Design Tools for Pervasive Computing in Urban Environments

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Abstract: In this paper we report on ongoing research in which the implications of urban scale pervasive computing (always and everywhere present) are investigated for urban life and urban design in the heritage environment of the city of Bath. We explore a theoretical framework for understanding and designing pervasive systems as an integral part of the urban landscape. We develop a framework based on Hillier's Space Syntax theories and Kostakos' PSP framework which encompasses the analysis of space and spatial patterns, alongside the consideration of personal, social and public interaction spaces to capture the complex relationship between pervasive systems, urban space in general and the impact of the deployment of pervasive systems on people's relationships to heritage and to each other. We describe these methodological issues in detail before giving examples from early studies of the types of result we are beginning to find.

1. INTRODUCTION

Developments in computing and architectural environments have evolved together to a surprising degree since the 1990s: Virtual Reality 'VR' represents one of these developments, however, this has remained of greater academic than practical interest for a number of reasons such as cost and the unfeasibility of working in a completely immersive environment (Penn et al., 2004). Virtual reality was soon followed by a growing interest in combining real with virtual environments, allowing people to interact with digital information within real physical space, and bringing live video imagery into virtual environments. It was argued that this type of Mixed Reality interaction fits more naturally with the way people act and interact with everyday objects offering them a greater sense of ‘embodiment’, a state of being in the world, compared to interacting with more abstract virtual representations (Dourish, 2001). At the turn of the millennium the focus has shifted again and attention has been drawn to the increasing importance of interactivity beyond the scale of the task at hand. Recently we have witnessed a shift in focus of interest from ‘cyber space’ to ‘ubiquitous computing’; digital technology is built into our environments, embedded in our devices, everywhere. Increasingly these technologies are networked.

Ubiquitous computing (also known as ‘ambient, physical, embedded, environmental or pervasive computing’) was first introduced by technology visionary Mark Weiser. He envisioned a world of fully connected devices with cheap wireless networks where information is accessible everywhere. A world in which computers and information technologies become invisible, and indistinguishable from everyday life: ‘any time, any where and always on’ (Weiser, 1991). Weiser proposed that computing would follow the evolutionary path of the electric motor. Early motors were very large and serviced the needs of many users. Today, a family is surrounded by hundreds of ‘invisible’ motors in the appliances around them. Similarly, in a pervasive computing environment, computers and information processing become ordinary, and penetrate into every object in our daily lives. Until recently the word ‘ubiquity’ was seldom heard, but now, like the word ‘cyberspace’ before it, ubiquity has quickly come to mean just about anything having to do with universal connectivity. As a result, information technology contexts are no longer valued so much for the immersiveness they offer as for how peripheral they appear to be, and in this way reducing information overload (Weiser and Brown, 1996). McCullough, 2004, noted that architecture has acquired a digital layer, which involves the design of organisations, services and communications and it seems that both architecture and interaction design together can help compose the necessary framework for a better integration. In this respect we believe that building pervasive systems into our urban environment requires a new way of thinking about the design and use of digital flow and how it interweaves with the built environment.

In this paper we report on Cityware, a current research project within the VR Centre, Space Syntax Laboratory and Centre for Sustainable Heritage at the Bartlett, UCL, in collaboration with the University of Bath Departments of Computer Science and Psychology, Imperial College London and HP Labs Bristol, Nokia, Vodafone, IBM and Node Ltd. This project aims to develop a better understanding of the urban landscape augmented with the digital landscape of a city, by providing tools, methods and a theoretical framework for designing pervasive systems as an integral part of the urban landscape. To achieve this we draw on two sets of relevant work, Space Syntax (Hillier and Hanson, 1984; Hillier, 1996) and the Public Social

Private 'PSP' framework (Kostakos, 2005). In our research we are interested in designing, not just the architectural space in which people move and interact, but also the interaction spaces (Kostakos and O'Neill, 2004; O'Neill et al., 2004) for information which they discover and use and which support their movements, behaviors and interactions within architectural space.

