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Privacy in AmI space: Designing for Private and Public Worlds

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Abstract

We live in an increasingly networked world. We conduct our daily activities moving through physical spaces, negotiating social and personal identities. At the same time we negotiate electronically mediated personalities, tasks and spaces. More often than not, these parallel worlds present insuperable conflicts that we are asked to resolve in ad-hoc ways. Moreover, we are confronted by challenges such as information overload, attention demanding machines and unusable interfaces while we move through information space. Physical space and our social behaviour in it, is eroded by new and emerging practices in our management of information.

While traditional HCI research deals with measurable quantities such as usability, error return and task completion, and cryptography with encryption algorithms and standards in the construction of information worlds, interfaces for privacy in AmI (Ambient Intelligence) space cannot be resolved with these methodologies alone. Ethnography and cognitive psychology have recently been added to the disciplines directly involved in the design of computer-mediated worlds.

What we are suggesting in this paper is to look at architectural theory and environmental studies in the organization of an integrated physical/information reality where the person moves seamlessly between activities and tasks, naturally negotiating social protocols and identities according to context. Physical space, by framing human activities informs the boundaries and protocols of our social behaviour. Information, in order to be managed and used to better our lives, should likewise follow the natural contexts of our social behaviours and respect the protocols of human-to-human interaction.

We propose to look at the design of privacy in computer-mediated worlds as the design of spheres of activities, some more private, some desirably public, in which the user is able to construct identity and trust using the physical world as a metaphor.

The thesis of this paper will be particularly informed by a project we recently completed. Modulor II is a physical architectural space mediated by information technology where public space is both virtual and physical. Social behaviour in Modulor II is informed as much from the physical reality of the environment as it is from the information exchanged with computers. Identity is constructed by a set of activities mirrored in physical and in virtual space. The distinction, however, between public and private selves in

Modulor II is as much controlled as it is artificial. As a hybrid artefact, Modulor II illustrates how information worlds need not be detached from physical reality. It addresses the design of a public space in which humans integrate information management with physical activity in real space.

Information technologies in physical space

In this section I will discuss the deployment of information technologies in physical space, specifically, home automation and communication technologies in housing design. The way ICT has been used in architectural design during the last two decades, points to directions on designing and implementing social architectural space that depart from traditional design methodologies. An approach which considers traditional divisions between public and private actions, activities, spheres and architectural envelopes to house them, emerging social protocols, as well as methods and technologies for the protection of the private sphere, which may take the form of protection of identity, personal data, personal space as well as informational calmness, is called for. This approach calls for a rethinking of the form of the "communication container", be it a physical building or an electronic forum. This analysis can be done at different scales. At the human scale, it means the management of wearable and sensing devices for the control and management of identity and data. At the architectural scale, it takes the form of reactive space for the management and control of social or personal activities. At the global scale, the communication container takes the form of policy support and design for remotely experienced collective experiences, that range from open and public to secure and trusted functions, like e-cities, e-government, e-voting, etc. For the purpose of this paper we will focus on the architectural scale.

Critique of architectural projects using home automation technology.

To understand how home automation technology has been put in practice in the design of domestic environments during the late 80's and 90's in Europe, I am going to look at three examples of home design. All three projects were pursued with the intention of implementing cutting-edge technology solutions and envisioning the house of the future.

"La Nature Technologique", Maison de Futur, Rosmalen, Pays Bas, arch. Cees Dam , 1988-89

The house in Rosmalen is the proponent of the integrated combination of architecture and new technology. Built by Cees Dam in 1989, the building was the result of the sponsorship of a number of companies who supplied the technology for the house and guaranteed the maintenance and upkeep of devices for the following seven years. The project started with 15 invested companies and at its completion one hundred names of different technologies were represented.

The interesting aspect of the Dutch villa is that it uses technology in a consistent and complementary role to the design concept. Instead of simply adding technology to a pre-existing and pre-determined design, the technology requirements and design concept evolve through interacting. The bedroom's function, for example, is dual in this house. It is both an isolated private space and the central headquarters of its residents. This is made possible through the use of a liquid crystal wall that separates and unites the bedroom space with the rest of the house without physical limits, just with the simple use of transparency. With transparency the wall is allowing privileged view and control of other spaces, with opaqueness the bedroom becomes a secluded, private room. In this case it is the behavior of the liquid crystal wall that makes designing the bedroom space as private and public, at the same time, possible.

Transparency and penetration of spaces into each other is also at play at the living room doors to the garden. Four double-height glass doors open up from the living room to the garden with hydraulic command. The doors are like a huge curtain walls when they are closed, preserving visual communication between interior and exterior, opening up to the natural landscape when the weather permits. Transparency is carried through to the most private parts of the house, the bathroom that is glazed on all sides. The glazed roof, which is voice-activated, maintains the transparency theme throughout the building.

The house at Rosmalen also employs more traditional technological applications like solar energy collection panels embedded discreetly in the structure and cabling fitted in floor paneling. Overall, it is a house that uses the available technology with a sensitivity that takes account of ecology, economy and aesthetics in the service of the spatial experience of its inhabitants.

