Urban Encounters: The game of real life

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Abstract
In this paper we describe our ongoing work on modelling urban encounters by extending Conway's Game of Life. We develop our model based on empirical data collected using a Tamagotchi-like mobile game that recorded people's encounters by sensing nearby devices using Bluetooth. Our findings include the identification of useful ways to capture and analyse data to derive a model of encounter, and a set of rules that can be used to drive our model. We also identify interesting patterns in the behaviour of our simulations that can help us understand, and in certain cases predict, urban encounter.

Keywords
Encounter, game of life, simulation, Bluetooth.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
In this paper, we describe a game that helps us model urban encounter. For our purposes, we consider urban encounters as instances when two or more people briefly meet or pass each other in the city, and during which time their mobile devices are within range of each other. Encounters can be considered as part of people's social context, while at the same time

encounters are opportunities for networking, both socially and digitally. Thus, informing our urban pervasive applications with an understanding of encounters can improve their integration with everyday urban life.

As part of our ongoing research in pervasive computing, we are interested in developing models of human movement and patterns of encounter in cities. Our aim is to gain a systemic understanding of cities and urban life, and subsequently use this understanding to aid in the development of urban pervasive applications.

The game we describe here, entitled "The Game of Real Life", is an extension of Conway's Game of Life [2]. While a user plays our game on the mobile device, the game gathers empirical data describing the user's encounters by periodically recording the presence of nearby Bluetooth devices. This data is used to drive the game itself, while at the same time is stored so that we can subsequently download it and analyse it for our modelling purposes.

Modelling human encounter in urban space

Relatively little research has addressed encounter, as opposed to simple movement in space. However, approaches to analysing encounter may be derived from existing work on spatial models and simulations. For example, large-scale simulation has been investigated for some time by means of agent-based pedestrian models. Such models can be broadly categorised into three levels: macro, meso, and micro [12]. The macrosimulation level is linked to transportation modelling, originating from Lighthill and Whitham's [8] continuum model that operates by solving differential flow equations. The mesoscopic level is also useful for agent simulation, although again it has been used mainly for vehicular traffic modelling. This class of system includes the cell-transmission model of Daganzo [5] and TRANSIMS, a cellular automata based system which can model 20,000 agent journeys concurrently. Microsimulation has to date focused mainly on granular-physics models of flow, with models such as Helbing et al's [6] crowding simulation again using predetermined directional paths.

Applications of encounter

Although no work to date has directly addressed the modelling of encounter in urban space, a number of applications make use of it both explicitly and implicitly. At the networking level, research on Delay Tolerant Networks focuses on utilising encounters as a means of transmitting and propagating data through a city [3]. Exploring the concepts of encounter and familiar strangers, Paulos & Goodman [11] describe a mobile application that reflects back to the user her encounter patterns. Similarly, Wireless Rope [9] uses Bluetooth to detect nearby devices, and keeps statistics of these encounters such as the amount of time spent near a person. Finally, a game that draws on incidental and intended encounter is Feeding Yoshi [1], a location-based game for mobile devices.

The game of real life

In our work we are interested in understanding the patterns of urban encounters. Ultimately, we are interested in developing models of these encounters, and informing our systems and designs with these models. To understand and model the dynamics of human encounter in urban space, we draw on the Game of Life as a basis for simulating how people encounter and interact with each other. The reason for using the Game of Life as a basis is that it is well

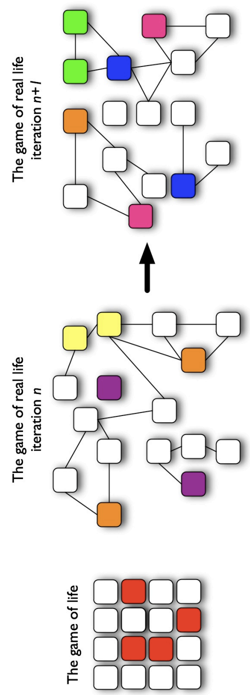

figure 1. At the bottom is a depiction of the original formulation of the game of life, played on a lattice. At the middle and the top is our game of real life, where nodes form a graph, and at any iteration both the links and the states of the nodes can change.

understood, and mathematical models have been developed that consider how the game progresses under different circumstances and conditions.

The game of life

John Conway's "The Game of Life" was first published in Scientific American in October 1970 [2]. The game is played on a finite matrix of cells. Each cell is in one of two states, dead or alive, and three principle laws govern the state of a cell at each iteration of the game:

- Survival: a living cell survives to the next generation if it has two or three neighbouring living cells.
- Death: a cell dies from loneliness from having only one or no neighbouring living cells, or from overcrowding when it has four or more neighbouring living cells.
- Life: a "dead" cell with three or more neighbouring living cells becomes a living cell.

Certain adaptations of the game of life have developed ways of projecting the physical environment onto a regular grid. For example, Cunha et al. explored this idea in [4] by mapping the location of sensor nodes into a 2D grid and using the energy level and state (whether the sensor node is active or in standby mode) of neighbouring nodes to determine a node's state at the next step of the simulation. A further adaptation [7] describes how a two-player Game of Life progresses under different player strategies.