To design these new integrated systems, we need to extend and adapt our understanding and practice of urban design by observing the existing situations and practices, experimenting with wireless, mobile and located technologies, as well as constructing installations to experiment with new forms of human interaction. Bath is interesting for this kind of experiment because first, it is (and always has been) a tourist city. Second, it is a heritage site – the only city in the UK currently on the UNESCO list of World Heritage Sites – this sets a hard context for the introduction of new technologies in that they must respect the fabric and sensitivity of their context. Third, the city has a rich tradition in literature figuring in the works of Jane Austen, and that literature provides one of the main attractions for some tourists. Finally, Bath is manageable in size and this makes it possible for us to experiment at the urban scale, but within a well constrained area. Here we are developing an approach based around the use of Space Syntax methods for the analysis of the spatial morphology of the city of Bath. In the next section we describe recent research projects that have addressed some aspects of pervasive systems in urban contexts.

1.1 Related work

Recent research has addressed some aspects of pervasive systems in urban contexts but has not considered the design of pervasive systems as an integral facet of urban design. Research to date has been mainly conducted through 'experiences' or 'performances' that cover a small area and in almost all cases are held over short timescales. When architecture has been considered in relation to pervasive technologies, it has typically been focused on the relatively small-scale architecture of individual buildings (Rodden and Benford, 2003) or even rooms (Krogh, 2000; Streitz, 1998) and has at times been used vaguely as a term simply reflecting the notion of built physical space (Wisneski, 1998). Our work includes architecture but focuses strongly on urban design at the scale of cities (Hillier, 2000). Previous studies have explored people's social behavior and relationships with urban space and pervasive technologies on which we can build (for instance: eGraffiti, Guide, Equator IRC, Mobile Bristol, Urban Tapestries and Intel's Urban Atmospheres). However, these studies have not solved the engineering challenges of implementing city-scale pervasive systems.

In our research we seek to extend our understanding and practice of urban design by looking at the urban environment as an integrated system mediating both the built environment and pervasive systems. It differs from other approaches by addressing three key research issues:

- It addresses pervasive systems design as a facet of urban design. Urban design is a key perspective for Cityware. We need to understand how pervasive technologies interact and interweave with the built environment to create the spaces that frame and influence people’s behaviour.
- It addresses the methodological challenges of longitudinal cohort studies.
- It addresses technical and engineering challenges of implementing city-scale pervasive systems.

In the next section we describe the first and third of these concepts in detail. First, we explain the PSP framework, used to conceptualise, design and evaluate pervasive systems, followed by a brief description of Space Syntax tools and methods as currently applied to understand the effect of the built environment on what happens in cities. It is this which we hope may throw further light on the intersection between the digital and spatial layers of behavior as part of the urban landscape. We then review early findings from the first studies including a radio survey and qualitative approach in our early observations of the digital landscape in the city. Finally, we draw conclusions on certain generic characteristics of both facets and highlight related issues that need further research.

2. SPACE AND PERVASIVE SYSTEMS

A systematic approach to designing the urban environment as an integrated system demands a coming together of Architecture and Computer Science. Key to this interdisciplinary integration is the concept of space, by which we mean not only physical location but also the social protocols, conventions and values attached to a particular physical space (Cole and Stanton, 2003; Harrison and Dourish, 1996; Kostakos and O’Neill, 2004; O’Neill et al., 2004). In this section we provide an overview of the two sets of ideas we draw on: the PSP framework and Space Syntax.

2.1 Understanding pervasive systems

The Public Social Private framework is used for understanding and designing pervasive systems (Figure 1). This framework is extensively reported in (Kostakos, 2005), and its application has been reported in

(O’Neill et al., 2004). In the following we provide a brief overview of its main concepts.

To illustrate the PSP framework in use imagine the following scenario: consider John who lives in London and wishes to visit the city of Bath. John arrives at Paddington train station (public architectural space) in London, and observes the departure times on the big screens at the station (public interaction spaces). At the same time John receives a text message on his mobile phone (private interaction space) about the weather in Bath. Once John is on the train (public architectural space), he is informed of the train's schedule via the intercom system (public interaction space).

John arrives in Bath, and observes a group of tourists discussing and pointing on a map they are sharing (social interaction space). John's phone receives a message asking him to send an SMS to a specific number if he wishes to receive further notifications throughout the city. John decides to sign up. He makes his way to the main Cathedral, where he receives a short message on his phone informing him that he has reached the main Cathedral. After spending a few minutes outside the Cathedral, he is identified as a ‘persistent’ user, and thus his phone is sent information about the Cathedral's history. Because John's phone has been identified as having a small screen, the information contains low-resolution photographs. Users owning a PDA with larger screens are sent photographs of higher resolution.