"Verte et Domotique", Maison a Chambray-les-Tours, Indre et Loire, arch. Jean Yves Barrier, Pierre Bideau, Home Automation, 1993

Three years after the house at Rosmalen is designed, Pierre Bideau (light designer of the Eiffel Tower) designs the domotic technology for a house at Chambray-les-Tours which uses not only the bioclimatic and ecological principles of design but couples them with a central control system from a computer operated in a panel on the ground floor. The computer coordinates the heating units, security, sewage and water circulation, and fire detectors in the house. Infrared sensors are embedded throughout the house. The house can be managed at a distance using a simple Minitel. All these high technology applications are coupled with traditional design strategies focusing on energy and economy efficience.[1]

In this house we have the appearance of two concepts for which there is no mention at the Rosmalen Villa: the concept of an intelligent house, tentatively, "comme on les dit les bureaux," and the idea of a house being a soft machine, so refined as to be invisible, destined to serve only the needs of its inhabitants. Here, we have a significant leap in the description of a house from one of a technological character (*la nature technologique*) to one which has become a machine, albeit a soft one.

The House of the Future, Evoluon Exhibition, Philips, Eindhoven, The Netherlands.

Three years after the house at Chambray-les-Tours, in 1996, Philips launches a research project whose goal is to provide a forum and initiate an inquiry on the image of the future house. Experts from such

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[1] Techniques et Architecture, n.407, April/May 1993, p.82-83. Cost of construction and function: 2.1 MF for 206m2 (without home automation costs 1.8MF, less than 3600 F per year for the heating)

diverse fields as sociology and engineering, anthropology and product design, get together to create scenarios for living in the future, develop simulated interfaces for interaction and build spaces for exhibition of their "Vision of the Future". Part of the design process and the technology is the development of intuitive interfaces, using what Philips calls "natural modes of communication," such as speech, writing and gesture.

Between 1990 to 1996 in the development of home automation technology we observe three distinct themes in evolution that together make up what is today the concept of an automated house. Use of new materials and information communication coupled with an ecological and bioclimatic consideration, centrally computer-controlled functions --the house as a machine-- and intuitive interface and ease of use.

The Immovable Permanence of Being (Domotique Inertia)

The polemic of Paul Virilio expounded in 1990 describes the domotic environment in its extreme manifestation as one of static permanence, inactivity and immobility of the body. He sees the domotic design as one in conflict with the traditional function of architecture as one of providing shelter for human activity and circulation. He draws a parallel between automated houses and bodies in coma, and expresses fear that the ideal automated house is a cell of minimal dimensions where economy of functions is the sole requirement. He sees in the following description of a hotel room the evolution of the human shelter:

"…no more a reception hall, just a machine which talks to your credit card; no more an innkeeper, just a code of access which expires automatically at the end of your stay; no more rooms, just cells of six to nine square meters; no more cleaning ladies, just cleaning companies... (sometimes) no more windows, just a sleep-cell ventilated by an air canal...the model here is car parking, a left-baggage room for humans."[2]

In this criticism an ominous future is foreseen, not quite unlikely to happen, especially if the domotic environment is designed only to reduce the circulation patterns of domestic life. Nonetheless, technology is a tool and it can be put to practice to facilitate the complexity and variability of modern life just as easily as it can be used in a reductionistic and strictly economical sense. Let's take a successful example of home automation technology in domestic appliances, the Microwave Bank, recently developed by London's Knowledge Lab.

This is a microwave oven that can be used in the usual context of cooking and defrosting but also has augmented functions, facilitating entertainment, learning, and management of domestic resources. It doesn't do away with the function of cooking instead it enhances it by adding layers of activity that match human desires. While cooking one might want to browse the net for a good recipe, order online those ingredients that are missing from the shelf, but also do a bank transfer to pay for this extra shopping. This pattern of simultaneous desires is a perfectly human phenomenon and one that is echoed by the multi-purpose oven-bank. I think that the difference between the two implementations is that in the latter case the domotic environment may reflect human complexity whereas in the dystopian reality described by Virilio the automated environment imposes a mechanistic and simplistic economy on human behavior.

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[2] Paul Virilio, "L'Inertie Domotique", Techniques et Architecture, n.390, June-July 1990 p.121

Virilio brings up another important point in relation to controlled environments. It is the issue of apparent omnipotence of the domotic man and its absorption by the environment he/she is supposed to control. He notes that the domotic man is no longer in an architecture which he/she inhabits but the architecture itself, the architecture of the electronic network, is the one that inhabits him/her, by being always ready to respond to the slightest reflex, desire or wish. For Virilio, the domotic house is not about controlling the environment in the traditional sense, arranging or inhabiting it; it is about control proper. A control which results in the omnipotence of the inhabitant --*omnipresence* and *omnivoyance*, as he calls the new state of living.

Virilio's is an image of another Panopticon at the center of which is the inhabitant and the radiating cells are windows to the world conditioned by his domestic organs. In such a reading the inhabitant is indeed an all-absorbing eye, a passive and immobile receiver and manager of information. But if we invert the direction of this model from a centripetal to a centrifugal one, then it becomes possible to see the domotic environment as the enabler of a multi-layered, multi-dimensional reality. In this reality, actions would not follow sequential lines but an open landscape of possible overlaying trajectories. Such an automated environment might be more appropriate to human behavior of simultaneous and sometimes conflicting desires, or might inspire new patterns of behavior, as is the case with the Microwave Bank.

