Real-time Dynamic Simulation of Special Event Crowds using ABM and GIS

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1. Introduction

The most important factor affecting the planning and allocation of all kinds of resources applied in special events is the crowd participating in the event. Therefore, a complete understanding of, and a precise prediction capability for, special event crowd dynamics are fundamental for the work of special event planners.

Crowd behaviour is complex, difficult to describe and predict, and although affected by individuals' behaviour, it often shows features that are very different due to the interactive relationships existing amongst individuals themselves and the nature of the collective environment. Experimental investigations have been used for the study of crowds but, in fact, it has been impossible to capture all such behavioural features and study is limited by 'practical, ethical, financial, and logical constraints'(Klupfel and Schreckenberg 2003). Empirical crowd surveys can be extended by the use of simulation to demonstrate crowd dynamics over a continuous time period and also allow experimenting with different crowd management plans which may not be possible to field-test.

The Agent-Based Model (ABM) has emerged as an effective technique for modelling complex systems, integrating socio-economic spatial dynamics into a single model (Epstein and Axtell 1996) and proving suitable for crowd simulation.

Such ABM-based modelling of crowds has mainly focused on mass evacuation (Egress, GridFlow , CRISP, and EXODUS(Johnson 2005)) and pedestrian traffic in densely peopled areas or in public buildings (STREET, PedGo, SIMWALK, NOMAD, SimPed (Harney 2002). Visitors to special events create different scenarios to these. A special event crowd has the largest positive utility of trave l(Ory and Mokhtarian 2005), meaning these individuals are willing to spend time on travel and wandering, rather than aiming for minimum navigation time. In addition, the special event crowds' behaviour tends to be located in a large spatial area. Previous work on such crowds (limited to Batty et al (2003)), shows only a final result of peak time crowd spatial features and with all agents released at once at the beginning of the simulation. The major aim of the project described here is to create a model for the real-time simulation and evolution of special event crowd dynamics and its analysis.

2. Methodology

The building of an agent-based simulation model for this research involved the integration of GIS with the ABM software platform CORMAS (agent-based modeling software). GIS is first used as a tool for integrating data obtained from different sources such as digital maps, paper maps and image files, all preparing for the input data required by a simulation. Secondly, GIS is a good tool for visualizing the simulation result. Though the ABM software chosen has its own visualizing capability, some spatial analysis results such as hotspot maps of congestion areas need to be visualized on the platform of GIS. Thirdly, GIS is used as the spatial analysis tool for prediction of further congested areas in the process of potential risk scenario building. For the first two of these functions loose-coupling integration is adopted, which means by exchanging files the ABM obtains some of its input data from the GIS and produces some of its output in a format that allows import and further processing and display with the GIS. The third function simulates a large number of time steps and it is unrealistic to transfer these as individual layers to a separate GIS file. Thus the functionality required (such as density analysis) is embedded into the ABM system.

The intention of the project is to simulate spatial crowd dynamics at a special event over an extensive site, to determine locations of congestion and risk noting the timing and intensity of such problem hotspots, to determine the impact of mitigating factors (such as improved stewarding or signage) and to assist planners in optimally locating different attractions within the site.

3 Modelling and Simulation

The project used a case study, the 2005 Tall Ships Race (TSR) hosted at the Quayside, Newcastle upon Tyne and Gateshead over a four day period in July 2005. The event occurred within an irregularly shaped site of approximately 2 by 0.25 km along the north and south banks of the River Tyne. The TSR today attracts more than a hundred competing ships, among them some of the largest sailing ships in existence: these provide a stunning attraction for visitors who can look at them and participate in an associated festival (with musical performances, stalls, funfairs, exhibitions, promotional events, and entertainment on site in addition to visits to the ships themselves). More than one million visitors participated in TSR 2005.

