A Descriptive Framework to Design for Mutual Location-Awareness in Ubiquitous Computing

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EPFL Technical report IC-2008

Abstract. The following paper provides developers, designers and researchers of location-aware applications with a descriptive framework of applications that convey Mutual Location-Awareness. These applications rely on ubiquitous computing systems to inform people on the whereabouts of significant others. The framework describes this as a 3 steps process made of a capturing, retrieval and delivery phase. For each of these phases, it presents the implications for the users in terms of interpretations of the information. Such framework is intended to both set the design space and research questions to be answered in the field of social location-aware applications.

Keywords: location-awareness, framework, cscw, ubiquitous computing.

1 Introduction

The possibility to support the representation of significant others' whereabouts in the physical environment has been one of the leading trends in ubiquitous computing. This class of application, enabled by location-aware technologies has been exemplified by early prototypes such as "Active Badge" [41] which proposed to transmit and represent the real-time location of a badge carried by a person in a building. In the last fifteen years, this topic has received a large amount of attention by researchers in ubiquitous computing (see [5] for a review) and some commercial products that support this awareness of others' location are now running on state-of-the-art cell phones (e.g. Plazes[1] or Dodgeball[2]) or in-car GPS (e.g. TomTom Buddies[3]).

However, the applications catalogued as "location-aware" technologies or "location-based services" are still broad and diverse. They often refer to both applications that convey information about others' location in space as the one

[1] http://www.plazes.com
[2] http://www.dodgeball.com
[3] http://www.tomtom.com

mentioned above and annotation systems that allow the association of digital information to physical locations ([13] for example). Some of them, such as in-car GPS-enabled systems, can be used individually and some others are multi-users. The latter are often referred to as 'mobile social software' or 'social location-aware applications'. There is thus a need to distinguish a different class of applications and interfaces that only focuses on what we termed "mutual location awareness" (MLA hereafter): the exchange of information about people's location in space through technologies and interfaces.

'Awareness" is the main concept at stake in MLA: this well-known notion in Computer-Supported Collaborative Work (CSCW) of 'awareness" corresponds to what Gutwin and Greenberg defined as the "*up-to-the-moment understanding of another person's interaction with the shared workspace*" [17]. More precisely, according to these authors, awareness refers to the perception of changes that occur in the shared environment. Gutwin and Greenberg also highlight that awareness is not only to perceive information but also to recognize the contextual elements required to carry out a joint activity. This is what Dourish and Belloti expressed by defining awareness as "*an understanding of the activities of others, which provides a context for your own activity*" [11]. These definitions emphasize the idea that awareness is meant to enrich the context of a social activity such as collaboration. In the MLA case, we are interested in a subset of the information that can be considered as being part of 'awareness': the location. What we mean by "location" can take different forms depending on how this information is conveyed for example a text message that indicates a person's whereabouts or dots on a map. Finally, the word "mutual" in MLA has been chosen to differentiate the knowing of one's own location to that of partners. By "mutual" we refer to knowing both one's and partner's location. This term also implies a notion of reciprocity. It means that a person A can be aware of her partners B and C's location, and that B and C also have access to that information (not necessarily in real-time).

As we describe afterwards there is a large diversity of systems and approaches that support MLA, and at the same time, there is little conceptualization or framing of the corresponding design space. As a consequence to this, it is often the case that designers and researchers working on interfaces to support MLA suffer from the "reinvention of the wheel syndrome", repeating mistakes or leaving asides certain issues and key problems [33].

This paper aims at providing a descriptive framework that presents the main characteristics of Mutual Location-Awareness interfaces. The idea is to formalize the different steps at stake when designing a MLA interface ranging from technological constraints to interfaces issues. Unlike existing models that we will detail later on, we propose to include a user-centric dimension by highlighting the expectations and interpretations of the people who employ these applications. This framework then takes the form of a list of components, which corresponds to each steps of the interaction process: the capture of one's location in space, its query by another user and the different interface to delivery that information.

We believe that such a unitary description is of interest to designers so that they can have a clear outline of the main characteristics they should define and structure when building an application that convey information about users' whereabouts.

