

Geographic Information Science and Crime Analysis

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Abstract: *This paper reviews modern crime analysis with regard to the research and educational challenges outlined by the University Consortium for Geographic Information Science. In the context of Geographical Information Systems (GIS), attention is devoted to the role that crime analysis currently and potentially plays in reducing crime and improving the efficiency of police activity. It is our aim to stimulate interest in advancing crime analysis in the areas of crime mapping and visualization. It is hoped that an outcome of this effort will be the attention that granting agencies may give to this rich and productive mixture of state-of-the-art technology and social responsibility.*

Introduction

The purpose of this paper is to briefly review how crime analysis lends itself to the specific and related research and educational challenges outlined by the University Consortium for Geographic Information Science (UCGIS). This article is an outgrowth of a series of papers, demonstrations, and discussions on the subject that took place at the 1999 Summer Assembly of the UCGIS in Minneapolis. Some of the contributors to this paper (see names above) are among the most active spatial analysts in the area of crime study.

In the following paragraphs we devote attention to the role that crime analysis plays and might play in reducing crime and improving the efficiency of police activity. The interested reader will find greater detail on many of these subjects in two excellent new books by Harries (1999) and Goldsmith, McGuire, Mollenkopf and Ross, Eds. (2000). Here we aim to stimulate interest in advancing crime analysis in the areas of mapping and visualization. Our goal is to inform the reader of what we believe is a productive mixture of the use of state-of-the-art technology and social responsibility.

The decreasing cost of desktop computers has allowed crime mapping to emerge from its traditional pin map mode to ever more sophisticated and flexible GIS representations. It will become evident to the reader, however, that even with the remarkable progress in crime analysis, the potential is great for GIS to help further the fight against crime. Spatial analysis and three-dimensional graphic representations are examples of two research avenues where GIS may make a decided impact on reducing crime. Questions of data acquisition, data exchange, and data format are just some of the areas in which research is needed. In addition, analysts and policy makers have only touched upon concomitant issues concerning the most effective ways to bring GIS knowledge into the law enforcement community.

The Scope of National Needs

A number of researchers have documented the usefulness of computer generated maps in developing crime-monitoring capability. In a recent survey of police departments most of those responding indicated that computer generated maps are valuable tools (Mamalian et al. 1999). Unfortunately, many law enforcement agencies have yet to take advantage of GIS, of which computer generated maps are a part. Only 13% of the respondents to the survey reported using any computerized mapping at all (Mamalian et al. 1999). The majority of users are large departments, employing more than 100 police officers. Those that employ computerized maps use them primarily for geo-coding and mapping offenses (automated pin maps), calls for service, and analysis of vehicle theft and recovery patterns. The maps are also used when making decisions on resource allocation and to inform local communities about criminal activity. Although clusters of crime (hot spots) are most often identified visually, about 25% of the large departments use various software packages for cluster identification, and, of these, very few use statistical and/or spatial analysis.

Mapping is the key to understanding the spatial and temporal occurrence of crime, but it is only the beginning. The fact that criminal activity is non-random in time and space raises questions about its location and the reasons for its location. GIS directly helps to answer the location question, but it is the spatial analyst with the use of GIS who is in the best position to clearly identify the patterns and suggest reasons for pattern characteristics. There is a compelling need in the law enforcement community to better understand the conditions that give rise to criminal behavior. Those conditions can be better understood by the suggestive nature of crime pattern analysis.

Centers for the Study of Crime in Law Enforcement

Fortunately, the U.S. is well served by a variety of agencies that promote the use of technology in crime prevention. Most of these agencies work with a variety of local law enforcement interests. At the national level, the Office of Administration in the Department of Justice (DOJ) houses Geographic Information Systems and a Spatial Crime Analysis System. The DOJ supports a National Institute of Justice (NIJ) Crime Mapping Research Center and a Crime Mapping and Analysis Program. In addition, the Federal Bureau of Investigation has extensive computer mapping capabilities.

National level initiatives also include National Community Demonstration sites. The goals of these projects are to: 1) inform decision making at the community level, 2) improve land and resource use, 3) transfer data between the Federal Government and communities, and 4) have communities contribute data sets to national data clearinghouses. Currently, the largest city participating in the project is Baltimore, Maryland. In addition, Vice President Al Gore has spoken out on the promise of the new technologies in the fight against crime.

