Geotechnologies and the Environment

Gregory A. Elmes
George Roedl
Jamison Conley *Editors*

Forensic GIS

The Role of Geospatial Technologies for Investigating Crime and Providing Evidence

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Editors

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Editors
Gregory A. Elmes
Department of Geology and Geography
West Virginia University
Morgantown, WV, USA

George Roedl
Department of Geology and Geography
West Virginia University
Morgantown, WV, USA

Jamison Conley
Department of Geology and Geography
West Virginia University
Morgantown, WV, USA

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Editorial

This book, *Forensic GIS: The Role of Geospatial Technologies for Investigating Crime and Providing Evidence*, presents ways in which geospatial technologies, including geographic information systems (GIS), global positioning systems (GPS), and remote sensing, contribute to the acquisition and analysis of forensic information today and provides timely illustrations in the form of case studies.

Initially, our interest in the forensic potential of geospatial technologies stemmed from a Forensic Science Initiative grant from the National Institute of Justice to the Forensic Science program at West Virginia University (2003-RC-CX-K001). Among many others, a task was initiated to investigate the characteristics of spatially enabled forensic science, with the goal of supporting the use of geographic information systems and science in a number of forensic-related research and teaching activities. During the course of the grant, I, Dr. Ge Lin, George Roedl, and a number of graduate students investigated the use of GIS and remote sensing in forensic contexts. Four important aspects of the spatial perspective of forensic science were examined: geographic profiling, time geography, high density scanning, and radio frequency identification. Among the outcomes were a special paper session on Forensic GIS at the 2009 Annual Meetings of the Association of American Geographers, a paper in the *Journal of Forensic Science* on space-time approaches to shoeprint matching; investigation of the coordination of measurements of indoor and outdoor spatial location (accommodating GPS); and experiments with time-space path analysis and point cloud analysis. These efforts included the development of a course in crime mapping and analysis. In 2010, Gregory A. Elmes and George Roedl were awarded a grant from the National Institute of Justice, Office of Justice Programs (2009-IJ-CX-0205) for "Increasing Student and Community Safety," which supported a research partnership with WVU and the City of Morgantown, WV Police Departments. The current work may be seen as a natural extension of the research interests generated by these NIJ-funded projects.

Strictly defined, forensic science is the use of scientific principles, methods, and techniques to establish facts or provide evidence used in a court of law. Here, we have adopted a broader working definition of forensics and forensic GIS, which includes the use of geospatial principles and techniques to establish facts or sequences of events, regardless of whether they are used in court. Thus, gathering and interpreting scientific data for regulation, intelligence, and national security purposes falls under this broader definition of forensic science. A further distinction may be made between criminal and civil forensics. Criminal law deals with offenses against the state—the prosecution of a person accused of breaking a law. Such offenses include crimes against persons and property. Civil law covers everything else, such as violations of contracts and lawsuits between two or more parties. The collection of data and presentation of evidence may be held to quite different standards, the process of data collection and imaging may be quite different, and the consequences of the case may have very different impacts. Examples of both will be found herein.

A relatively small literature on forensics exists in the discipline of geography, a larger one in environmental science, geology, soil science, and archaeology. In February 2009, the National Academy of Sciences published a report "Strengthening Forensic Science in the United States: A Path Forward" (National Academies Press, 2009). The committee had a mandate to identify the needs of the forensic sciences community. It was revealing that, in a search, the terms "spatial" and "geospatial" did not appear in this text of 352 pages and this observation provided further impetus toward the genesis of this book. It is evident that further research and a bridging of scientific communities are necessary to establish the best practice of the use of geospatial science and technology within forensic science. To that end, this book is directed to an audience comprising of law enforcement professionals, academics in a wide variety of fields, and students of criminology and forensic science.

Our initial call for submissions was made on October 15, 2012, with a chapter proposal submission deadline of January 31, 2013. After reviewing the submitted proposals, 14 manuscripts were invited to be developed into final chapters by June 2013. Each chapter was reviewed by the editor and two external reviewers in a double-blind process. Nine of the original 14 manuscripts were revised and resubmitted by August 2013. The chapters in Part I by Roedl, Elmes, and Conley were not included in the double-blind process and must therefore be considered as being monographic in nature. Our recognition and thanks are due to Dr. Michael Leitner for the guidance provided by his 2013 publication in this Springer series (Volume 8). Sincere acknowledgement is also due to the external reviewers of the manuscripts for their important contribution of time and effort.

In Part I, *Gregory A. Elmes*, *George Roedl*, and *Jamison Conley* draw attention to the theme and content of the book through a review of the various roles geospatial technologies provide in investigating crime, providing evidence, and developing policy within the legal system and how these roles have changed with advances in the technology itself and the challenges involved in using the technology for investigation and providing legal evidence.

The first chapter "Concepts, Principles, and Definitions" considers the ways in which geospatial information and technology (GIT) has significantly increased in prominence within the criminology and forensic fields in the last decade. Geospatial technology includes the tools and techniques applied to geographic or spatial data; additionally, the chapter recognizes the extensive nature and roles of GIT across many subject domains. In Chap. 2, “Geospatial Technologies in the Courtroom”, *George Roedl*, *Gregory A. Elmes*, and *Jamison Conley* continue to develop the theme of the book by examining key rules such as federal rules for the admissibility of evidence, Frye, Daubert, and other court decisions that have influenced the potential admissibility of spatial data and technologies in a modern courtroom. Chapter 3 develops the theme of Spatial Tracking Applications, and Chap. 4 details the main tools of forensic GIT in Spatial Technology Applications.

Part II focuses on a selection of case studies illustrating the breadth of contemporary applications of GIT in criminal justice ranging from collecting evidence for presentation in court to an open software Web-enabled application bringing crime mapping and analysis to a larger audience than is possible with commercial packages.

In Chap. 5, *Ronald E. Wilson* and *Ann D. Fulmer* apply spatial and temporal categorizations of the “near repeat” concept to measure the extent of foreclosures in order to identify concentrations of mortgage fraud and predatory lending. They demonstrate that near repeat spatiotemporal analysis can be applied to help fraud investigators identify loans for scrutiny that show geographically systematic patterns of foreclosure. In a post-conviction setting, *Mark R. Leipnik* and *Xinyue Ye* examine geospatial strategies for the management of registered sex offenders in Chap. 6. Documenting current practice in the United States, the authors argue that, while four-fifths of US states use Web maps to provide notification to the public of the location and criminal history of registered sex offenders, the notifications vary considerably in form and content and are such notifications open to misuse. In Chap. 7, *Manuel Rodríguez Herrera* and *Daniel Salafranca Barreda* introduce the Science, Data, Intelligence, Knowledge (SDIK) project, a geo-information international security endeavor for making visible the “invisible” conditions of communities and neighborhoods. The SDIK project incorporates a set of technical-scientific and geospatial innovations to help understand newly emerging activities within communities and help uncover evidence of possible criminal activity.

