UNIVERSITY OF SOUTHAMPTON
School of Electronics and Computer Science

A progress report submitted for continuation towards a PhD

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Information Lives in the City: the assisted dissemination of information in urban communities

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ABSTRACT

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This report presents an investigation into the social relationships found in urban areas, how these have eroded our sense of community and how new technologies may be able to contribute a solution. In particular, a coalition of technologies can be used to exploit subtle, transient social relationships, and the underlying spatial and temporal patterns, to distribute content within a local community. This solution will provide a localised and decentralised alternative to the Internet for disseminating information within a community, with the aim of increasing the opportunities for neighbours to initiate real social interactions. This report presents the background material behind the project, the approach it shall take and the plans for future work. The initial work to build a simulation in support of this research is also described.

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Author's Note

In the summer of 2001 I asked myself a simple, obvious and naïve question: What if every Bluetooth device was constantly on, constantly broadcasting 'information' and constantly receiving it? Over the course of two years I set about building the technology to support my envisaged scenario: I ported a multi–agent system to an embedded Java board, built a discovery and communication infrastructure to support these transient encounters and developed a few example applications[31, 32]. Unfortunately, during this period I had focused on creating the infrastructure for a solution rather than understanding a problem, its social context and the larger technological issues. The project described in this report is entirely independent of my earlier efforts but it aims to rectify my previous oversights and develop a comprehensive body of work on this theme.

Chapter 1

Introduction

1.1 Overview

This project considers a slightly different question: How could one utilise the transient encounters of wireless-enabled personal devices to disseminate information within a community, and, more importantly, what effects might it have on both the individual and society as a whole?[1]

This project draws together aspects from a variety of subjects, from sociology to the semantic web, in the attempt to identify a real social problem and a potential technological solution. The starting point for this project is the observation that urban residents have a very distant relationship with their closest neighbours — in many cases neighbours are strangers in all but address. Unlike the rural villager, urbanites have a large, dense, population from which to draw their social support and therefore they retain fewer social connections within their local neighbourhood. In turn, this has reduced the cohesion and strength of our neighbourhood communities (possibly to the gain of virtual communities). Ironically, the Internet now affords us the chance to participate, and influence, global communities to a much greater extent than is possible within our own suburbs. Indeed, there are now globally available resources to help us understand our local areas and connect together with other residents[2].

The solution explored by this project is to provide residents with a localised communication channel through which they can disseminate information to other community members. By allowing each individual to publish snippets of information (such as blog-style news posts, gossip, favourite recipes or photos from a recent school play), this project hopes to encourage a greater empathy within the community and provide a basis for initiating real–life social contact. In contrast to the recent enthusiasm for *Social Networking Services*[48], the core technologies behind this approach are not those of the global Internet but the localised emphasis of *Pervasive Computing*. By utilising mobile devices and short-range radio networks we can detect the *collocation* of individuals

[1]An alternative overview was presented in a position paper to the 1^{st} FOAF Workshop[33] and a poster, which won the best poster award, presented at the Equator Project's All-Hands Meeting (February 2004)[34].

[2]For example, UpMyStreet [`http://www.upmystreet.com/`], i-neighbours [`http://www.i-neighbors.org/`] and Neighbourhood statistics from the Office for National Statistics [`http://neighbourhood.statistics.gov.uk/`]

and transmit information between them. This content will be annotated using semantic web technologies to allow for the automated ranking, filtering and processing of the information.

The purpose of this report is to present the background material behind this research, explain the specific approach of the project and discuss the progress to date. The remainder of this report is structured as follows: Section 2 provides an overview of social networks within our modern cities, particularly the subtle social connections which lie outside our traditional view of relationships. An overview of the technologies that will form the basis of this project is also given. Section 3, presents an overview of the existing work and how it relates to this project. The penultimate section, Section 4, presents the project's approach and the plan for the remainder of the time. Finally, Section 5, describes the initial efforts at simulating the movement of pedestrians and modelling the emergence of collocation relationships.

Chapter 2

Background

2.1 Social Networks and Urban Environments

2.1.1 Urban Social Networks

Urban cities are traditionally places of anonymity: places where 'no one knows your name'. Such conurbations provide a wide choice of people with whom we can choose to be acquainted and consequently, as the locus of our social life moves away from the neighbourhood, we lose the connections necessary to disseminate news, raise issues and gauge views within our local communities. This decay of neighbourliness is further exasperated by the absence of a city 'sidewalk life', the serendipitous contact between neighbours, customers in corner shops and passers-by which reinforces a neighbourhood identity[25]. Without such a safe and convenient means of maintaining a public life amidst the anonymity of the city, the urbanite has only two choices; they must enlarge their private lives to encompass their neighbours or to withdraw from such contact altogether. Inevitably, it is the later choice that is taken:

> "Nobody can keep open house in a great city. Nobody wants to. And yet if interesting, useful and significant contacts among the people of cities are confined to acquaintanceships suitable for private life, the city becomes stultified. Cities are full of people with whom, from your viewpoint, or mine, or any other individual's, a certain degree of contact is useful or enjoyable; but you do not want them in your hair...
>
> Most of it is ostensibly utterly trivial but the sum is not trivial at all. The sum of such casual, public contact at a local level ... is a feeling for the public identity of people, a web of public respect and trust, and a resource in time of personal or neighborhood need...
>
> In city areas that lack a natural and casual public life, it is common for residents to isolate themselves from each other to a fantastic degree. If mere contact with your neighbors threatens to entangle you in their private lives, or entangle them in yours,... the logical solution is absolutely to avoid friendliness or casual offers of help. Better to stay thoroughly distant." [25]

Jacobs argues that within modern cities, casual public contact elicits a sense of identity, trust and respect within a community, and that where these casual contacts fail, individuals become increasingly isolated from their neighbours. Gehl also interprets these casual encounters as necessary to the health of a community: "these contacts appear insignificant, yet they are valuable both as independent contact forms and as prerequisites for other, more complex interactions"[16]. Putnam described these activities as "pennies in a cookie jar, each of these encounters is like a tiny investment in social capital"[54].

