there are often differences in data structure designs, data encoding approaches, data accessing and processing methods for these two types of geographic phenomena. Geographic coverage is a concept for continuous phenomena. Geographic coverage standards defines conceptual schema for coverage and analyze coverage types and components, e. g., [1]. These include characteristics of spatiotemporal domain coverage and attribute range, major coverage types, and operations on coverages. Geographic coverage standards provide a common technology language and guide the development of interoperable services on coverage data. Geographic coverage services perform various functionalities for coverage including collecting, archiving, cataloging, publishing, distributing, and processing of coverage data. Geographic coverage services compliant with standard schema and interfaces are interoperable. They can be described, published and found in standard service catalogues, be accessed by all compliant clients, and be connected in order to construct service chains to accomplish complex geospatial modeling tasks.

Cross References

► Geographic Coverage Standards and Services

References

1. ISO: ISO/TC211, ISO 19123 Geographic information – Schema for coverage geometry and functions (2005)

Crime Mapping

► CrimeStat: A Spatial Statistical Program for the Analysis of Crime Incidents
► Hotspot Detection, Prioritization, and Security

Crime Mapping and Analysis

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Synonyms

Spatial analysis of crime; Spatial aspects of crime; Statistical techniques; Geographical analysis; Environmental criminology; First law of geography; Rational choice; Route activity; Social disorganization

Definition

The term “crime mapping” is inaccurate as it is overly simplistic. Crime mapping is often associated with the simple display and querying of crime data using a Geographic Information System (GIS). Instead, it is a general term that encompasses the technical aspects of visualization and statistical techniques, as well as practical aspects of geographic principles and criminological theories.

From a technical standpoint, the term is a combination of visualization and statistical techniques manifested as software. This combination of techniques is shared between mapping, spatial analysis and spatial data analysis. Mapping is simply a visualization tool that is used to display raw geographic data and output from analysis, which is done through a GIS. Spatial analysis is the statistical testing of geographic features in relation to other geographic features for patterns, or lack there of. Spatial data analysis is the combination of spatial analysis with associated attribute data of the features to uncover spatial interactions between features.

From a practical standpoint, crime mapping is a hybrid of several social sciences, which are geography, sociology and criminology. It combines the basic principles of geographic analysis, sociological and criminological theory and makes it possible to test conjectures from these disciplines in order to confirm or refute them as actual. In essence it has developed into an applied science, with its own tools, that examines a range of issues about society and its relationship with the elements that contribute to crime. Thus, crime mapping is interdisciplinary, involving other disciplines that incorporate the spatial perspectives of social phenomena related to crime, such as inequality, residential stability, unemployment, resource depravation, economic opportunities, housing availability, migration, segregation, and the effects of policy. Using a geographic framework often leads to a more comprehensive understanding of the factors that contribute to or suppress crime.

Even though the term “crime mapping” is a misnomer it will continue to be widely used as a general term with regard to the study of the spatial aspects of crime. Users of the term need to let the context of their work dictate which standpoint is being referred to.

Historical Background

Starting in the 1930s, crime mapping was used with limited success in the United States due to lack of data and the means to analyze that data, computational capacity. Thus, its value was simple depictions on paper of where crimes were occurring. For social science these depictions were not important until researchers from the Chicago School of Sociology combined criminological theory with geographic theory on a map. The result was the theory of social disorganization. Using a map, Shaw and McKay (1942)

overlaid residences of juvenile offenders with the Park and Burgess (1925) concentric zone model of urban land uses, including demographic characteristics. They discovered a geographic correlation between impoverished and blighted places with those that had most of the juvenile offender residences. This fostered a new line of research that examined the spatial aspects of crime that spanned from 1950 to the late 1970s. Despite the impact this had on furthering spatial theories of crime there was not much more that could be done because the basic principles of geographic analysis had not yet been operationalized into what geographer Jerome Dobson (1983) would call, "Automated Geography." Personal computers soon came afterwards, but software permitting empirical testing of these theories did not come until much later. It was at this point that crime mapping became useful to law enforcement, primarily to depict where crimes were occurring in order to focus resources (Weisburd and McEwen, 1997). However, there was not yet a relationship between academic institutions and law enforcement agencies to couple theories with actual observations from the street.

Crime mapping with computers made an entrance in the mid 1960s allowing the production of maps of crime by city blocks shaded by volume of incidents. This was still of little interest to researchers studying crime. Even though criminologists were becoming interested in the spatial analysis of crime they were not looking to other disciplines, including geography, for help in analyzing data using a spatial framework. A manifold of software programs from geography were available that could have been used, but there is little evidence in any of the social science literature that demonstrate that these programs were being used. Also neglected were principles of geographic analysis, to analyze the spatial aspects of data. With practitioners, their struggle was different. To produce maps of crime required serious computing infrastructure that, at the time, was only available within larger city government agencies, which did not hold making crime maps in high priority (Weisburd and McEwen, 1997).