The game of real life

To make the Game of Life reflect urban encounter, we make two crucial extensions to Conway's original formulation of the game:

- The playing board becomes an undirected graph
- Cells are not limited to two states

Figure 1 illustrates our conceptual extensions to the Game of Life. With these extensions, the game more closely resembles everyday urban life and encounter. Our reformulated rules enable us to map each human in a city carrying a Bluetooth device to a cell within the game. During the course of a day we encounter different people, and although at some points we may be alone, at other times we have people (i.e. neighbours) around us. The original game allows for a constant of 8 neighbours, while in our version there is no such constraint. In urban life, we are not limited to eight constant neighbours, but rather spend some of our time alone, some of our time in small groups and some in large crowds. Furthermore, as humans we are not limited to two states (alive or dead) as in the original game, but experience a wide range of different states. Because our extensions are intended to closely resemble everyday life we refer to our formulation of the game as the Game of Real Life.

Note that in our reformulation we have abstracted away from the spatial aspects of encounter. This means that the game board does not represent a map of a particular city, and the position of the cells does not represent the geographic location of people in the city. Rather, our game presents a model of patterns of encounter between people. A key goal in developing this game is to derive a mathematical model of people's patterns of urban encounter. Such a formulation could provide an invaluable basis for simulating life in the city. For instance, it can be used to study patterns of behaviour and encounter over time, the diffusion of information and innovations, and ultimately to support the design and evaluation of many urban pervasive applications.

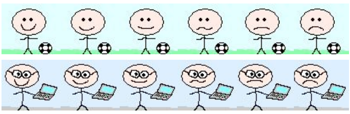

figure 2. Different states of the "Sporty" and "Nerdy" Tamagotchi.

To complete our formulation of the Game of Real Life we need to address two issues. First, we must describe the dynamics of the playing board – in other words define the set of neighbours that a cell can have at iteration *n* of the game. Secondly, we needed to define the rules that drive life, death and survival.

Describing the cell dynamics

Because no mathematical account exists that can accurately describe people's encounters in the city, we decided to make use of empirical data to give us a snapshot of real urban encounters. These data can then form an empirical basis for deriving the rules that determine life, death and survival in our game.

To help us develop an empirical basis for describing the cell dynamics in the Real Game of Life, we developed a data-gathering mobile application that utilises Bluetooth. Bluetooth is a useful method for gathering data on urban movement and encounter both because data collection can be automated and because patterns of Bluetooth movement and encounter around a city map very closely to patterns of people's movements and encounter [9,10,11].

In addition to recording data on Bluetooth encounters, our application also implements a version of the Game of Real Life in order to motivate users to keep it running on their mobile devices. Thus, a Tamagotchi-like entity is presented by our application (Figure 2), displaying different levels of happiness or sadness depending on the Bluetooth interactions recorded by the application. Additionally, users were able to select different personalities, for example "sporty" or "nerdy", thus changing the visual appearance of their Tamagotchi.

Each user's Tamagotchi is effectively a local implementation of the rules of the Game of Real Life: if we consider a city as a large playing board, then each cell of the game is a person with her mobile device, and the Tamagotchi is a representation of the current state of the cell. Thus, the only way for users to alter the Tamagotchi's state is by coming in contact with people.

Modelling life, death and survival

In the Game or Real Life, we represent the state of a cell as an integer. One or less indicates a dead cell while larger numbers indicate a live cell. A cell represents a specific mobile Bluetooth device, which in turn represents the owner of that device as she moves around the city. At each iteration of the game, the number of neighbouring devices is given by the results of a Bluetooth discovery scan. Based on this count, the cell's state may decrease (due to over-crowding or under-crowding) or increase (due to optimal conditions).

We analysed a week's data from three participants carrying a mobile phone running our application. From this data we derived a set of rules for changing the cells' state, and a finite set of states. Similar to other adaptations of the game of life, there is no specific guideline for measuring the "goodness" of the derived rules. In our case, we specifically aimed for a balance between all the states. This meant avoiding situations where the cell dies and is reborn after every single Bluetooth scan, and avoiding situations where a cell spends proportionately too much time in one state.

Having collected empirical data, we were able to re-analyse it, each time with different parameters. Specifically, we focused on optimising the rules that govern cells' life, death and survival. For analytical purposes, we represented death due to loneliness as a 0, and death by overcrowding as a 1. Additionally, to make our analysis manageable we capped the maximum number of states to 6, although this can be adjusted. Through our analysis we identified as optimum the following rules:

- Under-crowding is 2 or fewer neighbouring Bluetooth devices.
- Desirable number of neighbouring devices is 3-5.
- Over-crowding is 6 or more neighbouring devices.

Despite our attempts to avoid fluctuations between a pair of states, we were not able to derive a set of rules that completely eliminates such fluctuations. We addressed this by adding memory to the cell. Specifically, we experimented with slowing down the cell's reaction to changes in its environment by attaching weight to the results of previous scans. After experimentation we settled on the mean of the last 4 scans as the value that determines if the state should be changed. This resulted in a smoothing in the change of states, as shown in Figure 3.

