[DA-013] GIS&T in Criminal Justice and Law Enforcement

Abstract

Linking crime and place has been the objective of crime mapping since the early nineteenth century. Contemporary scholars have since investigated spatio-temporal crime patterns to explain why crime concentrates in certain places during certain times. Collectively, this body of research has identified various environmental and situational factors that contribute to the formation of crime hot spots and spawned widespread crime prevention and reduction strategies commonly referred to as place-based policing. Environmental criminology guides the bulk of this crime-and-place research and provides a means for interpreting place and crime. The chapter details theories behind place-based policing, examples of place-based policing strategies that leverage geographic information science and its associated technologies (GIS&T), and relevant data visualization tools used by law enforcement to implement place-based strategies to address crime.

Keywords: crime, law enforcement, place, place-based, police, social clusters, social justice, social sciences, spatial patterns, urban

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Explanation

1. **Definitions**
2. **Introduction**
3. **Background in Environmental Criminology**
4. **Place-based Policing**
5. **Crime Mapping Data Visualization**

1. Definitions

Environmental Criminology: a family of theories that examine crime related to distinct places and how individuals and organizations shape their activities by place-based or environmental factors.

Geographic Profiling: a place-based investigative tool used to identify the most probable area in which a serial offender lives or operates.

Hot Spot Policing: place-based law enforcement strategy that involves focusing limited resources on “small places in which the occurrence of crime is so frequent that it is highly

predictable" (Sherman, 1995, p. 36).

Repeat/Near Repeat Analysis: investigates the likelihood of people or targets being victimized more than once, which is greater than the likelihood of someone or someplace being victimized for the first time.

Routine Activities Theory: a framework for understanding how the likelihood of criminal victimization is affected by the convergence in space and time of three primary factors: a suitable target of victimization, a likely offender, and the absence of a guardian willing and able to prevent an incident.

2. Introduction

Linking crime and place has been the objective of crime mapping since the early nineteenth century when cartographers Adriano Balbi and André Michel Guerry developed a series of choropleth maps depicting suicide and crime in France (LaVigne, Fleury, and Szakas, 2000; Hunt, 2019). Contemporary scholars have since investigated spatio-temporal crime patterns to explain why crime concentrates in certain places during certain times. Collectively, this body of research has identified various environmental and situational factors that contribute to the formation of crime hot spots and spawned widespread crime prevention and reduction strategies commonly referred to as place-based policing.

Environmental criminology is the theoretical framework (Brantingham and Brantingham, 1991) that traditionally guides the bulk of this crime-and-place research. Further, environmental criminology provides a means for interpreting place and crime (vis a vi crime maps) through relevant theories such as routine activities theory (Cohen and Felson, 1979), rational choice theory (Clarke and Cornish, 1993; 2008), and the geometry of crime (Brantingham and Brantingham, 1995). The chapter provides further detail on the theories that guide place-based policing, examples of place-based policing strategies that leverage geographic information science and its associated technologies (GIS&T), and relevant data visualization tools used by law enforcement to implement place-based strategies to address crime.

3. Background on Environmental Criminology

Research in the existing environmental criminology literature (Brantingham and Brantingham, 2013; Brantingham, Brantingham, and Andresen, 2016) guides GIS&T in criminal justice and law enforcement. Environmental criminology is a family of theories that examine crime related to distinct places and how individuals and organizations shape their activities by place-based or environmental factors (Bottoms and Wiles, 1997). Environmental criminologists argue that crime patterns emerge from the opportunity structures in the environment for offenders to commit a crime, which three well-established lines of empirical inquiry can explain: routine activities theory (Cohen and Felson, 1979), rational choice theory (Clarke and Cornish, 1985), and the geometry of crime (Brantingham and Brantingham, 1995). It is essential to discuss these theories because they are directly applicable to the application and utility of GIS and crime mapping within the fields of criminal justice and law enforcement.

3.1 Rational Choice Theory

In the 1960s and 1970s, Ronald Clarke and Derek Cornish sought to understand the long-

term behavioral effects of various institutional treatments on juvenile delinquency (1985). When comparing rates of runaways and other forms of misconduct at treatment centers, Clark and Cornish found that the frequency of behavioral problems varied widely among youths, even though centers serviced the same types of minors. Subsequently, they began questioning whether specific environmental factors in the centers were associated with more misconduct and opportunities for delinquency. Contemporary proponents of rational choice theory argue that crime and delinquency are rooted in a rational decision-making process, but it is apparent that some environments create situations that afford more opportunities for offending than others (Cornish and Clarke, 2008).