Remaining at the neighborhood scale, *Jamison Conley* and *Rachel Stein* examine the relationships among the factors of neighborhood disorder and collective efficacy using measures of spatial correlation and spatial regression in Chap. 8. Their findings illustrate the potential of spatial analysis for informing policing strategies. They reason that the results of this type of analysis can lead to a better use of police resources to avert crime. Also recognizing the importance of place and neighborhood, in Chap. 9 *Matthew J. Hickman*, *Loren T. Atherley*, and *Geoffrey P. Alpert* describe the utility of geospatial analysis for monitoring, understanding, and responding to police use-of-force incidents. Their research stems from an investigation for the Seattle Police Department which had the aim of improving the quality of police monitoring and accountability. Through mapping spatiotemporal patterns of liquor law violation citations in the college town of La Crosse Wisconsin, *Gargi Chaudhuri*, *Steven Oxley*, and *Scott Wenzlaff* provide, in Chap. 10, a means to focus the deployment of intervention measures and increased vigilance to restrict alcohol consumption among underage youths and prevent associated crime and accidents.

Guiyun Zhou, *Jiayuan Lin*, and *Xiujun Ma* introduce in Chap. 11 a Web-based GIS for crime mapping, analysis, and decision support as an affordable option for small- and medium-sized police departments. The authors discuss the architecture, construction, and open software of the development of the prototype system. In Chap. 12 *William. C. Walker*, *Sunhui Sim*, and *Lisa Keys-Mathews* study the influence that a hurricane had on the space-time behavior of local patterns of crime. The authors explore the use of geographically weighted regression (GWR) for understanding aspects of the ecology of crime. The results reveal that more accurate prediction of crime types within cities is possible. Finally, Chap. 13, by *Irfan Ashraf*, *Urooj Saeed*, *Naeem Shahzad*, *Javed Gill*, *Shahid Parvez*, and *Akram Raja*, presents a detailed case study of the delineation of legal forest boundaries to identify and contest illegal forest encroachment. Forest boundaries and encroachments were mapped in coordination with the Punjab Forest Department, the Survey of Pakistan, the Punjab Revenue Department, and the World Wildlife Fund Pakistan. The study results were presented as evidence to the High Court in Lahore, Pakistan, as part of an effort to control illegal forest use.

The collection of insights and research presented here has advanced the literature on forensic GIS, albeit incrementally, and has raised the premise of the importance of continued research into spatially enabled forensics. The editors look forward to future developments in the integration of GIT and forensics. To that end we have included an annotated bibliography of court cases involving the legality of geospatial technology and its introduction in court. Selected cases involving GPS, remote sensing, and GIS have been included.

Contents

Part I
Fundamentals: Definitions, Concepts, Theories, and Principles

Chapter 1
Concepts, Principles, and Definitions

Gregory A. Elmes, George Roedl, and Jamison Conley

Abstract Forensics is the application of science to solve crime. Geographic Information Science, encompassing geospatial information and technology (GIT), has become established within the criminology and forensic fields in the last decade. Law enforcement agencies and forensic investigators embrace geospatial science and technologies for collecting, storing, manipulating, analyzing, and displaying spatial data, resulting in new information, procedures, and models for investigation, policy, and decision making. Applications, acceptability, relevance, and procedural legality of geospatial technologies vary substantially, leading to the assessment of their roles in law enforcement, rules of evidence, protection of privacy, and constitutional liberties. This chapter discusses the context and principles of geospatial technologies and the integration of geospatial tools, principles, and methods into a five-stage model of crime analysis and investigation.

Keywords Forensic science • Geographic Information Science • Geospatial technology • Geographic Information Systems (GIS) • Global Positioning System (GPS) • Remote sensing

1.1 Introduction

As geospatial science and technologies become ubiquitous in society, a wide range of disciplines and professions adopt them for collecting, storing, manipulating, analyzing, and displaying spatial data, resulting in the generation of new information and models for policy and decision making. Forensics is the application of science

G.A. Elmes (✉) • G. Roedl • J. Conley
Department of Geology and Geography, West Virginia University,
330 Brooks Hall, Morgantown, WV 26506, USA
e-mail: greg.elmes@mail.wvu.edu; groedl@gmail.com; jamison.conley@mail.wvu.edu

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to solve crime. It follows therefore that as geospatial science and its associated technologies emerge, they make a distinct and unique contribution to forensics (McKinley et al. 2008; Noond et al. 2002; Wolff and Asche 2009). Law enforcement agencies and forensic investigators have adopted geospatial technologies to profile serial offenders, track suspects, and guide crime reduction efforts, among other purposes. Legal experts utilize the analytical and visual capabilities of geospatial technologies to present, demonstrate, and explain complex information in the courtroom. Citizen groups have fought successfully against environmental discrimination and have engaged in class-action lawsuits, strengthened by the collection, analysis, and presentation of geospatial data.

Geospatial technologies have a long history of use in a broad range of applications such as environmental conservation, real estate, military and security, municipal planning, epidemiology, and agriculture. Recently, Listi et al. (2007) observed an increased popularity of what they described as the field of forensic spatial analysis, citing the evident increase in geospatial technology use presented at forensic-oriented conferences. Despite a relative lack of published research articles in criminology and forensic-related journals, geospatial technologies also serve as highly useful tools in criminal investigations. Geospatial technologies have unique capabilities which are ideally suited to collecting and analyzing spatial data. Traditional methods of investigation, such as pin maps, are largely unable to cope with volumes of multifaceted spatial information in any meaningful manner capable of assisting in identifying an offender or excluding possibilities. Digital spatial technologies result in a more efficient investigation, linking people, places, and objects in a way that assists in optimizing time and resources in pursuit of guilty parties. Conversely, traditional methods of investigation remain vitally important. The merging of spatial tools and methods into investigative practices to establish facts admissible in court is therefore a practice that should be recognized. The application of spatial tools to assist in established investigative practice by adding a spatial perspective is the focus of forensic GIS.

The widespread use of geospatial technologies has increasingly exposed courtrooms to the demonstrative powers of spatial technologies in civil and criminal cases. Section 1.5 of this chapter integrates a five-stage workflow for crime analysis and investigation with the comparable stages of GIS. In the United States of America, federal, state, district, and circuit courts, as well as the US Supreme Court, have ruled on the legality of the use of geospatial technologies under various circumstances. Higher courts have overruled the judgment of lower courts, which has introduced a degree of debate and contention into the legal uses of various geospatial technologies. This book is intended as a guide to understanding the various roles geospatial technologies provide in investigating crime, providing evidence, and developing policy within the legal system, broadly defined, and how these roles have changed with advances in the technology itself and the legal challenges involved in using the technology for investigation and providing evidence.

