Techniques and Tools for Three Dimensional Visualisation and Communication of Spatial Agent-Based Models

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Agent-based modelling (ABM) is increasingly being used as a tool for the spatial simulation of a wide variety of urban phenomena including: urban housing dynamics (Benenson *et al.*, 2002); urban growth and residential location (Torrens, 2006; Rand *et al.*, 2002; Brown *et al.*, 2005); gentrification (Torrens and Nara, 2007) and traffic simulation (e.g. Barrett *et al.*, 2001). At a more micro scale agent-based models have been used simulate of pedestrians in the urban centres (e.g. Haklay *et al.*, 2001); examine crowd congestion (e.g. Batty *et al.*, 2003) and emergency evacuation of buildings (e.g. Castle, 2007a). These applications demonstrate a growing interest in linking agents to actual places and with geographic data (see Castle and Crooks, 2006; Parker, 2005 for reviews) through linking or coupling with geographical information systems (GIS). The advantage of linking the two allows agent-based modellers to simulate agents related to actual geographic locations, thus allowing us to think about how objects or agents and their aggregations interact and change in space and time (Batty, 2005).

As agent-based models move into the spatial domain, we need new ways to visualise and communicate such models especially to those who we seek to influence and who we believe that such modelling will inform their activities. This has already been identified as one of the key challenges facing ABM (Crooks *et al.*, forthcoming). Visualisation is the main way to how we interact with computers and while in the past, before the development of intensive and all pervasive computation, communicating models was mainly through discussion and simplification, through pedagogy in all its various forms. Visualisation is now one of the main ways to communicating and sharing information from such models. Of course spatial outcomes from models can be mapped and this is a key medium for dissemination as well as for validation and other aspects of the simulation process. As Mandelbrot (1983) argues good models which generate spatial or physical predictions that can be mapped or visualised must 'look right'. Furthermore sharing and disseminating models is problematic. The development of online laboratories – collaboratories for example – where model building and users engage in mutual and shared development activities although their infancy are very much on the horizon. The development of web sites where many users develop agent-based models such as NewTies (Gilbert *et al.*, 2006) or Modelling4All[1] (Kahn, 2007) are examples of how this field is developing into a more sharing mode where collaboratories hold out great promise for new advances in social simulation to whoever has an internet connection.

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[1] http://modelling4all.wordpress.com/

Coupled with the challenges on how we communicate and visualise agent-based models is how we represent agents in space. The use of ABM for geospatial simulation has traditionally been dominated by the two dimensional (2D) view of the world with the third dimension (3D) rarely ventured into (see Dibble and Feldman, 2004; Thorp *et al.*, 2006[2]. for sample applications). We would argue, that this is due to the nature of the discipline where the focus is on theory rather than outreach and end user visualisation; and model builders not taking advantage in improvements in computer graphics, networked communication and associated technology.

At the Centre for Advanced Spatial Analysis (CASA) we are working on ways to visualise, share and communicate agent-based models specifically focusing on the third dimension. We will illustrate our early attempts with several examples utilizing 3D Studio Max, a computer aided design (CAD) package and Second Life, a virtual online world. These examples range through the movement of cars and pedestrians in a cityscape to evacuation of pedestrians from buildings in Second Life. Such models utilize advances in graphic card technology, networked communication and advances in physics based engines (e.g. Havok) which allow us to easily add dynamics into such systems. For example, industry standard tools such as 3D Studio Max has built in tools for crowd and delegate systems, which can be used to assign behaviour to agents or objects therefore providing the ability to create realistic traffic and pedestrian systems in 3D as we demonstrate in Figure 1. One can program simple ant like behaviours through to simulating shockwaves within traffic, various built in components enables high quality graphic outputs as well real time previews and outputs can additionally be exported to game engines such as Crysis.