Many states support crime mapping endeavors. The most prominent is the Illinois Criminal Justice Authority, which produces and disseminates perhaps the most widely used crime/cluster analysis package: Spatial and Temporal Analysis of Crime (STAC). At the local level, a number of police departments lead the nation in the use of computer mapping of crime and in crime analysis. Among large cities, New York with its CompStat system and Chicago with its ICAM2 system are well known. The Baltimore County Police Department currently works with the DOJ on a regional crime analysis GIS (RCAGIS). San Diego employs an elaborate and detailed data gathering system (ARJIS) and uses both in-house and third party analytical routines based on ArcInfo and ArcView mapping software. In addition, some smaller metropolitan areas such as Charlotte-Mecklenburg, North Carolina, use crime-mapping systems extensively.

A number of technologically oriented firms and universities conduct research in crime mapping. Environmental Systems Research Institute (ESRI), the largest producer of GIS software, financially supports in-house and external crime-analysis research. Several smaller firms, such as the Omega Group and GeoSpatial Technologies, are developing systems that are marketed to police departments around the country. The International Association of Crime Analysts is based at Tiffin University in Ohio. The University of Denver has a crime-mapping and analysis program. Among the most imaginative programs are the crime analysis and mapping tutorials used at the Heinz School of Public Policy and Management at Carnegie Mellon University. Several universities, including the State University of New York at Buffalo and Temple University, have received large grants from the NIJ for work in this area.

Linkages to Relevant UCGIS Research Challenges

For this section, we consider crime analysis in the context of the UCGIS research challenges (see Research Challenges White Paper at the UCGIS web page, www.ucgis.org). We ask ourselves: How does the application area called crime analysis relate to these challenges? The purpose of this section is to identify the interface between the fundamental research interests of UCGIS and the needs and characteristics of the crime mapping community. Only those UCGIS research challenges relevant to crime analysis are discussed here.

Spatial Data Acquisition and Integration. Police departments need large amounts of detailed location data on crime type, site of crime, perpetrator address, victim address, and the exact nature of the crime. Many departments have now developed or obtained some sort of computerized database management system to record this information. If the data are geo-referenced accurately, it is possible to create maps showing many aspects of crime patterns. It is especially helpful if accurate street maps are available for the GIS. In addition, there is a need for zoning, land use, terrain, and census tract maps. The major technical problems in this area involve the need to:

1. develop systems that make it possible to map combinations of information, such as census data and crime patterns;
2. match different sources of data collected at different times and scales;
3. find ways to share data between departments, agencies and communities; and
4. reduce barriers to data ownership.

In general, the goal is to standardize and integrate data. National standards for information recording, with regard to both maps and to non-mappable information, would facilitate this. At the least, there is a need for a strong effort to reduce inconsistencies among cooperating law enforcement and non-law enforcement departments.

Distributed Computing. Since a myriad of police and non-police reporting systems are currently in use, the dissemination of their information can be confusing and possibly misunderstood. It would be helpful to move toward having a core location for storage of regional or national crime and related data. Several agencies are already moving in this direction. For example, the ARJIS system, used by various agencies in San Diego County, stores police reports for all police departments within the county. It is the primary repository of information used by the San Diego Police Department. These data are easily transferred into a GIS for use on desktop computers. Because crime is not greatly hindered by jurisdictional boundaries, it is important that data from adjoining cities and suburbs can be integrated easily. On the negative side, the NCIC system in use for national criminal checks cannot be used in a GIS. In general, the existence of dif-

ferent reporting systems for each police department stands in the way of distributed computing.

Extensions to Geographic Representation. Many police officials would find it helpful to have available effective representations of crime location patterns. For analytical and decision making purposes, useful representations of hot spots and other location information are needed. Simulations are becoming more important as visualization techniques become more sophisticated. Care should be given to using logical formats for representations so that the chances of misinterpretation are minimized. New technology that features three-dimensional representations would be helpful to police, especially in the study of crime patterns in large buildings and underground structures. In general, geographic representation is an area with vast potential for developing new types of maps and charts that can aid police authorities.