1.2 Geospatial Technologies

Recent innovations in information technology have had "dramatic and profound effects in the criminal justice system and will likely have both intended and unintended consequences" (Byrne 2008: 10). Many of these new technologies, incorporating advances in both hardware and software, have proven to be effective improvements over previous technologies for the purposes of investigating, prosecuting, convicting, and exonerating suspects, as well as pursuing civil suits (Jacobson 2004). Geospatial information and technology (GIT), or simply geospatial technology or geomatics outside the United States, has increased in prominence significantly within the criminology and forensic fields in the last decade. While geospatial technologies have been commonly associated with hundreds of applications over the past 50 years, they have only recently begun to be employed in investigative applications as a common practice, as their acceptance in the legal system increases and decreased costs make their use effective.

To identify geospatial technology competencies within the general workforce, Cyndi Gaudet assembled a focus group consisting of geospatial industry stakeholders. This group defined geospatial technology as "an information technology field of practice that acquires, manages, interprets, integrates, displays, analyzes, or otherwise uses data focusing on the geographic, temporal, and spatial context. It also includes development and life-cycle management of information technology tools to support the above" Gaudet et al. (2003: 24). Although such a definition is very general and all encompassing, it recognizes the extensive nature and roles of GIT across many subject domains. DiBiase et al. (2010) recognized that because of their breadth and diversity, geospatial technologies mean very different things to different people, ranging from a scientific discipline to a collection of tools and from a profession to an industry. However geospatial technologies are interpreted, they are identified as an opportunity for many fields and many disciplines. Goodchild (2008: 352) called geospatial technologies "powerful extensions of the senses, revealing things that would be impossible to obtain in any other way." At a minimum geospatial technologies include those tools or techniques which are commonly applied to geographic or spatial data. Frequently, Geographic Information Systems (GIS), Global Positioning System (GPS), and remote sensing are categorized as the three main geospatial technologies (see Bossler et al. 2010) which are well-established fields of study and in general public use across a wide range of applications (e.g., conservation, real estate, military applications, municipal planning, epidemiology, and agriculture).

1.2.1 Geographic Information Systems, Science, and Studies

Although the acronym "GIS" is typically reserved as an abbreviation for Geographic Information Systems, it is often applied somewhat ambiguously to distinctly different subfields of study. Goodchild (1992) suggested GIS was not only a "system" but also a "science" reflecting substantial differences in usage. Scholars (Forer and Unwin 1999; Longley et al. 2005) later associated the "S" with "studies," expressing the GIS acronym as either Geographic Information Systems, Geographic Information Science, or Geographic Information Studies. To avoid confusion and provide the precise context of the acronym, distinctions can be made. Geographic Information Science is often differentiated as GIScience, GISci, or GIs(c), and the field of Geographic Information Studies is typically denoted as either GIStudies or GIs.

Goodchild (2008) and Longley et al. (2005) elaborated the differences of meaning in the various GIS acronyms. A Geographic Information System (GIS) is defined as a computer system for capturing, managing, integrating, manipulating, analyzing, and displaying geographically referenced data. It can be seen as consisting of five components: hardware, software, data, methods, and people connected by a computer network (Longley et al. 2005). In a GIS, location becomes the common denominator between disparate datasets, enabling them to be correlated, merged together, and managed to explore relationships between data in order to identify patterns and trends in the form of maps, analytical reports, and charts. Geographic Information Science (GISci) emphasizes underlying principles and fundamental questions, as well as the research and development raised by the use of GIS through strong scientific and intellectual components (Goodchild 1992; Getis et al. 2000). Research into, and extension of the concepts of, scale, dimensionality, topology, and spatiotemporal representation drives GISci inquiry. In a synergetic relation, GISci affects the implementation of GIS while the functionality of GIS advances the theory and practice of GISci (Gold 2006). Mark (2003) provided a more thorough explanation of GISci, which he summarized as a multidisciplinary research field for redefining geographic theories, concepts, and uses. Geographic Information Studies (GIStudies) emphasize GIS in a societal context and examine issues such as privacy, ethics, legality, and return on investment (Forer and Unwin 1999; Chrisman 2005).

GIS, GISci, and GIStudies each has associated applications and challenges in crime investigation and the production of evidence. In Chap. 13, surveying, GIS, and remote sensing are combined to merge spatial datasets to create maps of legal forest boundaries in Pakistan. Using this information, researchers and law enforcement agencies are able to reproduce, update, and distribute standardized maps and atlases to identify and monitor areas of illegal encroachment on protected forest land. The maps identifying encroachment within the legal forest boundaries are then used to provide evidence to the court system. Chapter 11 focuses on GISci as the authors develop a prototype crime mapping and decision support system for law enforcement agencies in the Web environment. A focus on publicly available Web maps of registered sex offender residences in Chap. 6 explores aspects of GIStudies to examine societal issues of geospatial technology that are both beneficial to public safety and potentially injurious to offenders who may become targeted victims of harassment, arson, assault, and murder. The challenges are numerous when applying GIS, GISci, or GIStudies to crime investigation or providing evidence arising from concerns with associated hardware, software, data, methods, and people. Problems arise with the selection of appropriate data collection, storage, analysis, integration, and display. Underlying theories and principles have been questioned as well as the interpretation of results and societal impacts. Chapter 2 explores such challenges to illustrate what is required under the rules of evidence and admissibility for geospatial technology.

1.2.2 Global Positioning Systems

Among the family of geospatial technologies, satellite navigation systems are perhaps the most familiar, of which the Global Positioning System (GPS) is the most frequently used. The availability of GPS devices for outdoor activities, such as hiking and geocaching, as well as vehicle navigation and location-based services provided through cellular phones and mobile computing devices permeate contemporary society. Equally, no other geospatial technology has affected the geospatial industry and discipline as profoundly as GPS (Bossler et al. 2010). Made public in the United States in the 1980s, the GPS has advanced to provide real-time, centimeter-level positional accuracy across much of the globe through the use of networks of 30+ satellites that orbit the earth. Galileo, GLONASS, and BeiDou (BDS) are the European, Russian, and Chinese equivalent satellite navigation systems in various stages of development and accessibility.

The advantages of real-time positional data for investigating crime and providing evidence are abundant. Law enforcement agencies, judicial systems, and citizens have embraced the tracking ability of GPS; for example, law enforcement agencies have solved criminal investigations armed with a record of a suspect's movements captured by a GPS device (Byrne 2008). Courts commonly order the attachment of ankle bracelets fitted with a GPS to offenders to ensure compliance with restrictions (e.g., in-home confinement or restraining orders). Citizens equip vehicle and equipment with devices such as LoJack which allow for tracking and recovery of stolen equipment; however, as with many other technologies, GPS has an established track record of misuse (e.g., for stalking victims) and has been subject to numerous legal controversies and challenges (e.g., violations of the fourth amendment (United States v. Jones 2012).