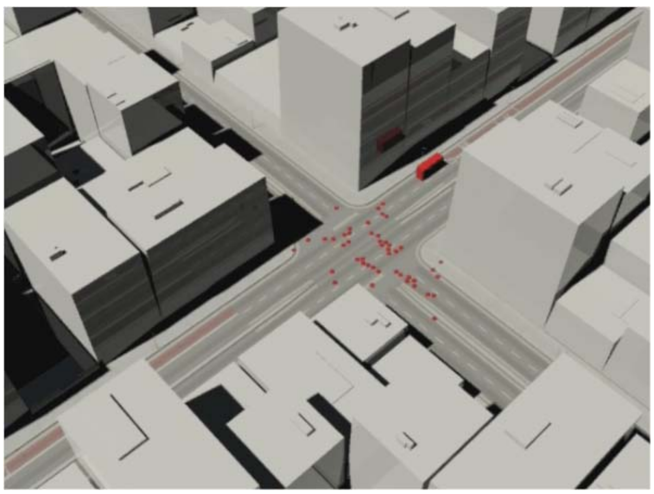


Figure 1: Pedestrian agents and a vehicle agent within a Cityscape created in 3D Studio Max.

Agent-based models are usually considered as forming a miniature laboratory where the attributes and behaviour of agents, and the environment in which they are housed, can be altered, and experimented with and where their repercussions are observed over the course of multiple simulation runs. Virtual worlds such as Second Life act in a similar

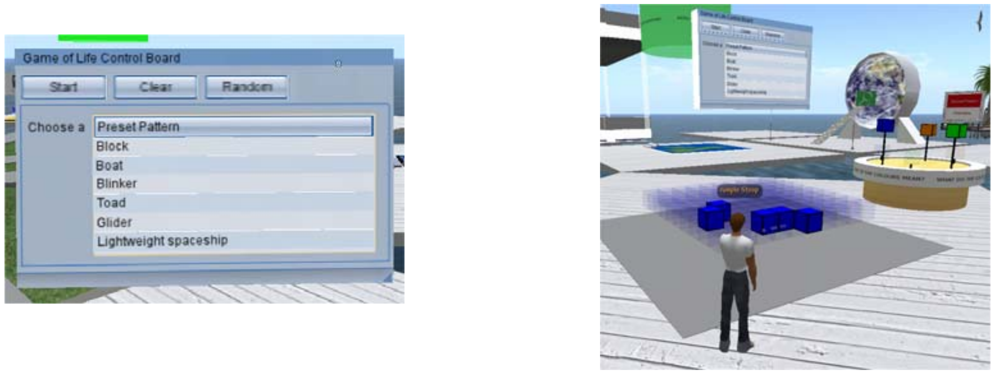
[2] Further information can be seen at http://www.redfish.com/wildfire/ and http://www.redfish.com/stadium/

way to agent-based models in the way they are artificial worlds populated by agents. The idea behind such systems is to engage a community of users where people as avatars can be active users contributing to sites and participating in site content in real time through the world wide web (WWW) which opens their use to whoever is connected.

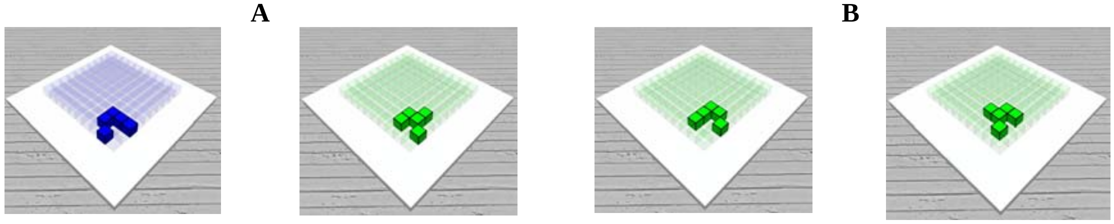
Virtual worlds such as Second Life have great potential for research in the social and behavioural sciences along with offering an environment for education and outreach (see Bainbridge, 2007). Such systems allow people to discuss and visualise models in real time, they provide an effective medium to clearly communicate models and results between the developer and the decision maker which in the past was the sole province of powerful scientific workstations. For agent-based modellers it offers a unique way for the exploration and understanding of social processes by means of computer simulation. Researchers have used agents within virtual worlds to study a variety of phenomena from human-to-agent interaction (e.g. Berger *et al.*, 2007); the study of norms between agents and avatars (e.g. Bogdanovych *et al.*, 2007); healthcare issues (Dieterle and Clarke, in press); to herding behaviour (Merrick and Maher, 2007). We are using Second Life as a collaborative geographic space (see Hudson-Smith and Crooks, 2008) for the dissemination of geographic content and for the exploration of agent-based models in an interactive 3D media.