The growth of environmental criminology in the 1980s, spearheaded by Paul and Patricia Brantingham, allowed the discipline of geography to make inroads into criminological theory (La Vigne and Groff, 2001). Environmental criminology fused geographical principles and criminological theory together with GIS and provided opportunities to empirically test the theories it was purporting. Significant contributions by George Rengert (1981 and 1989), Jim LeBeau (1987 and 1992) and Keith Harries (1974 and 1980), to environmental criminology using GIS and spatial statistics software continued, thereafter, to strengthen the role of geography in the study of crime. As a result, criminology now has several geographic theories of crime, including rational choice (Cornish and Clarke, 1986), routine activity (Cohen and Felson, 1979), and crime pattern theory (Brantingham and Brantingham, 1981). Social disorganization theory was also extended with geographical principles through the incorporation of simultaneous social interactions between adjacent neighborhoods. For a brief and succinct listing of these theories see Paulsen (2004). At this point, crime mapping branched out to become useful in a new practitioner-based area beyond law enforcement, the criminal justice agency. The confluence of geographic principles, criminological theory and advancing technology led to the development of crime prevention programs based on empirical evidence, such as 'Hot Spot' Policing.

In the late 1980s the Federal government played a role in advancing the use of the crime mapping. The National Institute of Justice (NIJ) funded several efforts under the Drug Market Analysis Program (DMAP) that brought together academic institutions with law enforcement agencies in five cities in the United States (La Vigne and Groff, 2001). The purpose was to identify drug markets and activities associated with them by tracking movement of dealers and users in and out of them. These grants were the first to promote working relationships between practitioners and researchers in the area of crime mapping to move them beyond the limitations each was facing not having the other as a partner.

Continuing improvements in GIS throughout the 1990s, and into the 2000s, made it possible to better assemble, integrate, and create new data. This is probably the greatest impact that GIS has had on crime mapping. Not only could a GIS assemble multiple and disparate sets of demographic, economic and social data with crime data, it could also create new units of analysis that better modeled human behavior. This capability afforded a more accurate understanding of the spatial interactions among offenders, victims and their environments that could be captured and analyzed in ways that more accurately represented human settlement and activity. This freed criminologists from being confined to the standard units of analysis, such as administrative boundaries from the US Census Bureau or other local governmental agencies. GIS provided the unique opportunity to represent boundaries of human activity more accurately through the creation of more distinct partitions, such as police beats or land use, as well as asymmetrical boundaries of human interaction created with buffers or density surfaces. In this regard, there is nothing else like GIS in the study of crime. For practitioners this freed them from having to depend on other government agencies to produce crime maps for law enforcement purposes, as well as provide opportunities to produce custom "on demand" maps for specific purposes, including search warrants or patrol deployment.

The late 1990s saw the advancement of crime mapping in not only both academic departments that study crime and law enforcement agencies, but also in the Federal government. NIJ established the Crime Mapping Research Center in 1997, now the Mapping and Analysis for Public Safety (MAPS) Program, for the purpose of conducting research and evaluation of the spatial aspects of crime. One year later NIJ provided money to the National Law Enforcement and Corrections Technology Center (NLECTC) Rocky Mountain Division to establish the Crime Mapping and Analysis Program (CMAP). This program was to provide assistance to law enforcement and criminal justice agencies specifically in the use of crime mapping. Into the 2000s all large agencies and most medium-sized agencies are using GIS as part of their analysis and operations efforts and are using crime mapping far beyond just the simple mapping of where crime is occurring. Research has continued to refine spatial theories of crime based on better coordination with practitioners, funding from Federal agencies and the development of software for the further understanding of crime through geography.

Scientific Fundamentals

Crime mapping, as an applied science, is ultimately about *where*. As a result, there are contributions from primarily two social science disciplines that make up the foundations of crime mapping. The first provides a set of principles that sets the stage for the study of crime within a spatial framework, geography. The second provides a set of specific spatial theories about criminal activity and environmental conditions that form the foundation of the spatial aspects of crime, criminology.

