Integrating an Agent-Based Model and a Population Microsimulation to Explore Crime Patterns

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1 Introduction

Crime is an extremely complex phenomenon. In order to understand and to predict crime patterns it is necessary to examine the behaviour of the offender(s), the physical attributes of the surrounding environment and the behaviour of other people who might be able to influence the event, such as the victims or passers-by. To further complicate matters, each of these elements are inherently local in nature; research that spatially aggregate these features will disregard important information [1] and are not able to truly capture the dynamics of systems that are non-linear and involve feedback [2] – such as the crime system.

For these reasons, the agent-based modelling methodology has started to be used in quantitative crime research to better understand and predict crime. The methodology involves simulating the individual components of a system directly (such as individual "offenders") and hence constructing an artificial geographic system that closely replicates the real system under study. To take advantage of the benefits offered by agent-based modelling, *BurgdSim* [4] is an agent-based model that creates a realistic representation of an urban environment and simulates the spatio-temporal behaviour of individual offenders to predict occurrences of residential burglary. Although the model contains individual houses, roads and burglar agents, other people who might influence the system (e.g. residents, passers-by) are included at an aggregate level due to a lack of individual-level data. This is a considerable drawback to the simulation because criminologists suggest that victim behaviour is an important determinant of crime risk.

Fortunately, although there is insufficient *primary* individual-level data to include in the simulation it is possible to use the technique of microsimulation to synthesise a population of individuals from aggregate-level data sources. This paper will present ongoing research into generating a spatially-explicit population of synthetic individuals from census data and using this as an input into an agent-based burglary model. Although still in early stages, preliminary results show that a lot of information about the demographics of potential burglary victims can be gained by aligning microsimulation and agent-based models.

2 Existing Tools

2.1 The Burglary Model

BurgdSim is an advanced agent-based model of crime that simulates the behaviour of intelligent "burglar" agents and predicts occurrences of the crime of residential burglary. The model has been implemented in Java using the Repast Simphony library (`http://repast.sourceforge.net/`) (as illustrated by Figure 1) and has also been adapted to run on the grid using National Grid Service (NGS) compute resources. The model uses real GIS data to create a virtual environment that consists of the following layers:

- **Household layer**. The household layer includes a representation of individual houses in the study area. As the geometry of each building is available, they have been analysed in

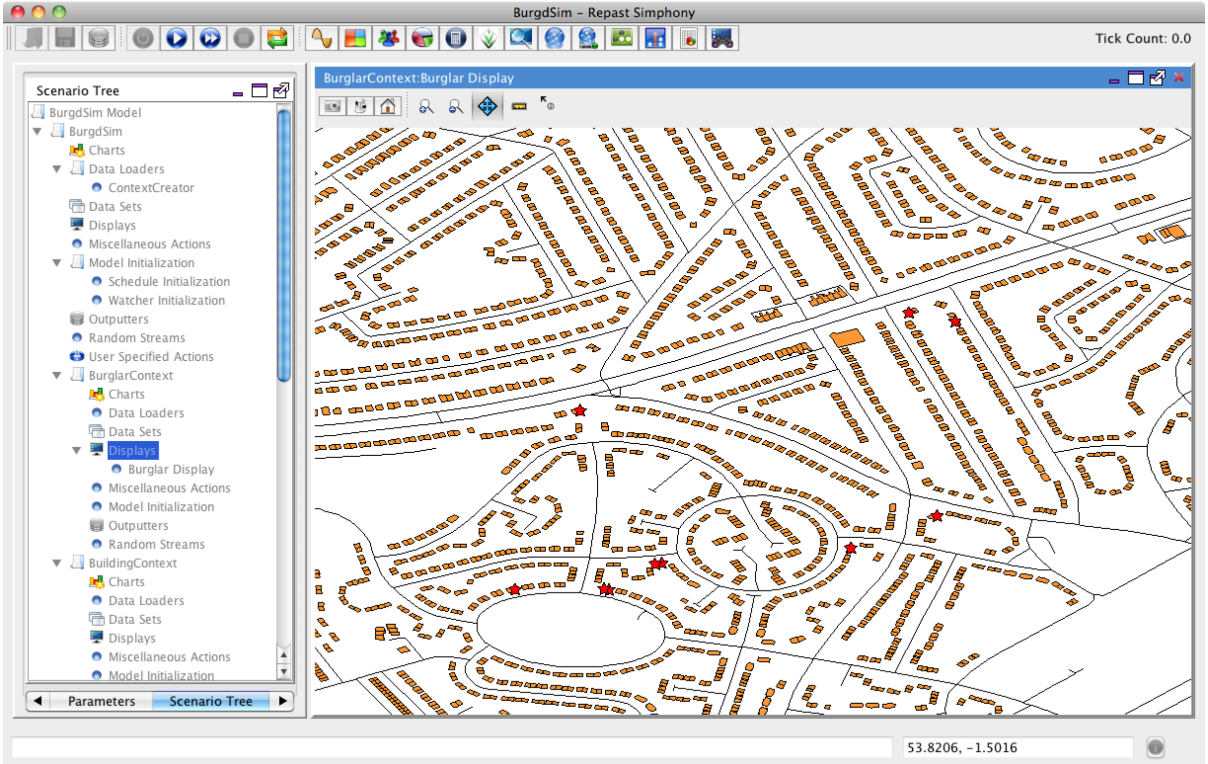

Figure 1: The *BurgdSim* user interface depicting a small number of burglar agents in the virtual environment – part of Leeds in this case.