This work has been developed based on variety of sources. At first, it expands on existing theories concerning awareness [17], location-based community systems [26] as well as technical taxonomies of location-aware systems [20]. Our framework is also based on a critical review of design and studies about location-sensing applications both by ourselves and other researchers.

Our aim here is to give an overall picture of MLA by (1) providing a list of possibilities and choices to be made, (2) suggesting key issues and topics that need to be addressed, and (3) enabling to explore new research areas. More pragmatically, the framework characterizes the relevant issues and requirements for developing MLA interfaces, rather than providing strict rules and guidelines.

The article is structured as follows. Section 2 covers the literature about existing models about awareness and ubiquitous computing related to location-aware systems. Section 3 describes the framework by outlining the different MLA characteristics. Section 4 then conclude the paper by discussing about its potential use for research and design.

2 Related Work

There are already some descriptive frameworks that can be applied to the MLA interface subclass, ranging from general contextualization to more precise requirements definition. In the following section, we present three frameworks that are related to MLA because of their global description of awareness, a focus on how these interfaces links groups of users and geographical places or the technical implementations they propose.

The most prominent one is the awareness theory proposed by Gutwin and Greenberg [17], which differentiate the core components of this concept. Defining "awareness" as the broadcast of information concerning the interactions of people with each others and with the environment, they use the "Who, What Where, When" questions as a way to set the general dimensions of what awareness should be made of. For example, the "Who" questions allows to define identity (who is participating) and authorship (who is doing what). Answering the "what" question enables to define what actions are performed, the goals and the artifacts that are deployed. Moreover, as they claim, awareness can be described in terms of the period of time it covers, conveying information about the present state of the environment ("synchronous awareness") and or about past occurrences of events ("asynchronous awareness"), which corresponds to the "When" question. Finally, the "where" category corresponds to Mutual Location-Awareness, which answers to the "where people are" or "what people look/what can they see" questions. Therefore, MLA can be seen as a subset of awareness [12]. Given that this descriptive framework aims to clarify awareness in a comprehensive way, it is too broad to articulate all the subtleties of MLA. However, certain features such as the difference between synchronous and asynchronous awareness are certainly of interest with regards to location of people in real time or in the past.

The narrower scope of "P3 Framework" by Jones et al. [26] defines a class of system they term 'People-to-People-to-Geographical-Places", which corresponds to community applications ('People-to-People') organized around the notion of place (Geographical-Places). The authors categorize these systems and propose a 2x2x2 design space based on 3 subdivisions. The first discriminates *People-Centered* versus *Place-Centered* applications. Where the former refers to techniques that use location information to support interpersonal awareness and allow or foster communication, the latter concerns techniques that link digital information to physical locations. Each of them can be subdivided along two different dimensions. Jones et al. distinguishes People-Centered techniques that employ *absolute location* from those using relative location or *proximity* between users. This distinction corresponds to applications that give users information about where their friends are and those which only tell who is in the vicinity. Place-Centered system proposes two types of representations: either showing *people's current use of a physical location* (e.g. displaying who is in the same building now) or *associating digital information to a physical location* (e.g. showing forum messages attached to a certain place). They alto retain Gutwin and Greenberg's differentiation of *synchronous* versus *asynchronous* location-awareness given that each feature can be instantiated in real-time or asynchronously. Although this framework interestingly describes some relevant aspects of location-aware interactions, its focus is too narrow to encompass the whole location-awareness experience. Given that it is limited to the link between people and places, the authors do not take into account how the information is delivered (e.g. a map, a message) or even the location-sensing techniques.

Other types of scholar work such as [19] and [20] adopt a different approach by giving a technological overview of the location-sensing techniques available so far. They focus on what can be captured, how as well as what can be delivered out of it. For that matter, [20] then defines some properties of such location-aware systems: the possibility to provide physical position (GPS coordinates, latitude and longitudes) or symbolic location ("home", "a car entering Los Angeles"), the difference between absolute and relative positioning (depending whether the frame of reference is shared or not), the accuracy (the grain size of the information that can be provided) and the precision (the odds to obtain that accuracy). Hazas [19] expands on that topic by making the distinction between coarse-grained systems and fine-grained ones. Due to their technical focus, these frameworks are limited because they only describe part of the user experience of MLA systems.