1.2.3 Remote Sensing

The oldest geospatial technology, remote sensing is a mature discipline with well-understood concepts and principles and a range of versatile applications ranging from aerial photography to LiDAR (Warner et al. 2009). Jensen (2007) provided eight definitions of remote sensing with the common premise that remote sensing is the art and science of acquiring data and information about an object without making physical contact with that object, ensuring the object is not disturbed or altered through the act of measurement. There are two types of remote sensing: passive and active. Passive remote sensing detects and collects energy emitted from an object, such as reflected sunlight captured in photographs or sensors. Active remote sensing emits energy in order to measure the reflected energy from the object of observation. Some active remote sensing (e.g., X-ray) has the potential of affecting targeted objects, but longer wavelengths such as visible light or RADAR do not. Remote sensing sensors can be employed on ground platforms (e.g., vehicles or structures), in the air (e.g., attached to aircraft such as unmanned drones), and in space (e.g., satellites).

Just as GIS and GPS have benefited investigations and provided evidence, the long history of remote sensing has ensured its widespread use. As new technological advances and capabilities continue to emerge, the potential applications for investigations and evidence will continue to increase. However, there are, and will continue to be, controversies and challenges associated with the surveillance and data storage capabilities inherent to remote sensing and other geospatial technologies.

1.3 Spatial Data

Spatial data are distinctive in that they contain linked information about location and attributes (Gabrosek and Cressie 2002). Goodchild et al. (2000) noted that the term spatial is in fact shorthand for spatiotemporal, as it refers to data and phenomenon that have both spatial and temporal dimensions of variation. In having integrated components of location (places and times) and attributes, spatial data require specialized data storage, handling, and management. Although the terms geospatial and spatial are often used interchangeably, spatial is the more generalized term denoting locational context at any scale, while geospatial refers to data with a location component that can be referenced to a point on the earth (Longley et al. 2005). Spatial data is an extremely valuable and versatile resource, which is subject to widely accepted international standards (Boer et al. 2007). Rooted in the spatial science tradition of the discipline of geography (see Martin and James 1993), the spatial perspective emphasizes the role of location and scale as important variables in understanding patterns, processes, and causality.

Because of its unique composition, spatial data are handled differently from nonspatial data to address the role of location. For example, any location has the potential for the occurrence of a crime incident; however, certain spatial relationships significantly increase the chances of places having an incident, such as *within* blighted neighborhoods, *near* alcohol outlets, *outside* gated communities, *along* particular streets, *adjacent* to wooded lots, or combinations of such factors. As may be gathered from these examples, location is an important component in not only understanding crime but also in the investigation and prosecution of crime. The use of geographic principles and spatial perspectives assist in efforts to investigate crime and apprehend offenders and increasingly takes on a forensic role, especially in the form of geographic profiling (Brantingham and Brantingham 1981; Rossmo 2000).

Spatial data have several advantages over nonspatial data. Given known location and attributes, spatial data can be mapped and analyzed readily. Mapping allows for the visual recognition and empirical demonstration of patterns from complex datasets, such as the detection of clusters of crime incidents within a large database of all police events. Crime mapping and analysis takes advantage of these clusters or hotspot areas for tactical and strategic planning to prevent and reduce crime (Boba 2005; Bruce 2001; Getis et al. 2000). A growing number of police departments routinely map and analyze crime data for different purposes (Mamalian and LaVigne 1999; Markovic et al. 2006; Nelson 1999; Wang 2005; Wartell 2003). Through georeferencing, spatial data also provides a commonality between disparate datasets based on their common geographic location or footprint. Consider the Internet for example – a user can search any set of locations and retrieve data on people, businesses, attractions, items for sale, weather, and news events for the set of locations. An investigator may become more informed in identifying vehicles, weapons, parolees, warrants, or calls for service to a particular location by querying disparate but georeferenced databases using one or more addresses. Similarly, the investigator is able to expand the query to include all records within a given distance of the address, without the need to know and query every specific individual address within the given distance.

Clearly modern spatial data are also digital. Whether collected by, or stored in computers, these data can be easily exchanged and shared through clearing houses like the National Spatial Data Infrastructure (NSDI). Vast amounts of spatial data have been produced by the federal government and state governments with many local government partners. In the United States, much of the governmentally produced spatial data is in the public domain and covers large geographic areas at ever-increasing spatial resolution, which allows for cross-jurisdictional analysis with little difficulty. The wide availability of spatial data generates a wealth of information for decision making, policy, and management, and the dynamic and interactive nature of spatial data provides an additional advantage. Given dynamic data, the user can update results and explore new relationships and trends. For example, a common application is to identify routes using an Internet map service. A user can specify whether the user wants the quickest route, the shortest route, the route with most or least use of interstate highways, or even a route which avoids tolls and construction activities. Regardless of the final choice, GIS presents the user with options, informs the user with results, and produces new information, while not altering the original underlying data in generating the results.

1.4 Forensic GIS

According to the American Heritage Dictionary of the English Language,[1] forensics is "the use of science and technology to investigate and establish facts in criminal or civil courts of law." More broadly interpreted, forensics is the application of any science or technology used to investigate and establish facts. As a result, the

[1] http://www.freedictionary.com

concepts of location, place, and scale are intrinsically embedded within forensic investigations, analyses, and through the presentation of evidence, as are spatiotemporal relationships.

Burrough and McDonnell (1986: 11) defined GIS as "a powerful tool capable of storing, retrieving, transforming and displaying spatial data for a particular purpose." Applying the Burrough and McDonnell definition with its emphasis on a particular purpose, the phrase "forensic GIS" can be said to establish that purpose. A distinction made for forensic GIS is necessary due to the overwhelming volume of literature pertaining to GIS in general and in other specific fields. The term and concept of forensic GIS is introduced here, not as a new or unique field so much as a way to provide the forensic and criminal justice-related communities with a distinction pertinent to their purposes and interests. As such, it is anticipated that new ideas and research in this area will not get lost among the volumes of GIS literature in general, but will stand out as a forensic GIS literature. The main utility of forensic GIS is to provide associative evidence, which assists in either proving or disproving links between people, places, and objects as they relate to the court of law. It should be stressed that a forensic GIS acts to assist traditional investigative techniques by adding a spatial perspective and should not be considered as a technological replacement for them.

Access to GIS technology and spatial data has accelerated over the last two decades and is clearly impacting the ways investigations are performed and evidence is presented in court. Technology has become a more reliable and efficient means of generating evidence than police hunches (Jacobson 2004). The National Institute of Justice (2009, 2010) identified high-priority needs for criminal justice technology within the scope of five functional areas, one of which was enabling informed decision making. The NIJ reports listed a range of needs for spatial analysis tools and technologies that included the need to analyze geographic linkages among people of interest to criminal justice agencies, extend the current capabilities of crime-related databases, provide compatibility with mobile/handheld devices, and identify and extract hidden relationships in large and complex datasets.