Experimenting with tools of information and communication technology may produce the worst-case scenario, "a predictable standardized construction and an environment where wealth of experience is sacrificed to higher productivity and efficiency."[3] However it may also produce in the best-case scenario, a space controlled by computers "able to accommodate an artificial intelligence that enhances experience rather than neutralizing it. An intelligence which instead of anticipating desires for safety, comfort and economy, responds to human intelligence."[4]

The Vision of Gordon Pask and Smart Materials are Past.

This is not a new idea. It has been presented in the literature thirty years ago by Gordon Pask, a Systems Research expert who, in an article on the "Architectural Relevance of Cybernetics,"[5] expounded the belief that architecture is a system which responds to its inhabitants needs by providing shelter and symbolic representation. The built environment, according to Pask, is the result of the negotiation and integration of parts and sub-systems of the architectural body. These parts and sub-systems could be organized in a self-organizing whole, which includes rules for growth and development in response to changing human and environmental factors.

He then goes on to develop in adequate detail how this would materialize through a computer which would control the visual and tactile properties of environmental materials by containing actuators, and be

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[3] Ole Bouman, "Real Space, Quicktime and Architecture" in Archis, n.1, Jan.1996 p.37
[4] ibid.
[5] Gordon Pask, "The Architectural Relevance of Cybernetics" in Architectural Design Journal, September 1969, pp 494-496

able to read simple or complex behavior of the inhabitant in space through sensors. Eventually, this would yield an environment with which the user cooperates and in which he/she can externalize his/her unspoken desires. Significantly, Pask does not describe this as a one-way exchange but an interactive relationship whereby the inhabitant is in dialogue with the computer --mediated through the material - the latter being able to learn and adapt to the former's behavior. As it has been noted by Hunt the natural consequence of Pask's vision is that this environment not only has a reactive potential but a predictive as well, being able to "anticipate the behavior of its users by the development of sensory and cognitive awareness."[6]

The future that Pask was seeing in 1969 is in some degree already past; maybe not in the building and construction industry but certainly in the aviation and defense fields. To demonstrate my point let me take the opportunity to review the history of advanced materials science in the last thirty years.[7] Smart Materials Research begun in 1959 when the interdisciplinary laboratory for advanced research (ARPA) became interested in the development of photochromic glass. In 1970, experimental results achieved in the laboratory had made their way into the commercial market. Scientists were looking for ways to control its sensitivity to temperature and thereby use it in the building and automobile industry.

Parallel to this endeavor, in the late 70's a need arose to find non-intrusive ways to test spacecraft structural conditions. The idea of having "nerves" managed by a central nervous system embedded in structures, was first developed at NASA. The first obvious method at hand was embedding fiber optic cables in the skin of spacecraft. Any change in the medium would signal a structural problem, strain or crack. Then in the 1980's the defense aviation industry invested a lot of resources in the research and development of an aviation sheathing which ideally, like living skin, would be able to repair itself, even in such extreme situations as a head-on attack.

The model at hand was the human body, and the agenda naturally grew to include research on materials beyond glass fibers, to any material that would be capable of sensing external conditions. Through sensors and actuators, the scientists could now see materials react to external conditions to counteract vibrations, eliminate flutter and change formal characteristics to accommodate different functions. Piezoelectric materials transformed electric signals into physical deformations and vice versa, while shape memory alloys could be manipulated physically with great precision responding to the heat applied to them. These materials are available; it remains to put them in practice in applications, which enhance spatial behavior of previously thought passive, inactive elements like walls, supports, and thresholds. This spatial behavior could be more than a structural enhancement of the material to make it more durable, efficient, and aware of its condition; this behavior could change the expressive qualities of space. There is the challenge.

Towards behavioral spaces and evolutionary architecture

I will return here to the Knowledge Lab and its visionary product of microwave oven, bank, Internet connection and television, all in one machine. The important thing about the wondrous appliance is not

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[6] Gillian Hunt, "Intelligent Architecture: Cybernetic Theory and Architecture", Proceedings of the International Symposium on Electronic Art (ISEA), Chicago 1997

[7] For an interesting, concise outline of major events in the development of smart materials look at Ivan Amato, <u>Stuff: the materials the world is made of</u>, Basic Books, New York, 1997, pp 170-179

that it combines all these functions from a unique interface. It is not even the fact that the oven demonstrates behavioral patterns, by choosing appropriate recipes for the individual diet or suggesting grocery products that haven't been ordered for some time (the oven is also equipped with a bar code scanner which enables direct ordering from a chain of contracted food markets).

What I think is the most important achievement of this technology is that if put in household use it will transform the experience of cooking and eating. To the best or to the worse it remains to see, but the power of this machine lies in attempting to change our daily habits, and eventually the way we live. Me, a sworn advocate of fresh ingredients, I would rather spend more time micro-defrosting pre-prepared dinners if I am going to get the latest news while at the same time I check my balances and order that detergent that has been escaping my memory because I never visit that aisle in the store. The microwave bank is not primarily about efficiency, productivity and timesavings, and she who fails to see that might only be interested in the procedural matters of life. Most of all it's a toy, a pretext for doing household chores in a fun way.

This could be a good starting point for an expressive machine. (The next item on the list is to have the oven comment on how the user manages her time, watching too much television, spending time balancing calories instead of balancing sheets, ordering junk food, again!) It opens up windows to the world instead of focusing on control. What we need are tools to facilitate complexity that might lead to unimaginable combinations of functions, human activities and experiences, not eliminate the spectrum of the unexpected. And I think this is the direction technology is taking; a direction that wants machines, and buildings likewise, responding to human, biological intelligence instead of producing mechanistic automation and control.

