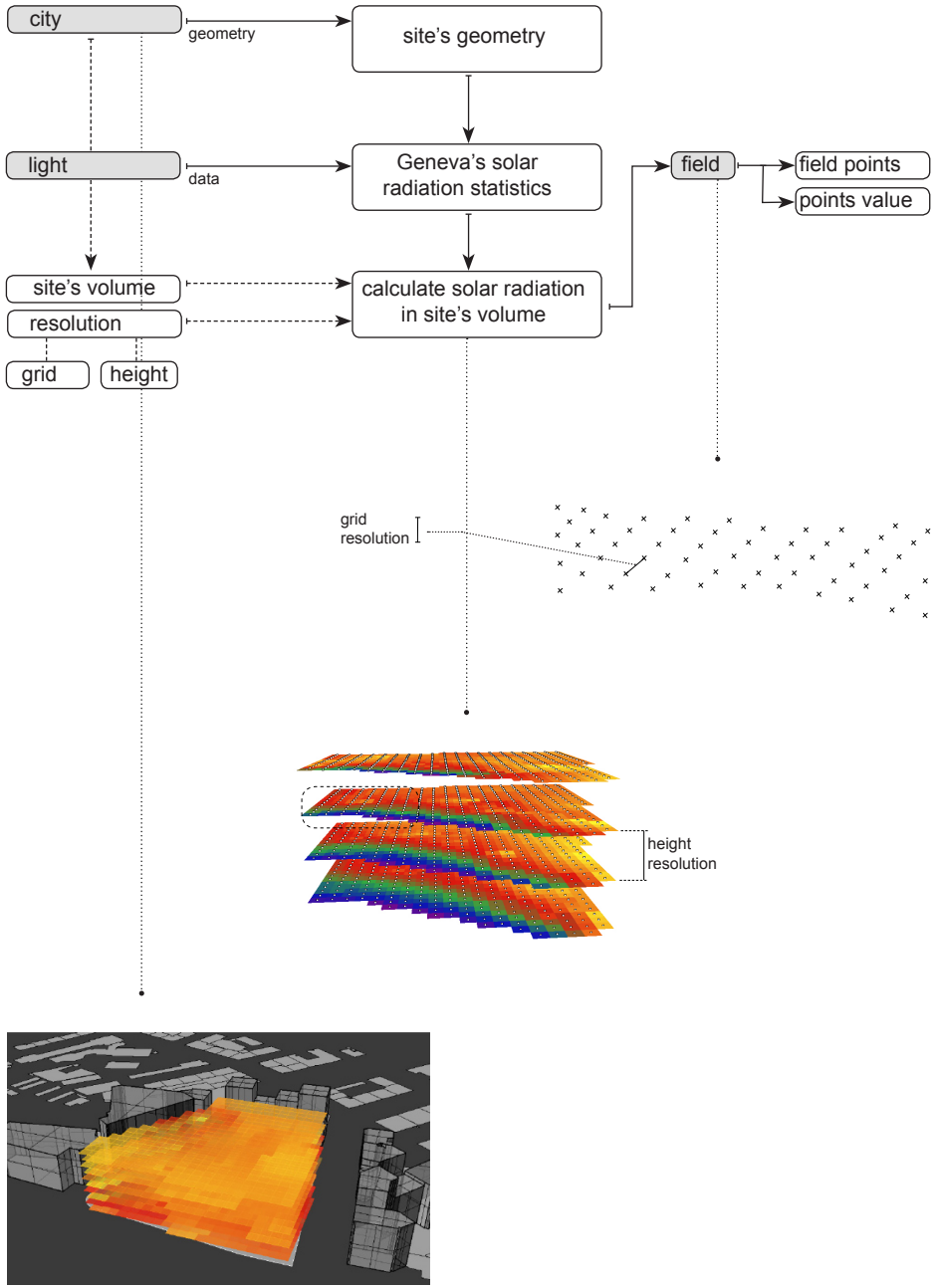
The field engine, valorizes the site points according to the radiation each point takes during the year. This field is calculated in the site under the study. The resolution of the field is decided by user. A three dimensional grid of points based on two parameters, the height resolution and the two dimensional grid resolution. Higher the resolution of the field goes , its data become more continuous.