The issues associated with conurbations are becoming more important: In 2007, over 50% of the world's population will live in urban settlements and these cities are expected to absorb the majority of the earth's 2 billion additional inhabitants over the next 30 years [46]. This represents a substantial shift away from the rural lives of our ancestors and brings with it many changes, not least in the nature of our social relationships. Unlike the concentrated relationships that characterise a rural community, urban relationships are formed through mutual interest or occupation but possess little spatial correlation. City dwellers have a much greater pool of people from which to draw their friendships and, as a result, these relationships are not concentrated in a single neighbourhood. Actually, the differences between urban and rural relationships are more subtle. Rural inhabitants typically maintain the same number of friendships within a 5 minute drive as their urban counterparts[15] but the differences cannot be evaluated from a purely geographical view. The friendships must be seen in the context of the surrounding population density: The city dweller will pass–by many more front doors of strangers to reach their friends than a rural villager would. Therefore, in a city, the number of strangers we encounter will always exceed the number of people of whom we have personal knowledge. Indeed, as Lofland notes, this is one factor that clearly delineates the city from a rural village:

> "in one respect, at least, the city is not like other kinds of places. The city, because of its size, is the locus of a peculiar social situation: the people to be found within its boundaries at any given moment know nothing personally about the vast majority of others with whom they share this space."[36]

The stranger represents the weakest relationship within a society but even these weak, inconspicuous and transient relationships can be worth studying[61].

2.1.2 Familiar Strangers

In the early 1970's Stanley Milgram performed a small study to investigate a phenomenon he called *Familiar Strangers*. Milgram defined a familiar stranger as someone who is observed, repeatedly for a certain time period and without any interaction[42]. Familiar strangers are common throughout our urban existence: The commuters we recognise at the bus stop or the old man walking his dog on the way to work in the morning. Milgram and his students performed a simple experiment to determine the extent of the Familiar Stranger phenomenon. They photographed the commuters on a busy platform at a Boston railway station and returned a week later to ask each person to identify other commuters in the photograph. The study revealed that 89.5% of the participants could identify at least one person which they recognised but had never spoken to, with each person identifying an average of four familiar strangers. A follow-up study using the same experiment was performed in 2003 by Paulos & Goodman and produced comparable results[51]. In their study, 77.8% of participants recognised someone in the photograph with an average of 3.1 familiar strangers identified.

There is a temptation to believe that familiar strangers are a unique attribute of western societies but circumstantial evidence, and personal experiences, would suggest otherwise. One hypothesis of this project is that familiar strangers are in fact an emergent property of the movement and temporal patterns common to any modern city. Despite the outward appearance of chaotic motion, urban inhabitants possess strong temporal, spatial and intentional patterns[27]. They travel with a purpose; to work in the mornings, home in the evenings, to meet friends at a café or pick up the children from school. Additionally, these activities have a strong temporal ordering around particular intervals, particularly the ‘rush hour’ periods in the morning and evening but also around social conventions for shopping, lunchtimes or dinner reservations. City dwellers are creatures of habit and these patterns do not significantly alter on a daily basis. This collection of well-defined behavioural patterns obviously increases the likelihood of familiar stranger relationships developing. Indeed, in this context, familiar strangers may now appear inevitable and widespread but there is more to the development of these relationships than just repeated encounters.

The familiar stranger phenomenon is a psychological manifestation of repeated collocation. As Paulos and Goodman suggest, prevalence is a key contributing factor in the formation of familiar stranger relationships but it is not the only factor. This is perhaps best demonstrated by Milgram’s discovery that 80% of participants remembered a single, obviously striking, individual: “she wore a miniskirt constantly, even in the coldest months”. Paulos also discovered socio-metric stars including “a man in a wheelchair, a flower vendor with a lavish display, and a long-haired homeless man”. Humans are acutely aware of differences, discontinuities and anomalies in their environment and it is for this reason we will notice those people who stand out from the crowd. The attractive woman among trench-coated commuters at the railway platform or the Goth in the financial district are more likely to arouse our attention than the commuters or businessmen. Consequently, these socio-metric stars will become familiar strangers faster than the other individuals present at the same time. No technological solution can adequately account for the subjective aspects of the familiar stranger relationship and therefore we use the term *collocation relationships* to describe familiar stranger–style relationships discovered through technology.

2.1.3 Collocation

Collocation is a condition under which all parties are located within a spatial region during a particular time period. Goffman offers another term, co-presence, to describe this event [17]: “Persons must sense that they are close enough to be perceived in whatever they are doing, including their experiencing of others, and close enough to be perceived in this sensing of being perceived.” Collocation can be further refined by specifying the maximum distance that can separate co-present individuals. For this we can draw on the work of Edward Hall in defining the boundaries of the human senses, in particular, the range at which we can perceive people as individuals. Facial expressions, hair styles and age become apparent at a distance of 30m, and at around 20-25m we can determine their feelings and mood[19].

A hypothesis of this project is that repeated encounters between the same parties indicates a shared interest or demographic. In addition, the strong behavioural patterns of urban dwellers will provide a definite correlation between repeated encounters at the same time period and the location of their occurrence. For example, if two commuters encounter each other at approximately the same time on a weekday morning, there is a high probability that they will be in the same approximate location for each subsequent encounter. Therefore, one potential commonality between co-present parties is just the use of the same spatial region. Jacobs writes that even this superficial shared interest can carry a high motivation for cooperation:

> Let us assume... that city neighbors have nothing more fundamental in common with each other than that they share a fragment of geography. Even so, if they fail at managing that fragment decently, the fragment will fail. [25]

In modern cities there is a strong connection between the local area and demographics of the people who frequent it. The offices of professional services such as lawyers, accountants and estate agents are often found on the same street; banks and other financial institutions occupy a different niche of real estate. Similarly, neighbourhoods are inhabited by people of a similar race, class, wealth or other social status. Therefore, it should be clear that collocation is most likely to occur between parties with *something* in common.

2.2 Content Distribution among Collocated Individuals

2.2.1 Information Sharing

The primary goal behind this distribution of content is to create a public awareness of the people and places we regularly frequent. That is, it is not designed to replace the social interactions that do exist within a community but augment and encourage them. Sharing content between neighbours will (hopefully) promote a greater understanding of each other and generate a common ground, however slim and trivial, upon which further social interactions can be initiated.

The type of content that this project will support includes local stories, photos of community events, opinions, news and gossip. But this not a definitive list and, like the Internet, there will be no central content control mechanism. In many ways, this type of content is not dissimilar to the content shared by the thousands of bloggers on the web today — the difference is that it will be distributed locally. And, much like the 'blogosphere', it will encourage memes and usage norms to develop [18]. For example, the distribution of one type of content, such as jokes, may encourage others to distribute their comic repertoire to the community. Other complex network effects can also be created, such as routing items of content from one individual to another person whom they do not have direct contact with. Or, by posing questions to the community, it would be possible to gather local opinions and information.

2.2.2 Personal Area Networks

Determining when a collocation relationship develops requires a strict awareness of regular encounters with other individuals and therefore, automated mechanisms are necessary to record and identify those encounters. *Personal Area Networks* (PANs) are radio networks with a short (10m) range and low resource requirements, making them suitable for deployment in personal devices such as mobile phones. By using these short-range wireless network it is possible to detect collocation encounters whenever two device-carrying individuals come within radio range of each other.