Ted Krueger, an architect looking at the relation of artificial intelligence and the built environment believes it is hard for architecture to do away with the function of control and a sense of regulation, that is culturally engrained in our minds. He also argues that "the complex interactive and adaptive behaviors can be obtained only with an increase in the autonomy of the agent", a functionality which "comes at the expense of control."[8] We are looking at an apparent conflict between the traditional mandate of architecture to provide shelter and symbolic representation through a formal language, and the role it is called to play in the new reality of agent landscapes and new immateriality of information transactions.

What could this new role be? For Neil Spiller, the future architect will be a manager of behavioral entities, which he parallels to cognitive clouds in the immaterial information landscape. For Krueger the focus for architecture should move from "formal gymnastics" to facilitating behavior and breeding autonomous agents. For others yet, architecture will become prehistory if it doesn't move on to designing "all kinds of environments including digital ones."[9] With these roles, important questions of an ethical nature are asked. Who will benefit from this experience? What kind of morals if any do we want to see in the new environment? Who are the makers? What are our standards for the quality of life in this new space?

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[8] Ted Krueger, "Intelligence and Autonomy" unpublished manuscript to appear in Convergence: Journal of Research into New Media Technologies, fall 1998, courtesy of the author.
[9] Ole Bouman, "Real Space, Quicktime and Architecture" in Archis, n.1, Jan.1996 p.37

The challenge for designers and engineers remains to produce spaces and products that enhance our lives, make them richer in nuances and experiences, facilitating our access to the multitude of reality. In the task at hand we need to design for successful hybrid spaces that combine social acceptance and the use of private and public architectural space dialectically with emerging communication spaces, enabled by new devices and technologies.

Managing private spheres and activities in cyberspace

We will now see how traditional design methodologies might inform the management of private and public spheres in cyberspace, such as clustering of activities and access rules using constructivist methods to enable the individual to model his/her communication container according to context. We will use four application scenarios in cyberspace and we will propose a model for the management of private and public personal space. In the first two cases spatial and social elements interweave.

In February 2001 the IST Advisory Group published a number of scenarios for Ambient Intelligence in 2010. In AmI space, and in these scenarios in particular, privacy emerges as a central sociotechnical challenge to be addressed, as devices are ubiquitous, networked and their transparency is largely required. The ISTAG scenarios envision new kinds of human relationships and interactions, and powerful

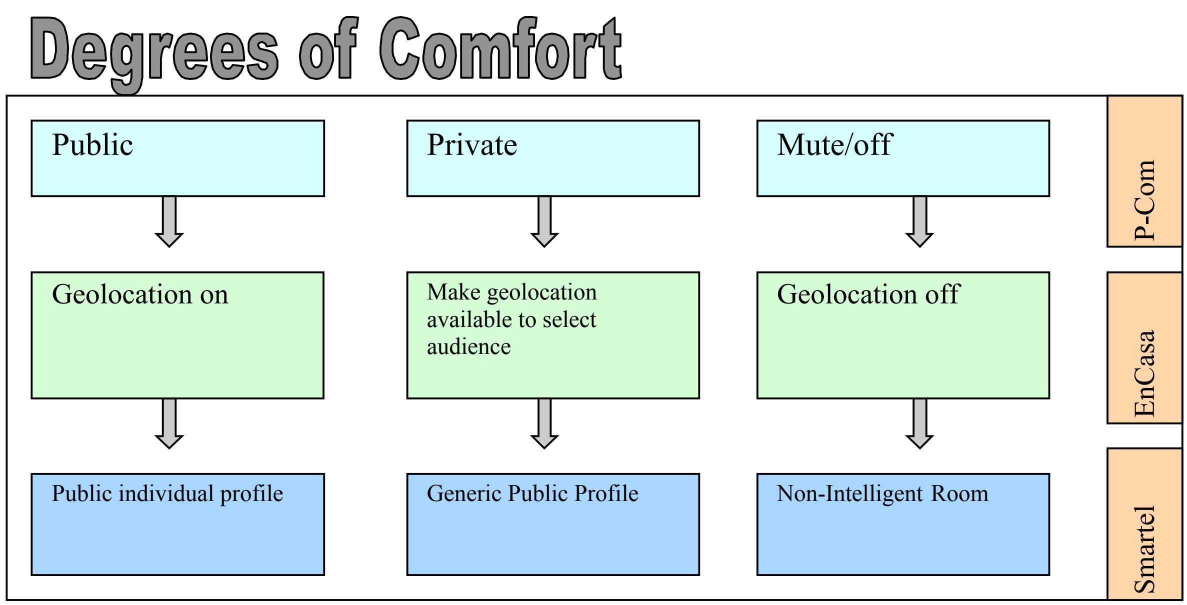

fig. 1: Maria's private and public personae

technologies to support them. In the report on Trust, Dependability and Privacy published in June 2002, ISTAG emphasizes the need to enter into new models of security and privacy management that are based on negotiation between agents or objects in cyberspace, as well as the need for transparency and proximity of the "off" button for the people who use them. In this document we approach the research issues of privacy from a HCI engineering point of view. How will the systems designed to support these interactions look like to the person using them, and what kind of controls will they afford him/her?