Geographic Principles

A complete understanding of crime is facilitated by two sets of factors: individual and contextual. Crime mapping deals with the contextual. Therefore, geographic principles are necessary to understand that context. These principles provide a framework for measuring the interactions between places. Analysis in that framework is possible combining long standing geographic principles that have been implemented through GIS and spatial data analysis software. GIS facilitates the visualization of raw data and the results from statistical analysis. Spatial statistical techniques extend traditional statistics to form a more complete approach toward understanding social problems, including crime. The following are the three basic geographic principles that are the foundation for the contextual analysis of crime.

Place

Criminology has a long history of looking at the geographical influences on crime. Some of the most significant pieces of work were in regards to the study of crime in neighborhoods, communities, cites, regions and even across the United States (Brantingham and Brantingham, 1981; Reiss, et al., 1986; Bursik and Grasmick, 1993; Weisburd, et al., 1995). These studies identify "places" in which criminology seeks to understand criminal activity. The focus of studying crime in place demonstrates the use of geography as a framework for contextual analysis that no other discipline can offer. Place becomes the cornerstone because it allows for the categorizing of space by defining a geographic unit of analysis for the systematic measurement of human and environmental characteristics in relation to neighboring places.

Tobler's First Law of Geography

Places are not isolated islands of activity. Interactions, such as social, demographic, or economic occur within and between places. These interactions form spatial relationships based on the concept that those things closer together in space are more related. That is, changes in human activity and physical environments change slowly across space, with abrupt changes being out of the ordinary. Named after Waldo Tobler (1970), this law forms the theoretical foundation for the concept of distance decay that is used for analysis of these spatial interactions and relationships which then allows for measurement in the strength of interactions between places.

Spatial Processes

Human interactions that occur within, and between, geographic places form two concepts: spatial heterogeneity and spatial dependence. Spatial heterogeneity is the variability of human and environmental conditions across space. At the local level this is change across a defined space where conditions, such as racial composition, economic stability, housing conditions, land use, or migration vary. These things are not evenly distributed across space and form various patterns, at different scales, and in multiple directions, all of which are asymmetric. Spatial dependence represents the strength of a relationship of some phenomenon between places that have influence on each other, a concept known as spatial autocorrelation. These patterns range from clusters to randomly distribution to dispersed to uniform. These are indications that human activity and the environments which they develop have a wide range of variability, one that usually follows systemic patterns.

Criminological Theories

Criminology has developed a set of spatial theories of crime that have utilized all three of the geographic principles listed.

Rational Choice

Rational choice theory is based on classical ideas that originated in the 1700s, with the work of Cesare Beccaria and others who took a utilitarian view of crime (Beccaria, 1764). This perspective suggests that criminals think rationally and make calculated decisions, weighing costs and risks of committing a crime against potential benefits while being constrained by time, cognitive ability and information available resulting in a 'limited' rather than 'normal' rationality (Cornish and Clarke, 1986). In this sense, rational choice theory also brings in economic ideas and theories into criminology.

Routine Activities

Routine activities theory helps explain why crime occurs at particular places and times. The theory suggests that crime opportunities are a function of three factors that converge in time and place, including a motivated offender, suitable target or victim, and lack of a capable guardian (Cohen and Felson, 1979). A fourth aspect of routine activities theory, suggested by John Eck, is place management. Rental property managers are one example of place managers (Eck and Wartell, 1997). They have the ability to take nuisance abatement and other measures to influence behavior at particular places. Criminals choose or find their targets within context of their routine activities, such as traveling to and from work, or other activities such as shopping, and tend not to go that far out of their way to commit crimes (Felson, 1994).

Crime Pattern

Crime pattern theory looks at the opportunities for crime within context of geographic space, and makes a distinction between crime events and criminality, that is, the propensity to commit crime (Brantingham and Brantingham, 1981). Crime pattern theory integrates rational choice and routine activities theories, with a geographic framework, place. The theory works at various geographic scales, from the macro-level with spatial aggregation at the census tract or other level, to the micro-scale with focus on specific crime events and places. Crime pattern theory focuses on situations or places where there is lack of social control or guardianship over either the suspect or victim, combined with a concentration of targets. For example, a suburban neighborhood can become a hot spot for burglaries because some homes have inadequate protection and nobody home to guard the property.

Social Disorganization

Social disorganization theory emphasizes the importance of social controls in neighborhoods on controlling behavior, particularly for individuals with low self-control or a propensity to commit crime. Social controls can include family, as well as neighborhood institutions such as schools and religious places. When identifying places with social disorganization, the focus is on ability of local residents to control social deviancy (Bursik and Grasmick, 1993). Important factors include poverty, as well as turnover of residents and outmigration, which hinder the development of social networks and neighborhood institutions that lead to collective efficacy (Sampson, Raudenbush, and Earls, 1997).