Although a definition of forensic GIS has yet to be formally established, Morrow-Jones et al. (2005: 19) set forth the concept of a "forensic GIS" as a way to "collect, explore, and analyze spatial data in order to detect irregularities that may violate law or fair practice." However, this definition is rather narrowly based on the terms "detect" and "irregularities." An alternative definition is the application of geographic and spatial tools, principles, and methodologies to investigate and establish facts within the boundaries of forensics. As such, under the basic definition of forensics, spatial science serves as a specified science, and geospatial technology is the technology used to investigate and establish facts that may be presented in criminal or civil courts of law.

The boundaries of forensic GIS are not clearly defined and may overlap with other forensic or spatial science subdisciplines. However, an examination of closely related fields reveals important characteristic differences. Forensic geography, geoforensics, forensic geoscience, forensic mapping, and environmental forensics are often closely associated with geospatial technologies and geographic theories and principles. Forensic GIS is set apart in that the use of geospatial technologies is not discipline specific and the geospatial analyst does not necessarily need to be an expert trained in spatial science. For example, anyone (from any discipline with any level of spatial expertise) can use an online Web mapping service to determine distances and time requirements for travel between two locations to determine the possibility, or improbability, of a suspect conforming to an established timeline of events.

Forensic geography is a subdiscipline of geography wherein a geographer or other expert does research and provides expert testimony appropriate to a court of law based on geographic theory and principles (Brodsky 2003; Schmitz et al. 2013). DeVorsey (1973; 1980) also referred to this as both forensic historical geography and historic geography when historical geographers conducted the research and testimony. Geoforensics and forensic geoscience are synonymous with each other and, although there are varying definitions, refer to the application of "geo" or earth sciences to forensic investigations (Morgan and Bull 2007; Pye and Croft 2004; Ruffell 2006; Ruffell and McKinley 2008). Schmitz et al. (2013) categorized forensic mapping as a field of forensic geography that maps criminal activity using location data from GPS devices and cell phone usage data. Environmental forensics focuses exclusively on environmental concerns and enforcement (Brilis et al. 2000, 2001; Grip et al. 2000; Ruffell and McKinley 2008). There are numerous other "forensic" fields, such as forensic archeology (Obledo 2009), forensic geology (Murray 2004), forensic geomorphology (Ruffell and McKinley 2005), forensic seismology (Ruffell and McKinley 2005), and forensic palynology (Mathewes 2006; Mildenhall et al. 2006). The time is ripe to develop the study of forensic GIS.

1.5 Stages of Crime Analysis and Investigation

Zhao et al. (2003) divided crime analysis and investigation into five workflow stages: (1) collecting crime data; (2) processing and storing crime data and documents; (3) searching, retrieving, and collecting additional information for crime analysis; (4) analyzing information to find clues; and (5) using information to prosecute (or defend) individuals. These workflow stages are organized to follow a seamless timeline (temporal continuum) beginning before a crime is committed and culminating in the obtainment of either a prosecution or acquittal before the cycle is repeated. Noticeably, the five workflow stages of crime analysis and investigation are similar to the six workflow stages used to define GIS (capture, manage, integrate, manipulate, analyze, and display spatial data). Calling it the "geographic approach," Dangermond (2007) referred to the integration of GIS as a new way of thinking. Conceptually, forensic GIS can be viewed as a new way of thinking which integrates the five workflow stages of crime analysis and investigation with the defining workflow stages of GIS along a temporal continuum that extends from a spatially enabled pre-crime capability to the courtroom presentation of spatial data.

1.5.1 Stage I: Collecting Crime Data

Crime scenes exist in time and space. Concepts of location, place, and relative location (next, near, overlapping) are intrinsic to investigation and evidence. Location, place, and scale are embedded within the data, as are spatiotemporal relationships. The challenge in establishing a spatially enabled forensic GIS crime database is first to collect and store the information and then to use and reuse it during the investigative process (Oatley et al. 2006; Rossmo 2006). Information about any particular crime should be collected with the understanding that it will be used in future analysis, including spatial analysis. Oatley et al. (2006) contended that while a single recorded crime may have little value, when a diversity of information from an event is collected and stored in a comprehensive crime database, it provides a powerful retrospective investigative tool. Rossmo (2000, 2006) similarly stated that information must be properly collected, analyzed, and shared if it is to be of any value to investigators. Because a forensic GIS identifies spatial relationships, it is important to have a precise and accurate location of a crime scene to facilitate confidence in the results of any future analysis.

1.5.2 Stage II: Processing and Storing Crime Data

As Nelson (1999) pointed out, law enforcement is about information management and location. Unlike traditional record management databases, a GIS database supports traditional tabular-based data, such as spreadsheets, and additional multimedia-based information, such as word processing documents, digital pictures, and video and audio recordings. However, analysis is currently restricted to the spatial and nonspatial component of the tabular data, excluding the images, video, and audio recordings. This limitation may eventually disappear with advances in technology. For example, integrating facial recognition software with GIS will provide further linkages between suspects and crime scenes based on collected and stored photographic evidence.

1.5.3 Stage III: Searching, Retrieving, and Collecting Additional Information for Crime Analysis

The investigation process involves asking specific questions, and the responses are essential in establishing links in criminal activity. A simple example is determining if a crime scene has distinctive characteristics that are similar to those at other crime scenes. Two crime scenes which share distinctive characteristics might indicate to investigators that the same offender was possibly involved in both incidents and provide a link between an offender and crime scenes; however, the ability of a forensic GIS to link criminal activities efficiently relies on an investigator formulating the relevant questions (Adderley and Musgrove 2001). Traditional GIS investigations have focused on suspect identification and pattern analysis in linking activities with offenses (Groff and La Vigne 1998; LaVigne and Groff 2001). Descriptive factors and locations of crime scenes serve as starting points to identify potential suspects from additional databases which can be linked to the GIS.

During this third phase, information collected is examined to determine what is available and what remains to be collected for further investigation. Any necessary additional information is then obtained. A common means of obtaining additional information is through the process of querying additional law enforcement databases, such as sex offender registries or parolee databanks, as well as government record databanks such as motor vehicle registration or through third-party databanks, such as utility companies and cell phone providers. A forensic GIS enables investigators to search for information not only based upon attribute linkages but also by spatial linkages. An example might be to identify registered sex offenders living nearest to a sexual assault scene (spatial link) or to identify a list of previous offenders on parole/probation who may not be properly registered (attribute link). The importance of dispersed systems to maximize the search is evident.

Discovering which crime incidents belong to a series is an essential and important step in serial crime investigation (Rossmo 2006). Link analysis, also known as comparative case analysis, is the process used to tie a series of crimes together based on three main methods: (1) physical evidence, (2) offender description, and (3) crime scene behavior (Rossmo 2000). A forensic GIS can be used to establish such links and display the locations where the potentially linked incidents occurred. Using a forensic GIS to link similar crimes or suspected offenders within a limited geographic area provides further associative evidence of a relationship. One of the benefits of linking cases is that it informs an investigator of a potential serial criminal, which permits the focus of the investigation to shift from multiple unrelated incidents to identifying a single suspect responsible for many incidents. As such, apprehension of one individual would have the potential of solving numerous linked cases. Once a suspect is apprehended, the link analysis informs the investigators to question the suspect about each of the linked cases and seek to prove guilt through a confession, physical evidence, or witnesses (Rossmo 2006). In contract to establishing links between multiple incidents and a single offender, using a forensic GIS in the link analysis process may also inform investigators of potential multiple offenders for similar incidents based on geographic location.