Cognition of Geographic Information. Information is understood and used in different ways by individuals and interest groups. For example, the police may interpret a particular map differently than do community leaders or business people. The objectives, experiences, and knowledge of the users condition viewpoints. The problem boils down to the question: Who needs what and in what format? Spatial decision support systems must be developed that allow map users to find common ground for the solution of crime related problems. In addition, these systems aid in helping to determine the types of further information needed.

Scale. Integrating spatial information obtained from a variety of map scales and finding ways to analyze data in a consistent fashion can be problems. Reducing all information to the same scale is clearly not the solution to these problems. Depending on the make-up of their region of jurisdiction, police departments need maps and attendant information at a variety of scales. Federal, state, local jurisdictional areas can overlap with other jurisdictions, creating a problem of who stores and has access to data. Multi-scale analyses and smooth scale change technology are needed to move easily from one scale and generalization to another.

Spatial Analysis in a GIS Environment. This is a critical challenge. Currently, spatial analysis programs and GIS systems are poorly integrated. Fortunately, this is a subject to which a considerable amount of attention has been given in recent years. The principal question is: What types of analytical routines can be developed within a GIS environment that will help answer societal questions about the intensity and type of crime and its spatial and temporal characteristics?

There is a need to improve analytical packages so that they can be integrated easily into mapping systems. Cluster or hot spot analysis is currently one area of concern. Ellipses or circles surrounding hot spots are of only limited value. Police need to know the exact dimensions of hot spots in time and space and to

evaluate them in terms of previous patterns or non-crime variables. They need to identify statistically significant patterns.

Currently, a number of packages in the early stages of development attempt to analytically explore crime data. Very promising is the Spatial Crime Analysis System (SCAS), a DOJ ArcView-based GIS application designed to enable police departments to perform spatial analysis and mapping. Others include STAC (mentioned above), Geographic Analysis Machine (GAM), CrimeView (the Omega Group), and CrimeMapper (GeoSpatial Technologies). Additional packages, not geared specifically for crime analysis, have the capability to analytically identify georeferenced clustering. Some of these are SpaceStat (obtainable from BioMedWare), BioMedWare (Ann Arbor), Point Pattern Analysis (San Diego State University), and InfoMap (University of Lancaster).

The Future of the Spatial Information Infrastructure. The main concern here is to consider the possibility of links among data storage, crime analysis, and daily police activities in a real-time environment. Questions regarding information access by police and the public and the technology that integrates information need to be answered for future ease of use. With technology changing at a rapid pace, how can a spatial information infrastructure be developed that has lasting usefulness? One understandable difficulty is the privacy or security issue, mentioned below, which inhibits the use of such information as exact addresses, thus distorting what otherwise might be a true representation of the spatial distribution of crime.

Uncertainty in Geographic Data and GIS-based Analysis. The problem of data quality has been an issue in the past and will continue to be in the future. All analyses are based on data. If police officers record data poorly or citizens give faulty reports to the police, any map or analysis based on the data will be suspect. In addition, representing the address of a large building spread over many acres as a point or giving an arbitrary address for a crime committed in a large open space may lead to errors in analysis. Efforts should be made to insure that great care and attention are given to the development of accurate primary databases.

GIS and Society. Perhaps the most important issue under this heading at this time is the movement to encourage community partnerships with the police. GIS can play a role by facilitating the development of the timely and accurate visualization of crime for the combined use of police and concerned civilians. GIS can support crime prevention efforts by illustrating the impact of crime on the community and of the impact of community efforts on crime. GIS can facilitate informed decision making on criminal activity and prevention. It can be useful for elevating interest and awareness of crime problems and can be instrumental in helping society learn the linkages between crime and other factors distributed in space, such as unemployment or drug use. By transferring local information to larger bodies such as state and federal government, the community can assist national ef-

forts to reduce criminal activity. Privacy and information dissemination are issues that the larger society must deal with when it becomes clear that the desire to protect citizens may be in conflict with constitutional guarantees of freedom. The issues of security, sensitivity, confidentiality, responsibility, reliability, data sharing, and data ownership are all of great societal importance.