There are a number of factors that affect when a collocation will be detected and if any information can be transferred: radio range, device discovery times, network architecture, connection setup times and bandwidth.

Range Obviously, the devices cannot detect each other unless they are within radio range but if the range is too great the devices will detect spurious, spatially–insignificant, collocations. Personal Area Networks are ideal because their range typically corresponds with the *social distance* defined by Hall[19] and is thus well within our normal sensory limits.

Device Discovery If it takes too long for devices to discover each other it will be possible for two individuals to walk past, within radio range, but not generate a collocation event. For example, assuming a radio range of 10m, two individuals walking at 1.5m/s will only be within range for just over 6secs. Therefore, the device discovery time will constrain the types of collocation encounters that are captured.

Network Architecture The architecture of the wireless network may also play a part in determining which collocations are actually recorded. Broadcast or Peer-to-Peer networks allow every node to discover every other node, whereas Master-Slave architectures may reserve this function for a single coordinating node.

Connection Set–Up In addition to the device discovery time, the time taken to begin transferring content (i.e., the connection setup time) will further restrict those collocations that result in a successful transfer of information.

Bandwidth The effective bandwidth of a radio will control the amount of information that can be transferred during each encounter and the total amount of data that a device will collect over the course of a day. For example, a higher bandwidth radio may require a larger storage capacity on the device or a smarter filtering and caching mechanism. For low bandwidth connections, it may be more appropriate to distribute a metadata description of a piece of content, which can then be accessed via the Internet.

2.2.3 Dissemination Policies

There are three possible methods to disseminate content during an encounter: freely distribute content at every encounter; distribute content only to those people you know (by some definition); or, broadcast snippets of information and allow the full content to only appear through repeated encounters. In the first case, information is openly distributed at every encounter and therefore no discrimination is made between close friends, regular contacts or complete strangers. This is the simplest mechanism in terms of computation but it is also the least socially acceptable – we do not currently share our thoughts and opinions with complete strangers. An alternative mechanism is to only distribute content to those people who meet a predefined criteria of social connection. For example, we might restrict the content to those people who appear in our phone book or email contact lists, or those we have encountered regularly over a given time period.

This process allows the user to limit the public distribution of their content whilst still making it publicly accessible to regular relationships. Unfortunately, this policy is both brittle, hard to manage and computationally difficult. The user must define the selection criteria and if this is not managed correctly it will no longer represent their actual contacts. The final policy would be to distribute small, random, snippets of content at each encounter. With a suitable algorithm, perhaps similar to tornado-coding[37] or self-healing key distribution schemes[5], these pieces can then be reassembled by those who have maintained a significant relationship with the user.

There are many other variables which could be used to control the dissemination. Does each device automatically redistribute content that it has received or only the user-specified content? Are the content exchanges anonymous or will a name (or nickname) be associate with each encounter? Can content be addressed to an individual and routed through the transient encounters much like 'chinese whispers' or Stanley Milgram's Small World experiment[41]? How will the network, and, more importantly, the individuals, respond to the spread of undesirable content such as copyrighted music or pornography?

2.3 From Data to Information

2.3.1 Annotating Content

Without annotation, the disseminated content will only be understandable to the human user but will remain as inpenetratable data to the user's device. In order to filter, rank and display the information to the user, it is necessary for the device to have some understanding of the content. A solution, explored by this project, is to use the emerging technologies of the Semantic Web[4] to annotate the disseminated content, thus transforming the data into information a computer can manipulate. Currently, the content available on the Internet in the form of HTML pages is readable only by humans in their native, natural language. This makes it very difficult for a computer to distinguish between a person's name and, for example, the titles of the papers they've authored. The Semantic Web is an effort to make the web readable by machines and the Resource Description Framework (RDF) is the principle means by which the Semantic Web aims to achieve this goal. RDF is a "*language for representing information about resources in the World Wide Web. It is particularly intended for representing metadata about Web resources, such as the title, author, and modification date of a Web page... However, by generalizing the concept of a 'Web resource', RDF can also be used to represent information about things that can be identified on the Web, even when they cannot be directly retrieved on the Web*"[38]. The basic structure of RDF is that of a graph, composed of a *subject* about which a *predicate* is asserted to have a particular value (the *object*). For example, this allows the expression of statements such as `Jamie (subject) wrote (predicate) this report (object)`. To give some meaning to the relationships, *ontologies* are used to specify the higher-level structures and relationships between concepts[14]. For example, an ontology might specify that the object of a daughter relationship must be female, or that a vegan is a subclass of vegetarian. Ontologies provide a 'web of meaning', where the meaning of a concept is not grounded in the real-world through sensory inputs but through its relative position and relationships to other concepts.

A number of RDF applications already exist to annotate content: Dublin Core (for general authorship); the Extensible Metadata Platform, XMP[1], (for visual content); Atom[2] (for syndication); and Creative Commons[3] (for licensing).

2.3.2 Mining Collocation Data

In addition to the content transferred during collocation encounters, the encounter itself can provide interesting data. Each collocation event can be represented as a triple of the form
`<device1, device2, timestamp>`. A key aspect of this research is the construction of data–mining systems to extract the meaningful relationships hidden among the high ratio of noise (i.e., strangers) within the collocation data. Collocation data can contain at least three different classes of encounters: *a)* casual or random encounters, *b)* collocation encounters that represent familiar strangers, and *c)* conventional social network encounters (e.g. between friends and colleagues). Data–mining and statistical techniques can be used to identify and eliminate casual encounters, leaving encounters that represent some form of social relationship. Friendship and colleague relationships may be identified from a number of external sources, such as more traditional social networking tools, or from personal sources such as electronic address books. By eliminating these from the collocation events, a set of familiar stranger-style relationships can then be identified.

Alongside the development of social networking services, there has been work on representing relationships using semantic web technologies. The FOAF project[8] is an attempt to model the network of friends which connect two people together (hence the acronym FOAF: Friend of a Friend). It is an RDF vocabulary that principally defines a `Person` class and a `knows` property that can express a relationship between two people. The `knows` relationship is not strictly defined in any semantic sense and ultimately its meaning is a subjective decision taken by the author of a FOAF file. A separate vocabulary, RELATIONSHIP, builds upon this simple `knows` property to define additional relationships such as `employedBy`, `friendOf` and `childOf`. Ontologies such as FOAF and RELATIONSHIP support this simplified, binary representation of the overt relationships within our lives but they are unable to model the contextual information (such as spatial and temporal properties) arising from repeated collocation encounters. There are numerous issues with representing relationships in FOAF, particularly due to the lack of expressivity, nuance and social context. However, these issues can be largely avoided if FOAF is used only as an internal representation format and not publicly shared.