Analysis of Scenarios

Degrees of Comfort : Maria –The Road Warrior

Maria in this first secnario (fig.1) moves through contexts of different values of public and private spaces. She starts her journey at the airport, she moves in a public space and a public invidualized profile seems convenient and comfortable at this stage as her P-Com helps her clear passport controls quickly and to be instantly contactable and recognizable. In the car from the airport to the hotel, she is in a semi-public space and maybe she desires to concentrate on her thoughts and be disturbed only by a select group of people, maybe her family and work associates – En Casa is recognized as a cyberspace object in her select group. In the Smartel hotel she is in semi-private space, as it is offered in temporary privacy to successive inviduals. She may want the room therefore to behave like a trusted private space or she may feel more comfortable switching her AmI space off.

HCI for Privacy

In the Road Warrior scenario privacy can be managed in a linear way, by establishing profiles that are preconfigured by the user, by context, audience/communication group, time or day, location, etc. Private, semi-private, public, semi-public and mute profiles with all the possible nuances inbetween may be identified or 'learnt' by use and pattern. Maria would feel more comfortable setting her P-com intentionally in the degree of comfort that she would require in each situation or teaching it to understand her personal social protocol of what is comfortably public and what is safely private.

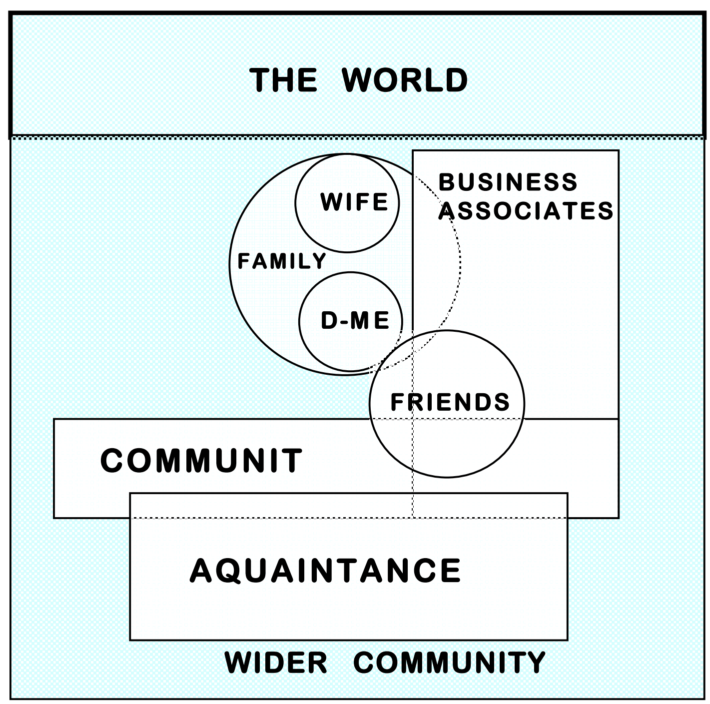

fig. 2: Dimitrios' spaces

The Role of AmI

AmI understands context, and its spatial awareness adapts to the socially accepted natural modes of interaction between people. In Maria's case, her P-Com enables her to be public to the authorities but not to the crowd in general, although some degree of surprise and unexpected meeting might be welcome by her. In the taxi her P-Com enables her to retain a moment of reflection and contemplation by respecting some privacy, which fits well to the occasion. At the hotel, she would feel better to switch it off altogether, or to make it selectively public depending on her mood.

Spheres of Influence: Dimitrios and the Digital-Me

In Dimitrios' case (fig. 2), the technological challenge is more complex. His, is a privacy negotiated case at each and every moment by spheres of influence and context. His world is structured around spheres, others concentric, others at intersection, others not touching at all. His private and public spaces, shift in and out of focus at every moment adapting to the local contextual reality. While he allows his family to enter the innermost circle of his world, entry is not always guaranteed but negotiated according to context. The wider community has certain entrance privileges in his personal sphere but it rarely gains entrance as the context is never quite conducive. His privacy is much more related to contextual awareness and therefore it can be more easily compromised, or become out of control. A high level of trust is required.

HCI for privacy

The user presets the spheres of influence by specifying the permissions for each group. Context aware software agents are appropriately given weight allocations by the user, or are 'taught' what are Dimitrios' personal allowances and natural social behaviors and how he prioritizes his interactions with different people.

The role of AmI:

AmI understands Dimitrios' spheres of influence and manages convention successfully by avoiding conflicts between those spheres that are better avoided in real life as they tend to threaten private space: negotiating attention between personal life and work, negotiating time between helping your kids at school and your boss to complete a successful deal, juggling telephone calls between wife and loved ones. AmI structures communication space around Dimitrios by strict definition of what belongs where in the public and private realm, and allowing the combinations to be fluid only within certain boundaries of negotiation. The degree of fluidity and negotiation is predetermined by the user at the onset.

No Privacy? Yes, thank you! : Carmen, traffic, sustainability and commerce

In this third scenario, the application area is decidedly public and any privacy protection might be harmful to the community. Indeed, if you are to be picked up by a total stranger and are about to share a ride with him/her in a car that they he/she is driving, then you would welcome all the knowledge you can muster about them. Does she/he have a criminal record? How many times has she/he been responsible for road accidents? Is she/he laid back and does not mind to be late to work?