In order to model the crowd, the ABM software required the identification of entities and the construction of an initial class diagram showing attributes, methods and structural relationships. While the attributes can characterize the entity, methods are the tasks which the entity can undertake in the model (Figure 1). The generic ABM model entities to the left of Figure 1 have been supplemented by the specific entities created for this project, all portrayed in UML. The 'Tourist' is the agent object in TSR model and the 'Cell' is the spatial entity object. 'LargeAttraction' (i.e. a facility which the crowd might be interested in visiting) and 'Congestion' (areas defined as having a certain density) are aggregated spatial entities objects in the TSR model. Tourist behaviour is encoded in rules and programmed in the frame of the Tourist object by setting parameters such as 'targets'and 'records'. The behaviour of Tourists can be classified into 5 linked categories: entering the site; self-positioning; visiting attractions (which itself may involve identifying target, walking towards target); lingering; and exiting. The way these agents behave and interact among themselves will influence the dynamics of the model.

Agents representing visitors were introduced dynamically through a series of entrances to the site throughout the day in a manner which replicated the predicted numbers. It was decided to set one modelling time step equivalent to 4 seconds in reality and modelling a 16 hours day therefore meant 14400 time steps. Every time step, the Tourist agents undertake a range of possible actions such as 'enter', 'findCoodinate' and 'addTargets'. Further setting of Tourist parameters such as 'records' and 'lifeTime' allows the agents to have memory and ensure structured, focussed and intelligent perambulation. This allows for the running of dynamic simulations which can ensure that the correct number of visitors (Tourist agents) are introduced to the area over a one-day period, and that each agent (representing the visitors) can react to the attractions available, and to congestion patterns which emerge.

The embedding of spatial analysis functions into the ABM, which has obviated the need for tedious export of results from the ABM platform to GIS for each time step in the simulation, has been accomplished by setting dynamic evolution of the Cell in TSR model. The parameter 'riskValue' and the method 'countRiskValue'help to evaluate the potential congested area and the parameters 'conFre'and the method 'countConFre' evaluate the potential high frequency actual congestion hotspots. Thus, spatial analysis such as hotspot detection can be done on the platform of the ABM.

The Cell entities are raster grid cells created from scanned OS Master Map data, supplemented by landuse information, event site information from the local council's site plan and the locations of the Tall Ships themselves from the Berthing plan (see Figure 3).