2.4 The Dark Side of Information

This report has asserted, and implied, that the dissemination of information is a *Good Thing* for society but before undertaking this project it is worth reflecting on this assumption. The maxim, 'information wants to be free', is not a universal law of nature but a cultural assumption and, as such, it should be questioned.

[1] `http://www.adobe.com/products/xmp/`
[2] `http://www.atomenabled.org/`
[3] `http://creativecommons.org/`

Neil Postman described *technocracy* as the age in which "society [is] only loosely controlled by social custom and religious tradition" and where "tools are not integrated into a culture; they attack the culture"[52]. However, he believed that we had moved beyond that age and into a *technopoly*, a period where technology has monopolised our lives by redefining the meanings of religion, art, family, politics, history, truth, privacy, and intelligence. Postman attacks our info-centric view of the world by asking exactly what major political, social or personal problems can be attributed to a *lack of information*. Indeed, this *infologic* approach to the world's problems has been described as a "sort of social and moral blindness"[9]. There are other concerns too, not only about the effect of information on society but on the increasing volume that an individual is exposed to[21]. In recent years we have an increased wealth of information available to us but there is also an increased volume of information with which we have to personally deal with. Hallowell and Ratey, two experts on Attention Deficit Disorder (ADD), have remarked that "our cultural norms are growing closer and closer to the diagnostic criteria for ADD"[20]. They describe *pseudo-ADD*, a non-clinical condition reminiscent of ADD, as a side-effect of the modern culture of information:

> "Most people know what it feels like to be bombarded with stimuli, to be distracted by overlapping signals all the time, to have too many obligations and not enough time to meet them, to be in a chronic hurry, to be late, to tune out quickly, to get frustrated easily, to find it difficult to slow down and relax when given the chance, to miss high stimulation when it is withdrawn, to be hooked to the phone and the fax and the computer screen, to live life in a whirlwind."

It is for the reasons outlined above that we cannot assume that throwing more information at a problem will automatically solve it. Certainly, we must strive to avoid increasing the information burden on the individual and contributing to this "ADD-oid culture". It is unlikely that a computer scientist can effectively answer the question of whether information is beneficial to society[4] but, nevertheless, as the principle enablers of information, it is a question that a computer scientist must ask.

[4]indeed, the Hacker Ethic includes "the belief that information-sharing is a powerful positive good"

Chapter 3

Related Work

This project does not stand alone in the fields of ubiquitous computing or the semantic web: it borrows assumptions, approaches or ideas from a variety of work. However, this section will argue that no other project has exactly the same aims or expected outputs. This section introduces a selection of the most interesting projects and highlights how the approach of this project differs in both intent and execution.

Recently, the commercial interest in social networks has risen to fever pitch: hundreds of *social networking websites* have appeared catering to every conceivable relationship we may have, or may desire in the future. As of July 2004, there were 45 business networking sites, 35 common interest sites, 53 dating sites and 59 friendship sites[1]. There are even 5 pet-networking sites because, apparently, hamsters need friends too[2]. There is also a growing body of work analysing 'communities of practice'[1, 40]. All of these activities focus on the type of relationships that an individual would be reasonably cognisant of; namely friendships, collaborations, professional relationships and even common interests. In contrast, this project will utilise the weakest of human relationships; so weak indeed that many people are not consciously aware that they possess them. These are the hidden connections between inhabitants of the same neighbourhood, between workers in the same district and indeed between anyone who regularly frequents a particular place. It is these weak relations that are most prevalent within our modern cities but which cannot be captured with the simple social networking technologies of these sites. Although this project will attempt to capture the network collocation relationships there is no intention of sharing these representations due to the privacy and personal implications. There is also anecdotal evidence to suggest that users of social network services are more interested in using them to visualise and explore their social network than exploit them through the supplied service[11].

The *Urban Tapestries* project[3] "is a software platform for annotating geographic places with content (text, images, sounds) and making relationships between places"[30]. The prototype application allows the user to 'tag' locations with a discussion board and then post messages via a mobile phone or PDA[29]. The subject of this report shares many of the same assumptions and goals as Urban Tapestries (e.g. community building) but instead of the structured tagging of space, the boundaries of the information flow will emerge from the temporal and spatial patterns of the community.

[1]Taken from a survey by the Social Software weblog [`http://socialsoftware.weblogsinc.com/`]
[2]See HAMSTERster [`http://www.hamsterster.com`]
[3]http://urbantapestries.net/

In addition to revisiting Milgram's Familiar Stranger study, Paulos and Goodman also prototyped a number of 'familiar stranger devices', which they called *Jabberwockies*[51]. In one form, the Jabberwocky was a small keyring based on the mote platform and, in another, the Jabberwocky was a small application running on a Bluetooth-enabled mobile phone. In either form, the Jabberwockies were designed to record the encounters between devices and present this information to the user. Unlike the research presented in this report, the sole purpose of the Jabberwockies is to display which familiar strangers are currently in close proximity but not to transfer any content between them. Hence, although the devices presented the user with a novel and interesting view of their temporal patterns, they didn't act as information distribution mechanisms.

Kortuem has developed *Proem*[28], a platform to support the transient interactions within *Wearable Communities* (communities of individuals using wearable computers). Kortuem's Wearable Communities act as "an alternative model of human communication [to cyberspace] that relies not on shared imagination but on real-world encounters and first-hand experiences". Proem has been used to develop a number of case study applications including a mobile buy–and–sell marketplace, a community music guide and a collaborative errand notifier. Kortuem has also investigated the design process for such applications and developed a small set of guidelines that are highly relevant to this project. Kortuem's work has the most in common with this project, particularly in terms of the underlying ideology and implementation, but it was situated within the context of a generic community of wearable computer users. In contrast, this project is framed by the ideas of familiar stranger-style relationships, the temporal and spatial patterns of cities and the provision of a information distribution channel within a local neighbourhood.

Umbrella.net[43] is a project that explores the spontaneous formation of communication networks during unavoidable circumstances. The network is formed when users open specially adapted umbrellas during an unexpected rain shower. Each umbrella subsequently glows to indicate its network status and allows communication between the attached PDA's. Umbrella.net is a piece of performance art, choreographed by a change in weather conditions, rather than an attempt to explore the communication abilities of collocated devices.

MIT Media Lab has produced many projects that combine ubiquitous computing and social interactions. *Meme Tags* [7], and their predecessors *Thinking Tags*[6], allowed participants at a conference to share small snippets of text between each other and display these on a communal resource. In contrast with this project, Meme Tags could only share small amounts of textual information using an infrared connection and they required user intervention to initiate the meme propagation. The *Sociometer*[10, 13] is a wearable device designed to measure the face-to-face interactions within groups by recording the identity, proximity and conversation between individuals. This data is then collected and analysed to build a model of the participant's social network. In contrast to the project presented here, the Sociometer is concerned with relatively strong, stable relationships between group members, particularly in face-to-face meetings and conversations.