Complicating the idea that a likely offender is motivated by rational choices is the notion that individuals often operate under a limited knowledge about alternatives or bounded rationality (Simon, 1979). The decision-making process of offenders varies by individual and social context (lifestyle). For instance, Jacobs and Wright (1999), sampled active armed robbers and found that street offenders placed a more considerable value on intrinsic rewards such as status over the financial return of their actions. Copes and Vieraitis (2009) interviewed individuals serving time for identity theft. They found that even though economic incentives were a primary motivator, decisions are bounded by desired lifestyles and perceptions of law enforcement's (in)effectiveness.

3.2 Routine Activities Theory

Routine activities theory suggests that a likely offender and a suitable target must converge in space and time, without the presence of a “guardian” who is capable and willing to intervene for a crime to occur (Cohen and Felson, 1979). The initial focus of routine activities theory explored macro-level factors that influenced human behavior and linked these behaviors to increased crime rates during the post-World War II era. Researchers have since focused on how agents move through the built environment and how everyday movements shape the likely convergence of potential victims, offenders, and guardians (Felson, 2016). Although the current focus of routine activities theory is still primarily based on the three elements necessary for a crime to occur, it recognizes the critical role the environment plays in influencing how we move through the physical landscape and the subsequent link between that movement and criminal opportunities (Felson and Eckert, 2016).

For example, Eck and Madensen-Herold’s (2018) research focuses on the relationship between neighborhood-level characteristics and crime, by examining the decisions made by a specific type of guardian called a place manager. They argue that one of the most important reason that some neighborhoods have higher levels of crime compared to others is that high-crime neighborhoods tend to have a greater proportion of place managers who are not willing or capable of preventing suitable targets from being victimized by likely offenders. In short, they show that place managers’ decisions can directly impact the high concentration of crime in particular environments.

3.3 Crime Pattern Theory

The geometry of crime emerged from the work of Paul and Patricia Brantingham (1991, 1995, 2013) and their efforts to understand and explain spatio-temporal crime patterns. The Brantinghams’ approach to understanding crime incorporated elements of environmental psychology, transportation research, and research from criminology. New

concepts emerged from the geometry of crime theory that demonstrated how agents move through the physical world, the relationship between those movements and criminal opportunities, and how crime patterns emerge from this spatial behavior. These concepts include activity nodes, activity space, awareness space, pathways, and the environmental backcloth that defines the physical landscape. Crime generators (i.e., activity nodes that create criminal opportunities due to high flows of people) and crime attractors (i.e., activity nodes where individuals who have a greater willingness to commit crimes congregate) are also fundamental concepts related to this perspective. These theories as combining into the meta-theory of crime pattern theory which emphasizes the role of context (built environmental) influences human behavior as it relates to crime (Brantingham, Brantingham, and Andresen, 2016). Since its introduction, place-based researchers have studied how these concepts explain where crime occurs at a micro-geographic level.

4. Place-based Policing

Environmental criminology helps us understand why crime is not randomly distributed in space and time. From this growing body of empirical evidence, we know that a small proportion of urban areas typically accounts for a disproportionate amount of crime, a phenomenon known as the law of crime concentration (Weisburd, 2015). In response, law enforcement agencies can identify criminogenic places within their jurisdictions so that they can apply various place-based policing strategies designed to prevent and reduce crime. These strategies typically involve focusing on crime “clusters” and employing various techniques to influence offender behavior in these locations (Weisburd and Braga, 2006). Hot spot policing is one of the most common place-based policing strategies used by law enforcement today, and GIS&T is a crucial component of this effective crime-fighting approach (National Academies of Sciences, Engineering, and Medicine, 2018).

4.1 Hot Spot Policing

Hot spot policing is a place-based law enforcement strategy that involves focusing limited resources on “small places in which the occurrence of crime is so frequent that it is highly predictable” (Sherman, 1995, p. 36). The number of law enforcement agencies using hot spot policing has increased over the past few decades; today, hot spot policing is used by most police departments in the U.S. (Braga, Papachristos, and Hureau, 2012). The widespread adoption of hot spot policing can be attributed to myriad reasons, including a growing body of empirical evidence that shows it is a practical approach to reducing crime. Furthermore, this method allows agencies to implement strategies tailored to their jurisdiction and specific crime types or order-maintenance problems. Agencies engaged in hot spot policing can also leverage powerful GIS&T to keep the public, and other agency stakeholders informed quickly and easily about their crime-fighting efforts and their impact on crime (National Institute of Justice, 2013). See Hot Spot Mapping below for more information.