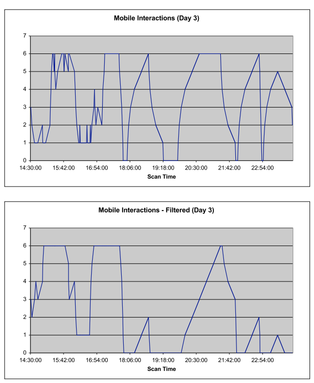

figure 3. Transitions without cell memory (top) and with cell memory (bottom).

In these graphs we see the state of the cell during day 3 of our study. Here we can visually identify when participant was alone and the cell died of loneliness (e.g. at 19:20), or when the cell died of overcrowding (e.g. at 16:00). The changes in state, as we have defined them, are not completely arbitrary but follow a temporal rhythm dictated by the participant's lifestyle.

Discussion

In our simulations we set out to achieve an equal distribution of the time spent on each cell state. Yet, we found that inevitably most of the time was spent on death (states 0 and 1) and state 6, which was the maximum possible. Additionally, we found that the states between the two extremes typically act as buffers and are occupied only temporarily. This observation is crucial in developing a mathematical model describing human encounter. To derive such a model we can take an approach similar to the one described in [7], which involves assigning a probability to each possible value that a cell can have after n iterations of the game. From our analysis we have identified that this probability is disproportionately shifted in favour of the extreme possible values. Using this probability we can derive a mathematical account of the dynamics of the game by relying on simulation. This can be done by identifying the asymptotic behaviour of the game given our rules.

Also, we identified that adding memory to the cells (up to 4 cycles) produces graphs with smaller and fewer fluctuations. This also allows for certain predictions to be made. For example, we observed that using cell memory a change of state by more than 2 almost always results in a shift of the cell's state to the opposite extreme. Furthermore, these predictions can be made by the cells themselves, as the data required to do so is in their memory.

Conclusion and ongoing work

In this paper we describe our attempts at modelling urban encounter using an extension of Conway's Game of Life. We describe our extensions to the game that make it more closely resemble human encounters. We also present a mobile application that acts both as a game for users and a data collection tool.

Our findings indicate that in the Game of Real Life, cell spend most time on the extreme states, and that equipping each cell with a 4-cycle memory enables it to predict its state by utilising its own memory.

As part of our ongoing work, we are engaged in developing a mathematical account of human encounter as informed by our empirical data on urban encounters. This paper provides the groundwork for developing such an account. Specifically, we are attempting to determine the asymptotic behaviour of our model as influenced by different set of values for life and death, and ultimately develop a mathematical account of cell dynamics that closely matches the encounters recorded by our Bluetooth scanners.

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References

[1] Bell, M., Chalmers, M., Barkhuus, L., Hall, M., Sherwood, S., Tennent, P., Brown, B., Rowland, D., and Benford, S. (2006). Interweaving mobile games with everyday life. Proc. CHI 2006, 417-426.

[2] Berlekamp, E.R., Conway, J.H., and Guy, R.K. (1982). Winning Ways for your Mathematical Plays. Academic Press, London, 1982.

[3] Chaintreau, A., Hui, P., Crowcroft, J., Diot, C., Gass, R., and Scott, J. (2006). Impact of Human Mobility on the Design of Opportunistic Forwarding Algorithms. Proc. INFOCOM.

[4] Cunha, R.O, Silva, A.P., Loureiro, A.A., and Ruiz, L.B. (2005). Simulating Large Wireless Sensor Networks Using Cellular Automata. Proc. IEE Symposium on Simulation, 323-330.

[5] Daganzo, C.F. (1994). Cell transmission model: a dynamic representation of highway traffic consistent with the hydrodynamic theory. Transportation Research, 28:269-287.

[6] Helbing, D., Molnár, P., Farkas, I.J., and Bolay, K. (2001). Self-organizing pedestrian movement. Environment and Planning B, 28:361-383.

[7] Levene, M. & Roussos, G. (2003). P2life: a two player game of life. Int. J. Modern Physics, C14(2): 1-7.

[8] Lighthill, M.H. & Whitham, G.B. (1955). On kinematic waves II: a theory of traffic flow on long, crowded roads. Proceedings of the Royal Society of London, A(229):317-345.

[9] Nicolai, T., Yoneki, E., Behrens, N., and Kenn, H. (2006). Exploring Social Context with the Wireless Rope. LNCS 4277: 874-883.

[10] O'Neill, E., Kostakos, V., Kindberg, T., gen. Schieck, A.F., Penn, A., Fraser, D.S., and Jones, T. (2006). Instrumenting the City: Developing Methods for Observing and Understanding the Digital Cityscape. Proc. UbiComp 2006, 315-332.

[11] Paulos, E. & Goodman, E. (2004). The Familiar Stranger: Anxiety, Comfort, and Play in Public Places. Proc. CHI 2004, 223-230.

[12] Turner, A. & Penn, A. (2002). Encoding Natural Movement as an Agent-Based System. Environment and Planning B, 29(4):473-490.