As a conclusion, this section has shown that the available frameworks about location-awareness are either too broad for MLA (which is a subset of awareness) or too focused on specific characteristics (how to connect communities and places or sensing techniques). Therefore we believe in the need to define a proper framework for Mutual Location Awareness that would, (a) focus on the "where" category of awareness, (b) be global enough to encompasses properties ranging from the expectation of the user to the capture of location information as their interpretations after being delivered, (c) describe MLA from the user point of view and not from the system's. That is why we favor a more holistic approach that build upon the above framework, put them together and add some other properties to create a more comprehensive framework of MLA.

3 A Framework for MLA Interfaces

Through the analysis of the literature, we have discriminated that the user experience of MLA interfaces corresponds to a 3-steps process. As represented on Figure 1, the participants' *location need to be captured* by the system, a user can *query and retrieve* this information that is *delivered* in a certain way. On top of these 3 steps, *the cognitive dimension of the user* concerns his or her expectations as well as the interpretations that can be drawn out of the locative information. For each of these steps, we will hence describe the user implications.

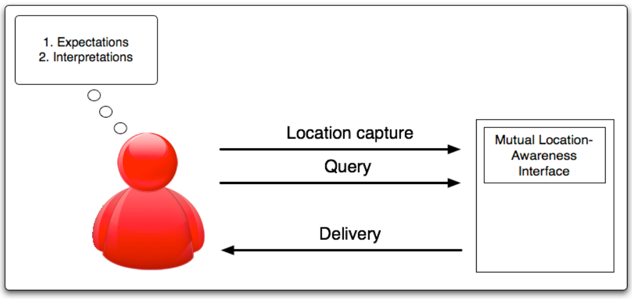

Figure 1. Main criteria to describe the framework.

3.1 Capture

This first step concerns the capture of the individuals' location in the physical space. Considering this phase form the user's point of view should lead the designer to consider who should realize this capture: should it be delegated to the system that will thus automatically detect people's whereabouts with different degrees of accuracy? Or should it be left to the user? For example, the user can be asked to send his or her own location so that it can be displayed on the contacts' lists of his or her partners. We can distinguish the mode of capture along two axes: *automatic* and *self-disclosed*.

Although a large majority of projects in computer sciences focus on the former, let us first consider the advantage of the latter. Leaving the agency to the user raises an important issue regarding communication and spatial information: compared to automatic positioning in which location is just information, self-declared positioning is both an information and an act of communication act, intentional by definition. If A tells B where he or she is located, not only B knows A's location but he or she also knows that A considers that it is useful for B to know it. In other words, self-disclosed location add some intentional weight that help providing mutual intelligibility to communication because people gives information they estimate as being relevant for their partners. Another advantage for self-disclosing one's location is that it allows people to employ the location names that make sense for the participants. The difficulty of location-based applications in conveying a meaningful semantic of places makes it more efficient to let users express their location by using their own description, a topic already discussed by [35]. This finding, on the benefits of manual location disclosure, is confirmed by what Benford et al. revealed [7]: self-reported positioning could be reliable low-tech alternative to automated systems like GPS. In addition, our findings go further by proving that letting users declare their position themselves is better with regards to various processes like communication or the construction of a mental model about the partners [32]. Finally, the last advantage of self-disclosure of one's location is that it may allow to communicate one's future location. [14] describes a physical device that enables user to turn a knob to see the past location of family members (captured through GPS reporting and radio beacons scanning) as well as their planned location. This is also the approach taken by Dopplr[4], a social software in which people disclose their future trips. The inherent intentionality of such messages about future location is beyond grasp of technological means, even though automated systems are being developed to infer and predict certain trajectories like driving behavior [28].