4.2 Geographic Profiling

Although not a specific place-based policing strategy, geographic profiling is a place-based investigative tool used to identify the most probable area in which a serial offender lives (Rossmo, 1999). Based on the known locations of crime events believed to be committed as part of a series of offenses, geographic profiling focuses on “the probable spatial behavior of the offender within the context of the locations of, and the spatial relationships between,

the various crime sites" (Rossmo, 1999, p. 161). A psychological profile is created from the known spatio-temporal crime data that provides investigators with insights into an offender's likely motivation, behavior, and lifestyle. This enables criminal investigators to connect an offender's spatial activity to a geographic profile that can be used to develop a picture of the person responsible for the crimes being investigated. At the heart of geographic profiling is the idea that serial offenders are less likely to commit offenses close to their homes, and that offenders will not travel too far to commit additional crimes (Townsley and Sidebottom, 2010). These journey-to-crime assumptions were used to create the original geographical profiling algorithm (Rossmo, 1999).

4.3 Repeat/Near Repeat Analysis

Repeat (R) and near repeat (NR) pattern analysis has received considerable attention from environmental criminologists and law enforcement agencies engaging in place-based policing. This analytic technique is built on the empirical evidence that shows the likelihood of people or targets being victimized more than once is greater than the likelihood of someone or someplace being victimized for the first time (Groff and Taniguchi, 2019; Townsley, Homel, and Chaseling, 2003). Two competing explanations are used to understand R/NR patterns. The boost account suggests that R/NR crime patterns emerge in data because the same offender returned to where they successfully committed their initial offense because familiar environment and opportunity structure. Alternatively, the flag account suggests that characteristics of a person or target entice potential offenders and that these characteristics remain constant over time, resulting in repeat victimization. Simply put, the boost account explains repeat patterns in crime data in terms of the offender, whereas the flag account explains it in terms of the target or victim. R/NR patterns can easily be identified using the Near Repeat Calculator, which is available as a standalone software from Ratcliffe (2008) and in an R implantation from Steenbeek (2018).

5. Crime Mapping Data Visualization

Ratcliffe (2016) points out that placed-based policing serves as a targeting mechanism for intelligence-led policing. In practice, this type of policing strategy depends on GIS-based crime mapping for identifying both non-random spatial patterns (i.e., hot spots) (Eck, Chainey, Cameron, and Wilson, 2005) and temporal patterns (Ratcliffe, 2002; Hart, 2021) of crime.

5.1 Hot Spot Mapping

Hot spot mapping often utilizes an interpolation method, a transformation technique in developing crime patterns, called density estimation. This technique is carried out by overlaying a map layer containing the known geographic locations of crime incidents -- typically visualized as points data -- with a grid. Interpolation is an increasingly popular method for visualizing the distribution of crime and identifying hot spots (Eck et al., 2005). A popular interpolation method for visualizing crime patterns on maps is called Kernel Density Estimation (KDE). Density estimation takes data points and transforms them into a continuous crime risk surface based on a predefined spatial resolution of an overlay grid of cells is informed by the parameters of the kernel function (often symbolized as k). The cartographic output of density estimation, or smoothing, produces aesthetically pleasing maps that use color transition between class breaks. Therefore, the weights produced for each cell are related to the kernel's functional form, along with its search radius. Eck et al.

(2005) describe the application of the kernel density method in three steps:

1. A fine grid is generated over the point distribution. In most cases, the user has the option to specify the grid cell size.
2. A moving three-dimensional function of a specified radius visits each cell and calculates weights for each point within the kernel's radius. Points closer to the center receive a higher weight and contribute more to the cell's total density value.
3. Final grid cell values are calculated by summing the values of all circle surfaces for each location.

The primary objectives of k-means spatial interpolation approach, as given in Grubesic (2006), are (1) to minimize the total weighted squared difference in cluster group membership subject to the constraints (2) to ensure that each observation is assigned to a cluster group and (3) to impose integer restrictions on decision variables.