Radiation of each point is a scalar quantity measured based on the information on [appendix.1]. This method is based on the calculation of cumulative annual radiation using the solar radiation data of Geneva.

[schema.2] Next page: Process inside the field engine, producing the radiation field

This field similar to an electrical field that move the electrical charges can be the base for interacting with the objects that has a light sensitivity. In the next chapter we see that the elements according to their *lighting sensibility* move or position in the radiation field. The lighting sensibility is a method that quantifies the lighting necessities for an space into certain intrinsic properties. Such as charge weight for electrical charges.

[radiation field valorizes the points of the space according to their annual radiation gain]



[schema 3] Next page: Process inside the program engine, producing the space organization

5.2. Program Engine

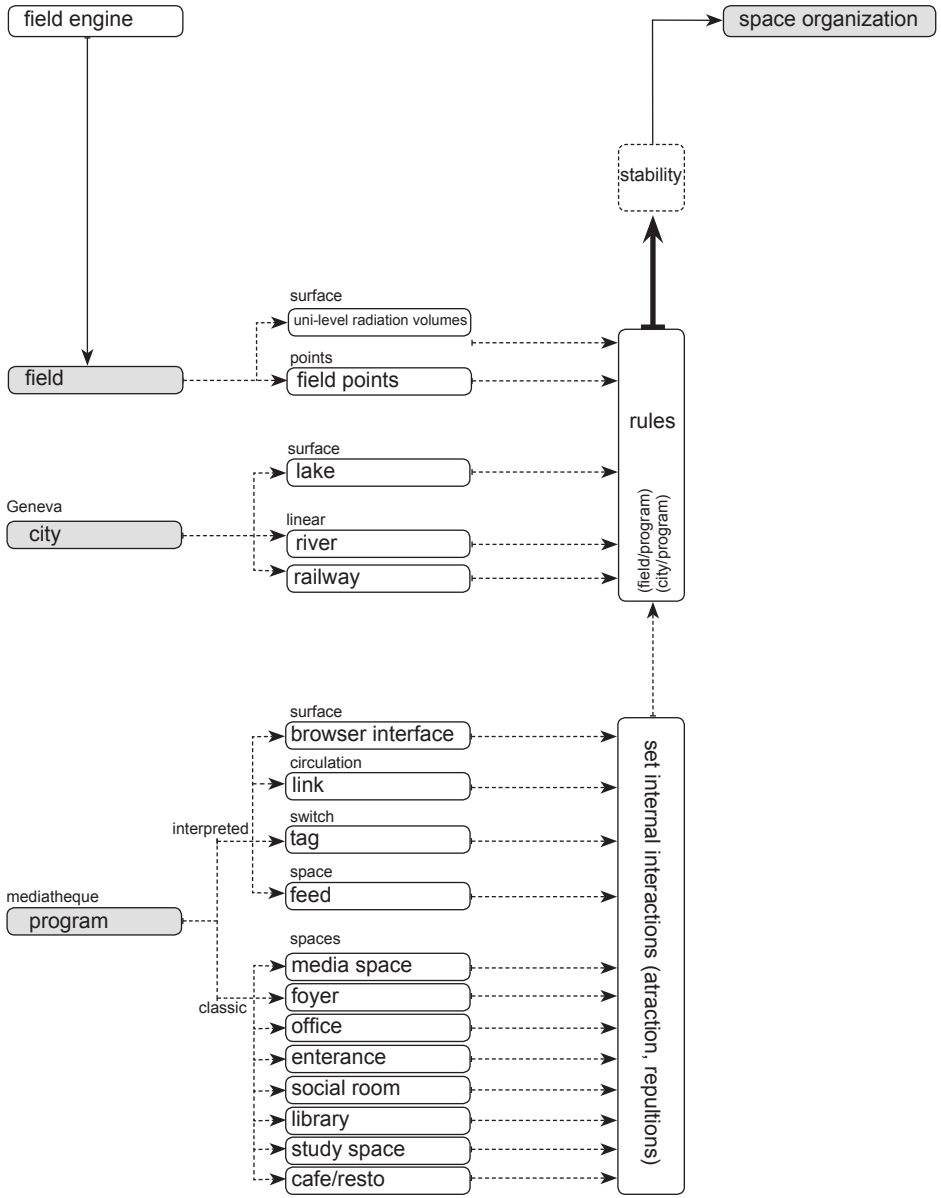
Second engine is the program organizer engine that works according to the radiation field taken from the previous engine. In this engine the program input is elaborated. Firstly, the relationship among the program elements (either classical programmatic definitions or the programmatic definition that we discussed in chapter 4) will be defined. This definition can lead to a property graph, for instant, the *link* elements should be placed close to the *feed* elements because they have a circulation property. They should be distributed at the same level of importance according to major spaces.