However, there are two disadvantages to self-disclosure of location. First, the potential network connectivity and lag issues are harder to detect technically simply because, unlike automate location-awareness, there are no regular expectation of incoming data [7]. In consequence, the potential delay in the delivery of the information increases the uncertainty in the communication. This type of ambiguous situation occurs whenever expected information does not get delivered, raising the doubts on both the system operation and the human intentions. An automated broadcast of information is expected and we know there is something wrong when not transmission takes place. Another drawback is the additional workload that is created by such an approach since users would have to send explicit information. Further, scholars have reported how people are very poor at remembering to update system representations of their own state [3]. A second major consideration is of course the context of the activity. Let us transfer the problem of showing people's location in a real-world situation. If we had two groups of airplanes in flight, one with radar and one without, the planes without radar would certainly spend a lot more time communicating with one another to check on their mutual locations. The new fangled airplanes that had adopted radar would lack the mutual awareness that the non-radar group had. The issue, in other words is that it matters a great deal what sorts of work mutual awareness tools are supporting or disrupting. The number of collaborators and the level of decentralization are certainly of importance. For some workplaces letting the user declare where they are is fine but in contexts such as air traffic control or the navigation of shipping lanes it is not a practical possibility.

When location capture is automatic, the agency of sensing the individuals' position in space is left to the system. Various technologies are available for that matter [20] using various radio waves ranging from GPS to cell phone communications, WiFi or TV signals. Using diverse techniques like triangulation, proximity measures or scene analysis, one can then determine where objects and people are located. Apart from techniques, platforms such as Place Lab [29] provide easy-to use software architecture that allows to position devices such as cell phones, PDA or laptop computers indoor and outdoor.

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[4] http://www.dopplr.com

The advantage of an automatic capture is first and foremost because the administrative burden is lighter for the user. Through the automation of the capturing process, he or she does not have to choose the location information and find how to send it to the peers. To some extent, it can be worthwhile in specific cases when people do not know how to express where they are, in terms of granularity. For instance, while people generally know which city they are visiting, the district, area of blocks is not always easy to term.

Nevertheless, the most important problem regarding the automatic capture is certainly that it raises privacy concerns. Location privacy that [8] defined as "t*he ability to prevent other parties from learning one's current or past location*" is thus harmed by location-aware technology. The applications we described indeed allow people to have access to timely and positional information and hence generate potentially sensitive information. This then leads to difficulties in the social acceptance of MLA technologies in terms of user rejection or reluctance to employ certain features. A possible answer to these concerns is to provide abilities to switch off or to define different levels of permissions to access to the location information. The fact that awareness threatens privacy has been acknowledged both for virtual environments and ubiquitous computing (see [3] [4] on this topic) since both enable the capture and storage of people's positions and their activities. This relates to the long-term debate in the CSCW field about the balance between awareness and privacy intrusion [24]. Designers of multi-user applications face the problem of providing enough information transmitted to others (so that they can benefit from it) without threatening the protection of users' privacy. [31] and [1] show how a certain level of privacy loss can be accepted if the benefits perceived are sufficient enough.

A second problem of automatic capture is the lack of control for the users. [25] showed the lack of value of automatic MLA, which does not support the possibility to lie or plausible deniability in communications. The first issue can be solved with spatial cloaking techniques [16]. The latter is important given the desire from people to deceive or deny reply for situated purposes only relevant to them. These two works highlight the importance to preserve imperfect sensing and communication of location information.

3.2 Retrieval

The second step in the process concerns the retrieval of the captured information: how do people access information on their contacts' location? What do they have to do to obtain it? What does it take to be mutually aware of others' whereabouts? One can distinguish two aspects regarding retrieval: the mode (how information are retrieved?) and the scope (how to select the information to be retrieved?).

The mode of retrieval corresponds to how user can access MLA: is it upon request or by receiving it automatically? As we have seen in the preceding section, the point here is also to decide where to the agency of the system: should the user ask for MLA or is it preferable to delegate it to an interface? The same argument can be applied here about the advantage and disadvantages of automation, depending on the situations in which users are engaged in. Besides, from a technical point of view, a constant update of location information is often not feasible when considering the positioning of a large number of artifacts or people. Information can be derived from various sensors and context, which leads to different accuracy. There is thus a need to have update protocols that take this problem into account [30] .