1.5.4 Stage IV: Analyzing Information

Whether investigating a major crime or a crime series, vast amounts of data are generated, and the sheer volume of these data invariably obscures possible underlying relationships and linkages (Adderley and Musgrove 2001). Nelson (1999) stated without analysis that data is useless. A GIS allows a database and a map to be linked for the purpose of data analysis and visualization. Markovic et al. (2006) described such GIS maps as "heuristic devices, or effective tools for stimulating investigatory processes, exploration, and reexamination" with the advantage of being able to empirically validate hypotheses generated through discussion and an interactive discovery process performed by patrol officers, detectives, and crime analysts. While collected information alone is useful within an investigation, further analysis can allow investigators to confirm or reject identified links. Within a forensic GIS, the analysis is centered on spatial information to inform the investigative process. Longley et al. (2005) suggest six generalized types of spatial analysis common to GIS: (1) queries, (2) measurements, (3) transformations, (4) descriptive summaries, (5) optimization, and (6) hypothesis testing. A detailed discussion on the various types of spatial analysis remains outside the scope of this chapter; suffice it to say there is a wide range of spatial analysis techniques available to investigators, and the choice of which types of analysis to use would depend upon each unique investigation case.

1.5.5 Stage V: Using Information

GIS technology allows the analysis of data to identify, apprehend, and prosecute suspects (Nelson 1999). Suggs et al. (2002) discussed the benefit of link analysis as a widely accepted tool for criminal and environmental investigations which assists in providing an understanding of complex relationships during trial presentations. Wilson et al. (1997) described computer-generated evidence from GIS as being highly reliable. One of the most common applications of GIS in criminal prosecution cases is in validating distance measurements. For example, when a drug sale occurs near a school, a GIS map clearly marking whether the location of the suspect's arrest falls within a GIS-measured drug-free buffer zone often suffices to enact enhanced penalties. In an investigation of high-crime areas, Leipnik and Albert (2003) discussed the application of GIS to prove significant relationships between the location of crime and certain establishments, such as liquor stores. In these cases, civil enforcement actions and license revocation were actions taken in lieu of proving criminal activity on the part of the establishments, although the GIS provided both graphic and geographic proof of localized crime when taken to court or liquor control board proceedings.

1.6 Summary

The management of the large amounts of raw data and derived information generated during criminal investigations call for new approaches using spatial information technology (Adderley and Musgrove 2001). In order to perform meaningful analysis, practitioners are finding an increasing need for the transfer of new knowledge and technologies from other disciplines (Haggerty 2004). Many of these new technologies have proven to be improvements over existing forensic technologies for the purposes of demonstrating compelling evidence in lawsuits (Jacobson 2004). Different types of geospatial technology have been used to investigate crime, prosecute and convict offenders, and exonerate suspects. Common examples of geospatial technologies include GIS, remote sensing, ground-penetrating radar, high-definition 3-D laser scanning, Light Detection and Ranging (LiDAR), thermal imagery, radar, sonar, magnetic resonance imaging, X-ray, GPS-related tracking, and radio-frequency identification. The applications, acceptability relevance, and procedural legality of each technology vary substantially, leading to a number of considerations still being addressed by the court system, ranging from the rules of evidence to the protection of privacy and constitutional liberties. Although considerable precedent exists for the use of geospatial technology, new issues and challenges are emerging as the technology evolves, generating new legal considerations.

The main utility of geospatial technology has been to provide associative evidence to assist in proving or disproving links between people, places, and objects as they relate to the court of law. Spatial data, inherent to geospatial technologies, are a valuable and versatile resource when used to investigate and establish facts in a court of law. Forensic GIS, defined here for the first time, is the application of geographic and spatial tools, principles, and methodologies to investigate and establish facts within the boundaries of forensics. The main utility of forensic GIS is to provide correlated evidence, which assists in either proving or disproving geographic, spatial, or temporal links between people, places, and objects as they relate to the court of law.

References

Adderley RW, Musgrove P (2001) Police crime recording and investigation systems – a user's view. [General review]. Policing Int J Police Strateg Manag 24(1):100–114

Boba R (2005) Crime analysis and crime mapping, 1st edn. Sage, Thousand Oaks

Boer A, Engers TV, Peters R, Winkels R (2007) Separating law from geography in GIS-based eGovernment services. Artif Intell Law 15(1):49–76. http://dx.doi.org/10.1007/s10506-007-9042-4

Bossler JD, McMaster RB, Rizos C, Campbell JB (2010) Manual of geospatial science and technology, 2nd edn. Taylor & Francis, Boca Raton

Brantingham P, Brantingham P (1981) Environmental criminology. Sage, Thousand Oaks

Brilis GM, Gerlach CL, van Waasbergen RJ (2000) Remote sensing tools assist in environmental forensics. J Environ Forensic 1:63–67. doi:10.1006/enfo.2000.0009

Brilis GM, van Waasbergen RJ, Stokely PM, Gerlach CL (2001) Remote sensing tools assist in environmental forensics: part II digital tools. Environ Forensic. doi:10.1006/enfo.2000.0033

Brodsky H (2003) Retail area overlap: a case in forensic geography. Prof Geogr 55(2):250, 259

Bruce CW (2001) A thousand words for a picture. Is the overvaluation of GIS disrupting a critical balance in crime analysis? [Crime Analysts' Round Table, Spring 2001, Massachusetts Association of Crime Analysts, Hyannisport Massachusetts]. http://www.macrimeanalysts.com/rt/f2cb1p.htm. Accesssed 15 Feb 2012

Burrough PA, McDonnell RA (1986) Principles of geographical information systems. Oxford University Press, Oxford

Byrne JM (2008) The best laid plans: an assessment of the varied consequences of new technologies for crime and social control (Newsletter). Fed Probat 72(3):10–21