After setting the internal interaction of the program elements they would be placed in the radiation field. Each programmatic element has a *lighting profile (sensitivity)*, this profile describes the need of this element to the natural light. So that, when the programmatic elements are located in the radiation field their placement will be disturbed according to the effect of radiation field on them which is related to their lighting profile.

The programs are also under the influence of the city parameters, which are the lake, the river and the railway. They act parallel to the radiation field. So that, the final organization is a result of both radiation field and the city parameters.

This engine will be simulated as a particle (physics) simulation which means the program elements will be taken as particles with initial constant characteristics and the lighting profile and the city parameters and the radiation field are taken as the forces.

[the program engine defines the interactions of the program/city and the program/radiation field]



[schema 4] Next page on top: process inside the grammar engine, producing the interior divisions

5.3. Grammar Engine

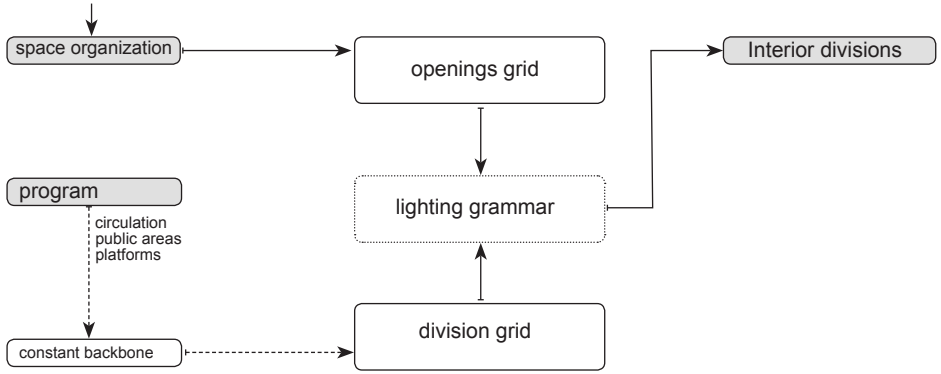
In the grammar engine based on the case study two in chapter three, we use a lighting grammar to define the interior divisions. This process is the reversed process that we went through in the light and interior case study. Here we start form a proposition for the lighting zones of the space and then we interpolate the interior divisions. To do this we need to have a grid that the lighting grammar could be projected on. So that the interior divisions' grid comes from the program. It is very delicate that the division grid can be formed based on the selective elements of the program that are decided not to involve in the program engine, or it can be formed directly based on the program organization. In other words it is either an external grid projected to the space organization or it is a grid taken from actual space organization which the output of program engine.