The PSP framework provides the designer with two main insights. First, that a pervasive system can be conceptualised by considering three main aspects: architectural spaces, interaction spaces and information spheres. Secondly, each of these aspects can be classified as Public, Social or Private. Designing a pervasive system involves understanding which types of architectural spaces, interaction spaces and information spheres are being designed for. The PSP framework enables the comparison of alternative design decisions, and draws the designer’s attention to potential problems. In the following we focus on architectural spaces and interaction spaces.

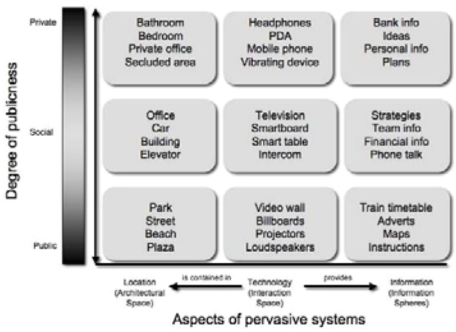

Figure 1. The PSP framework. Y axis represents the degree of publicness. X axis represents three main features of pervasive systems and the relationship between them

Architectural spaces

Architectural spaces have values attached to them and as such tend to convey cultural meaning and frame our behaviour. In addition, the presence of others within an architectural space has an effect on how we behave and perceive the space. One might say that architectural space has embedded understandings and protocols of what is regarded as appropriate behaviour. Despite the variety of characteristics found in individual spaces, we can still abstract over them in attempting to support systematic design.[1]

Green, 2002, in her sociological work discusses how architectural spaces can be thought of as public or social. Building on that the PSP framework provides a top-down approach that categorises all possible architectural spaces in three main groups: public, social, and private architectural spaces. These notions carry with them a great number of characteristics and understandings that are peculiar to each society or social group. Public spaces are open to everyone, mainly because they usually belong to the community itself, e.g. a town square is a public space. On the other hand, private spaces are spaces controlled by an individual, which can be used in whatever way the owner sees fit. Private spaces promote a sense of security and privacy, such as a toilet. Covering the range between the extremes of the public-private spectrum, social spaces are those spaces that are neither private nor public. It is important to stress that public, social and private architectural spaces are not simply defined by their geographical co-ordinates. It is not helpful therefore to try to categorise ‘pure’ public, social or private spaces; for example, is a park a public space? The criteria for categorising a space need to address the values attached to the space and the things that happen there. The boundaries between the three types of spaces we propose are both fuzzy and mobile. A good example is ‘the office’, which at different times may be a social and a private space (e.g. a group of colleagues discussing in an office vs. a single person alone in an office).

Interaction Spaces

Interaction spaces describe spaces that are created by designed artefacts. These spaces define the physical boundaries within which the device or artefact is usable (O’Neill et al., 1999). Interaction spaces can also be categorised as public, social or private. For instance a large display, in a train station, showing departure times could create a public interaction space. On the other hand, time information presented on people’s mobile phones would

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[1] We do not, of course, use “space” to carry mere 3D volume attributes.

create a private interaction space despite being in a public architectural space. An example of a social interaction space is the one created by a map viewed by a group of tourists, since the group of tourists are included in it but not everyone in the area. Interaction spaces may also be auditory or wireless. For instance the wireless interaction spaces generated by GPRS or 3G masts define volumes of space within which certain artefacts (such as phones and PDAs) and services (email, browsing) are usable. We can differentiate between such mast-based wireless interaction spaces and more mobile wireless interaction spaces. The former tend to be static in relation to location within the city. On the other hand, the wireless interaction spaces created by technologies such as Bluetooth[2] are often mobile, and move around with users and devices. For instance, Bluetooth interaction spaces can be used for accessing information and services, as well as for communication between users. They move around with users, and come in contact with various other features of the digital landscape: services beaming out of an interactive poster, Bluetooth phones belonging to friends, colleagues or even strangers, as well as various Bluetooth devices such as headsets, keyboards and mice. An artefact, such as a mobile phone, generates various interaction spaces. The phone’s screen generates a visual interaction space, the phone’s speaker generates an auditory interaction space, while its wireless capabilities generate wireless interaction spaces.