Eck et al. (2005) provide a brief overview of the various methods that can be used to identify crime hot spots and some of the common software applications used in crime pattern analysis. In their report, they argue that the most suitable method for visualizing crime data is as a continuous surface derived from quartic KDE (see Yin [2020] for an expanded description of KDE methods). Hart and Zandbergen (2014) discovered that the predictive accuracy of KDE hot spot maps can be influenced greatly by the various parameters (i.e., the density function and search radius) that must be defined during the KDE process and that these settings may be unique for specific types of crime. For example, they found that KDE hot spot crime maps varied significantly by interpolation method and that predictive accuracy for robbery varied with search radius cell size. Generating hot spot maps from incident data is fairly straightforward in modern GIS software packages. The map in Fig. 1 provides an example for auto-thefts in Redlands from 2016-2020, with the kernel density function applied at a specified raster cell scale which is most typically utilized by law enforcement agencies.

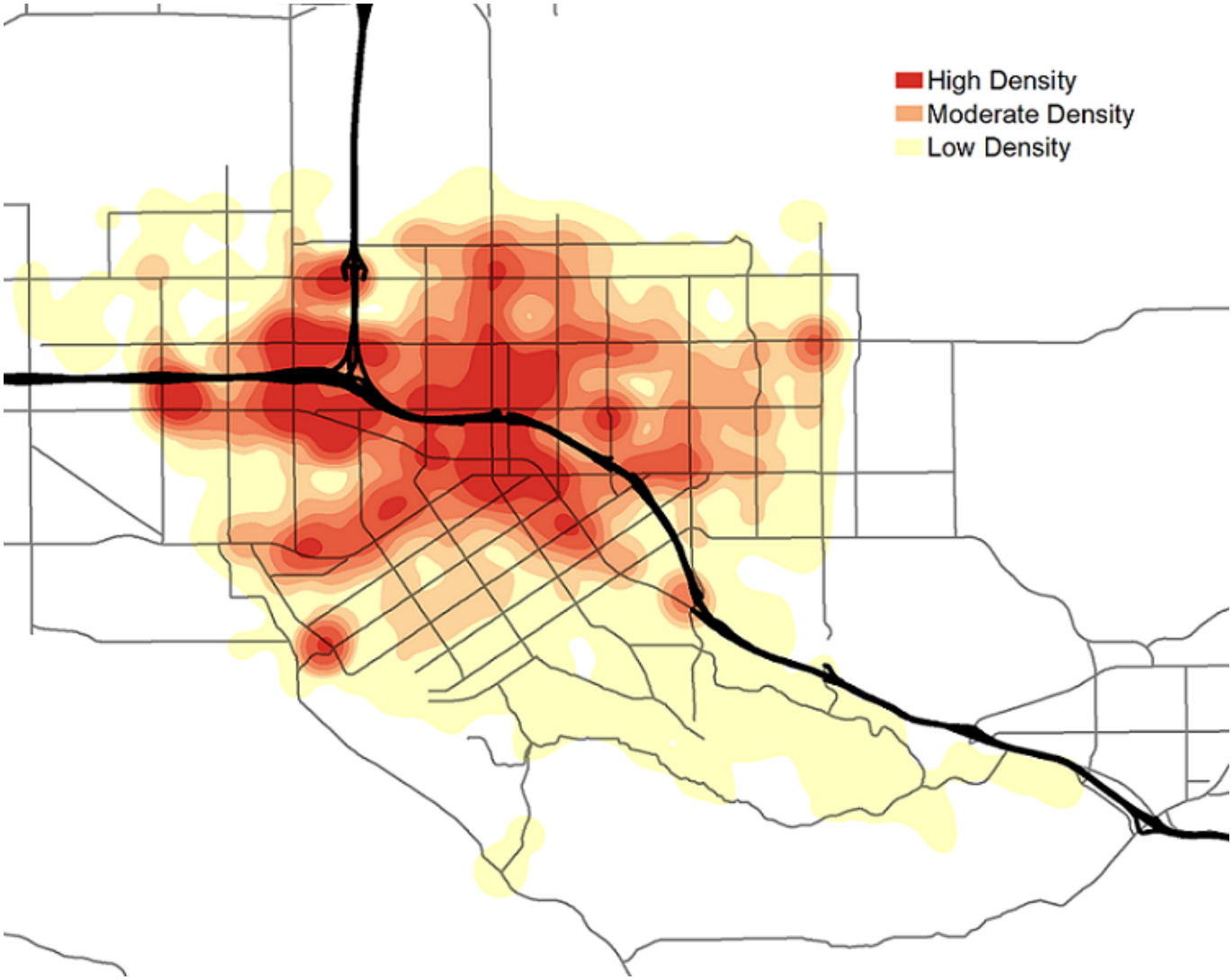


Figure 1. Hotspot map with kernel density function at raster cell scale. Source: authors.