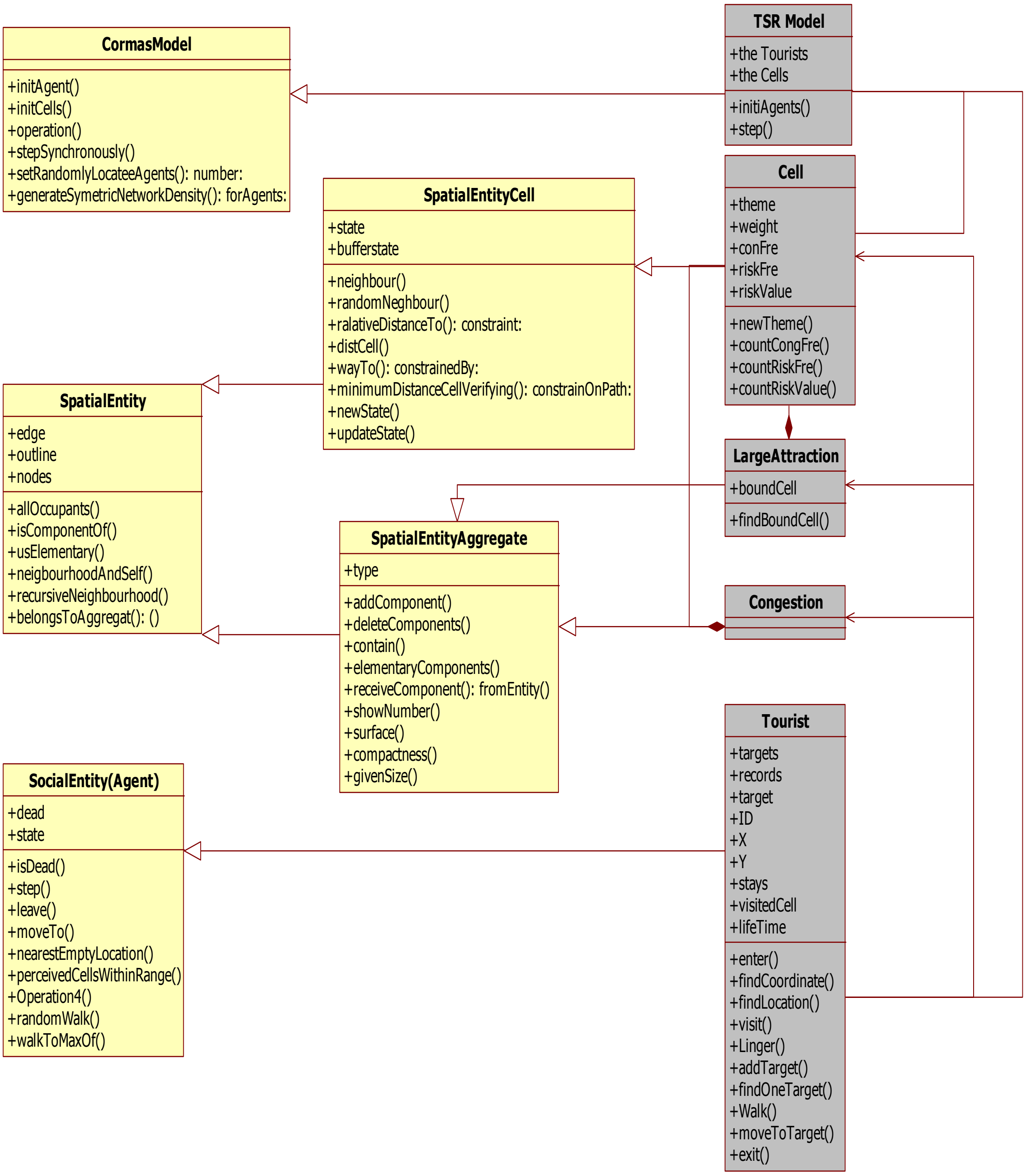

Figure 1 Hierarchy of CORMAS abstract classes (yellow blocks) and TSR model for crowd simulation (grey blocks)

4 Results

During the simulation, results showed realistic modelling of crowd size and distribution. Furthermore, the model automatically and continually demonstrated the potential ‘risk’ areas (potentially close to pedestrian standstill) of highest crowd density and the actual areas of congestion at each time point, and detected those cells of highest potential frequency of risk. Figure 2 shows the areas at ‘risk’, with 100,000 visitors in total over one day, using the visualisation capabilities of the CORMAS platform.

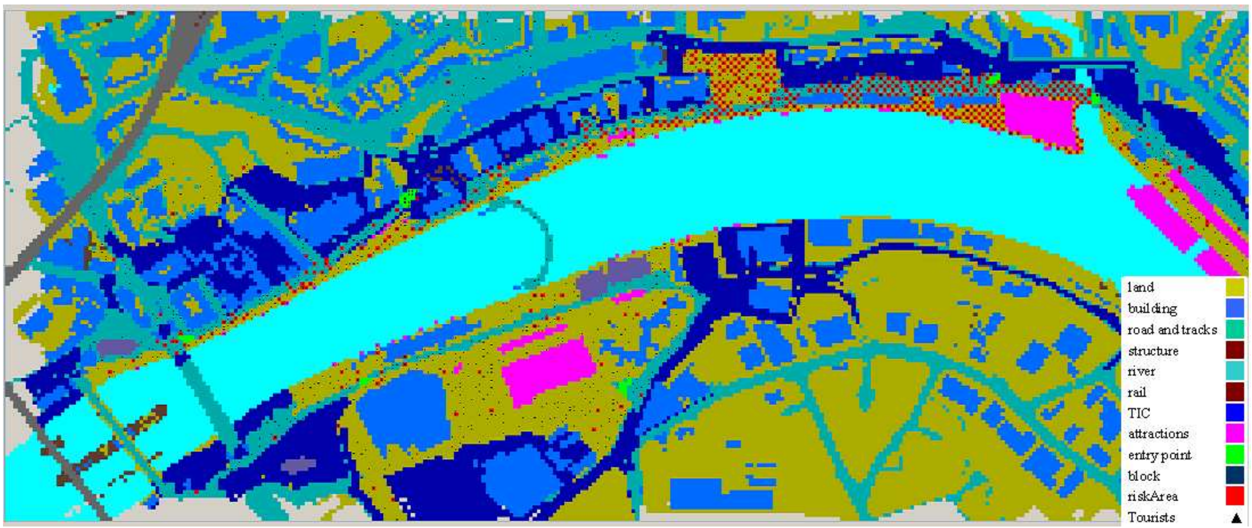

Figure 2 Risk areas detected on the base map

The model was then modified to demonstrate the effects of changing parameters, specifically those related to tourist numbers, tourist behaviour and special event assistance that can be provided, such as signposting and volunteer guides. The impact of improved signage was improvised by widening the agents' radius of perception, in effect bringing more attractions onto the list of targets. Figure 3 shows that this has an effect on the number of cells labelled as being at 'risk' of congestion.