BlueFOAF[4] is a small application that notifies the user if any of their acquaintances are within range of the Bluetooth network. It works by creating a mapping between Bluetooth device identifiers and Person instances defined in the user's FOAF file. This

[4] `http://usefulinc.com/edd/blog/2004/2/1#22:47`

work focuses on well-defined and understood social relationships, and doesn't provide any information sharing mechanism between people.

Terry et al. have investigated the inference of shared interests from physical proximity using wireless devices[60]. *Social Net* would facilitate mutually beneficial introductions by inferring shared interests between individuals based on their repeated collocation and a simplified model of their social networks.

> "Joe and Mark both share a passion for racquetball, yet they do not know each other. They do, however, have a friend named Amy in common. When Joe and Mark play racquetball near each other at the same time, their Social Net devices make note of their close proximity. Over the course of several days, their Social Net devices record their encounters and a shared activity is inferred. When Joe later meets Amy for coffee, Joe's Social Net device communicates to Amy's device and indicates that Joe and Mark likely share a common activity but that they don't know each other."[59]

In contrast to this project, Social Net was a mechanism for facilitating human introductions rather than disseminating information *per se*. However, Social Net did define a threshold function to determine the shared interests between individuals, based on the number and duration of encounters. Social Net was trialled at a conference but the experiment was limited in duration and scale and produced few usable results.

Encounter Bubbles[5] is a novel visualisation of collocation encounters based on the mobster project[6]. This visualisation uses a bubble to represent a recent encounter; the size of the bubble conveys the total number of previous encounters, the brightness represents the frequency of encounter and the colour can be assigned to members of particular groups such as family, friends or colleagues. This is one possible visualisation of the collocation data that will be generated by the simulation and collected by the application.

Numerous simulations have attempted to model the behaviour of pedestrians. Some of this work has modelled the *micro*–movement of pedestrians to account for collision avoidance, following and clustering[58, 49]. *STREETS* is another urban pedestrian model, which attempted to model the *macro*–movement of pedestrians and how they were affected by the influence of spatial configuration (e.g. street layout) and the locations of attractions (such as employment or shops)[56]. STREETS built upon the theory of *Space Syntax*[23] to model how the structure of the streets influenced the movement of pedestrians. Space Syntax, and particularly Axial Visibility Mapping, is a method of describing the importance of a street based on its accessibility and visibility. The theory that this analysis can predict pedestrian flows has been subsequently confirmed through observational experiments[12]. The simulation developed within this project is a macro-movement simulation but the goal of generating collocation events has necessitated a different approach to the pedestrian model. Section 5 contains more details.

The project proposed within this report has many aspects in common with previous research. However, this project combines the urban setting and the ideas of familiar strangers with the use of pervasive computing and semantic web technologies, to facilitate the localised transfer of information, in a unique manner. Whilst other research projects have focused on the centralised annotation of space, this project will create a fluid notion of community that arises from the movement activities of local inhabitants.

[5] `http://www.seansavage.com/encounter-bubbles/`

[6] `http://scott.lederer.name/projects/mobster.html`

Where other projects have sought to capture strong social relationships, this project will simulate and utilise the weakest social relationships. Where some research has explored the collocation patterns of urban environments, this project will exploit them.

The following section, Section 4, presents the project plan and research approach.

Chapter 4

Approach

This project aims to exploit the spatial and temporal rhythms of the city and the transient encounters between its inhabitants. It will use Pervasive Computing and Semantic Web technologies to enable the distribution of information between these collocated individuals. This peer-to-peer dissemination channel is designed to provide a source of ambient, unobtrusive, background knowledge within a local community as a means of building social capital, maintaining community awareness and providing a starting point for further social interactions. Whilst this work is situated in the environment of the urban neighbourhood, and in the context of declining neighbourliness and increased anonymity in these areas, it may also be applicable in other settings. One of these potential application domains is that of knowledge dissemination in large corporations or technology campus'.

The goals of this project are to:

1. Investigate and design the methods for using collocation encounters to disseminate information
2. Build and trial an application to perform information sharing using some or all of the conceived methods
3. From the field trial, evaluate the types of collocation relationships discovered and how the information distribution channel is used

This project will investigate the methods by which information can be disseminated within a community using an *idealised personal device*. This device would feature a processor, data storage, battery and personal–area wireless network and can be seen as a future successor of the mobile phone, PDA and Apple iPod. The purpose of framing the work in this context is to ensure that the methods are not constrained by the features of a particular class of device or technology. However, this work is not science fiction and some aspects of the work will need to be implemented and trialled, within the lifetime of the project, using consumer products such as mobile phones. Therefore, this project will attempt to balance the vision for the future with the realism necessary to complete a field trial.

The initial phase of this project will focus on investigating the mechanisms of collocation within an urban neighbourhood. In particular, this will involve understanding what aspects of urban life affect the occurrence of collocations and obtaining useful collocation data that subsequent phases can exploit. The next stage will be to design the overall architecture of the system, investigate the proposed dissemination policies, specify the semantic annotations and invent the filtering, ranking and data mining mechanisms. An initial outline of the architecture is discussed in Section 4.2. This architecture will be implemented using readily-available consumer devices and standard computer systems. Finally, the system will be tested in a field trial to demonstrate the viability of the architecture and elicit user feedback on the system.

The Gantt chart in Figure 4.1 describes the plan for the remainder of this project. During 2004, the project shall focus on finishing the implementation of the agent–based simulation and performing several experiments to confirm the validity of the collocation data. The first half of 2005 will be spent researching and designing the algorithms for disseminating the content and mining the collocation relationships. During the later half of 2005, this project will concentrate on implementing the application and utilising the collocation data generated by the simulation. This application will eventually be ported onto the selected hardware, for a field trial during the first half of 2006. The remainder of 2006 will be spent analysing the trial results and writing up.