There are situations, and car pooling is one of them, where people have to enter the agreement by accepting that they will have to relinquish a certain degree of their privacy. A community contract to share car transport to work, might be one such example. Carmen would have to accept that the personal data she would provide to be part of this community plan, would be freely shared with everyone within the plan. And she sure will feel happy that she is protected in the same way.

When Carmen goes shopping, it seems that she welcomes again leaving her private affairs at home, and 'going on' public. As a good consumer she relies on targeted advertising to make choices quickly and effectively. She delights in being notified on the latest promotion and travels miles to find a special item on sale. Again, Carmen belongs to a special interest group in which action presupposes relinquishing certain aspects of one's privacy.

Who is controlling the Ambient? Annette and Solomon, and social learning.

This last scenario, touches on familiar privacy issues. The Ambient is a next generation internet. It is an amorphous, powerful knowledge depository, where encryption technologies that are robust and trusted by the users will be the main tool for the protection of privacy. How these encryption technologies are negotiated, formulated, and managed is key to the kind of privacy that can be provided to the people. In a sense the users have no immediate visible control of their identity, as the scope of profiling is vast. The data the ambient can require, although negotiated based on ad-hoc permissions, are neither site-, nor time- or domain-specific. Trust and the security of the system play therefore the key role in the definition of the comfort level of the users. This scenario in many ways takes after current internet privacy examples. It does not call for AmI space-specific privacy considerations.

HCI for privacy:

Trust in the system can be enhanced by providing transparent information about data protection control policy to the users and by a series of permissions according to group, or type of transaction or exchange of information; similar to the disclaimers and site-security certificates that we thread in our passage when navigating, The difference here might be that the ambient is "suggesting," by auditory or gestural signals, rather than displaying information on a screen. Privacy in AmI space will need to be context-dependent, socially and emotionally intelligent and negotiated on natural, intuitive grounds. In AmI space more opportunities of control will be given to the users if only because of the complexity of real life which for some time –by 2010 at least --will remain unapproachable to machines. At the same time there will be more opportunities for desired absence of privacy and therefore some social contracts will have to drafted relinquishing some aspects of personal privacy in domain- site- and time-specific applications. In AmI space traditional models for privacy protection (ad-hoc permissions, trust in encryption technologies) will continue to be used.

Creating Public Activities in Hybrid Space

At the other side of the ISTAG scenarios and the mandate for the protection of privacy is the design project we recently completed for an architectural competition requiring the creation of a public entertainment site that would take the form of an time-dependent built structure enabled by information technology.

The Brief

An ephemeral structure was requested. The building would have to be easily demountable and transferable to any part of the city where it could have a life of 1-3 days. It was required that it 'parasites'[10] the urban grid and the city itself, possibly drawing on a symbiotic relationship with it. More importantly, it was essential to provide a *city-leisure generator* for urban entertainment (Theodorou, 2002).

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[10] word used explicitly to denote the parasitical nature of the project as well as it being on 'side of the site' (from greek parasito=parasite and greek para=on the side and latin site=place

The Design

A labyrinth is proposed. The mounted structure provides the basic spatial elements of the labyrinth, while the labyrinth itself is invisible. Citizens are invited to participate in solving the labyrinth by making the invisible, visible. By walking through the structure, participants discover the thresholds and barriers of the labyrinth. Their goal is to complete the structure. The basic elements of the labyrinth are physical, built elements. The invisible part of the labyrinth is mediated through information technology. Sensing technologies in the physical structure enable the geographical positioning of the participants in relation to the visible labyrinth. Context-aware software technologies weave the 'real' labyrinth and the movement of people in it with a superimposed 'virtual' labyrinth. Participants are made aware of the presence of the virtual labyrinth through computation-controlled sound and light cues, every time a participant passes an invisible barrier or threshold.

The participant's role is to react to the cues. This is achieved by threading a line (Ariadne's thread) through the pillars --provided upon entry to the Modulor. Each day the participants are asked to rebuild the labyrinth. At the end of each day the threads complete the structure, and each night the completed structure is different. The structure relies on the participatory element of the game and takes its form according to the urban element it parasites on.

The structure is a parasite on the city because the plan of the labyrinth feeds from the plan of the surrounding urban grid according to a process described below. The site provides the event infrastructure --the form of the labyrinth and the audience/participants-- and the Modulor, as a collective activity of the citizens, enhances and supports the site as a point of social interaction.