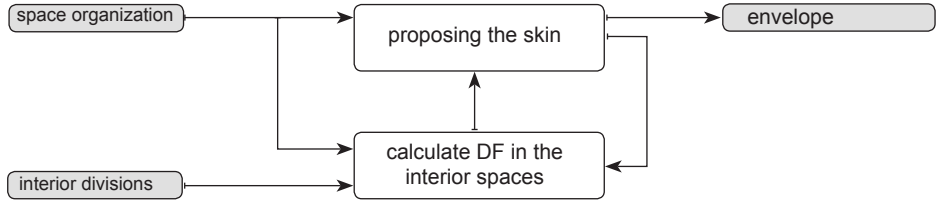
[schema 5] Next page: process inside the skin engine, producing the envelope

5.4. Skin Engine

The skin engine is rather a classic engine. It is based on the result of the space organization and creates an skin. This skin can be created with primitive methods such as connecting the peripheral points of the resulted geometry by a triangular mesh. In this step different methods of panelization and tessellation will be tested to find the appropriate facade textures (concerning the iconic and contemporary image of the building in Geneva as we discussed in section four).

After proposing the envelope the detailed openings will be proposed and in a recursive procedure the amount of daylighting factor will be measured and the proposition will be modified to rich to an optimized DF factor. Although the DF factor is not the most precise method to evaluate the interior space lighting quality in this study we focus on this metric because it is more convenient and it provides the results with a calculation rather than a simulation. This metric in the skin engine can be replaced in future by more precise factors.





[grammar engine uses a reverse process based on the case study 2 to create interior divisions]

5.5. Summary

5.5.1. Discussion

In section one we induced that with the current state of materials and architecture a tectonic response system is a relevant response system. A tectonic response system integrates the response of the building components in the tectonics of the building. The proposed engine is the continuation of the same logic because we are proposing a distribution based on a radiation field which is rather constant. If the set of the rules translated into attraction and repulsion will be set correctly the equilibrium will be meaningful. It means incase the system reaches to an equilibrium state, a parameter is in its optimum level.

The critical point to create this response system is to define the correct lighting profile for the architectural components so that they can behave well in the radiation field.

When the building parameters reach to an equilibrium, which means we optimise a factor related to the lighting, if we take the engine's output and freeze it into an architectural space we have integrated this lighting qualities in the tectonics of the building. This way the building would behave during its life with the best possible performance to the lighting situation.

5.5.2. Method

The response engine which will be produced is based on a simulation. The main inspiration of this simulation is the behaviour of the electrical field and the charges. Each engine would be programmed independently with consideration of minimizing the interference. As the introduced engines are working in different layer the concern of interference becomes less. During the simulation phase the highest concern would be taken into consideration to avoid pseudo-scientific simplifications. And the engine outputs would be tested with the lighting metrics to prove their performance.

5.5.3. Programming

The code will be written mainly in Processing and C# and the lighting analysis will be done by Diva plugin in Rhino software. The physics simulation code will be based Traer and ANAR library[1] in processing and Kangaroo plugin in Grasshopper.

5.5.4. Critics

The idea of creating an engine to solve complex design problem always have had certain weak points. Because of the complexity of the phenomena under the study, finding a well-behaving simplified model is rather difficult. Sometimes the simplifications are not correct and don't orient the system to optimise the correct parameter.

For instance using the concept of a surface with attraction points for a parameter in the context that is interesting in terms of users' view to this parameter (like a lake) is a rather far translation.

Designing a response engine in some steps the architectural decisions enter the design process, there is no measure to see if the architectural decisions are correct and the are in the orientation of satisfying the correct parametric aims.

[*a light tectonic response system should correctly model the design parameters*]

1 This processing library is created and developed by Guillaume LaBelle and Julien Nembrini. http://anar.ch

6

Synthesis

Responsive systems in architecture could be designed by modelling the built environment by intended parameters. A response engine has the role of producing design configuration based on optimization of a criteria. Intellectual process in an architect's mind is a similar process. (S)he also searches for the best solution (response) to a design a problem.