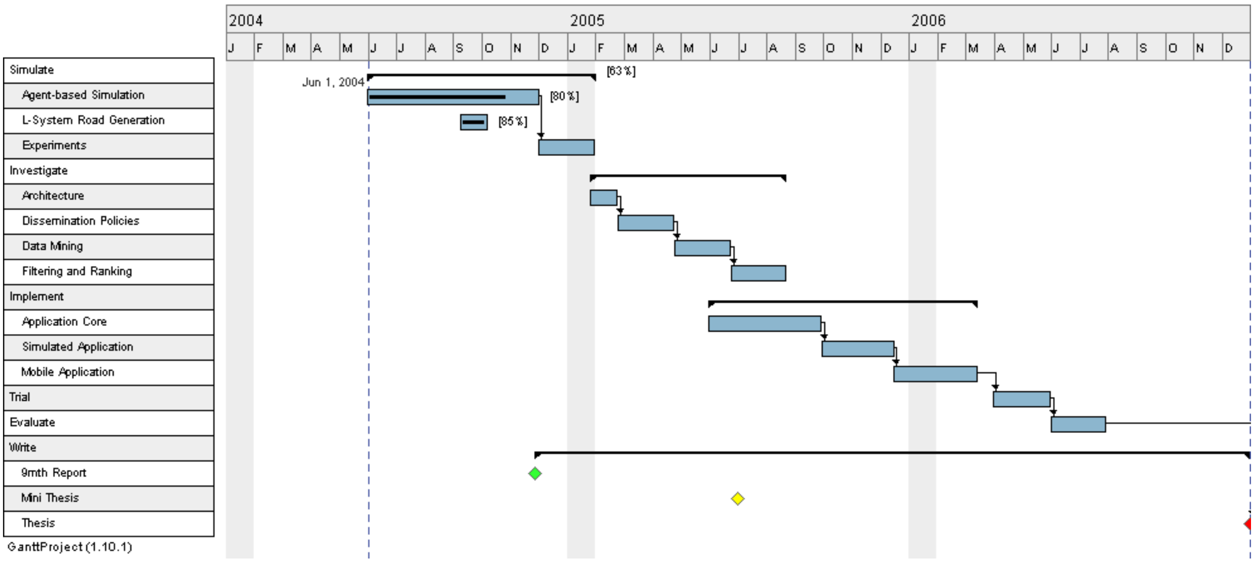


FIGURE 4.1: The plan through to the end of 2006

4.1 Simulate

Before a collocation application can be developed, this project needs to obtain solid data on when, where and between whom encounters occur within an urban setting. The observation of subjects is the usual method for discovering underlying social processes in the social sciences. Unfortunately, traditional observation methods cannot capture every encounter between each of the participants in anything other than a trivial population. Even observing a single individual would take considerable effort as the observer would need to record each collocation event, when it occurred and with whom. An alternative method is to instruct the participants to keep detailed diaries of where they went, when and who they passed-by on the way, but this fails for many of the same reasons as observation. Other more imaginative methods could be envisaged using digital cameras or videos to record a diary of encounters but these are difficult and time consuming to filter and annotate.

An ideal experiment would be to attach a wireless computing device, such as a *Mote*[22], to a each individual in a large community and use these devices to collect collocation data. Indeed, some similar experiments have already been performed by equipping a small number of subjects with GPS tracking devices[35, 2] and using this data to infer movement behaviour. However, as desirable as such an experiment is, there are problems. First, unlike learning the behaviour of an individual, collecting collocation data is highly sensitive to the number of participants involved in the experiment. If six participants (as in Ashbrook's second study) were randomly chosen, the collocation data would not accurately reflect the frequency of collocation because so many of their real-world encounters would be with non-participating individuals. Any individual not participating in the trial would appear as *dark matter* and therefore be completely invisible to the experiment. So, in order to gain a realistic understanding of collocation, an experiment would have to include a significant portion of a community. The exact participation level required to understand collocation is not yet understood. Secondly, there are obvious management issues when running a large-scale trial including organisation, control, provisioning and funding. Finally, it would be prohibitive to repeat or explore variations of such a time– and resource–consuming experiment. Consequently, the approach that this project shall take is to implement an agent-based simulation of pedestrian movement, which will allow the exploration of collocation within a virtual urban environment. This simulation is discussed further in Section 5.

4.2 Investigate

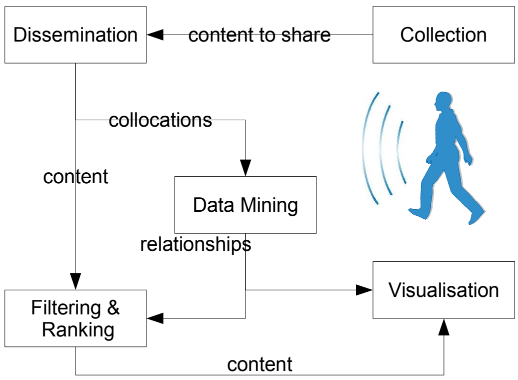


FIGURE 4.2: The tentative architecture for the information dissemination system

The investigation phase of this project will concentrate on defining a overall architecture for this system and designing the various components. An initial outline of the architecture is shown in Figure 4.2. There are 5 components to this system: Collection, Dissemination, Data Mining, Filtering & Ranking, and Visualisation. The *Collection* component is a user-facing module that allows the user to specify what data sources to share and what the rules are for sharing it. It is responsible for retrieving the data from the disparate data stores and making it available for dissemination. The *Dissemination* module is the component that performs the transmission and reception of information during an encounter. It is also the only component that must be situated on the mobile device. A selection of the dissemination policies were presented in Section 2.2.3 but further investigation is required to determine the exact algorithm and its effects on the spread of information. The *Data Mining* module will sift through the collocation events and determine which represent significant relationships. These relationships can be used by the *Ranking and Filtering* module to sort the content according to the user's predefined preferences. Both the content and the discovered relationships can be shown to the user through the *Visualisation* component. The visualisation is both an interactive component that will allow the user to view, sort, explore, manipulate and annotate the information, and a ambient display that can present the information in a passive, non-intrusive manner.

4.3 Implement

The implementation of the system will target readily-available consumer products and standard computer hardware. This project will not undertake the development of a bespoke device to support the proposed information distribution, although the ideas could be readily applied to one in the future. There are two consumer electronic devices which would appear to be suitable for the deployment of this system: the mobile phone and the digital music player.

Mobile phones are moving towards, and indeed subsuming, the role of the PDA. Many of the mid– and top–of–the–range mobile phones use operating systems previously used in PDA's (Symbian, Palm and Microsoft Windows Mobile) and represent an open platform onto which the user can install applications and synchronise with a desktop computer. In addition, there is a wide-spread deployment of Bluetooth radios within these classes of mobile phone. Most of the phones contain a few MB of Flash RAM for program and data storage, and some of the higher–end phones contain memory card slots. The leading candidate for cross–platform mobile development is the Java 2 Micro Edition (J2ME)[1]. This is a version of the standard Java language and libraries, cut–down for use on resource–constrained devices. In addition to the standard libraries, there are numerous API's to support mobile–specific functionality such as messaging, multimedia and Bluetooth. Unfortunately, the adoption of these API's in not uniform across the market and the nature of the Java runtime means that it is not possible to replace any missing functionality by calling the operating system directly.