Within this world we have created a number of agent-based models using the Linden Scripting Language (see Rymaszewski *et al.*, 2007). It is the purpose of these models to act as pedagogic demonstrators and as a "proof-of-concept", thus we have chosen Conway's Game of Life (Figure 2), Schelling's (1971) Segregation model (Figure 3). These models were chosen as they highlight how classical automata styles of models which have inspired a generation of modellers can be created and explored in Second Life. The third model we present is a prototype pedestrian evacuation model (Figure 4) which is more complex than the previous two and highlights at the variety of models that can be potentially created in Second Life. This model relates to the genus of such models of which the social forces model developed and popularised by Helbing and Molnár (1995) is typical.

Agents within the evacuation model have been designed to mimic 'real' people with realistic anthropomorphic dimensions which exit a building when an alarm is sounded. We represent the building (enclosure) as a continuous space as apposed to the more common regular lattice (as is the case for the Schelling and Game of Life models above) or course network enclosure representations of other pedestrian models (see Castle, 2007b). Agents are therefore not restricted to discrete cells nor are they represented as flows thus enabling us to simulate pedestrian movement more explicitly. The agents within the model interact with each other and their environment (e.g. obstacle avoidance) both of which can have an effect on occupant movement, for example, agents adjust their walking speed when approaching congestion. Users can explore several room configurations which allows them to study exit route choice, way finding and the identification of bottlenecks in building design.



A B

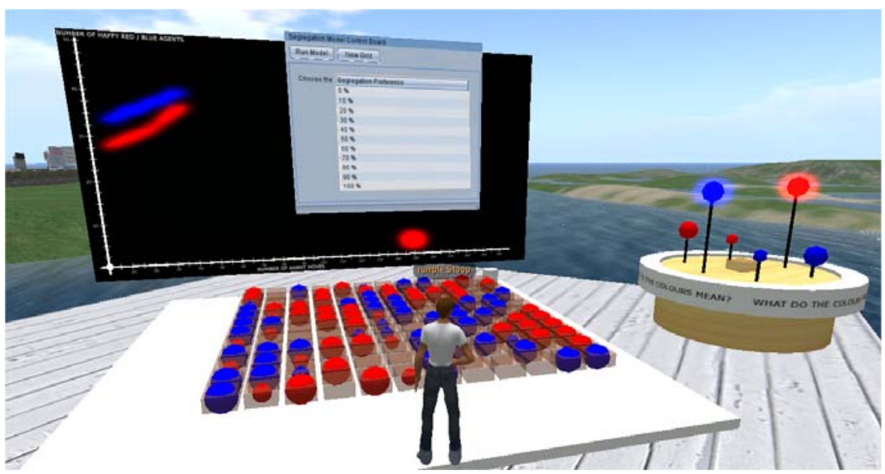


Initial Condition Time (T)1 T2 T2

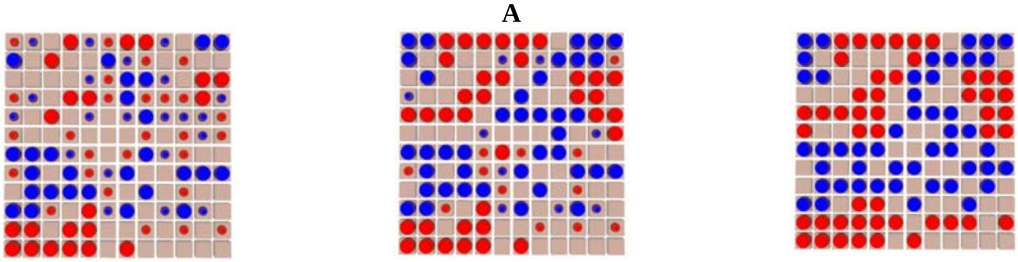
C

Figure 2: Game of Life in Second Life.