Chrisman N (2005) Full circle: more than just social implications of GIS. Cartogr Int J Geogr Inform Geovis 40(4):23–35. doi:10.3138/8u64-k7m1-5xw3-2677
Dangermond J (2007) A framework for understanding, managing, and improving our world. GIS – the geographic approach. ArcNews 29(3):1–3
De Vorsey L (1973) Florida's seaward boundary: a problem in applied historical geography. Prof Geogr 25(3):214–220. doi:10.1111/j.0033-0124.1973.00214.x
De Vorsey LJ (1980) Dating the emergence of a Savannah River island: an hypothesis in forensic historical geography. Environ Rev 4(2):6–19
DiBiase D, Corbin T, Fox T, Francica J, Green K, Jackson J et al (2010) The new geospatial technology competency model: bringing workforce needs into focus. URISA J 22(2):55–72
Forer P, Unwin D (1999) Enabling progress in GIS and education. In: Longley P, Goodchild MF, Maguire DJ, Rhind DW (eds) Geographic information systems: management issues and applications. Wiley, New York, pp 747–756
Gabrosek J, Cressie N (2002) The effect on attribute prediction of location uncertainty in spatial data. Geogr Anal 34(3):262–285
Gaudet CH, Annulis HM, Carr JC (2003) Building the geospatial workforce. URISA J 15(1):21–30
Getis A, Drummy P, Gartin J, Gorr W, Harries K, Rogerson P et al (2000) Geographic information science and crime analysis. URISA J 12(2):7–14
Gold CM (2006) What is GIS and what is not? Trans GIS 10(4):505–519. doi:10.1111/j.1467-9671.2006.01009.x
Goodchild MF (1992) Geographic information science. Int J Geogr Inform Sci 6(1):31–45
Goodchild MF (2008) Geospatial technologies and homeland security research. In: Sui DZ (ed) Geospatial technologies and homeland security: frontiers and future challenges, vol 94, GeoJournal library. Springer, Dordrecht, pp 345–353
Goodchild MF, Anselin L, Appelbaum RP, Harthorn BH (2000) Toward spatially integrated social science. Int Reg Sci Rev 23(2):139–159. doi:10.1177/016001760002300201
Grip WM, Grip RW, Morrison RD (2000) Application of aerial photography and photogrammetry in environmental forensic investigations. Environ Forensic 1(3):121–129
Groff ER, Vigne NGL (1998) The use of geographic information systems (GIS) for state and local crime analysis. Paper presented at the conference of European statisticians, Ottawa, 5–7 Oct 1998
Haggerty KD (2004) Displaced expertise: three constraints on the policy relevance of criminological thought. Theor Criminol 8(2):211–231. doi:10.1177/1362480604042244
Jacobson M (2004) Reply to Kevin D. Haggerty. Theor Criminol 8(2):233–238. doi:10.1177/1362480604042246
Jensen J (2007) Remote sensing of the environment, 2nd edn. Pearson Prentice Hall, Upper Saddle River New Jersey
LaVigne NG, Groff ER (2001) The evolution of crime mapping in the United States: from the descriptive to the analytic. In: Hirschfield A, Bowers K (eds) Mapping and analysing crime data: lessons from research and practice. Taylor & Francis, New York, pp 203–222
Leipnik MR, Albert DP (2003) Overview of implementation issues. In: Leipnik MR, Albert DP (eds) GIS in law enforcement: implementation issues and case studies. Taylor & Francis, New York
Listi GA, Manhein MH, Leitner M (2007) Use of the global positioning system in the field recovery of scattered human remains. J Forensic Sci 52(1):11–15
Longley P, Goodchild MF, Maguire DJ, Rhind DW (2005) Geographical information systems and science, 2nd edn. Wiley, New York
Mamalian CA, LaVigne NG (1999) The use of computerized crime mapping by law enforcement: survey results. National Institute of Justice Journal Research Preview, January, Washington, DC
Mark DM (2003) Geographic information science: defining the field. In: Duckham M, Goodchild MF, Worboys M (eds) Foundations of geographic information science. Taylor & Francis, New York, pp 1–15
Markovic J, Bueermann J, Smith K (2006) Coming to terms with geographical information systems. Police Chief 73(6):60–73
Martin GJ, James PE (1993) All possible worlds: a history of geographical ideas, 3rd edn. Wiley, New York

Mathewes RW (2006) Forensic palynology in Canada: an overview with emphasis on archaeology and anthropology. Forensic Sci Int 163(3):198–203
McKinley J, Ruffell A, Harrison M, Meier W, Kemp H, Graham C, Barry L (2008) Spatial thinking in search methodology: a case study of the "No body murder enquiry", West of Ireland. In: Ritz K, Dawson L, Miller D (eds) Criminal and environmental soil forensics. Springer, New York, pp 285–302
Mildenhall DC, Wiltshire PEJ, Bryant VM (2006) Forensic palynology: why do it and how it works. Forensic Sci Int 163(3):163–172
Morgan RM, Bull PA (2007) Forensic geoscience and crime detection. Identification, interpretation and presentation in forensic geoscience. Minerva Medicoleg 127(2):73–90
Morrow-Jones HA, Anacker KB, Chen W, Horner MW, Malecki EJ (2005) Rapid property transactions and price changes: an exploratory study in forensic Geographic Information System (GIS). FOCUS Geogr 48(3):19–25
Murray RC (2004) Evidence from the earth: forensic geology and criminal investigation. Mountain Press, Missoula
National Institute of Justice (2009) High-priority criminal justice technology needs. In: Office of Justice Programs (ed). U.S. Department of Justice, Washington, DC, p 6. http://www.ncjrs.gov/pdffiles1/fs000237.pdf. Accessed 20 Jan 2009
National Institute of Justice (2010) High-priority criminal justice technology needs. In: Office of Justice Programs (ed) U.S. Department of Justice, Washington, DC, p 37
Nelson L (1999) GIS. A powerful weapon for law enforcement. ArcUser, Jan–Mar 1999
Noond J, Schofield D, March J (2002) Visualising the scene: computer graphics and evidence presentation. Sci Justice 42(2):89–95
Oatley G, Ewart B, Zeleznikow J (2006) Decision support systems for police: lessons from the application of data mining techniques to "soft" forensic evidence. Artif Intell Law 14(1):35–100. doi:10.1007/s10506-006-9023-z
Obledo MN (2009) Forensic archeology in criminal and civil cases. Forensic Mag 6(4):31–34
Pye K, Croft DJ (2004) Forensic geoscience: introduction and overview. Geol Soc Lond Spec Publ 232(1):1–5. doi:10.1144/gsl.sp.2004.232.01.01
Rossmo DK (2000) Geographic profiling. CRC Press, Boca Raton
Rossmo DK (2006) Geographic profiling in cold case investigations. In: Walton RH (ed) COLD CASE HOMICIDES: practical investigative techniques. CRC Press, Boca Raton, pp 537–560
Ruffell A (2006) Feature: forensic geoscience. Geol Today 22(2):68–70
Ruffell A, McKinley J (2005) Forensic geoscience: applications of geology, geomorphology and geophysics to criminal investigations. Earth-Sci Rev 69(3–4):235–247
Ruffell A, McKinley J (2008) Geoforensics. Wiley, Chichester
Schmitz P, Eloff C, Talmakkies R, Linnen C, Lourens R (2013) Forensic mapping in South Africa: four examples. Cartogr Geogr Inform Sci 40(3):238–247. doi:10.1080/15230406.2013.800273
Suggs JA, Beam EW, Biggs DE, Collins W Jr, Dusenbury MR, MacLeish PP et al (2002) Guidelines and resources for conducting an environmental crime investigation in the United States [Guest Editorial]. Environ Forensic 3(2):91–113
United States v. Jones (2012) 615 F.3d 544
Wang F (2005) Geographic information systems and crime analysis. Idea Group Publishing, Hershey, p 345
Warner TA, Nellis MD, Foody GM (2009) Remote sensing scale and data selection issues. In: Foody G, Warner T, Nellis MD (eds) The Sage handbook of remote sensing. Sage, New York, pp 1–17
Wartell J (2003) Crime mapping and data sharing. In: Leipnik MR, Albert DP (eds) GIS in law enforcement: implementation issues and case studies. Taylor & Francis, New York
Wilson AC, Jones SG, Smith MA, Liles R (1997) Tracking spills and releases: high-tech in the courtroom. Tulane Environ Law J 10:371–394
Wolff M, Asche H (2009) Towards geovisual analysis of crime scenes – a 3D crime mapping approach. In: Sester M, Bernard L, Paelke V (eds) Advances in GIScience. Springer, Berlin/Heidelberg
Zhao JL, Bi HH, Chen, HC (2003) Collaborative workflow management for interagency crime analysis. In: Intelligence and security informatics, proceedings. Lecture notes in computer science, vol 2665. Springer, Berlin, pp 266–280