Digital music players, epitomized by the Apple iPod, are a recent addition to the consumer electronics marketplace. These device are usually composed of an embedded operating system, low–end processor and digital signal processing chips, and a large storage medium (either flash memory or miniature hard drives). In contrast to mobile phones, digital music players are not currently equipped with a wireless connection and neither do they act as a open platform onto which the user can install applications. However, they do feature a large amount of storage onto which content could be stored before dissemination or collect during collocation encounters. It also seems possible that these devices will eventually adopt a wireless connection but, instead of Bluetooth, it will

[1]http://java.sun.com/j2me/

probably be the longer–range, higher bandwidth 802.11b standard[2] or the PC–oriented Wireless USB[3].

As the dominant personal area network, Bluetooth will probably provide the basis for the implementation of this research. Although the 10m range of Bluetooth is ideal at limiting the encounters to those that are spatially significant, the technology is not without its problems. Bluetooth uses a master-slave network structure, which makes it less than ideal for strict P2P applications, and a slow device discovery time may hamper the type of encounters it can capture. An analysis of the Bluetooth inquiry process[4] has shown that, theoretically, two devices can discover each other within 4secs but this assumes that on both devices are in the appropriate modes (either `inquiry` or `inquiry-scan`)[62]. In the case of collocation detection, the two devices cannot be assigned their respective states *apriori* and therefore, only those encounters of a longer duration will be recognised: transient encounters such as walking past each other will be lost whilst longer encounters at a bus stop will be recorded.

Due to their prevalence, and the support for the Bluetooth wireless network, it seems inevitable that mobile phones will be used as the deployment platform for the field trial.

4.4 Trial and Evaluate

The final phase of this project will be a field trial and subsequent evaluation. For the reasons outlined in Section 4.1, it will not be possible to run an experiment involving a significant number of participants from a community. Therefore, the field trial will not be able to statistically validate the results of the simulation. The main purpose of the field trial will be to understand what content is shared within the network, how it is disseminated among the members, what the structure of the collocation relationship network is, and how the users feel about the experience. The exact nature of the trial has not been decided but, tentatively, it will include user diaries, interviews, direct observation and, of course, snapshots of the data collected. The field trial will also demonstrate the technical feasibility of the research.

[2] `http://grouper.ieee.org/groups/802/11/`
[3] `http://www.intel.com/labs/wusb/`
[4] the process by which a device can discover if there are any other Bluetooth devices within range

Chapter 5

Simulation

5.1 Purpose

The primary purpose of this simulation is provide the artificial collocation data upon which an information sharing application can be developed. The simulation cannot be used to infer grand theories of urban activity patterns since it does not accurately model the complexities of the human decision process or the boundless possibilities in modern life. Nor should it be described as a model of familiar strangers, since familiar strangers are a psychological manifestation of collocation rather than a predictable result of it.

Since collocation events are the desired outcome from the simulation, they cannot be modelled directly. Instead, the simulation must model the underlying social, spatial and temporal processes from which collocation relationships emerge. To ensure that the collocation data is a reasonably faithful reproduction of real-world events, the simulation uses statistics and data collected from numerous sources to control its variables. For example, the mean distance between intersections[24] and the distribution of road categories[47] is used when generating the street network. The actions of the pedestrians are informed by a number of travel studies including those by Schlich and Axhausen[57], Jones et al[26] and several recent reports by the National Statistics Office (UK)[44, 45, 55].

The simulation will help to understand the attributes of urban rhythms. Do regularly collocated individuals share a common demographic, as this project has assumed? What properties does the network of collocation relationships possess? What type of activities will produce well–connected individuals?

5.2 Design

5.2.1 Agent-based Simulation

Agent-based simulations are models in which the atomic units of concern are agents — discrete, autonomous entities that interact with each other and their environment. They have been widely deployed in pedestrian modelling[3] and other fields of simulation.

Agent-based simulations are particularly suitable for modelling social, economic or ecological phenomena in which the individual displays a high degree of autonomy and where global features emerge from these local actions.

In the pedestrian simulator, each agent represents a pedestrian moving about the city in accordance with an internal schedule. The agent's schedule is composed of a number of activities, each of which is associated with a particular place. An activity has a start time, end time and duration but only two of these needs to be specified. This accounts for an agent that *starts* work at 9:00 but *finishes* at 5:30. The agent will schedule a movement action in order to arrive at the the activity's location before it is scheduled to begin. To make the simulation more realistic, each time has a probability function associated with it. This function will determine the exact time used for a particular instance of an activity. For example, an individual may be due to start work at 9:00 but they actually arrive between 8:55 and 9:10. Each activity can be repeated on a daily or weekly period, which are the most significant periods identified by current research[57].

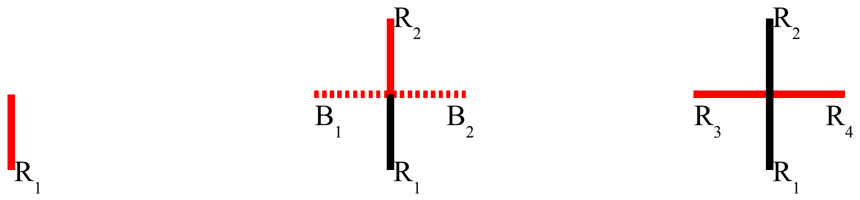
5.2.2 Spatial Representation

The traditional 2-dimensional spatial model has been discarded in favour of a simpler graph structure. This is possible due to two observations: although pedestrians have free-roam of the city, in practice they are highly constrained by barriers, road traffic, buildings and social norms to follow well-defined routes; secondly, collocation occurs within the boundary of social space, a distance of approximately 10m between individuals. These facts enable us to effectively ignore the micro-movement of a pedestrian and constrain their motion to a bidirectional network of predefined paths. This graph consists of nodes, representing places which the agents visit, connected by edges that represent a pavement, street crossing or typical route through an open space. Another simplification can be found in the encounter detection algorithm: the spatial collision detection used in 2D models is replaced with the simple rule that an encounter takes place whenever any two individuals are travelling in opposite directions along the same edge. Agents present at the same place will also create a collocation event during that time period.

5.2.3 Street Generation

The simulation requires a semi-realistic street grid upon which the agents will move. This street layout should possess a number of properties: streets typically shouldn't fly-over each other, there should be few dead-ends, roads don't cross water or other boundaries (except in the exceptional cases of a bridge or tunnel), roads should follow "natural" looking patterns and there must be a method to differentiate between road types. A suitable street grid is essential for creating natural routing algorithms (since pedestrian movement is not strictly confined to the shortest routes), possibly using Space Syntax [23] to inform the pedestrian flows on individual streets. Since the simulation is only concerned with the movement of non-vehicular traffic, no consideration needs to be given to artefacts such as one-way or pedestrianised streets.