Figure 4 has increased the number of visitors to a more realistic 200,000 per day and the resulting actual congestion (not just risk of congestion) pattern is visualised in ArcGIS. When the number of Tourists is doubled, the number of congestions tripled or even quadrupled. The pattern of actual congestion areas appears to be close to some entry points for the smaller number of Tourists, spreading to a more universal picture of congestion with the higher number.

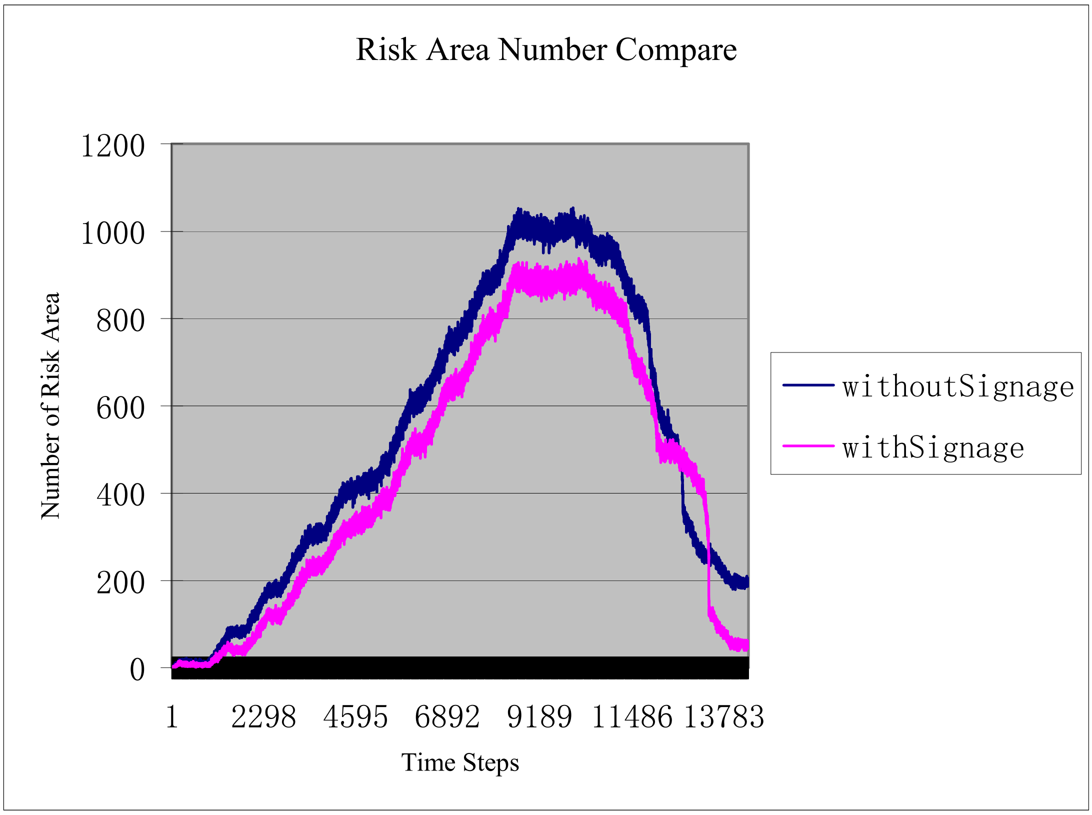

Figure 3 Comparison of numbers of risk areas (cumulative number of cells at risk without signage=7571567, cumulative number of cells at risk with signage=6474820)