If the retrieval is based on the user's initiative, it can be based on different scopes. As we have seen in [26], the user can look for information about people (*People-Centered*: "Display my friends location") or look who is located in a specific place (*Place-Centered*: "Who is in that room"). But we add two other scopes: a particular event and time. People might indeed want to access to be aware of others' whereabouts when a certain event occur, that is to say when the state of the environment changed. In emergency situations (e.g. earthquake, car accident), the system can be triggered in such a way that MLA is automatically conveyed to known ones. Finally, the scope of information that needs to be retrieved can be bound to a specific period of time. This last characteristic corresponds to the difference made in [17] between synchronous (information about real-time position in space) and asynchronous MLA (information about real-time and post position in space).

3.3 Delivery

Delivering people's whereabouts needs to take into account different aspects such as the users expectations, the format of the representation, granularity as well as how to represent the time dimension.

Expectations Towards MLA As described in [27], users of mobile location-aware services expect availability in special and spontaneous situations. This demands technological settings that can support flexible, nuanced, and contextualized social world. However, the user expectations of MLA can be easily obscured by the limitations of modeling the subtlety of social settings and problems in terms of service coverage, stability, connectivity, mobility, cost, privacy and accuracy. As shown in [7], users struggle with the shortcomings of location-aware technologies deployed in real-world settings. These observations reveal a social-technical gap known in CSCW [2] "that divides what we know we must support socially and what we can support technically". For MLA, that exposes the need to handle inadequate location information without undermining the benefits of location-aware systems. Different scholar works suggest pragmatic solutions to bridge that gap and in consequence meet the user expectations. Chalmers and Galani [9] observe that people accommodate and take advantage of seams and heterogeneity, in and through the process of interaction. In the same vein, [32] reported the reactions of players of a location-based game when confronted to a discrepancy concerning their partner's position: believing the system, saying that the system was wrong or not understanding. When asked why they questioned the system, players said that this information was contradictory with what they expected. In consequence, Chalmers and Galani advocate that designers of ubiquitous systems may consider selectively revealing differences and limitations of systems, in ways that support social interaction, an approach they refer to as "Seamful design". In that approach, [39] developed a visualization that shows black spots to GPS users and therefore prevent frustration caused by inaccuracy or availability.

Output Format Although other channel of communications can be employed, the final format of how the output is generally displayed visually in 3 ways. It can be verbal (name of a place), symbolic (shown as a symbol), or geographic (depicted on a map metaphor).

The simplest form of MLA is a verbal or text-based description of people's whereabouts. This is obviously the case for explicit disclosure of one's location by cell phone (audio communication, audio message or SMS). Yet, MLA can be conveyed verbally by various systems, which automatically capture the user's position (either in virtual or physical space) and display it to the partners with a short sentence, such as a place name. The Clicmobile service[5] allows a user to send his or her position as text and the system replies with the friends and friends-of-a-friend's positions in the vicinity (10 blocks) as shown on Figure 2a. Unlike Clicmobile, which rely on an active model (the user has to send his or her's position to get the contact's ones), Jaiku[6] is more passive: the information about others' whereabouts is displayed as a line in the phone book updated in real-time (see Figure 2b). It is also possible to use a verbal display to indicate the proximity of a person. An example of such MLA interface is The Hummingbird [23]. An early prototype of location awareness on a pager, this application displays the ID of persons in the vicinity.

Figure 2. Displays of two MLA interfaces on cell-phones: (a) Clicmobile: MLA based on verbal description of location, (b) Jaiku: MLA a one-line description in the phone book.

A second form of MLA representation consists in displaying people's location as a symbolic representation with "place descriptors" as in the Microsoft's Whereabouts clock shown in Figure 3 [38]. Designed for the context of the kitchen, this MLA interface displays family members, essentially for family activities coordination (e.g. planning a meal, knowing whether someone is on his way to home). The clock metaphor is used to provide coarse-grained information such as "home", "school" or "work" and no precise position, which can be irrelevant in the context of the use of this artifact. In this example, information about others' whereabouts is automatically

[5] http://www.clicmobile.com
[6] http://www.jaiku.com

provided by SMS that are sent to a family member when one of them moves from one registered zone (“work” for instance) to another registered one (such as “home”).

Figure 3. Microsoft’s Whereabouts clock’s prototype depicting family members’ location for one day. The discrete locations that have been chosen for this prototype are: “home”, “work”, ”school”.