5.2 Space-Time Mapping

The cartographic representation of crime faces an ongoing challenge from mobility. The practice of mapping a crime is traditionally realized by highlighting a single point or an aggregated single point, which can be aligned with the convergence of the elements of the conceptual crime triangle (offender, opportunity, and victim). However, reducing a crime event to a single point may not effectively serve the investigative process. Due to their inherent mobility, certain crime events (such as theft on a crowded public vehicle in transit) defy cartographic representation, at least by conventional means.

Unless there is a personal record victim or other documented evidence of a crime, many crimes occur at times that are not specifically determinant. In these cases, such as vacant home burglary or vehicle theft, a method for narrowing the temporal scope is helpful for investigation. The aoristic analysis provides a methodology for calculating the probability that an event occurred at a location within a given time range resulting in a probability weighting that should be useful for crime (Ratcliffe and McCullagh, 1998). The aoristic weighting then occurs when a temporal query interrogates a linear/unidirectional timeline

or span across which a given crime could have occurred. For instance, we know that the business location burglarized between 6 pm and 8 pm (a defined search parameter). Aoristic analysis has been proposed for estimating a probable incident at a known location and holds utility for police over an unknown time (Andresen and Jenion 2004).

We can visualize the concept of aoristic analysis by extending the temporal variable along the third dimension (3D) at the crime locations mapped onto the two-dimensional (2D) plane, allowing us to (Ratcliffe, 2000). Each column in this example represents a period across which the crime occurred (Fig. 2).

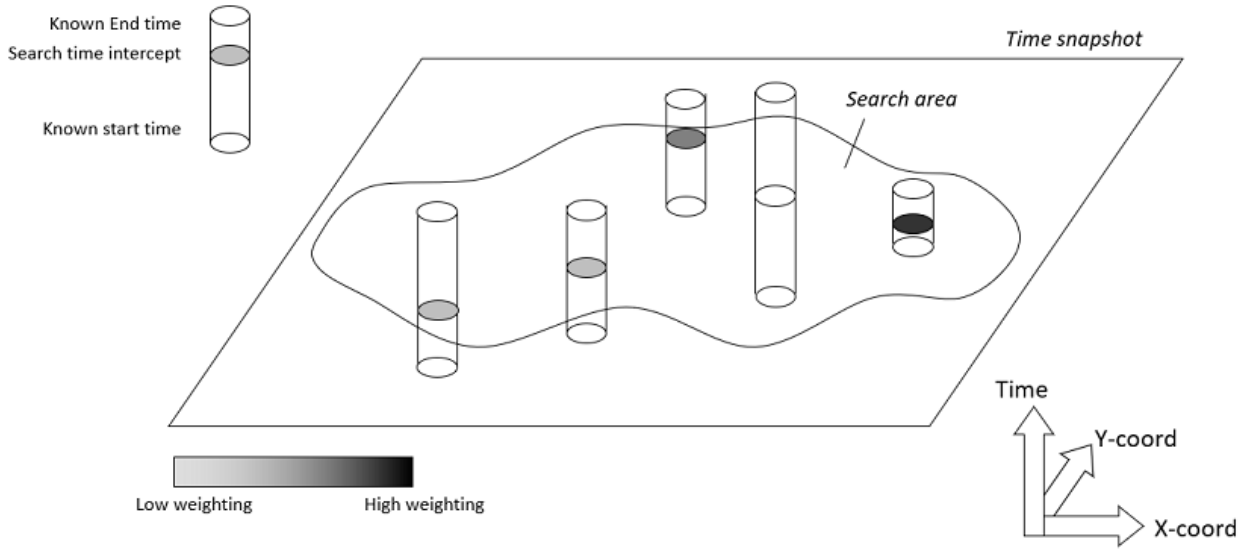


Figure 2. Graphic example of aoristic mapping adapted from Ratcliffe (2000). Source: authors.