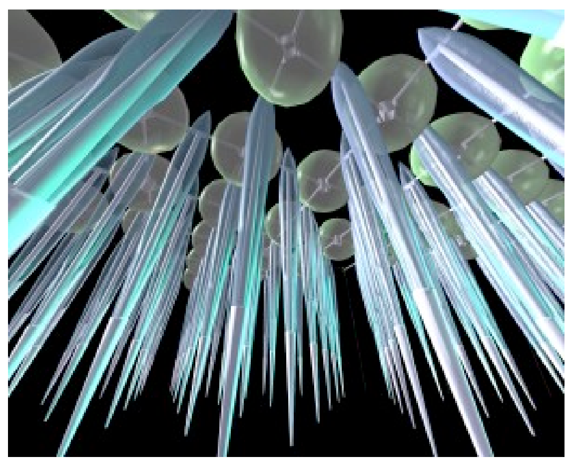

fig.3: The Modulor at the start of the day

The Modulor starts life as a grid of self-supporting elements (see Fig. 3). It is an alien object, a predatory parasite, and incomplete in itself as only its material face is apparent to the eye. With time, and over the duration of a day, and as the citizens take over, the immaterial face of the labyrinth takes form in the collective process of shaping the invisible barriers. The Modulor is constantly in the process of becoming something other than what is apparent, and therefore can never be other than ephemeral. Every day a new route needs to be followed so the solution, and the final form of the building, is always escaping. A glimpse of it, or a version, can only be appreciated during the night when the Modulor wears its transparent skin (a cover and a screen at the same time). As actions and paths in the labyrinth are recorded during the day by the central processing unit, they can be replayed asynchronously during the night as well as mirrored synchronously on the Internet for remote access. The structure at night is a collective piece of sculpture offering the passer-by an oblique view of the city itself.

While the Modulor is a place of action (and reaction) during the day, at night it carries the memory of the day's history and is the repository of that history; it can be appreciated as an object.

The goal of the game however, is constant: to make the intangible part of the labyrinth, tangible, a solution that cannot be reached without collaborative collective participation. In that the generator acts as a socializing opportunity, a 'device through which individuals make attachments with their fellow inhabitors' (Theodorou, 2002).

The Game: Description of Functionality

The Modulor is penetrable by all. However, only those who have Ariadne's 'thread and sword' will play the game. The labyrinth is host to a terrible creature, the Minotaur. Each day a team of seven young women and seven young men from Athens confronts the Minotaur. The team's aim is to complete the labyrinth by weaving the invisible passages. But they have little time and the Minotaur is chasing them. They have to work together. Their only help is Ariadne, the computer who sits in the terminal station just outside the labyrinth. Before they enter the labyrinth, each young man and woman receive instructions from Ariadne. She offers them the thread (which they have to use to find their way through the labyrinth in constructing the invisible barriers); the sword (which is a small badge attached to a harness equipped with an infrared sensor which can communicate wirelessly to each column's infrared beacon and pass to Ariadne, the position and state of each member); and their map. This map contains clues to the labyrinth's solution. It is a part of the Athenian urban plan which has been chosen for that particular day as a blueprint for the form of the labyrinth. Ariadne can update on-the-fly the state of each pole. The only constraint conditioning the particular choice of the plan is that its scale and size should map on the labyrinth's grid so as to provide a good balance of binaries either barriers or thresholds. As an example we mapped part of the Athenian plan to the Labyrinth's grid by matching the streets to the passages of the labyrinth. Using simple abstraction techniques we derived for a total of 241 possible passages (a 10x11 grid), 101 thresholds and 140 barriers.

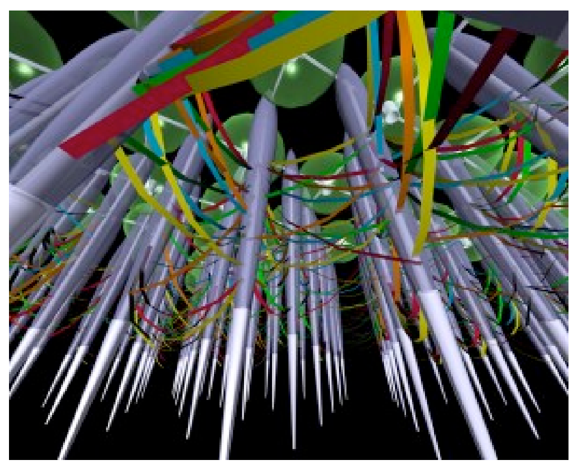

Fig 4: The Modulor at the end of the day

In this instance, 140 barriers would have to be constructed in the duration of the day as users respond to the cue denoting a barrier (see Fig.4). As the players pass through gates, there is a sequence of events that take place. If the gate is an invisible barrier, the sensors enclosed in each pole detect the player passing through and send the signal to Ariadne. Concurrently, if the passage is a barrier there is a light and sound cue and the player is notified that he/she should construct a barrier. While the team is in the process of weaving the gates, the Minotaur (not a physical person but a light signal in the superstructure of the labyrinth) can appear randomly at any point in the labyrinth's grid and by this annihilate the player. The goal of the team member is to reveal as many barriers as possible before 'losing his/her life' and preferably before any member loses his/her life with the minimum of invisible barriers crossed. The team member with the best record of the day is named Theseus for the day and can go on the next round. More than a hide and seek game this is a game of strategy that requires planning the best passage through the map of any city from point A to point B (which are given to the players at the beginning of the day) and high orientation skills. Ergonomic principles have been used to make the space usable by people on wheelchairs or older children/teenagers, as the design allows for different mobility and height levels.

Discussion

In the first part of the paper, we have examined the architectural elements of the Modulor. In the description of the system's functionality we have looked at the elements of the game: the rules, the strategies, the incentives. Now we will see the Modulor in the light of HCI theory as an interaction device. We will also introduce the proposition that the participatory element and constructivist approach of the game make for infinitely variable social interactions. The Modulor is a place of collective creation; an architecture evolving in time; and a machine supporting open-ended user-defined outputs. As a narrative instrument, the Modulor has the capacity to contain and reproduce traces of the actions of its inhabitants and the city's history.