Key Applications

There are five key applications in crime mapping. These applications are thematic mapping, non-graphical indicators, hot spots, spatial regression and geographic profiling. They make up a full compliment of techniques from elementary to advanced.

Thematic Mapping

Thematic maps are color coded maps that depict the geographic distribution of numeric or descriptive values of some variable. They reveal the geographic patterns of the underlying data. A variable can be quantitative or qualitative. Quantitative maps provide multiple techniques for categorizing the distribution of a variable. Qualitative maps provide a mechanism for classification of some description, or label, of a value. They are often shaded administrative or statistical boundaries, such as census blocks, police beats or neighborhoods. For example, robbery rates based on population can be derived for neighborhood boundaries giving an indication of the neighborhoods that pose the highest risk. However, locations can be symbolized to show quantities based on size or color of the symbol. For example, multiple crime events at a particular location give an indication of repeat victimization, such as common in burglary. However, simple visualization of values and rates can be misleading, especially since the method of classification can change the meaning of a map. Spatial statistics are then used to provide more rigorous and objective analysis of spatial patterns in the data.

Non-Graphical Indicators

Non-graphical statistical tests produce a single number that represents the presence of the clustering of crime incidents or not. These are global level statistics indicating the strength of spatial autocorrelation, but not its location. They compare actual distributions of crime incidents with random distributions. Positive spatial autocorrelation indicates that incidents are clustered, while negative indicates that incidents are uniform. Tests for global spatial autocorrelation within a set of points include Moran's I, (Chakravorty, 1995), Geary's C statistic, and Nearest Neighbor Index (Levine, 2005). After visualizing data in thematic maps these are the first statistical tests conducive to determining whether there are any local level relationships between crime and place exist.

Hot Spots

Hot spots are places with concentrations of high crime or a greater than average level of crime. The converse of a hot spot is a *cold spot*, which are places that are completely, or almost, devoid of crime. Identification and analysis of hot spots is often done by police agencies, to provide guidance as to where to place resources and target crime reduction efforts. Hot spot analysis can work at different geographic levels, from the macro-scale, looking at high crime neighborhoods, or at the micro-scale to find specific places such as particular bars or street segments that are experiencing high levels of crime (Eck et al., 2005). Depending on the level of analysis, police can respond with specific actions such as issuing a warrant or focusing at a neighborhood level to address neighborhood characteristics that make the place more criminogenic. A variety of spatial statistical techniques are used for creating hot spots, such as density surfaces (Levine, 2005), location quotients (Isserman, 1977; Brantingham and Brantingham, 1995; Ratcliffe, 2004), local indicators of spatial autocorrelation (LISA) (Anselin, 1995; Getis and Ord, 1996; Ratcliffe and McCullagh, 1998), and nearest neighborhood hierarchical clustering (Levine, 2005).

Spatial Regression

Regression techniques, such as Ordinary Least Squares (OLS), have been used for quite some time in criminology as explanatory models. This technique has a major limitation, in that it does not account for spatial dependence inherent in almost all data. Holding to geographic principles, a place with high crime is most likely surrounded by neighbors that also experience high crime, thereby displaying spatial autocorrelation, i. e. a spatial effect. Spatial regression techniques, developed by Luc Anselin (2002), take into account spatial dependence in data. Not factoring these spatial effects into models makes them biased and less efficient. Tests have been created for identifying spatial effects in the dependent variable (spatial lag) and among the independent variables (spatial error). If tests detect the presence of spatial lag or error, this form of regression adjusts the model so that spatial effects do not unduly affect the explanatory power of the model.

Geographic Profiling

Geographic profiling is a technique for identifying the likely area where a serial offender resides or other place such as their place of work, that serves as an anchor point. Geographic profiling techniques draw upon crime place theory and routine activities theory, with the assumption that criminals do not go far out of their daily routines to commit crimes. Geographic profiling takes into account a series of crime locations that have been linked to a particular serial criminal and creates a probability surface that identifies the area where the offender's anchor point may be (Rossmo, 2000; Canter, 2003). Geographic profiling was originally developed for use in serial murder, rapes, and other rare but serious crimes. However, geographic profiling is being expanded to high-volume crimes such as serial burglary (Chainey and Ratcliffe, 2005).