Additional Research Challenges Discussed by the Panel

Spatial Forecasting, Prediction, and Projection. There is a need to spatially identify the natural fluctuations in crime levels and to recognize crime types by season, by day versus night, and by weekday versus weekend. Surveillance statistics must be developed so that leading indicators or trends in crime occurrences can be monitored in a meaningful way. In addition, crime needs to be placed into a space-time format, since these two basic dimensions are critical for understanding the subject.

Verification, Validation, and Evaluations of Research and Operations. GIS can be used to evaluate the effectiveness of police operations. Meta-types of analysis can be used to compare and contrast results found among different academic studies reviewing similar phenomena. Since local authorities do much crime research, there needs to be a clearinghouse so that duplication of effort is minimized. It would be useful to know precisely which measures are the most successful at evaluating crime analyses. Furthermore, study results need to be disseminated from readily available venues. This subject naturally is related to challenges mentioned above, such as the issue of creating consistent data standards.

Computer Power Versus Data Set Size. As data sets become larger because of the greater ability to record criminal activity and the greater interest and competence in considering crime in detail, the GIS community will be faced with the problem of hardware and software capability to handle extremely large data sets. Although computers may have the capacity to handle the current data sets, there is still the challenge of computer congestion. While the computer is running one problem is it may not be available for other work.

Mapping the Causation of Crime. In addition to mapping crime, it would be useful to map what can be considered the causes of crime. Mapping such factors as low income, low educational levels, juvenile delinquency, unemployment, and so forth can be enormously helpful for crime analysis. The question of relevant crime-related variables and their spatial representation is also an issue. For example, can mapping domestic abuse help in crime prevention?

Linkages with UCGIS Education

In the area of understanding and preventing crime, there are a number of issues related to having an informed populace (including law enforcement personnel) use GIS technology. Currently, there are a host of new technologies available for delivering GIS education. The most promising of these with regard to crime analysis is that produced by Wilpen Gorr at Carnegie Mellon University (Gorr and Kurland 1999). The program is built around the advanced use of GIS in a police data environment. Internet modules have been developed. These fit nicely into distance learning and CD-ROM tutorial pedagogy discussed in the on-line white papers of the UCGIS educational challenges committee. Gorr's program contains videos and CDs with transcripts and full search capabilities.

Access and Equity. Most users of crime-analysis GIS are employed by large metropolitan police departments. With the increased availability of affordable powerful desktop machines and software, however, we can expect that police departments of all sizes will be increasingly engaged in this type of work. Low-cost training for using GIS is becoming available, but there are still few workshops oriented to specific crime-analysis workshops. There are problems with regard to finding and retaining personnel who are familiar with modern data retrieval, software use, and technology maintenance techniques. More web sites with white papers and links to available data and curricula are needed.

Perhaps most important at this juncture is the need to find ways to share information, data, and technology. The problem of the difficult trans-jurisdiction interface looms as a formidable barrier for small as well as large police departments, and particularly for poorly funded small departments. National and state grants should be made available so that personnel in small departments can be trained in geographical information sciences. There should be strong governmental support for data sharing and storage between agencies.

Alternative Designs for Curriculum Content and Evaluation. It would be helpful if GIS curricula identified crime (as in the Carnegie Mellon University example) as one possible base for learning. These curricula could include a course that focuses on the use of GIS in a crime lab or police beat environment. This same idea can be extended to community development applications. Police officers, analysts, and citizens could be schooled in GIS use, mapping, projections, relational databases, address mapping, feature extraction, and crime analysis case studies. The training curricula should be user-needs driven. For example, police officers could gain classroom-type experience in choropleth crime change mapping, pin mapping, bringing together crime diagnostic data, and studying site profile information. The crime analyst can learn about data warehouses, aggregate crime codes, land use mapping, trend statistics and graphics, program evaluation, and districting. Detectives could study hot spot analyses, serial criminal patterns, and variable linkage analysis. Citizens might better learn how police departments are organized, how

information is gathered and entered into databases, about GIS capabilities, evaluating crime interventions, forecasting criminal activity, and detecting significant changes in crime patterns. Clearly, a number of useful pedagogical paths could be taken.

