Agent-Based Modelling and Crime in Leeds

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Crime and the Environment

Criminologists are becoming increasingly aware of the important role that "place" plays in crime occurrences [23]. However, the relationship between crime and the physical environment is complex [11]. It has been shown that the physical form of an area, including natural features and the design of the built environment, has a significant impact on local communities and on crime in those communities [7].

As well as considering physical characteristics, it is important to understand that individual peoples' *perceptions* of their environment will also affect their behaviour [4]. Using burglary as an example, most offenders will only commit a crime if they are certain that residents are not home [47], are familiar with the chosen area [23] and do not think that other neighbours will notice them or intervene [14, 38].

How an area is built socially will also have an affect on crime because, as Bottoms et al. [7] comment, "communities, like individuals, can have careers in crime". The socioeconomic status and demographics of an area are particularly important, but their relationships to crime are non-trivial. For example: burglaries occur disproportionately in areas with high socioeconomic status and in particular when those areas are close to areas with high offender rates [2, 8, 44]; but other crime types, such as violent crime, are often associated with areas of high unemployment and low socioeconomic status [11]. Social cohesion also has extremely important relationship to crime [14, 30, 38, 45, 47] and therefore social relationships must be considered and implemented in the model.

Environmental Criminology

In an attempt to explain what drives offender movements and what effect people other than the offender will have on individual crime occurrences, various criminological theories have been developed. *Routine activities theory* stipulates that for a crime to occur a motivated offender and a victim must converge in space and time in the absence of a capable guardian [19]. Many authors have found that at least some of the basic concepts of routine activities theory can be used to explain their observations and, therefore, the theory is generally supported [4, 37, 36, 40, 47]. The individual behaviour of victims, guardians and offenders is explicit in routine activities theory, but many methodologies typically used for modelling crime face difficulties experimenting with these micro-behaviours.

Although routine activities theory will help to establish what offenders, victims and guardians will do on a "normal" day, it does not address the decisions people make or the actions they take which will clearly have an affect on whether or not a crime will actually occur. These factors can be modelled by crime pattern theory [9] and the rational choice perspective [22]. Crime pattern theory is closely linked to routine activities theory but works at a more local scale. Offenders do not search for targets at random, instead they look for targets near important "nodes" such as friends' houses and leisure or work places [11]. Crime pattern theory, therefore, examines these important *nodes*, the *paths* between them and *edges* which mark social boundaries. These elements lead to the generation of activity spaces which will determine the areas which people know well and feel safe in.

Originating from ideas commonly used in economics, the rational choice perspective suggests that an offenders' decision can be modelled as a formal process whereby the potential gains of a successful crime are compared with the potential losses if apprehended. In this manner, a crime will only be committed if it is perceived as profitable. Some studies have illustrated how strongly emotions are associated with criminal events [47] and it therefore seems unlikely that a rational decision is made. However, a form of *bounded rationality* can be used which could take emotions and other human factors into account.

Therefore, by using routine activities theory to establish peoples' general routines, crime pattern theory to model travel on routines more accurately and the rational choice perspective to model individual assessments of a situation, a well-rounded view of behaviour from the city-wide to cognitive scales can be established.

Modelling Crime

Traditionally, crime occurrences have been modelled by the statistical technique of logistic regression [31]. Although such techniques have provided interesting results, they work at relatively large scales so do not take local factors (at the person, street or neighbourhood level) into account. The local physical environment has been shown to have significant effects on crime [2, 7, 15, 18, 20, 21, 42, 37, 43, 47], but it is very difficult to investigate this detailed spatial component using purely statistical techniques. To address some of these short-comings, computer simulations of crime have been developed which can work at much smaller scales. These include spatial interaction models and microsimulation techniques [31]. However, *all* of the above techniques face difficulties with regards to incorporating human behavioural factors.

Described as a "breakthrough in computational modelling in the social sciences" [24] and "one of the most exciting practical developments in modeling since the invention of the relational database" [32], agent-based modelling (ABM) is a new method for modelling systems. An agent-based model is comprised of autonomous, decision making entities called agents who can interact with each other and their environment [6]. In this manner, large systems can be created which mimic real scenarios and produce a dynamic history of the system under investigation [1]. At every iteration of the model, each agent individually assesses its situation and, based on set rules, makes a decision about what action to take [6]. In this manner, using production rules, the agents can be implemented with simple human behaviours [35].