Future Directions

The advancement of research and practice in crime mapping rests on continuing efforts in three areas: efforts by research and technology centers, software development, and expansion into law enforcement and criminal justice. Crime mapping research and technology centers, such as the MAPS Program, the CMAP and the Crime Mapping Center at the Jill Dando Institute (JDI), are primary resources for research, development and application of GIS, spatial data analysis methodologies and geographic technologies. These three centers serves as conduits for much of the work conducted in both the academic and practitioner communities. The MAPS Program is a grant funding and applied research center that serves as a resource in the use of GIS and spatial statistics used in crime studies. The program awards numerous grants for research and development in the technical, applied and theoretical aspects of using GIS and spatial data analysis to study crime, as well as conduct research themselves. As a counterpart to the MAPS Program, CMAP's mission is to serve practitioners in law enforcement and criminal justice agencies by developing tools and training materials for the next generation and crime analysts and applied researchers in the use of GIS and spatial analysis.

In the UK the Jill Dando Institute of Crime Science has a Crime Mapping Center that contributes to the advancement in understanding the spatial aspects of crime with an approach called "crime science." This approach utilizes theories and principles from many scientific disciplines to examine every place as a unique environment for an explanation of the presence or absence of crime. They conduct applied research and provide training with their unique approach on a regular basis. The MAPS Program and the Crime Mapping Center at the JDI hold conferences on a regular basis. These events form the nexus for practitioners and researchers to work together in the exchange of ideas, data, experiences and results from analysis that create a more robust applied science.

Software programs are vital to the progression of the spatial analysis of crime. These programs become the scientific instruments that researchers and practitioners need in understanding human behavior and environmental conditions as they relate to crime. Software, such as CrimeStat, GeoDa and spatial routines for 'R' are being written to include greater visualization capabilities, more sophisticated modeling and mechanisms for seamless operation with other software. For example, in version three of CrimeStat the theory of travel demand was operationalized as a set of routines that apply to criminals as mobile agents in everyday life. GeoDa continues to generate robust tools for visualization based on the principles of Exploratory Data Analysis (EDA). New and cutting edge tools for geographic visualization, spatial statistics and spatial data analysis are being added to the open statistical development environment 'R' on a regular basis. All of these programs provide a rich set of tools for testing theories and discovering new patterns that reciprocally help refine what is known about patterns of crime. The emergence of spatial statistics has proven important enough that even the major statistical software packages, such as SAS, SPSS, and Stata are all incorporating full sets of spatial statistics routines.

The application of crime mapping is expanding into broader areas of law enforcement and criminal justice. In law enforcement mapping is taking agencies in new directions toward crime prevention. For example, the Computer Mapping, Planning and Analysis of Safety Strategies (COMPASS) Program, funded by the NIJ, combines crime data with community data where crime is a characteristic of populations rather than a product. That is to say crime is, at times, a cause of conditions rather than the result of conditions. It is an indicator of the "well being" of neighborhoods, communities or cities. Shared with local level policy makers, COMPASS provides a view into this "well being" of their communities. Resources can be directed to those places that are not "well" and helps to understand what makes other places "well." Combined with problem-oriented policing, a strategy that addresses specific crime problems, this approach can be effective in reducing crime incidents and a general reduction in social disorder (Braga et al., 1999). Coupled with applications in criminal justice, mapping can be utilized to understand the results of policy and the outcomes. This includes topics important to community corrections in monitoring or helping returning offenders, including registered sex offenders. Or, mapping can be of use in allocating probation and parole officers to particular geographic areas, directing probationers and parolees to community services, and selecting sites for new community services and facilities (Karuppannan, 2005). Finally, mapping can even help to understand the geographic patterns of responses to jury summons to determine if there are racial biases are occurring in some systematic way across a jurisdiction (Ratcliffe, 2004).

These three elements will persist and intertwine to evermore incorporate the geographic aspects of basic and applied research of crime through technology. The advancement of knowledge that crime mapping can provide will require continued reciprocation of results between research and practice through technology (Stokes, 1997). The hope is that researchers will continue to create new techniques and methods that fuse classical and spatial statistics together to further operationalize geographic principles and criminological theory to aid in the understanding of crime. Practitioners will implement new tools that are developed for analyzing crime with geographic perspectives. They will also continue to take these tools in new directions as "improvers of technology" (Stokes, 1997) and discover new patterns as those tools become more complete in modeling places.

Cross References

- ▶ Autocorrelation, Spatial
- ▶ CrimeStat: A Spatial Statistical Program for the Analysis of Crime Incidents
- ▶ Data Analysis, Spatial
- ▶ Exploratory Visualization
- ▶ Hotspot Detection, Prioritization, and Security
- ▶ Patterns, Complex
- ▶ Spatial Econometric Models, Prediction
- ▶ Spatial Regression Models
- ▶ Statistical Descriptions of Spatial Patterns
- ▶ Time Geography
- ▶ Visualizing Constraint Data

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