Initially, the simulation used a random street generation algorithm that created the roads from an existing road endpoint to a uniformly-distributed, random location on the map. Fly-overs were prevented by union-ing the lines together, thereby creating an intersection at each cross-over. This layout exhibited several undesirable artifacts such



(a) A road

(b) A road and its successor road and two derived branches

(c) Generated branches will eventually turn into roads

FIGURE 5.1: The Road Generation Process. Red lines are candidate roads, black lines are confirmed roads

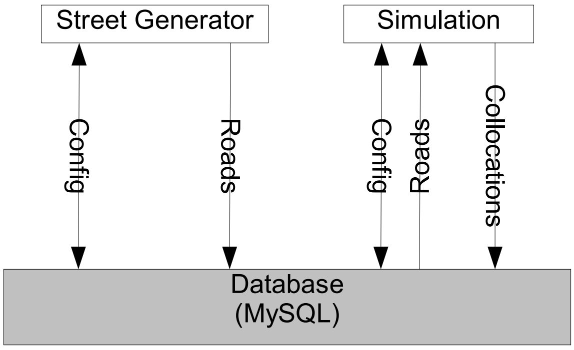


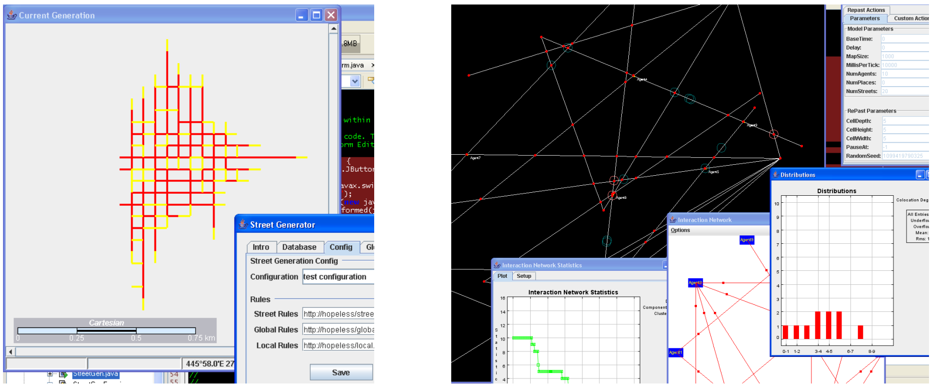
FIGURE 5.2: Simulation Architecture

as central clustering, long straight roads to nowhere and the occasional high densities of very short roads (typically where multiple roads crossed over each other near the same point). In response to this initial experience, a more substantial generation algorithm has been implemented. This new approach was originally developed by Parish and Müller[50] and uses environmentally-sensitive L-Systems, which were previously used to model natural plant structures[39]. *L-Systems* (also known as Lindenmayer Systems) are a "parallel rewriting system operating on branching structures known as bracketed strings of modules"[53]. A *module* is the smallest atomic element of a L-System and in this simulation the modules are either *Roads* or *Branches*.

The method implemented by Parish and Müller is effectively divided into three components: a generator of idealised roads and branches; a *global goals* function that instantiates the roads according to the input data (such as population, relief and road patterns); and a *local constraints* function that ensures that the generated roads do not cross boundary areas, or create fly-overs and dead-ends. As shown in Figure 5.1, each Road will generate a successor road and two branches, which in turn will also become roads. In contrast to Parish and Müller's system, the algorithm implemented within this project generates a string of objects rather than a textual representation and, consequently, the generation rules have been greatly simplified.

5.3 Implementation

The simulation has been implemented in two parts: the *Street Generator* and the *Pedestrian Simulator* (as shown in Figure 5.2 and 5.3).



(a) Street Generator (b) Pedestrian Simulator

FIGURE 5.3: Screenshots taken during testing of the simulation

The Street Generator will produce a road network from a set of input data maps (population, relief, road patterns, boundaries) and store the generated roads in a database. The L-System that controls the generation process is implemented on top of a forward-chaining inference engine[1] but uses custom code to maintain the L-System module strings and enforce the parallel rule-firing process. The L-System implementation supports two methods of controlling this process: a *context-sensitive mode* which uses the surrounding modules to determine a predecessor's context; and a parametric mode which allows the interrogation of a module's attributes. In practice, the Street Generator operates as a parametric L-System. The global goals and local constraints functions are implemented as separate rules engines (again, using Drools) that instantiate and modify the roads attributes. The functionality for representing and manipulating the road geometry is provided by the GeoTools library[2] and the Java Topology Service (JTS)[3], both of which build on the OpenGIS[4] definitions. MySQL was chosen as the database because it supports OpenGIS features as native column types. Since the street network is stored in a database, the street generator may be run independently of the simulation and a single map can be reused in multiple simulations.

The Pedestrian Simulator retrieves a named road network from the database and instantiates the world with a specified number of agents. The actual simulation is controlled by the Java-based RePast toolkit[5], which facilitates the agent scheduling, display, introspection and data collection. RePast also supports the display and manipulation of geospatial data using the same GeoTools library as previously mentioned. During every simulation tick, the Pedestrian Simulator generates a collocation event for each pair of collocated agents and then stores these in the database. In the future, the simulation will need to be distributed across several machines to achieve acceptable performance but this has not yet been implemented.

[1] Drools: http://www.drools.org
[2] GeoTools: http://www.geotools.org
[3] Java Topology Service: http://www.vividsolutions.com/jts/
[4] OpenGIS: http://www.opengis.org
[5] RePast: http://repast.sourceforge.net

Chapter 6

Conclusions

Modern cities possess unique features that differentiate them from rural settlements. These characteristics include the anonymity of the individual, the declining interaction with neighbours and the large proportion of strangers by whom the urban dweller is surrounded. However, other aspects of urban life, such as the strong temporal and spatial ordering of activities, have created new relations called *Familiar Strangers*. These relationships can be generalised from a subjective experience of an individual into a definable event, a *collocation*, which is captured by pervasive computing technologies. This project will focus on exploiting these collocation encounters to share information within a local community. This information may take numerous forms but could, for example, include pictures of a school fête, advertisements for local organisations or snippets of neighbourhood gossip. The stated goal of this distribution channel is to provide an unobtrusive means of disseminating news within a local area and provide a thin, latent, level of shared knowledge upon which further social relationships can form within the neighbourhood.

This report has presented the principle ideas and aims of the project, and outlined a workplan for the remaining $2\frac{1}{4}$ years. In summary, this project will develop an agent–based simulation of pedestrian movement in order to generate realistic collocation data. This data will then be used to design and develop an application for sharing information during repeated collocation encounters. Finally, the application will be ported to existing consumer hardware and field trialled during the first half of 2006.

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