GUT FEELINGS, CRIME DATA AND GIS

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Abstract

Identifying locations susceptible to crime and the reasons for its occurrence have often been based on the "gut" feelings of police officers and others involved. As a result, those crimes where offences are highly visible may be over policed, whereas those locations truly requiring attention, receive little. In order for crime mapping to be truly meaningful the data held by police should not be the only data that informs the maps. Rather, information on the "spatial neighbourhood" involving physical, environmental and social factors can be used to detect interesting relationships and crime pattern information that may either confirm or disprove the "gut" feelings. This paper will examine how such "neighbourhoods" can be identified.

Introduction

The topic of "crime" is one that affects all of us in some way or another. Our personal experiences often inform the views we form on the causes of crime and the cures for its prevention. Despite the plethora of criminological theories, a number of pertinent questions remain unanswered. Where does crime occur? Why does it occur there? What information can be gleaned regarding crime locations, patterns and trends? Can we identify factors related to crime? What areas and neighbourhoods have a greater crime risk than others? Are there better methods of analysing crime? Are there adequate resources and tools to use the relevant information to improve our understanding and assist in the prevention of crime?

Within the discipline of criminology new theory is often developed in an attempt to falsify older theories. Theories rarely build on pre-existing knowledge. The new theories that develop often ignore other important information, or simply lack application in certain communities. The representation of all the different data sets and the availability of techniques to manipulate that data is problematic in itself, and for that reason researchers have often ignored factors that could be critical to understanding crime. This has often resulted in broad theories being developed that may ignore certain factors, or not be relevant to a particular location. It is true to say that different crimes have different causes. The different ways of understanding and explaining the causes of crime may
each be equally valid in differing circumstances. At best we can say that a variety of equally valid theories assist our understanding of crime.

In this paper the benefits of using geographic information systems (GIS) to examine and understand the relationship between environmental factors and crime will be explored. The factors and situational approaches in analysing crime are first introduced. From this, the importance of space and the local neighbourhood can be identified for crime analysis. The paper then describes the work being undertaken within the SpaNEx project to develop techniques and tools for analysing spatial neighbourhoods.

Factors in analysing crime

In the past, explanations for crime were based on whole societies. The causes of crime were seen as homogeneous over an area, and the antidote to crime was just as broad. Rarely were prevention strategies specific or local. Crime reduction strategies have been aimed at particular suburbs but it is necessary to become even more specific. Crime prevention strategies must focus on particular streets, laneways or reserves. More recently we have observed a greater understanding of the causes of crime and a tendency to focus on particular localities. To come up with local solutions we must have the ability to look at local causes. Over the last decade there are an increasing number of methodologies and tools to assist in analysing crime (for example, see Stonor and Karimi 2000, CPTED 2000a). Geographic information systems (GIS) are increasingly being used to integrate, manage and display (map) many types of data and information over a geographic area enabling us to examine and analyse particular local areas.

Of late a number of criminologists have advocated an integrated approach to understanding crime. This approach is summarised by Vold; "…different theories do not contradict each other, but focus on different aspects of the same phenomenon and therefore make different predictions about it" (1998:300). Crime maps enable various causal factors to be represented visually, rather then simply as a set of numbers on paper. In this way we are able to identify patterns and relationships not seen before. A truly meaningful crime map will include factors other than just the location of crime. GIS provide analysis tools and techniques to examine causal factors within the local spatial environment. Crime maps that integrate a range of factors are more meaningful and assist to identify patterns and relationships previously not observable. GIS can faciliate the understanding of relationships between certain factors and crime, thereby allowing coordinated multifaceted localised crime prevention strategies to be developed.

GIS provide the ability to take into account a greater range of factors than has been previously utilised to examine and understand crime in a particular area. It allows the examination of why particular crimes may be occurring in particular areas informed by a number of causal factors. In this way the understanding of crime in particular areas will not be based on gut feelings, but on scientific evidence. Relevant factors may include anything for which data exists: average income for families, age of the general population in a given area, reliance on welfare payments, health care requirements, road patterns, population density, distance from cities, size of houses, zoning in areas, height of fences surrounding houses, amount of alcohol sold at liquor outlets, etc. If there is a data set linked to spatial location, it can be included in a crime map. GIS allows us to more easily examine relationships not previously identified when the data is presented in a table format, in this way we are able to develop new understandings of crime within particular localities. This not only allows targeted prevention strategies that involve a range of responsible agencies but also legitimates particular crime reduction initiatives that are adopted. Through GIS we are able to identify local causes and develop local crime prevention initiatives. Identifying the local causes of crime is necessary if we are to understand what prevention strategies are most appropriate (Mitchell 1993). Crime prevention is irrelevant if it fails to recognise that different areas may have different
causal factors.