2.2 Understanding space with Space Syntax

Space syntax, first developed by Hillier and Hanson (1984), analyses cities as systems of space created by the physical artefacts of architecture and urban design. It takes the position that the key to urban function, at the level of movement of people, is the way in which each space is accessible from every other space in the city, not merely in terms of metric distance, but rather in terms of topological distance, or the number of changes of direction needed to move from one space to another. Space syntax analysis methods represent the open space of the city as a graph and use graph measures to quantify morphology. Using a range of observation methods Space Syntax gathers data on people’s overt behaviours and revealed preferences. Using the quantitative analysis of spatial morphology one can then investigate the degree to which behaviors appear to be related to spatial design, and the degree to which other explanatory factors must be invoked. Some key studies in Space Syntax are reported in (Hillier et al., 1987, Hillier

[2] Bluetooth: a radio standard for short-range of up to 100 meters wireless communication of cellular phones, computers, and other electronic devices.

et al., 1993, and Read, 1997). For instance if we ask an individual in Bath about her pattern of movement, she is likely to respond in terms of purposes of journeys. However, cities are very dense and heavily populated, and hence the collective activity gives rise to a pattern of use and movement that is independent of the intentions of individual but reflects morphological factors in the setting itself (Hillier, and Hanson, 1984).

Figure 2 is a representation of part of the street network of Bath as the 'fewest and longest' lines that cover the system (the axial map). Observations are then made at different times of day of movement flows along each street segment by counting people passing points on a street, 'imaginary gates [3]', and indexing them in flows per hour through that gate. The various spatial values for the lines are then compared to the movement flows by simple and multiple regression. The only other variable required to model movement is knowledge of the special attractors, for instance average building height, development densities and land uses in an area. The reason for the use of Space Syntax as an aid to understanding the urban space, is to a great degree based on correlations found between the measures generated by this analysis, and flows of people counted in real urban space. This is supported now by many studies, mainly of pedestrian movement, indicating that under normal conditions the spatial configuration of the urban grid is in itself a consistent factor in determining movement flows (Hillier, 2000).

Figure 2. left: Axial map of Bath, right: gate locations in the city of Bath

2.3 Design support with the PSP framework

The concepts of architectural spaces and interaction spaces – public, social and private – aid us in mapping from locations to the technological artefacts that are available to us and the forms of interaction we wish to

[3] "A brief lesson in Observations" Space Syntax Lab, 1997.

support. With the advent of mobile and pervasive technologies, interaction spaces can range from being ‘persistent’ (such as the displays at the train station, or a desktop computer’s WiFi network), to having ‘medium-term presence’ (such as the mobile phone or laptop of a coffee shop customer), to being ‘highly transient’ (such as the phones of people walking down a street). The PSP framework, however, does not describe ‘operationalised methods’ that the designer can use to identify the architectural spaces and interaction spaces in an urban environment. Therefore, a challenge we face as designers is recognising the different types of interaction spaces scattered throughout a city. How can we identify, both at design and run time, the appropriate architectural and interaction spaces through which information may be delivered or accessed? Furthermore, how can we evaluate our design decisions in deployed pervasive systems?

In order to address these questions, the Cityware project is applying a series of different methods. These include:

- **Mapping the physical and digital flows in Bath** (macro level): Using Space Syntax methods for spatial observation and analysis (axial and visibility). Mapping the digital flow, by scanning Bluetooth devices, allows us to identify the presence of potential interaction spaces.
- **Observation of static space use** (micro level): Using methods drawn from ethnography, including people following and observation of static activities, local movement and the pattern of social behaviour and interactions. This method is complemented by mapping the types of mobile device usage behaviours that occur at various locations in order to understand the regular and persistent patterns of space use.
- **Longitudinal cohort studies**: Using 30 participants for engagement throughout the duration of the project (3 years). This method puts the individual’s view in the foreground. Data collected through the cohort will be regularly analysed and integrated in the analysis.
- **Experimental installations and interventions:** Installations will be used to engage the general public in our research, encouraging playful use of technology. Various installations will be introduced using plasma screens in building interiors, and very large projected displays in public exterior space. In these experiments it is hoped that interventions can serve as a methodology for better understanding of social and digital interactions and underlying affordances.