What is also noticeable in both projects is that MLA is conveyed without any geographical representation. Location is divided into discrete categories, which are supposed (or designed) to be meaningful for the user and the granularity of these categories is loose and provides a context to family members. For instance, in the Clock device, since the MLA is mostly meant to support family coordination, there was no need to show detailed information about workroom positions. These projects illustrate the difference between space and place we already mentioned: the location conveyed by them is related to people’s places rather than spatial coordinates. The designers indeed chose the locations that make the most sense from a socio-cultural standpoint such as work, school or home.

The third type of MLA interfaces is based on the RADAR paradigm (Radio Detection And Ranging) that displays persons or artifacts present in the vicinity. As a recurrent representation for locating objects in the physical world (e.g. air traffic control, military applications), this paradigm inspired virtual space versions. This type of MLA interface has a relative format of delivery (that we could call proximity awareness), since some elements remain hidden (those which are not in the vicinity). Moreover, even though the “Radar view” displays the positions of participants, it does not provide the users with a representation of spatial features like topography or position of area boundaries (apart from circles than indicates distance to the user). The representation is limited to a small portion of the space and is only directed towards the presence of objects and people in the area. Such display can be illustrated by the application Jabberwocky used in the “Familiar Stranger” project from Intel Research [34]. The authors created a mobile phone application that displays the proximity of familiar strangers (i.e. the person you often come across but you don’t know) as shown on Figure 4. The projects presented here do not reveal the identity of users in the vicinity, but this is not an intrinsic feature of Radar views; one could design non-anonymous radars.

Figure 4. Display of Jabberwocky, providing a quick way to visualize the current and past strangers encountered. Newly encountered strangers appear at the top of the screen as red squares. As time elapses, the strangers slowly move down towards the bottom of the screen. Once they reach the bottom they slowly fade out.

Slightly related to the Radar paradigm, is the mapping of participants' position on a representation of the environment in the form of a map. The difference between this type of MLA and the Radar is that in this case, the environment is depicted and not the sole elements in the vicinity. Mobile computing applications (on PDA or cell phones) offer a peculiar situation since there is a direct mapping between the physical environment and the information displayed on the device. A well-known example of such MLA interface is the "Active Badge" system depicted on Figure 5a.

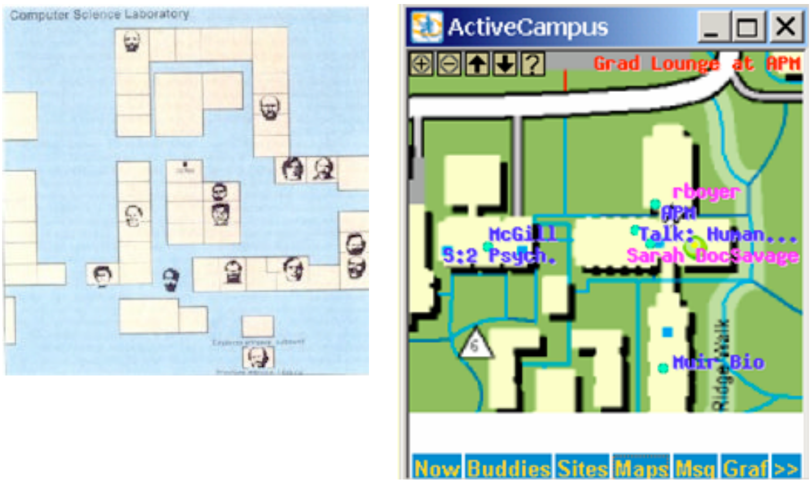

Figure 5. Two examples of reduced maps MLA: (a) Active Badge running on a desktop computer, (b) Active Campus running on a PDA.

Active Badge [41] showed people's positions in the physical environment on a desktop computer display. Active Campus [15], depicted on Figure 5b, expanded this idea at the campus level. Both proposed a reduced version of the environment with people's location superimposed on top of it; Active Badge, as a desktop application could show the whole environment on a map whereas Active Campus required users to scroll on the map. This sort of MLA interface is prominent in location-based games such as BotFighters [22] that shows the whole environment on the small display or Can You See Me Now? that only depicts small part of the environment [6].