Crime statistics have often been ignored for allocating resources in developing crime prevention strategies, or developing crime prevention strategies for particular neighbourhoods (Mitchell 1993). Crime statistics alone do not present the whole picture, being often presented in large unintelligible tables that are more of a historic record over broad areas, rather than an up to date record that takes into account local circumstances. The problem with statistics are well documented, and beyond the scope of this paper. Crime maps that simply represent crime statistics are interesting historical records of reported crime hotspots, but do not allow us to make connections with other data sets. Without integrating information in respect of crime we can say that crime prevention strategies continue to be based on gut feelings and individual experiences rather then on scientific evidence. Those who are much closer to the "scene", as it were, such as police officers and involved community groups, have much to contribute using their experiences and local neighbourhood knowledge. However, the local community and environment, is a complex configuration of space, physical structure and people. Even those with local knowledge and experience cannot possibly comprehend all the complex variables and interactions that take place in a community. This complexity is difficult to measure, difficult to control, and therefore also difficult to analyse and model (CRC 1999, Hillier 2000a, Stonor and Karimi 2000).

The relationship between crime and environmental factors have often been ignored. As Hillier (2000b) notes, "Crime and space research has a poor record for a number of reasons. First, too little effort has been made to isolate the effects of spatial design from those of social composition… Second, too little attention has been given to spatial detail since studies have been at the level of the estate or the area rather than the individual crime. Third, too many different kinds of crime have been lumped together. It is likely that each type of crime has its own spatial logic which need to be identified. Fourth, studies have been too loose statistically in dealing with the interaction between factors, and so the work has been criticised." The examination of the physical and social environment and crime is not something new. Park Burgess and McKenzie (1928) examined particular neighbourhoods in coming to an understanding of crime. This approach was developed by Shaw and McKay (1969) as well as Sampson (1995) and is highlighted in the approach of Crime Prevention Through Environmental Design (CPTED 2000a).

**Situational Approaches to Crime**

The location of crime is not homogenous throughout any given geographic area. Park et al. (1928) developed the Chicago school theory of crime. By focusing on human behaviour as determined by social and physical environmental factors, rather than genetic, personal characteristics they concluded that human behaviour was a product of a person's social environment. The Chicago school studied housing, welfare and crime statistics. What is significant about the Chicago school theory is that instead of focusing on entire societies it focused on neighbourhoods. Park et al. identified concentric zones surrounding a city as having variable crime rates. The variable crime rates were attributed to the social environment within the various zones.

Shaw and McKay (1969) further developed the Chicago school theory and concluded that areas adjacent to heavy industry or commerce and those areas that had a large number of condemned buildings, had the highest rates of delinquency. Areas where there was a reliance on welfare, and where health problems were also prevalent, experienced higher rates of delinquency. Shaw and McKay also observed that areas of high crime also had greater concentrations of foreign-born and African-American heads of families.

Sampson (1995) more recently developed Shaw and McKay's theory further identifying the fact that neighbourhoods that have a strong sense of community and have less crime than areas where the
sense of community does not exist. Where the community lacked control over public areas, these areas were free to be taken over by criminals. Sampson's basic proposition is that crime rates can be affected by change to the physical environment and by empowering the people. In adopting this approach graffiti was to be cleaned off immediately, rubbish to be cleaned up, activities were organised between young people and adults, and communal local management was encouraged.

More recently there has been an interest in the physical environment and empowering the community through initiatives such as CPTED. CPTED concentrates on four key areas; territoriality, natural surveillance, activity support and access control (CPTED 2000a). Basically, CPTED encourages people to feel at home in their community. This results in a feeling of responsibility for the local environment in which persons with criminal intentions may be easily recognisable. The relationship between CPTED and crime is often difficult to observe and monitor. Crime maps that include relevant environmental factors can be used in providing evidence for the effectiveness of CPTED. Collecting this information may well require police officers to collect more information about the physical features surrounding the location of certain crimes. Once collected this information is likely to show interesting relationships between crime and environment that previously were not observable.

GIS are very powerful tools that provide a means of bringing together information about people and the physical environment in a spatial context so that relationships and patterns with respect to crime can be identified. Even so, further tools for extracting information and knowledge need to be developed to enable crime researchers to identify and explore patterns and relationships more fully (Hillier 2000a, NIJ 2000, Thorne 2000). GIS need to be extended to incorporate techniques and tools that will "mine" the information in a spatial neighbourhood and sift through the relevant data to identify the situational factors affecting crime (Fayyad et al. 1996).