3. METHODOLOGY AND DATA

In this section we report on the first studies that were carried out in Bath. To date, three pilot studies have been conducted with the intention of capturing data on both the physical and the digital flow represented by pedestrian movement and Bluetooth presence. These represent the first steps towards building an integrated spatial and functional database for the study area bringing together observation-based surveys of land-use, space-use and pedestrian flow in addition to the information related to the digital landscape.

3.1 Understanding the physical flow in Bath

As part of the first phase of understanding the city, we have carried out a two-day observation study and spatial analysis of the city of Bath using Space Syntax methods. The study was aimed at establishing:

- patterns of movement at different times of the day and assessing the degree to which the spatial layout influences the patterns of pedestrian movement and social behaviour of visitors in comparison to local people.
- patterns of space use and interaction by observing static use of space.
- and observing existing social practices (e.g Graffitti) and its relation to space in respect to the heritage value in the city of Bath.

The structure of the built environment in Bath is by no means a unified, planned whole. The expansion that took place in a relatively short time span in the 18th and 19th c. created a collage of separate, largely unconnected, and often incomplete pieces of speculative development, each shaped apparently by accident (Forsyth, 2004). Data about pedestrian movement were gathered using an observation-based pedestrian survey conducted in the study area. The study used the 'gate method' for 96 different street segments between street intersections. The observations were made throughout 5 time periods between 8:30 am and 4:00 pm – spread over 2 working days – by a group of 12 observers. Pedestrians were classified as locals, and tourists, for both men and women. This study was coupled with a rapid survey of land use for the main retail area, which was supplemented by the retail survey of central Bath undertaken in 2004 by the Bath Council. The city of Bath was analysed embedded into its surroundings as well as an independent system. The local integration was correlated with pedestrian movement data (Figure 2). The configurational analysis of its spatial patterns shows a background level of correlation (R^2=.47) with outliers above and below the regression line. Some spaces attract more people because they may contain or lead to important tourist attractions (Figure 3). Other streets appear under used given their context (Fatah gen. Schieck et al., 2005).

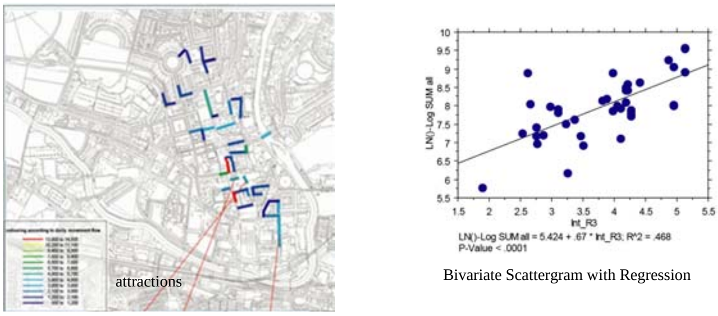

Figure 3. Movement flow and scattergram with correlation of movement and local integration

Early findings indicated clear differences between the behaviour of tourists in comparison to locals, which for the purposes of the study includes students currently based in the city. This appears to be determined, to some extent, by the spatial configuration of the city. Identifying the social interactions within various social groups and their locations would allow us to recognize opportunities for delivering appropriate types of information and services. For instance, some of the streets were mainly used by locals. Other static locations were dominated by students (Figure 4).

Figure 4. left: passage mainly used by locals, right: static space used by students

It has been argued that new technologies tend to undermine existing social practices, requiring new ones in their place (Feenberg, 1999). In our study an attempt was made to map and understand existing social practices in relation to the space and in respect to the heritage value in Bath. We believe that identifying these practices and their location within the city would help gain a better understanding of the underlying affordances, which can then be addressed and taken advantage of in designing the new technologies and interventions.

3.2 Understanding the digital flow in Bath

In section 2 we noted that interaction spaces, whether visible, audible or wireless, can range from being highly persistent to highly transient. Focusing on wireless interaction spaces, we currently lack the tools to differentiate between the different types of presence. Such a measurement would help us identify opportunities for delivering the right type of applications. Information about wireless interactions spaces may also be related to location and time of day. Furthermore, knowing whether interaction spaces remain static or move dramatically can help designers determine what information to deliver and how present it (for instance, visible, audible, etc). Finally, using information about device characteristics, for instance, mobile phones vs. laptop computers might help achieve a greater understanding of the digital landscape.