These different MLA formats can also be defined using two factors defined in [40] as the *environment model* and the *viewpoint*. The former refers to the number of dimensions employed to visualize the environment ranging from three dimensions (3D model of the environment) to no dimensions (no environment representation). The latter corresponds to the perspective given to the users, whether it is a first-person or a third-person view of the environment. Most of the applications we have described in this section corresponds deploys 1D (Jabberwocky) or 2D (Active Campus, Active Badge) model of the environment. Regarding the viewpoint, maps propose a "third person view" because the users view both the location- based data and his or her representation. First-person views can be exemplified by a system like Jabberwocky in which people views the location information about their partners from a user-centric view, and the location-based data is spread around him or her.

Spatial Positioning, Place and Granularity. When MLA is conveyed verbally or through a symbolic vector (the two first categories from the previous section), the underlying question at stake concerns the spatial qualification to adopt. One can indeed distinguish two approaches that correspond to the space and place distinction made by Harrison and Dourish [18]. To put it shortly, this difference opposes space defined as a range of x and y coordinates or latitude/longitude to the naming of places such as "home" or "London". These authors indeed advocated for talking about place rather than space. They claim that even though we are located in space, people act in places. By building up a history of experiences, space becomes a "place" with a significance and utility; a place affords a certain type of activity because it provides the cues that frame participants' behavior. This choice can have important consequences given that human beings generally favor the notion of "place". Hightower et al. [20] also raised this issue by saying that location-based technologies have the problem of moving from "location" to "place"; for instance, of making geographical coordinates meaningful to the users. In most cases, the solution is to show the MLA information on a map of the environment, turning the naming problem into a tuning of the map to show finer-grained information.

This example leads us to a second relevant issue: the granularity of the spatial information, that is to say, which scale to choose with regards to the representation of the environment. This is of interest for all the 4 categories mentioned in the previous section. For instance, if a person A is located in the kitchen of a restaurant in London: should the verbal MLA indicate that A is " "kitchen", "restaurant" "London", "England" or "UK"? Should it be depicted as small dot on a map at a street level? Or, instead as an arrow on the map of England? Very often, this leads to problems in interpreting the information sent by the MLA interface, as we will see in the "user" section afterwards. In their experiment of various MLA systems, [10] underlines how the display of location information provided little assistance to users in interpreting the associated state of the person. As a matter of fact, when a user was lost or not making any progress, participants were disconcerted because there was not enough information to understand what the problem was. This kind of uncertainty in interpreting locational information can lead to detrimental effect of MLA on users' understanding of the situation. Another important limit is that the position offered or described by technology often does not correspond to the positions people want to refer to when they are conversing [36], hence the value of self-disclosed MLA. That said, the existence of different levels of granularities could be worthwhile in specific contexts. For example, it can avoid privacy intrusion by allowing to adjust the granularity depending on who requested the person's location: family can access the exact location and co-worker sonly at the city level. Privacy here is not just a matter of being on or off the grid but also the level of granularity one can accept to disclose to others [37].

The Importance of Time. MLA interfaces also propose a decay function that represents the past position of persons in space. In that case, it corresponds to the asynchronous MLA we mentioned previously, as shown by (area)code[7] example represented on Figure 6b. Past positions of people are connected and represented as a path on the environment map.

Figure 6. (area)code map interface, showing the path of participants: an asynchronous MLA.

In addition to spatial accuracy discussed above, the temporal accuracy of the location information plays a determining role in the usefulness of MLA. While often advertised as is, location information rarely comes in real time. First, the capture of a position comes sporadically (e.g. every 1 seconds). Second, MLA systems rely on the network but also on update protocols used to broadcast the data [30]. As a consequence, when delivered, a depiction of MLA is already a representation of a past situation. Moreover, such spatio-temporal information can decay and become irrelevant, misleading or even as a cognitive burden for the user. As time impact MLA, a system reporting on mobile persons or objects needs to answer the combined question of "where and when" and convey the time of a location sighting. In the case of real-time systems, the schedule of the location update protocol can increase the uncertainty of the location information. In consequence, a representation of this spatio-temporal uncertainty can be useful to inform users on the timeliness of the

[7] http://www.areacode.org.uk/

delivered location information. A seamful design approach would share the maximum uncertainty of the location sighting by adding the distance the object or person can have traveled to the uncertainty of the sensor system.