**Spatial complexity and the spatial neighbourhood**

As previously mentioned, the community is a complex configuration of space, physical structure and people. The important component here is “space”. It is “space” that defines the physical environment and the movement of people. The physical environment and people are interrelated through space. Space can be viewed as the “language” through which people interact with their physical environment (Hillier 2000a). Being able to understand the complexity of space is therefore a key component in the analysis of crime.

This also explains one of the reasons why GIS is an excellent tool for use in crime analysis. GIS are very good at manipulating spatial data and spatial relationships (Bailey and Gatrell 1995, DeMers 2000). In providing tools and facilities for managing and analysing geographic information, GIS essentially assists in understanding some of the complexity of space. To understand crime and the reasons for it, one need not explore geographically distant regions. Rather, the reasons for crime lie in the vicinity of its occurrence. The spatial neighbourhood is a good starting place for analysing crime. The local environment may be able to “explain” much crime. For example, crime may be related to existing local land use (nearby residential, commercial, park, etc. areas), traffic and transit (nearby road layouts, footpaths, bus routes, etc.), characteristics of neighbours (tenants versus owners, youth versus elderly residents, neighbour relations, etc.) and neighbourhood conditions (vacant blocks, unkept and overgrown lots, concealed houses, etc.) (Taylor 1999, CPTED 2000b).

The spatial neighbourhood can then be explored by various spatial analysis tools such as nearest neighbour analysis, spatial autocorrelation and cross-correlation analysis (Bailey and Gatrell 1995). The neighbourhoods can be based on either point, area or line based features such as crime point locations, postal code areas, or road centerlines, respectively. Nearest neighbour analysis will then,
for example, examine the relative distances to the single or multiple nearest neighbours to ascertain whether or not a pattern (either clustered or regular) exists. Similarly, spatial autocorrelation will examine whether there is spatial clustering, spatial regularity or randomness among the "neighbours". In these, and other types of analysis, it is important to know what "neighbourhood" must be examined. The choice of neighbourhood will affect the resulting patterns being identified.

Various methods for defining the spatial neighbourhood can be identified. The following list identifies some of the ways in which the spatial neighbourhood can be defined. Examples of how that neighbourhood can be utilised are also provided:

- Single closest feature (eg. using centroid for areal or linear features). For example, identifying the closest crime location for each crime spot.
- The $n$ closest features. For example, examining patterns that may exist among the 10 closest crime locations for each crime spot.
- Distance. The neighbours within a specified distance are selected. As an example, patterns among crime locations within 200 meters of each other may be examined.
- Adjacency. Neighbours are chosen based on whether or not they are topologically adjacent. Examining adjacent housing lots to identify patterns among their properties is an example.
- Boundary length. This is an extension of adjacency, where the length of the common boundaries to adjacent neighbours is considered. For example, the length of boundaries of adjacent public access open spaces and reserves may be considered for each housing lot.
- Direction. Neighbours may be chosen based on their direction from given features. For example, crime locations in the direction of the central business district (CBD) may be selected to identify patterns.
- Restricted neighbours. This is where potential neighbours are selected on the basis of specific identified characteristics. For example, only crime locations of a specific nature (eg. burglaries), or homes with a high average income, may be chosen as neighbours.
- Interaction. Neighbours may be selected on the basis of their interaction, or amount of interaction. For example, homes on the same street may be identified as having a greater interaction (eg. via pedestrian access) than nearby homes facing different streets.
- Higher order neighbours. The definitions above generally refer to the "first-order" neighbourhood. However, higher order neighbourhoods can be defined using these definitions. For example, the adjacent housing lots define the first-order neighbours, whereas homes that are two housing lots away define second-order neighbours, three lots away are third-order neighbours, etc.

For each of these neighbourhood definitions, various characteristics of the features (whether housing lots, crime occurrences, or streets, for example) can be utilised in performing the analysis, including crime types, time of incident, socio-economic status, traffic flows (car and pedestrian), home security levels, property zoning type, and level of home screening (eg. fences, shrubbery, lighting). Different neighbourhood definitions can be explored to identify and compare patterns that may exist.

It is possible to use combinations of the above methods in selecting a neighbourhood. This allows us to easily examine various factors together to understand their interrelationships. Note also, that the neighbourhood need not only be defined as a binary relation (ie. either it is a neighbour or it isn’t) but can also be identified as the "amount of neighbourliness" on a continuum (eg. length of adjoining boundary, level of interaction, etc.). In this context, it is recognised that certain neighbours have more influence than others. For example, adjacent houses on the same street may be identified as having more of an influence on crime in the locality than adjacent houses facing a neighbouring street.
Spatial Neighbourhood Explorer

A set of techniques and tools are being developed at Curtin University to facilitate the exploration of spatial neighbourhoods for various applications. Referred to as the Spatial Neighbourhood Explorer (SpaNEx) project, it provides the ability to identify various spatial patterns and trends in relation to different “definitions” of the spatial neighbourhood. The explorer techniques and tools are in the developmental stage and are being implemented as an extension to the ArcView GIS software (ESRI 1996).