Similar to the provided example of aoristic mapping, the time-geographic mapping of crime events utilizes the 3D approach to space-time representation. Uncertainty is captured at the space-time map intersection as a shaded disk in the middle of the column (aroistic weighting). The higher aoristic weights are provided in a darker shade, while the lower ones are lighter, allowing for a bivariate choropleth mapping. In a similar approach, Morgan (2010) proposed utilizing Hägerstrand's (1970) time geographic framework to carry out the creation of a serial offender geographic profile (Fig. 3).

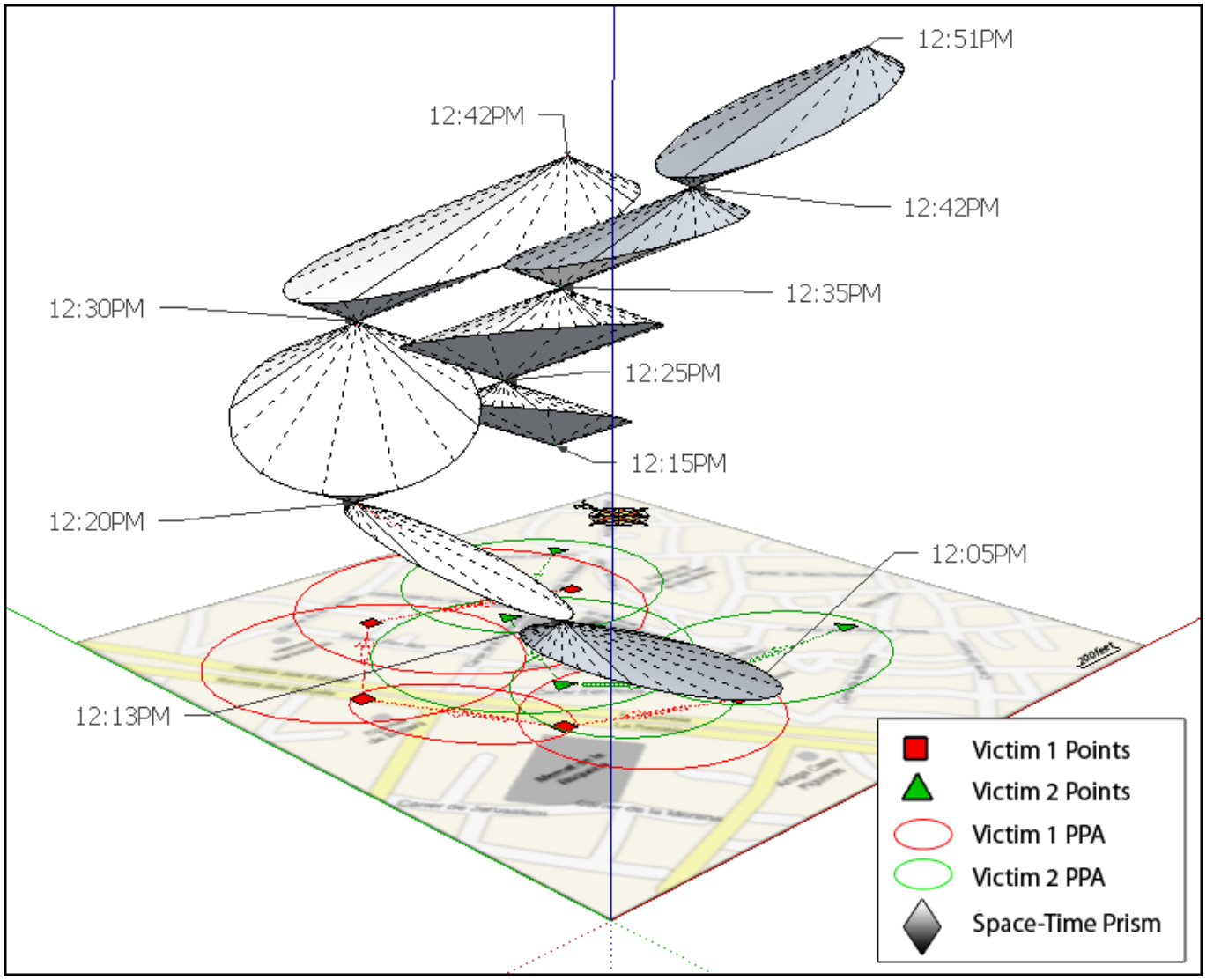


Figure 3. Conceptual example of time-geographic mapping for offender profiling. Source: authors.