6.1. Theoretical

The response systems integrate the performance in the built environment. They are based on permanent and temporary informations of the context and response to one or more criteria. In non-kinetic architecture, tectonic response is one of the relevant ways to optimise building's performance in one or more aspects. Tectonic response means to decide the structure and tectonics of the built environment to have a good response for all the situations a building will face during its life.

Because the big scale light information in the space for the build environment is rather constant, tectonic systems can be good light response systems. Considering informations based on human behaviour in the space, those behaviours which are following major constant patterns can be translated into the tectonic human response systems. However, the temporary and *situational* information related to the human behaviour in the space are more likely to be used in the smart response or feedback response systems.

6.2. Practical

In chapter three talking about the light mapping we studied light by surveying its effects on the space by mapping the radiation field in the different scales.

Case study 1, proposed that the light can affect human decisions in the space. In urban public space, light zones and light sequences have a substantial effect on the activities. New indexes such as Average Light Zone Change Distance (alzcd) can be defined to evaluate the quality of urban public spaces. These indexes can be reliable factors to compare to built environment.

Case study 2, showed that a geometry according to its openings and divisions, defines different light footprints. This footprints if studied independent of the geometry will produce a grammar, the lighting grammar exists for any geometry, but it should be revealed by light mapping.

Light mapping method case studies showed that studying light by its effect concerning architectural space can be a very interesting framework in architectural point of view. Experimental studies and the light mapping methods can be developed to study other variants and scales of light related problems.

6.3. Possible Further works

Two more case studies on: light and building and light and skin, were planned to be carried out in this thesis. But because of the time restrictions and domain of the thesis topic they were left behind to be done in future works.

Light mapping in building scale (5-50 meter) can release the effects of a building mass in its settling area. In this scale we face in-between spaces; Spaces that are not clearly interior or exterior and spaces that are both interior and exterior. Light mapping in in-between scale has high potentials to investigate results on entrance position and lighting, and transitions from exterior to interior and vice versa.

Light mapping and skin case study was planned to study effects of details on interior light maps. It is another topic for th possible further work.

Concerning the responsive systems chapter, smart and feedback response systems also have areas of undiscovered subject. Questions like how can we propose a feedback responsive system or a smart responsive system in architecture can be good questions for future work.

[.]

7

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7.4. Images Credits

Chapter 1

[fig.1] Flickr user: Camilo - A
[fig.2] http://www.gilbert-garcin.com
[fig.3] Flickr user: Maryline Cox
[fig.4] Flickr user: m.schuit
[fig.6] Daniel Rozin
[fig.9] http://www.emerson.arch.ethz.ch/
[fig.10] http://en.wikipedia.org/wiki/Abacus
[fig.11] Flickr user: urban don
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[fig.16] http://mediacup.teco.edu/
[fig.17] Adrian Donughue
http://www.1x.com/
[fig.18] http://nedkahn.com/

Chapter 2

[fig.1]Adrian Donoghue
http://www.1x.com/
[fig.2] James P. Warfield
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[fig.6] Google image
[fig.8] http://www.billviola.com/
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[fig.10] Flickr
[fig.11] Google image
[fig.12] Google image

Chapter 3

[fig.4] Louis Kahn
http://architectureplusart.com/orange84/2011/11/moving-lines/

Chapter 4

[fig.1] Jean Blaeu, 1641
[fig.3] http://en.wikipedia.org/wiki/Geneva
[fig.5] Flickr
[fig.6] Maroi Klingemann
https://plus.google.com/101387543199434443057/posts
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[fig.12] http://www.facebook.com/
[fig.13] http://www.gilbert-garcin.com/
[fig.14] http://www.bing.com/maps