The data structure used for representing the neighbourhood is a proximity matrix. This matrix identifies, for each pair of features, whether or not they are neighbours and the amount of “neighbourliness”. SpaNEx provides the user with an interface from which the neighbour definition can first be chosen (see Figure 1).

The defined neighbourhood can then be utilised in a pattern analysis tool such as, for example, spatial autocorrelation (Figure 2). The autocorrelation analysis in SpaNEx provides an overall indication of pattern using Moran’s I or Geary’s C statistics (Bailey and Gatrell 1995). The user (analyst) also has the option of providing more localised statistics by performing the calculations on quadrants of the region where the number of levels of quadrant subdivisions are specified.

Figure 3 indicates the results of autocorrelation for 5 levels of nesting where areas of positive, random and negative autocorrelation are highlighted using graduated shading (ranging from red to blue). The quadrant level corresponds to the amount of data available within the quadrant. Hence, a quadrant will only be further subdivided if there is sufficient data within the quadrant to be able to identify further (more local) patterns. Hence, the user is provided with a multi-scale view defining variable-size localities. The user can decide at what level of detail they wish to conduct the analysis, ranging from a broad regional level, down to a local situational level. Note, from Figure 3, how the pattern can change from near random at a regional level, to clustered or regular at a more local level. Once again, this highlights the importance of establishing an appropriate neighbourhood for spatial analysis.

The user can, at a glance, identify interesting areas highlighted by particular patterns. The user is then able to examine the area more closely by performing the pattern analysis at a different scale (Figure 4). This highlights the aspect that the extent of the spatial neighbourhood can vary, depending on the amount and distribution of the available data. For example, as is illustrated in Figure 4, regional areas may have sparser crime events than built-up areas, with the result that their neighbourhoods extend further over a larger geographic area.

In addition to the extent, the neighbourhood can be characterised by different properties. By changing the neighbourhood definition, the user can observe patterns using only selected characteristics. For example, Figure 5 indicates the resulting pattern using only crime locations where burglaries have occurred. Using the restricted neighbours method, the user first selected crime locations with the crime type of “burglary”. The spatial neighbourhood was then redefined for only those selected points using the multiple nearest neighbours method (using 3 neighbours for this example). Finally, an autocorrelation using this defined neighbourhood was performed to derive the result of Figure 5.

By simply changing some properties of the neighbourhood definition, new patterns and relationships can be identified. For example, rather than the neighbourhood being defined on multiple nearest neighbouring burglaries, it can be defined on all burglaries that have occurred within 250 meters. The result can be a very different looking pattern (Figure 6). The difference in pattern can be explained by the fact that the multiple “nearest” neighbouring crimes do not take
distance into account. In high crime rate areas, these nearest neighbours may only be several of many crimes occurring in the same locality – hence the relationship to the other local crimes are ignored. For sparser regional areas, the nearest neighbouring burglaries may be at a greater distance away and hence burglaries within a prescribed distance may form only part of this “extended” neighbourhood that influences occurrences of burglary. The definition of the neighbourhood is, indeed, very important in identifying and analysing patterns and relationships.

**Conclusions**

Spatial neighbourhood information involving the physical and social environment provides the context in which analysis can be performed. Such a neighbourhood can be defined in many ways based on the spatial properties and characteristics of surrounding features and events. The SpaNEx project is extending GIS to investigate techniques and tools to define various “neighbourhoods” that can be utilised in spatial pattern analysis. Crime analysis is an application that can benefit enormously with the use of GIS and spatial analysis.

The development of GIS for use in crime analysis provides the ability to integrate information and analyse the occurrences of crime at a local level. Rather than dealing only with broad statistics and the gut feelings of those with local knowledge and experience, the analysis of spatial neighbourhoods can highlight particular patterns and relationships that can improve the understanding of crime occurrence.

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**References**


Figures

Figure 1: SpaNEx interface for defining the proximity matrix

Figure 2: SpaNEx interface for autocorrelation analysis with a defined neighbourhood
Figure 3: Identifying patterns using 5 levels of nested quadrant areas

Figure 4: Examining pattern within a redefined area of interest
Figure 5: Identifying patterns of burglaries

Figure 6: Using a different spatial neighbourhood to explore patterns of burglaries