This shows that MLA is also sensitive to time. Such spatio-temporal can decay and become irrelevant, misleading or even as a cognitive burden for the user.

4 Conclusion

4.1 Summary

The framework we presented here simply revolved around the notion of a 3-steps process made of capture, retrieval and delivery of location information. Based on existing frameworks as well as the research literature about MLA studies and development, we described the design space regarding these elements, as summarized in Table 1.

Table 1. MLA framework summary.

Phase	Criteria		Advantages for users
Capture	Automatic		More reliable, less burden for users
	Self-disclosed		Respect privacy, intentionality, control, mutual intelligibility of naming locations
Retrieval	Mode	Automatic	Less a burden
		Upon request	User in control
	Scope: People-Centered / Place-Centered / Time-Centered (synchronous, asynchronous)		Relevance of criteria chosen to retrieve information,
Delivery	Output format: text/verbal, symbolic, map (RADAR/overview)		Relevance of format depending on context and technical issues.
	Granularity: space versus place		Place is more user-friendly and allows mutual intelligibility
	Time: synchronous versus asynchronous		Depending on context.

Yet, the linear description of this framework should not obscure the fact that MLA systems do not necessarily fall in these specific subclasses. Indeed, the presentation of this framework does not exclude combination of characteristics. An application like

Plazes[8] applications combine several of the features presented here: allowing both automatic and self-disclosed capture of one's location, as well as different forms of query people- or place-centered.

4.2 Use of the Framework

The descriptive framework of MLA we have presented here can be used both to reveal the design opportunities or challenges and the possible vectors of user research concerning this class of applications.

We believe that this framework can impact the work of developers and designers of MLA middleware and applications. Each layer provides consideration to the social-technical gap formed by the constraints in capturing, retrieving and delivering location awareness to support the riche yet nuances social world. So far, middlewares for ubiquitous systems have been mainly modeled and developed from the technological constraints and opportunities. Extended work have been performed to develop middleware that embrace contextual change, facilitate sharing and support both local and global computation. However, user studies very rarely influenced the architect, programmers and system designer's viewpoints on that issues. For example the implication of asynchronous information retrieval could influence to choice on messaging and protocol handling. Moreover, this framework suggests that system designers can profit from a description of the user expectation when the information is captured (e.g. leaving control/agency to the user), retrieved (e.g. level of automation), and delivery (e.g. granularity of information) and consequently impact the dynamics of the middleware. For example, a consideration of the user expectations of granularity of information should impact the measurement and modeling of the physical location to fit to the user understanding of the space and place. Similarly, observations on how user retrieve location information should inform on the system designer's choice of a location update algorithm and its adaptability. An understanding of the everyday user requirements in the delivery of location information can influence the settings of a middleware-based spatial and temporal cloaking technique. Finally, application designers can evaluate the several output formats we define based on contextual and technical issues in location data capture. For example we have mentioned the underwhelming effects of automatic positioning in MLA [32]

Moreover, the framework we presented here could also be of interest for user research, as a way to structure the research questions to be addressed. As we have seen, each of the steps in the MLA process lead to research questions in terms of user interactions and interpretations. Although we summarized some of the studies about them, a large number of questions remain unanswered, and even unasked. The present article does not answer to these questions but clearly set research tracks about what to investigate regarding MLA. The description we gave clearly shows that most of the research studies have investigated the "delivery" and the "capture" phase, leaving aside what concerns the mode and scope of "retrieval". This said, there are two categories of questions that can emerge from this framework. On one hand, the

[8] http://www.plazes.com

consequences of design choices is a good starting point to understand what are the general implications of automating the capture, providing asynchronous awareness or changing the granularity of the information. On the other hand, the articulation between design choices and situational aspects is also very important: in what context automating the retrieval would be important? What situation requires users to need intentional locations? Both type of question will eventually lead to more specific design guidelines than the descriptive aspects we presented here.

Further out, the next step in our work is to apply this framework both to designed MLA systems and research studies in order to have a clear overview of existing material. A classification of that sort would help us to define more deeply what has been done and the opportunities to design novel MLA applications.

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