In the following we discuss our attempts to identify the presence, type and distribution of wireless interaction spaces over space and time. Here we focus on wireless interaction spaces generated by Bluetooth devices. The vast majority of Bluetooth interaction spaces are created by small, personal, mobile devices such as mobile phones. Thus, in contrast to the interaction spaces created by typically static WiFi access points, the wireless interaction spaces created by Bluetooth devices map very closely to the movements of people around the city, which in turn can be measured by Space Syntax methods. We carried out a trial measuring Bluetooth activity on a single gate located on Bath University campus over a 6-week period (Figure 5).

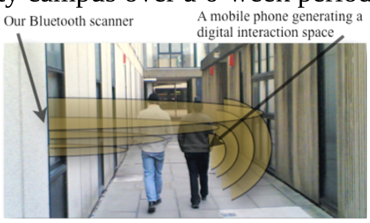

Figure 5. Our gate consisted of a scanner placed on the inside of a window in a long narrow passageway between two buildings

During the six-week trial, our scanner continuously searched for and recorded Bluetooth devices within a 10-metre range. A device was recorded if it had Bluetooth and was set to discoverable mode (Figure 6). For each record we had the following information: serial number, name of device (provided that the device was within the range), date, time, class of device (e.g. phone, laptop), and services offered by the device.

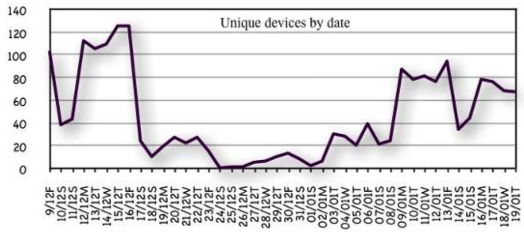

Figure 6. Bluetooth activity during our six-week trial. X axis show the date, y axis shows number of unique Bluetooth devices. Number of devices dips during weekends, with low values for the week leading up to Christmas (19-23 Dec.)

Furthermore, by applying filters on the recorded data, we were able to classify devices as persistent or transient (Figure 7). In this case, persistent activity was due to the presence of laptop and desktop computers in nearby offices, which generated high Bluetooth activity. Another example of a persistent device is the mobile phone of someone who came into the office for a relatively long time.

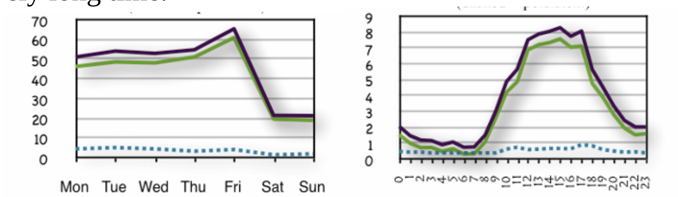

Figure 7. Summary of the data shown on a per day basis (left) and per hour basis (right).The top lines show total activity, the lines below show transient activity, while the dashed lines shows persistent activity.

During our study a number of issues were identified:

Accuracy of Bluetooth scanning: A number of issues relating to the accuracy of Bluetooth scanning became apparent during our trial such as the effectiveness of Bluetooth dongles for scanning purposes. Our scanner consisted of a single Bluetooth dongle, which meant that if many Bluetooth devices passed our gate simultaneously, less information (or in some cases no information) would be recorded. One way of overcoming this limitation is to scan with more than one Bluetooth dongle simultaneously. Another one would be to reduce the amount of information recorded for each device.

Persistent vs. transient interaction spaces: It is easy to differentiate between highly persistent (such as a printer or desktop) and highly transient interaction spaces (a user passing by our gate once and never seen again). However, we still need to explore how to usefully interpret the data that lies between these two extremes (Figure 8).

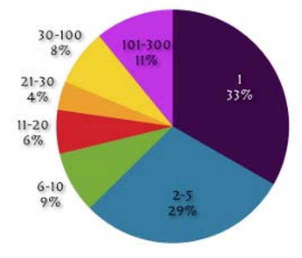

Figure 8. A breakdown of Bluetooth activity, based on the number of times a device was seen within an hour

Device attributes and people attributes: A characteristic of Space Syntax observations that we were not able to achieve in the Bluetooth study was the ability to classify pedestrian flow depending on people's characteristics. For instance, human observers can classify traffic in terms of men, women, locals, tourists, children or adults. However, Bluetooth data reveals information such as custom names that users assign to their devices. In our study, for instance, a number of devices appeared to have names that were catchy phrases, nicknames, or in some cases insulting remarks. This data may help us understand more about people's projected identity, and also to trace people's projected image over space and time.