A: Control board for the Game of Life with preconfigured patterns, B: An avatar watching a simulation evolve, C: Example of a glider moving across the board.



A

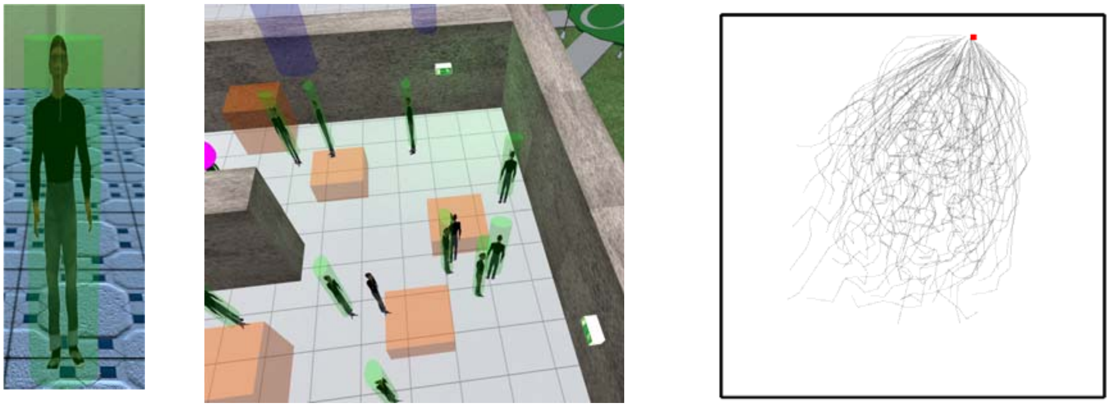


Start of simulation Middle End of simulation

B

Figure 3: Schelling's Segregation Model within Second Life

A: The graphical user interface of the segregation model, B: A typical simulation when agents desire 50% of their neighbours to be of the same type as themselves (note that the small circles represent dissatisfied agents).



A B C

Figure 4: Pedestrian Model within Second Life

A: A pedestrian agent within the model and its body ellipse (Fruin, 1971) in green, B: Pedestrians and their environment, C: Tracing the pedestrians routes to the exit (red dot).

Modelling cities is thwart with difficulties and while these are our preliminary steps acting as "proofs of concept" we believe such work has the potential to interest and engage both geographers and planners. Not only do our models roughly approximate the notion of generative social science articulated by Epstein (2007) which proposes that models should be 'grown' within simulation laboratories. The models also demonstrate how different theories and concepts can be incorporated into highly visual 3D virtual environments. The visualisation of such models in 3D CAD software or virtual worlds provide outputs to models which non-expert users can easily relate to and thus allow such models to come under greater scrutiny than was possible in the past, therefore aiding the use of agent-based models as a tool for decision support.

In the past the communication of models was mainly done through discussion of model results, through Second Life it is possible to share modelling processes and its outcomes with various non-expert participants and potentially allows non-experts to participate in actual model construction. The tools and techniques presented show the potential of virtual worlds CAD and game engines to act as portals for allowing modeller, policy makers and citizens to communicate, share and visualise 3D spatial agent-based models.

Wider implications of such linkages between CAD software, virtual worlds and agent-based models is that often in architectural and planning profession, it is fairly typical for designers to build 3D models of their own building design within CAD. Coupling or embedding agents to such systems allows us to introduce behaviours into such geometric models and test implications such as evacuation scenarios on various room configurations. Specifically how the spatial configuration of the built environment impact on movement.

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