A time-geographic approach to mapping crime is visually robust, as the representations can include more specific elements of uncertainty, such as the space-time prisms shown in Fig. 3. However, as was noted in Ratcliffe's (2000) discussion on aoristic mapping and Morgan and Steinberg's (2003) assessment of criminal time geographic profiling, the benefits of these additional visual constructs should be balanced by the context of use in crime analysis.

Commercial GIS implementations to time-geographic tools within the context of crime mapping have most notably in GeoTime (Uncharted Software Inc.). For instance, Rossmo, Lu and Fang (2012) utilized GeoTime to investigate the spatial-temporal patterns of repeat offender activity spaces. More recently, Schmitz (2016) used GeoTime to explore fraud cases in supply chain systems. Finally, in recent versions of its popular desktop GIS tool, Esri has provided functionality within its GIS software to support this type of space-time mapping. These additional tools hold promise for the future of integrating temporal analysis tools into standard GIS tools.

References

Andresen, M. A., and Jenion, G. W. (2004). The unspecified temporal criminal event: What is unknown is known with aoristic analysis and multinomial logistic regression. Western Criminology Review, 5(3).

Bottoms, A. E., & Wiles, P. (1997). Environmental Criminology. In M. Maguire, R. Moran, & R. Reiner (Eds.), The Oxford handbook of Criminology (pp. 620-656). Oxford: Clarendon Press.

Braga, A., Papachristos, A., and Hureau, D. (2012). Hot spots policing effects on crime. Campbell Systematic Reviews, 8(1), 1–96.

Brantingham, P. J., and Brantingham, P. L. (1991). Environmental criminology (2nd ed). Prospect Heights, IL: Waveland Press.

Brantingham, P. J., and Brantingham, P. L. (2013). Crime pattern theory. In Environmental criminology and crime analysis (pp. 100-116). Willan.

Brantingham, P. J., Brantingham, P. L., and Andresen, M. A. (2016). The geometry of crime and crime pattern theory. In R. Wortley and M. Townsley (Eds.). Environmental criminology and crime analysis (2nd ed., pp. 119-136). Abingdon, Oxfordshire: Routledge.

Brantingham, P. L., and Brantingham, P. J. (1995). Criminality of place: crime generators and crime attractors. European Journal on Criminal Policy and Research, 3(3), 5–26.

Clarke, R. V., and Cornish, D. B. (1985). Modeling Offenders' Decisions: A Framework for Research and Policy. Crime and Justice, 6, 147-185.

Cohen, L. E., and Felson, M. (1979). Social change and crime rate trends: A routine activity approach. American Sociological Review, 44, 588-608.

Copes, H., and Vieraitis, L. M. (2009). Bounded rationality of identity thieves: Using offender-based research to inform policy. Criminology & Public Policy, 8(2), 237-262.

Cornish, D. B., and Clarke, R. V. (2008). The rational choice perspective. In R. Wortley and L. Mazerolle (Eds.), Environmental Criminology and Crime Analysis (2nd ed., pp. 29–61). Abingdon, Oxfordshire: Routledge.

Cornish, D. B., and Clarke, R.V. (1987). Understanding crime displacement: An application of rational choice theory. Criminology, 25(4), 933–948.

Cullompton, UK: Willan Publishing. Eck, J., Chainey, S., Cameron, J., and Wilson, R. (2005). Mapping crime: Understanding hotspots. NIJ Special report.

Eck, J. E., & Madensen-Herold, T. D. (2018). Place Management, Guardianship, and the Establishment of Order. In Daniel S. Nagin, Francis T. Cullen, and Cheryl Lero Jonson (Eds.) Deterrence, Choice, and Crime (pp. 269-308). New York: Routledge.

Felson, M. (2016). The routine activities theory. In R. Wortley and M. Townsley (Eds.). Environmental criminology and crime analysis (2nd ed., pp. 87-97). Abingdon, Oxfordshire: Routledge.

Felson, M. and Eckert, M. (2016). Crime and Everyday Life, 5th Edition. New York, NY: Sage Knowledge.

Groff, E. R. and Taniguchi, T. (2019). Using citizen notification to interrupt near repeat residential burglary patterns: The micro-level near repeat experiment. Journal of Experimental Criminology. 15, 115-149.

Grubesic, T. H. (2006). On The Application of Fuzzy Clustering for Crime Hot Spot Detection. Journal of Quantitative Criminology, 22(1), 77-105.

Hägerstrand, T. (1970). What About People in Regional Science? Papers of the Regional Science Association 24(1): 7–21.