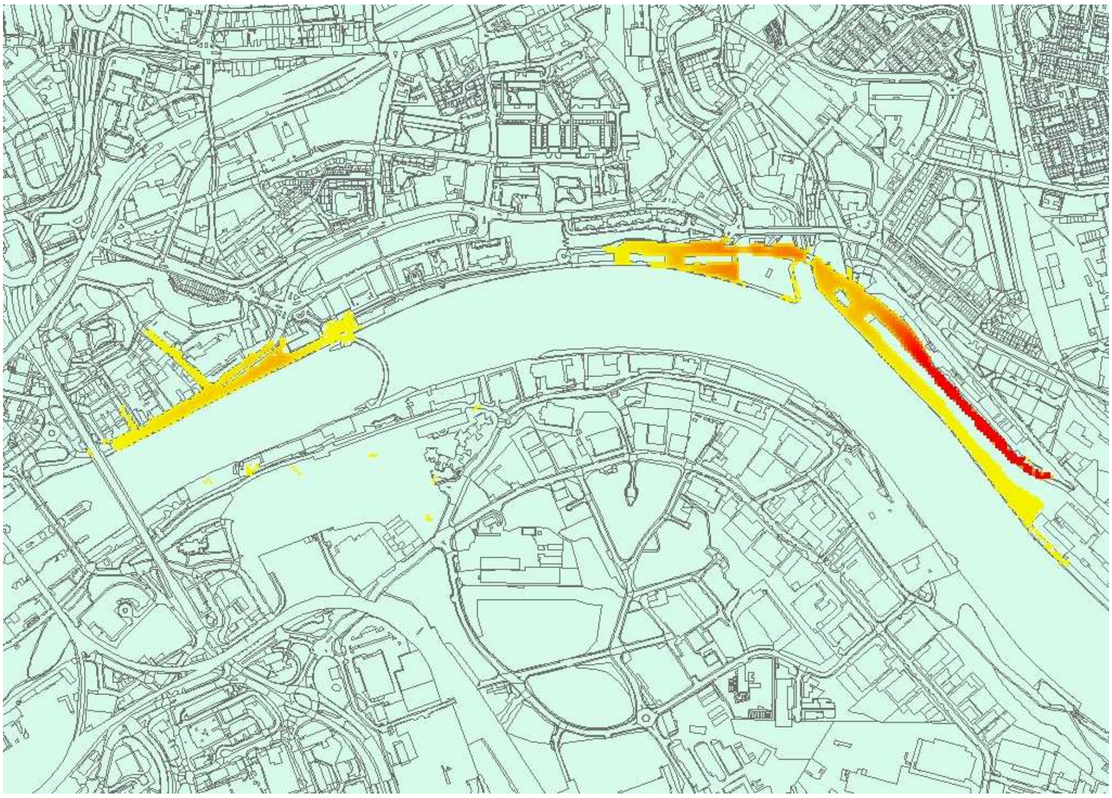

Figure 4 Summary high frequency congestion area map for one day (the coloured areas have been congested at least once during the day, the red areas showing highest frequency congestion areas)

5 Conclusions

The real-time TSR simulation model has provided a means of better understanding the spatial features of crowds and provided ways to visualize the spatial and temporal performance of special event crowds. It has shown that GIS technology can be integrated with ABM to establish a spatial-temporal process model aiming to capture the spatial features of the evolution of a complex system. Although the Tourist behaviour rules designed in this research were very simple, they imply a great potential for simulating intelligent agents by using ABM. It is possible to modify the visitors' behaviour rules to let the simulation results become much closer to reality.

6 References

Batty, M., J.Desyllas, and E.Duxbury (2003) "The discrete dynamics of small-scale spatial events: agent-based models of mobility in carnivals and street parades." International Journal of Geographical Information Science **17**(7): 673-697

Epstein, J. and R.Axtell (1996) Growing Artificial Societies. Brookings Institution Press

Harney, D. (2002) "Pedestrian modelling: Current methods and future directions." Road & Transport Research **11**(4): 2-12

Johnson, C. (2005) "Lessons from the evacuation of the World Trade Center for the development of computer-based simulations" Cognition, Technology & Work **7(4)**: 214-240

Klupfel, H. and M.Schreckenberg (2003) „Models for Crowd Movement and Egress Simulation" Traffic and Granular Flow '03, Berlin, Springer**:** 357–372

Ory, D. and P.Mokhtarian (2005). "When is getting there half the fun? Modeling the liking for travel" Transportation Research Part A **39** 97-123