8

Appendix

8.1. APPENDIX 1 : Radiation Map Calculation Method

The instantaneous luminance distribution throughout the sky vault may be described, relative to some reference point, using an expression due to Perez et al (1990):

$$\lambda_i = f(Z, \theta) \qquad \ldots(1)$$

where Z is the zenith angle of the considered sky point, θ the angle between this point and the sun. Now, if we discretise the sky into a set of p sky patches, of solid angle Φ and mean altitude γ then, given a diffuse horizontal irradiance Idh, we may define a (relative luminance to absolute radiance) hemispherical normalisation factor:

$$\chi = I_{dh} \Big/ \sum_{i=1}^{p} \lambda_i \Phi_i \sin \bar{\gamma}_i \qquad \ldots(2)$$

From this we may calculate the absolute diffuse radiance R of a sky patch:

$$R_i = \lambda_i \chi \qquad \ldots(3)$$

Alternatively the product of this absolute radiance and a diffuse luminous efficacy ηd (say using the model due to Perez et al [4]), defines an absolute diffuse luminance L distribution: $L_i = R_i \eta_d$.

In GenCumulativeSky we use the discretisation scheme due to Tregenza in which the vault is split into seven azimuthal strips in which the azimuthal range of the composite patches tends to increase towards the zenith (12°, 12°, 15°, 15°, 20°, 30°, 60°), at which there is a single patch so that there are 145 in total. Each patch subtends a similar solid angle, as given by the azimuthal range Δα (radians) of the ith patch and the corresponding maximum and minimum heights of elevation γ:

$$\Phi_i = \Delta\alpha_i \left(\sin \gamma_{i,\max} - \sin \gamma_{i,\min}\right) \qquad \ldots(4)$$

The cumulative radiance (Whm-2Sr-1) / luminance (lmh.m-2Sr-1) for a given period is simply the aggregation of the

instantaneous results within these patches. Now, if for computational efficiency we wish to describe a global sky radiance distribution, we must increase the radiance of the patch in which the sun is
located (that for which the angular distance between the sun and the patch centroid is the least): $R_{i,s} = I_b / \Phi_i$. Again, for a luminance distribution the numerator should be multiplied by a beam luminous efficacy.

Alternatively, the properties of the full / binned set of suns should be defined. In this case we simply determine the angular coordinates (as a unit 3D vector) as well as its radiance, using an identical expression to that for the global sky, but substituting the solid angle with that of the solar disc (~0.222Sr, based on a half angle of 0.2665o).

8.2. APPENDIX 2 : Geneva City Solar Radiation Statistics

Monthly Statistics for Solar Radiation (Direct Normal, Diffuse, Global Horizontal) Wh/m²:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Direct Avg	644	1662	2555	3293	3651	3215	4436	4179	3278	1672	961	378
Direct Max	3417	6379	5844	7869	8701	8779	8455	7655	7277	6197	4472	3773
Day	10	27	13	14	13	25	5	18	7	3	15	31
Diffuse Avg	680	985	1626	2056	2674	3194	2620	2289	1798	1315	767	622
Global Avg	881	1646	2969	4069	5184	5521	5843	5077	3697	2086	1094	733

Maximum Direct Normal Solar of 8779 Wh/m^2 on Jun 25

Average Hourly Statistics for Direct Normal Solar Radiation Wh/m² :