Hart, T. C. (2021). Investigating Crime Pattern Stability at Micro-Temporal Intervals: Implications for Crime Analysis and Hotspot Policing Strategies. Criminal Justice Review, 46(2), 173-189.

Hart, T. C., and Zandbergen, P. (2014). Kernel density estimation and hotspot mapping: Examining the influence of interpolation method, grid cell size, and bandwidth on crime forecasting. Policing: An International Journal of Police Strategies & Management, 37(2), 305-323.

Hunt, J. (2019). From crime mapping to crime forecasting: The evolution of place-based policing. National Institute of Justice, (281).

Jacobs, B. A., and Wright, R. (1999). Stick-up, street culture, and offender motivation. Criminology, 37(1), 149-174.

LaVigne, N. G., Fleury, J. K., and Szakas, J. (2000). Auto Theft and Detecting Chop Shop Locations. In: Linda S. Turnbull, Elaine Hallisey Hendrix, Borden D. Dent (eds.), Atlas of crime: Mapping the Criminal Landscape, 60-67.

Morgan, J. D. (2010). A visual time-geographic approach to crime mapping. Ph.D. Dissertation, The Florida State University.

Morgan, J. D. and Steinberg, P. E. (2013). Testing the Usability of Time-Geographic Maps for Crime Mapping. In: Leitner, M. (eds) Crime Modeling and Mapping Using Geospatial Technologies. Geotechnologies and the Environment, vol 8. Springer, Dordrecht.

NASEM, National Academies of Sciences, Engineering, and Medicine. (2018). Proactive Policing: Effects on Crime and Communities. Washington, DC: The National Academies Press.

National Institute of Justice (NIJ). (2013). Practice Profile: Hot Spots Policing. Accessed August 27, 2021.

Ratcliffe, J. H. (2000). Aoristic analysis: The spatial interpretation of unspecific temporal events. International Journal of Geographical Information Science, 14(7), 669–679.

Ratcliffe, J. H. (2002). Aoristic Signatures and the Spatio-Temporal Analysis of High Volume Crime Patterns. Journal of quantitative criminology, 18(1), 23-43.

Ratcliffe, J. H. (2008). Near Repeat Calculator [Apparatus and software]. Philadelphia, PA: Temple University. Accessed August 21, 2021.

Ratcliffe, J. H. (2016). Intelligence-led Policing. Routledge.

Ratcliffe, J. H., and McCullagh, M. J. (1998). Aoristic Crime Analysis. International Journal of Geographical Information Science, 12(7), 751-764.

Rossmo, D. K. (1999). Geographic Profiling (1st Edition). CRC Press.

Rossmo, D. K., Lu, Y., and Fang, T. B. (2012). Spatial-temporal crime paths. In Andresen, M. A. and Kinney, J. B. (Eds.), Patterns, Prevention, and Geometry of Crime (pp. 38-64). London: Routledge.

Schmitz, P. (2016). The use of supply chains and supply chain management in the production of forensic maps using data from a fraud case. South African Journal of Geomatics, 5(2), 156-174.

Sherman, L. W. (1995). Hot Spots of Crime and Criminal Careers of Places. In John E. Eck and David Weisburd, (Eds.). Crime and Place (pp. 35-52). Washington, DC: Police Executive Research Forum.

Simon, H. A. (1979). Rational Decision Making in Business Organizations. The American Economic Review, 69(4), 493-513.

Steenbeek, W. (2018). Near Repeat. R package version 0.1.1.

Townsley, M., and Sidebottom, A. (2010). All offenders are equal, but some are more equal than others: Variation in journeys to crime between offenders. Criminology, 48(3), 897-917.

Townsley, M., Homel, R., and Chaseling, J. (2003). Infectious Burglaries. A Test of the Near Repeat Hypothesis. The British Journal of Criminology, 43(1), 615–633.

Weisburd, D. (2015). The Law of Crime Concentration and the Criminology of Place. Criminology, 53(2), 133–157.

Weisburd, D. L., and Braga, A. A. (2006). Hot spots policing as a model for police innovation. In D. L. Weisburd and A. A. Braga (Eds.), Police Innovation: Contrasting Perspectives (pp. 225–244). New York: Cambridge University Press.

Yin, P. (2020). Kernels and Density Estimation. The Geographic Information Science & Technology Body of Knowledge (1st Quarter 2020 Edition), John P. Wilson (ed.).