Static vs. mobile Bluetooth scan: In planning to deploy numerous Bluetooth gates throughout a city, a secure and convenient setup is not always possible. We are therefore considering how the 'long-term' gates we discussed in this section can be combined with 'short-term' mobile scans of the city. In planning such a mobile-scan study, we need to take into consideration that Bluetooth activity may be very limited in certain parts of the city. More recent, an attempt was made to generate a 'snapshot' of the city's digital landscape. Various locations in the city were selected based on the study described in section 3.1. An observer covered these locations by moving throughout the city with a laptop and recording Bluetooth activity at each one of them. Early findings suggested that ~10% of people in Bath seem to have Bluetooth switched on. However, in some places we have identified different percentages, which could be for a number of reasons such as the nature of the location. For instance, in more open areas no single observation 'gate' catches all the flows of people, and in addition there may be static people hanging about within Bluetooth range. In order to verify the effect of these factors on the results more locations need to be scanned.

Bluetooth digital trails over space and time: By establishing a network of gates throughout a city, a specific device can be traced throughout a city (each Bluetooth device carries a unique MAC address) by looking at the recorded data from multiple gates. This data carries with it date and time signatures, and thus we can extend our following of devices over time as well. Recording people's 'Bluetooth trails' could prove useful in two main ways: First, digital trails could be used to study the effects of 'digital attractors' (such as Bluetooth enhanced posters) placed throughout a city. For instance, a poster broadcasting Bluetooth messages could influence people's movement in favour, or against, a specific location. By looking at people's digital trails we can measure this effect. Secondly, Bluetooth trails could be studied to gain insights about people's use of other technologies. A Bluetooth signal usually originates from a mobile phone or laptop. By studying the Bluetooth trails of mobile phone users, or laptop users, it is possible to identify patterns that can then be attributed to other technologies such as GPRS, 3G or WiFi.

Finally, associating the type of device, its interaction space, and the integration of the specific location, we can make use of the PSP frameworks' design suggestions. For instance, we can assume that an interaction space within a not-so-busy street (as predicted by Space Syntax and observed by ‘gate counts’) will have a greater degree of privacy as opposed to an interaction space within a highly integrated street (Figure 2).

3.3 Exploring mobile and digital behaviour in Bath

As well as capturing quantitative data we are carrying out complementary qualitative analysis of behaviour as an additional part of our methodology. This process addresses people’s behaviour towards technology in social and public spaces. A one-day pilot study was conducted with the intention to gather initial evidence about the use of mobile and digital technology in the urban space. Observations were made throughout 5 time periods between 10:30 am and 5:00 pm by a group of 8 observers. Types of behaviour in reference to use of e.g mobile phones and PDAs were observed and their locations were recorded in 7 selected urban spaces. This was complemented by an observation in a public café in Bath. Different types of behaviour were observed in relation to space properties. For instance, in pedestrianised areas mobile device usage was more obvious close to the locations of heavy movement flow. In contrast, in areas close to vehicle movement less mobile phone usage was recorded, these tended to occur near bus stops and waiting locations (Figure10: left). People at the bus stops used the phone to give updated information on temporal uncertainties: ‘no sign of a bus yet, I'll let you know when I am on it’.

In these locations the social behaviours and the interaction spaces appear to take a shape which provides the person with more privacy (Figure 9: left). This seems to be supported by the properties and affordance of the physical environment encouraging a certain type of behaviour.

Figure 9. Mobile phone use supported by the properties of the physical environment

We also noted differences in the walking pace (e.g. fast, slow) of the mobile phone user which may be related to the age (e.g. young teenager, business woman) and apparent social class of the user. But it might also be related to the area in which the mobile was being used (e.g. fast in the integrated areas, slow in the less integrated area with a tendency to move body orientation to be a ‘removal from distraction’ or avoiding interrupting others with one's conversation. People on the phone tended to place their back to the main space, often facing windows or other objects on the wall, or gazing into shop windows from the street while on the phone. This also applies to the observations which were conducted in a public café in Bath (Figure 10: right).