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0:01- 1:00	0	0	0	0	0	0	0	0	0	0	0	0
1:01- 2:00	0	0	0	0	0	0	0	0	0	0	0	0
2:01- 3:00	0	0	0	0	0	0	0	0	0	0	0	0
3:01- 4:00	0	0	0	0	0	0	0	0	0	0	0	0
4:01- 5:00	0	0	0	0	0	0	0	0	0	0	0	0
5:01- 6:00	0	0	0	0	0	1	0	0	0	0	0	0
6:01- 7:00	0	0	0	4	82	76	92	38	0	0	0	0
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8:01- 9:00	0	59	101	201	290	249	323	326	213	98	24	0
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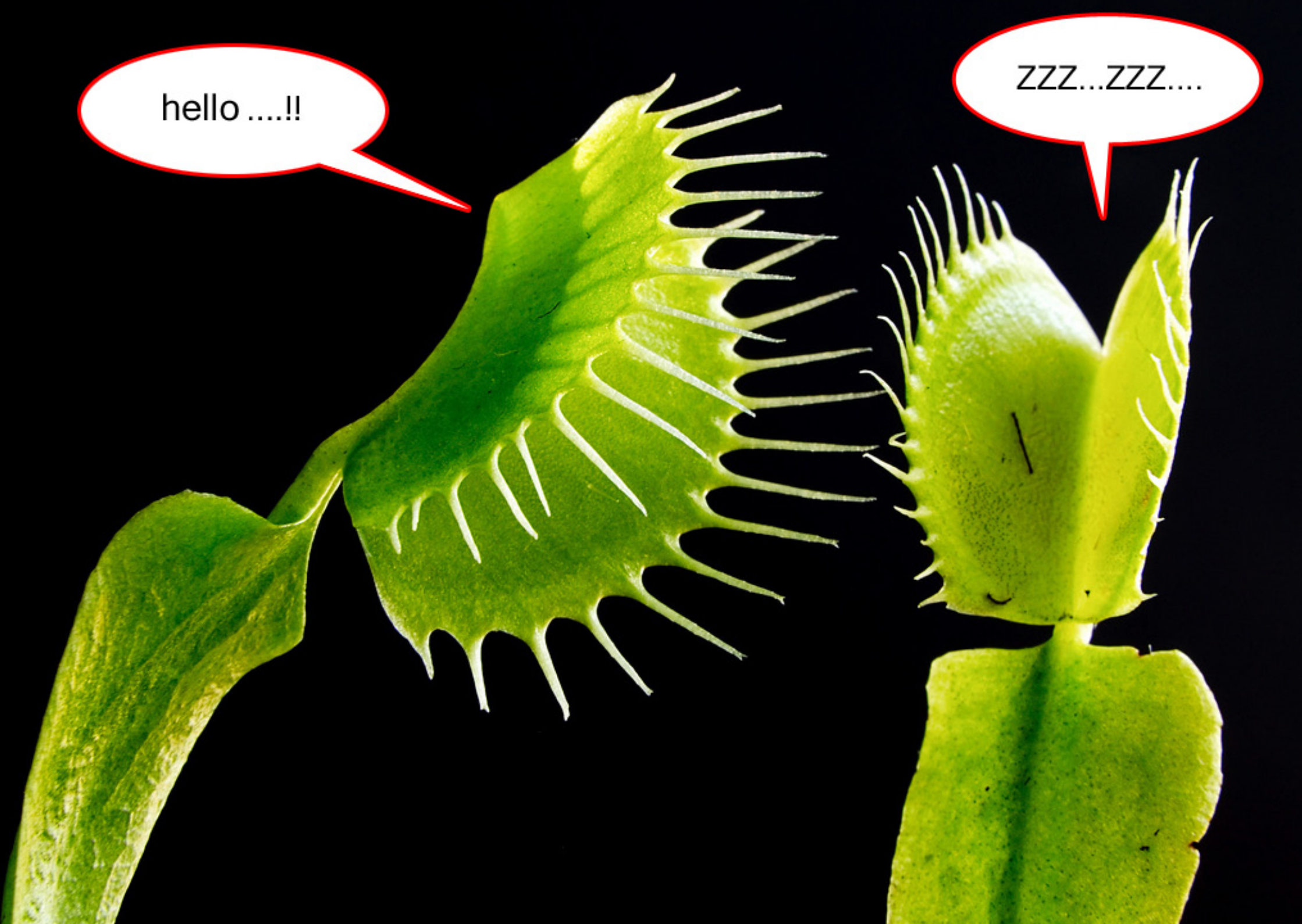
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Responsive Systems

Light and Human Responsive Systems in Architecture

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January 2012, Lausanne