Building Time-Dependent Architecture: Action, Activity and Audience

In the Modulor, action is closely related to cue-driven, guided movement through a physical structure. Physical structures enhanced by information technology to guide orientation have been the ground of experimentation with users in prototype development in the past (Halkia & Solari, 1999). In this particular case, movement is either inhibited or encouraged according to the rules of the game – the labyrinth's invisible barriers and passages –reconfigured on the fly by the central processing unit. The Modulor is a game in 3-d physical space, but also a structure built collaboratively by the participants. On another level, the Modulor is a socializing machine: passers-by in a public space are encouraged to socially interact through a project of collaborative weaving (see Fig.5).

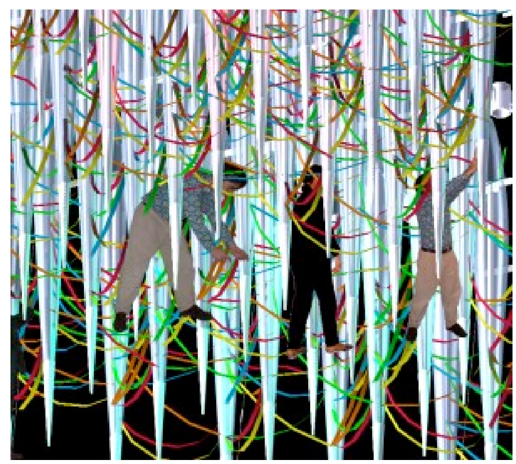

Fig 5: Constructing the labyrinth (worm's eye view)

In the light of Activity Theory models (Kuutti, 2001), the Modulor supports contextual interaction by 'situatedness', 'active actors', and 'constructivity'. Interaction is situated in the symbolic space of the city as reflected in the labyrinth's plan, actors are encouraged in movement and performance of specific tasks and rewarded through the game itself, and the end result is an artifact constructed by collaborative learning and practice.

The system is robust inasmuch as the goal of the participants' actions in the Modulor is simple: to tie the 'thread' through pairs of poles when a cue is heard; the motivation of the exercise being the weaving and construction of the final image of the structure that one needs to navigate. Activity is motivated by the completion and solution of the path through the city's grid, reflected on the labyrinth's plan, to reach a specific point in the maze. In the process, the participant is encouraged to reflect and learn about the city plan as s/he needs to apply strategic orientation reasoning. Demands on audience skills are low: knowing how to use a map as an aid to the labyrinth's plan, the ability to react to sound and light cues, weaving skills, and a sense of environmental awareness and teamwork. In the Modulor, participants are equal. The audience can be composed simultaneously of able, disabled and children: social weaving is promoted.

A Place Designed by the Participants

The Modulor is *designed for* interaction; it is not just a 'designed' space. Inasmuch as the structure in itself is not complete without the actions of the users, the system is not complete but open to appropriation. (Dourish, 2001). The Modulor is a platform for interaction that provides clues to what the final image of the structure may be but it is left open-ended to be revealed by the users. The way it can be revealed is infinitely variable and that is where the unexpected may take place.

The Modulor creates 'place' (Dourish, 2001, p91), which is inhabited on a day-to-day basis. It is designed not as an experiment with a limited lifespan, nor as an art installation, but as a container for social interaction. It is part of the urban grid, a place and a context for communication and exchange. As a public entertainment container mediated by computation and located in an open urban space, it is recombinant architecture (Mitchell, 1996) that has left the computer box and has taken the streets. Moreover, the Modulor's final form is created by the inhabitants, rather than prescribed for them.

Function Creates Form

We have discussed responsive architecture before (Halkia, 1999). The concept of the 'hyperbody' (Oosterhuis, 2002) as a programmable building body that changes shape and content in real time has been partly introduced in architectural practice during the 1990's. The Modulor derives from these theories the notion that a building can be manipulated to be a time-dependent interactive machine. In the Modulor, action and audience dialectically create the meaning and form of the artifact and the building becomes the image and the memory of this interaction. Rather than form allowing function (Oosterhuis, 2002), *function* (and system functionality) *creates form*: form being created in the process of embodied interaction.

Narrative in 3-d Space

The notion of narrative unfolding in 3-d physical space, enabled by computation, and supporting a time-dependent architecture recording and playing back the evolution of the building as a container for social interaction, has been suggested in the past (Halkia & Streitz, 2000). The Modulor encapsulates the actions of the participants, and the process of the construction of the artifact. It replays the history of the day during a contemplation period through the night. Additionally, the memory of the city and its urban form is reflected symbolically in the series of re-configured (possibly historical) plans of the labyrinth.

Conclusion

Augmented reality experience design may be seen at least in part in dialectic development with architectural design. As problems of space management become pressingly more time-dependent, being increasingly linked to dynamic management of information, architectural design may be informed by ubiquitous computing and other time-dependent design methodologies of personal and collective use. On the other hand, as architectural practice addresses societal and human needs and provides containers for 'analogue' interaction and communication, it may inform the way we design experiences in augmented reality so as to create infinitely variable interactions between humans, as well as spatially inclusive, human-centred and socially useful solutions to non-computational problems.

While the need for physical shelter from the natural elements will continue to exist, and with it architecture as we know it, the need for physical shelter from information elements will be increasingly felt. The other side of this coin may just as well be, in HCI terms, designing against information overload. Opportunities for cross-fertilization between design disciplines, which call for systematic study, are beginning to emerge.

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