a GIS to estimate features that might influence their burglary risk, such as visibility to neighbours or passers-by and the building structure (terraced, detached or semi-detached).

- **Road network**. As with the household layer, the road network is built up from real GIS data to create a model of the network that agents can use to traverse the study area. Different types of roads have been included (such as motorways, alleyways, minor roads etc) and these affect the speed of travel across a road as well as the types of vehicle that are permitted.

- **Communities layer**. The purpose of the communities layer is to simulate the effects that *other people* (i.e. non-burglars) might have on occurrences of burglary. The layer uses UK census data to estimate at what times a house in the community might be unoccupied, how wealthy the residents are and how cohesive the community is.

The burglar agents themselves have been implemented using the PECS cognitive architecture to simulate intelligence [5]. They all have a home and exhibit dynamic behaviour that changes depending on their current circumstances. The agents require money for certain behaviours (such as drug-use and socialising) and, in these cases, must attempt to commit a burglary first. Therefore, although the model is able to accurately represent individual burglar agents and the houses that they might attempt to burgle, the victims of burglary are represented in the communities layer and are therefore homogeneous across all houses in the community. This is a drawback for a model that is otherwise able to simulate at the level of the individual. However, the problem is purely a result of data availability; demographic data obtained from the 2001 UK census have been aggregated. As the following section will discuss, there is software available that can be used to disaggregate the census and, hence, produce an estimate of the individual people/families who live in each house.

2.2 NeISS and the Population Reconstruction Model (PRM)

The National e-Infrastructure for Social Simulation (NeISS: http://www.neiss.org.uk) is a multi-disciplinary project that aims to develop new tools and services for social scientists and planners. The tools will enable users to run their own simulations and visualise/analyse results as well as share them for future discovery and reuse. A tool of particular relevance is the Population Reconstruction Model (PRM) as this can be used to disaggregate the UK census.

The PRM is a *microsimulation* technique which uses a combination of Small Area Statistics and anonymised individual records to provide a synthetic population of individual people and families for any region which has available census data. Although it is not possible to validate the resulting synthetic population directly (as data comparable to that which the procedure generates are not available), re-aggregation of the population show an extremely close match to the distributions from which they are derived [3], adding confidence to the accuracy of the results. The individual level data that are generated can be extremely valuable for subsequent applications, such as *BurgdSim*, as the following section will discuss.

3 Preliminary Results

In order to improve the representation of crime victims in the *BurgdSim* model, the microsimulation was used to generate individual-level demographic data from the 2001 UK census and this was subsequently used as an additional input into the agent-based model. Therefore the model could be adapted so that the wealth levels of potential victims and their occupancy behaviour (the times that they leave their houses unoccupied as estimated from their employment) were no longer homogeneous across all houses in a community, but were unique to individual houses. Therefore, when burglar agents decide which houses they will target for burglary they take individual-level victim characteristics into account, rather than assuming that all people in a neighbourhood are identical.

Although the procedures used to combine the synthetic population data with the agent-based model are in their infancy, preliminary results suggest that already the improved model is able to offer additional insights into the simulated burglary victims. Figure 2 illustrates the demographic characteristics of the population once all people have been assigned to virtual houses in the model and compares these to the demographics of burglary victims after a simulation has been completed. With the exception of *social group*, none these attributes (*age*, *gender* and *ethnicity*) are taken into account by the burglar agents during their assessment of where to commit a burglary. Therefore these trends are a result of *where* in the city the individuals live as well as the types of houses and neighbourhoods they inhabit rather than an artefact of model rules. The *managerial* social group is a prime example of this. Although in the synthetic population there are a similar number of people with managerial employment to those with manual jobs or unemployed/students, people with managerial jobs are rarely predicted to be victims of burglary. This is most likely because they live in places that the burglar agents are unaware of or do not consider suitable for burglary.

Clearly further research is needed to clarify and confirm these findings, but the results suggest that the combination of agent-based and microsimulation techniques have a lot to offer in terms of geocomputational prediction and modelling.

Figure 2: Demographics of the synthetic individual population generated using the PRM and the subset of individuals who were burgled in the agent-based model.

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