Figure 10. left: Mobile phone use near a bus stop and close to the ATM, which is situated in a way failing to create a private interaction space for an interaction involving private use, right: Mobile phone use in the café supported by the properties of the physical layout

In these observations two key factors seem to emerge. First, people tend to use the mobile phone while queuing to place their order. This is likely to happen close to the sale’s counter and could be a sign of people giving updated information on temporal uncertainties. ‘I am in the queue, where are you?’ Second, many people put their mobile phone on the table immediately after arriving and leave it visible. This might be to mark a territory or perhaps to take the place of a ‘potential other’ person. We also observed differences between singles and groups in this behaviour. In a group we see people toying with their phones when talking to the rest of the group. Other type of mobile behaviour include receiving a phone call or making one or even talking on the phone while approaching their table (Figure 11).

Figure 11. Mobile phone use in the café supported by the physical layout, but also related to the individuals intentions

All these reflect a repetitive pattern of generic behaviour, which could take different forms and would reflect different intentions. In this observation based methodology we try to understand these in relation to the properties of the architectural space. However, we are also interested in looking at the social and mobile behaviour from the individual’s view. This raises some questions related to the intentions of the individual, for instance the level of certainty and uncertainty in timing of a meeting which would encourage the usage of a mobile phone at a certain point. To address these questions in detail relatively longer term observations are needed to capture the transitions between the states that will allow us to make sensible deductions about these readings of observations such as the 'potential other' status of the phone on the table-the frequency of usage, the differences between singles and groups in this behaviour. Engaging our cohort of volunteers over a three year period will enable more extensive insight into social and digital interaction around the city, alongside more extensive observational studies.

4. CONCLUSION AND FUTURE WORK

We have argued that the urban built environment plays a critical role in the construction and reflection of social behaviours. This can be seen in the way it acts to structure space, which not only reflects and expresses social patterns, but can also play a part in generating these patterns (Hillier and Hanson, 1984). Having said that, the design of pervasive systems may also change the environment for interaction and so stimulate the emergence of new social behaviours. Inevitably then, designing new technologies tends to modify existing social practices, and on occasion stimulate new ones. However, the design of new technologies is often accompanied or guided by speculations about their social effects, and it is here that designers working with radically new and distruptive technologies tend to work on the boundary of existing knowledge. With the advent of mobile and pervasive technologies and the rapid adoption of Bluetooth mobile devices which can be detected in public and busy urban spaces, we need to gain a better understanding of the role of context as an emergent situation – both physical and social – of surrounding aspects that give meaning to our activities. We then need to address its impact on shaping social patterns. The mobile phone, for instance, as a particular socio-cultural object, as Ito has argued, is not so much about a new technology as much about a personal and intimate techno-social device supporting constant, lightweight, and mundane presence in everyday life (Ito et al., 2005). Public spaces such as cafes or public transport hubs are the 'stages' on which people negotiate boundaries of a social and cultural nature, in an attempt to carve out personal territories in public space. In order to understand these facets of socio-technical behaviours we need to deploy various methods covering different perspectives related to the physical and social context.

In this paper we have presented a methodology providing tools, methods and a framework for designing pervasive systems as an integral part of the urban landscape. We described three pilot studies and illustrated the methods deployed for mapping the physical and digital flow in relation to the proposed methodology. Here we draw on two main concepts that address issues of urban space, interaction space and the relation between the two.

However, at this stage we are only able to report our methodological intentions and the earliest of results. We cannot, for example, fully assess the effectiveness of a set of observation gates scattered throughout a city as a methodology to capture 'context'. Part of our ongoing work involves establishing multiple gates throughout the City of Bath and combining data from multiple Bluetooth gates. This should help us form a better picture of the digital landscape in the city. However, we are certain that spatial sampling of this kind will only give a very partial view of the complexity of social and technological interaction. We are therefore also applying 'snapshot' observation techniques in the context of cafés and restaurants where people are likely to use mobile and wireless technologies in order to address questions such as 'how do people physically orient their laptops in public spaces', and 'what wireless activities do they feel safe with'. To answer these questions we are planning to deploy scanning equipment that will record both Bluetooth and WiFi activity, complemented by human observations in the café or restaurant.

Of particular concern are the security and privacy of interaction between people and the private information sphere services in relation to physical space. We believe that the effect such issues have on people's perception of different spaces, and of what informs the definition of boundaries between the personal, private and public domains, requires considerable further research before it can be used to inform the design of new pervasive technologies in the urban realm.

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