Professional GIS Education Programs. Since most users receive their GIS training on the job, it is important to insure that there are qualified personnel in the work environment who are able to effectively train personnel. Training and certificate programs should be made available in colleges and universities as part of their outreach activities to increase the competence of public employees in this area.

Research-based Graduate GIS Education. Graduate education in GIS crime analysis would contribute further support and advancement of the field. It would provide qualified employees in crime-analysis units. There would be an upgrading of the standards for crime-analysis activities. It would create an environment that generates research in new approaches and techniques that would result in improved analyses, user-system interfaces, and general crime theory as well as in the investigation into the effective application of new technology and methods.

There is a strong need to link universities with local police departments to better utilize research resources in both environments. A symbiotic relationship would go a long way toward bringing the fruits of the university research experience into the hands of those faced with the practical everyday requirements of law enforcement personnel.

Accreditation and Certification. Still unresolved within the UCGIS is the idea of accreditation and certification in the area of GIS. Currently, forensics personnel in crime-analysis laboratories must be certified. The pressure for such formalization usually comes from the official needs of courts of law. Currently being debated are whether GIS crime analysts should be certified and whether GIS training programs should be accredited.

Additional Educational Challenge

When they are able to work together, benefits accrue both to those engaged in crime analysis and to the users of the fruits of the analysis. Relationships between universities and police departments open the door to many worthwhile projects and associations. When what might be called “research culture” interacts with “police culture,” which in turn responds to “public culture,” the result may be practical solutions to many crime prevention problems. In addition, it is helpful for the public to be made fully aware of the activities of the analysts and practitioners so that they can appreciate the ways in which GIS and other technologies can improve community life.

Policy Implications

A number of outcomes can result from the use of GIS in a crime-analysis environment. Police departments find that they can im-

prove their efficiency in the application of resources and more easily generate improved proposals for resource requests. Requiring improved data for GIS work will strengthen proposals for public support. Good quality data and analysis encourage community leaders to support police operations in neighborhoods and enable police to internally investigate their own policies for effectiveness and efficiency. In addition, the new technologies make possible changes in police department actions with regard to patterns of crime discerned by GIS crime-analysis efforts. A better understanding of patterns of crime will result in more successful police outreach activities.

Priority Areas for Research and Education

At this juncture, the major thrust in crime control and prevention is to incorporate appropriate advanced statistical techniques into the GIS for crime analysis. Also, it is important to match the output of a GIS analysis with the needs of police and the communities they serve. Behind these needs is the critical area of meaningful data collection and organization. Effort must be expended to develop appropriate geo-referenced data gathering systems and database management systems. Concomitantly, it is important to improve accessibility to crime-analysis education both in police departments and in universities. Another compelling need is for a central information contact that can be of assistance to police departments as they begin their GIS initiatives. Information needed includes such topics as the start-up procedures, what software to use, the costs involved, and whether training is available. Currently, most police departments are at the mercy of the sales pitches of the various vendors.

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Keith Harries is a Professor in the Department of Geography and Environmental Systems at the University of Maryland, Baltimore County. He is the author of a dozen books, most relating to the geographic aspects of crime and justice, most recently *The Geography of Execution: The Capital Punishment Quagmire in America* (with Derral Cheatwood) and *Mapping Crime: Principle and Practice*. The latter, was published by the National Institute of Justice.

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Additional Sources of Information

- Charlotte-Mecklenburg Police Department - <http://www.cicp.org>
- Crime Mapping and Analysis Program - <http://www.nlectc.org/nlectcrm/cmaptrain.html>
- Crime Mapping Research Center - <http://www.ojp.usdoj.gov/cmrc>
- CrimeStat - <http://www.icpsr.umich.edu/NACJD/crimestat.html>
- Heinz School - GIS Tutorial - <http://www.heinz.cmu.edu/gistutorial/>
- Illinois Criminal Justice Information Authority - <http://oicj.acsp.uic.edu>
- Office of Community Oriented Policing - <http://www.ojp.usdoj.gov/cmrc/welcome.html>
- San Diego Police Department - <http://www.sannet.gov/police/>