ABM is being increasingly recognised as an important tool for social scientists [35], particularly because people are trying to model very complex systems which make traditional modelling methods unsuitable [32]. The ability of agent-based models to describe heterogeneous individuals or groups is a much more natural way to describe systems than it is to try to build aggregate equations to control them [6]. In some cases using equations might be impractical or even impossible [17]. The ability of models to represent separate individuals is particularly important when investigating micro-theories such as routine activities theory. Brantingham and Brantingham [10] note that with ABM it is possible to treat offenders in a similar manner to non-offenders and explore the effects that non-criminal activities will have on crime. In this manner, the "natural variety" of cities becomes part of the model, rather than being smoothed out by aggregate methods [3, 10, 17].

The technique of agent-based modelling has been applied to a vast number of subject areas, including computer systems which assist car drivers [34], models of pedestrian movements [16, 41],

simulations of human immune systems [29] and models of petrol station prices [28]. However, studies of *direct* relevance to this project are rare. Some authors have discussed the need for agent-based modelling of crime and have outlined frameworks [10, 12, 13], others have implemented relatively simple agent-based models of crime [25, 26, 27] and there are some agent-based investigations into general crime features [33, 46]. Birks [5] created a multi-agent model based on current theories in environmental criminology, although the work is currently unpublished. Therefore an agent-based model of crime is a novel and under-investigated approach with relevance to the fields of agent-based modelling, crime modelling and criminology.

Summary

The aim of this research is to create a computer model of crime in Leeds. The model will attempt to predict the levels of different types of crime and will depend upon the physical environment and the behaviour of offenders, victims and other citizens. Governments and policy makers are eager to understand crime better, but even after investigation by researchers from an array of different disciplines (including economics, biology, social science and psychology), theories remain disconnected and crime in general is still little understood [18]. The model produced here will not only be used to experiment with criminological theories but will also have practical applications. It could be used by local governments and the police to investigate the effect that new environmental or crime reduction initiatives might have on a local area, testing them before their implementation. The first part of the methodology involves establishing the factors that affect crime and which must be included in the model. These are mostly determined through a literature review that covers criminology, psychology and sociology. The second part is a formulation of the model structure, i.e. the agents and the rules. This paper will provide a summary of the main rules governing burglary offender behaviour and a basic ABM structure.

Although modelling human behaviour is a daunting task, it is possible nevertheless [39]. The are proposed methodologies (including the PECS reference model [39]) which can be used to build agents with behaviours that reflect those of humans. Fortunately it is not necessary to attempt to model all forms of human behaviour. The formulation of the research question will determine which factors are necessary to include in a model in order to investigate the phenomena of interest [39]. In this case, the components of a simple model of offender/non-offender behaviour is illustrated by Figure 1.

Intensity functions will determine the most intense drive and will be used to derive the agent's cur-

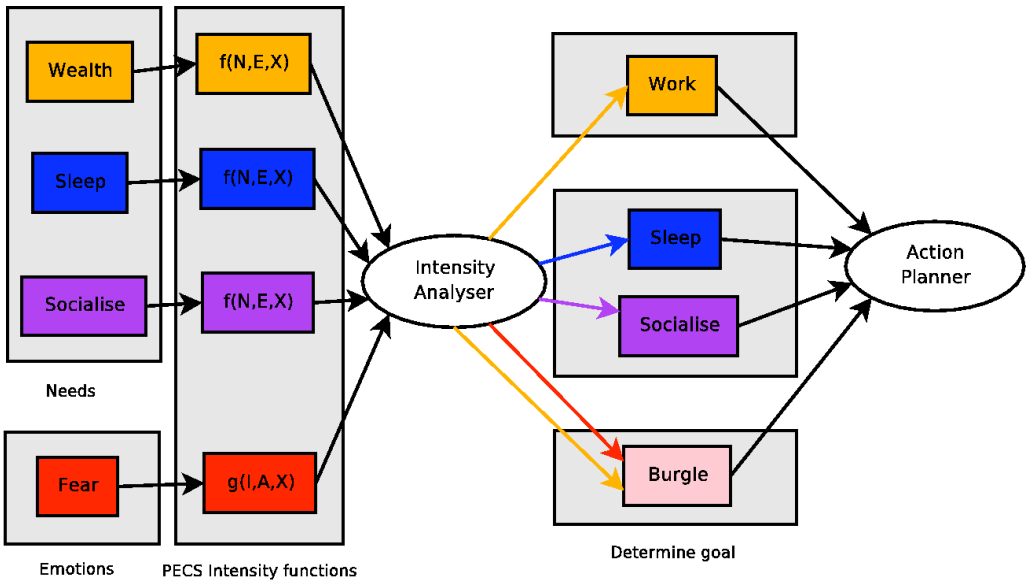

Figure 1: Simple method of simulating offender/non-offender behaviour, based on the PECS [39] reference model.

rent goal. They take individual personalities, the perceived physical environment and other factors into account. Using this relatively simple model it should be possible to experiment with human behaviours and test the effect that these behaviours will have on crime patterns.

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