Chapter 2
Geospatial Technologies in the Courtroom

George Roedl, Gregory A. Elmes, and Jamison Conley

Abstract The function of a court is to resolve disputes through a legal process. With few exceptions, the progression of a legal case will follow the strict guidelines of rules and codes developed from numerous court decisions to fairly and efficiently securing a just determination. All federal courts adhere to a flexible set of rules published in the Federal Rules of Evidence (FRE). The FRE provides rules and definitions governing general provisions, judicial notice, presumptions, relevance, privileges, witnesses, expert witnesses, hearsay, and authentication. However, there are as yet no special rules governing the use of geospatial technologies or spatial data. From a pragmatic legal perspective, spatial data differs immensely from the traditional form of evidence. However, the power of spatial information is extremely persuasive and compelling in litigation. While the acceptance of spatial data and methods has increased in litigation, there are also several issues that merit careful consideration when using spatial data. This chapter examines key rules and court decisions that impact the potential admissibility of spatial data and technologies in a modern courtroom.

Keywords Admissibility • Rules of evidence • Demonstrative evidence • Scientific evidence • Computer-generated evidence • Frye test • Daubert • Expert witness

2.1 Introduction

Crowsey (2002a) described spatial information as one of the most powerful comprehension and communication tools available to legal practitioners. The likelihood of a successful litigation is greatly enhanced through an effective means

G. Roedl (✉) • G.A. Elmes • J. Conley
Department of Geology and Geography, West Virginia University,
330 Brooks Hall, Morgantown, WV 26506, USA
e-mail: groedl@gmail.com; greg.elmes@mail.wvu.edu; jamison.conley@mail.wvu.edu

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of communication and visualization that aids in a greater understanding of the truth (Crowsey 2002b; Cohen 2008). Spatial technologies, and the associated spatial information derived from spatial technologies, provide the tools and methods for persuasive communications by those who adopt them as well as harm those who are hesitant to adopt them (Crowsey 2002a; Gonzalez 2009). When effectively and properly used, spatial information is capable of providing a persuasive understanding of the facts of a case (Crowsey 2002a, b; Cohen 2008). Fiedler (2003) described humans as visual learners who prefer visual evidence, citing an 87 % retention rate of visual information as opposed to only a 10 % retention rate of oral information alone. Pratt (2001) acknowledged information retention rate statistics as the difference between winning and losing a case. On the other hand, however, effective visual information communication may be the admissibility of spatial tools and data in legal proceedings requires an understanding of proper procedures. Since judiciaries from one country to the next can vary, a discussion of procedural processes and the admission of spatial data in courts is necessarily restricted. Cho (2005) provides an introduction to spatial law, legal systems, and legal theories of various jurisdictions around the world, whereas this chapter addresses the legal system in the United States exclusively.

The function of a court is to resolve disputes through a legal process. Based on the English common law court model, the US court system uses an adversarial process in which facts are presented to a judge and jury in a persuasive manner intended to support an argument effectively or to refute an opponent's argument. The role of the court in an adversarial system is to act as an impartial referee for the parties presenting facts in a dispute to ensure due process is followed. There are two basic types of courts: criminal court[1] and civil court.[2] In a criminal court, the adversaries presenting facts are the prosecutor and the defender. The prosecutor provides compelling evidence to support accusations of illegal activities by the defender. If the prosecutor successfully presents a persuasive argument, the defender can be punished through fines or imprisonment. Therefore, criminal court cases require a prosecutor to provide proof beyond a reasonable doubt to help ensure an innocent defender is not punished. By contrast, a civil court resolves disputes between parties in which one party prevails by providing the most compelling argument which supports their position more favorably than the opponent's argument. The judge serves as the fact finder to first determine if a party was wronged and then either assesses damages or issues a judicial order to start or stop an action petitioned to the court (Cohen 2008). For example, in a car accident between two citizens, the judge would listen to arguments on each side to first determine who was at fault and then make a decision as to what the remedy should be (e.g., repair costs).

Both criminal and civil courts can hold two types of trials. The first type of trial is a trial by jury. In a trial by jury, ordinary citizens are called upon to become fact finders. For criminal cases, a trial by jury is standard with few exceptions. Because

[1] See also http://www.uscourts.gov/uscourts/rules/criminal-procedure.pdf

[2] See also http://www.uscourts.gov/uscourts/rules/civil-procedure.pdf

selecting jurors is a lengthy process and not all trials (e.g., probate) necessitate a jury, bench trials are an alternative. In a bench trial, a judge serves as the finder of facts and administrator of justice. Every US state has a court system making criminal and civil trials available. In addition to state courts, there are federal district courts which preside over trials of specific matters. District courts preside over cases involving constitutional law, treaties, maritime law, interstate law and cases, and cases in which the US government is either the plaintiff or defendant. There are currently 89 districts and 94 district courts in the United States. There are also an additional 13 (11 district, 1 D.C., and 1 federal) judicial courts (also called circuit courts or courts of appeals) which preside over district court cases that have been appealed when issues regarding errors in the law are suspected (e.g., misinterpretation of a constitutional amendment or overstepping/lack of jurisdictional authority).[3] A US court of appeals typically serves as the final arbitrator for most federal cases and often sets legal precedent through its decisions (Hemmens et al. 2007). Unlike state and federal courts, an appeals court does not hold trials. Decisions are determined entirely through records presented at the lower court, although attorneys may be permitted to provide a brief oral argument. After an appeals court reaches a decision, either party may apply to the US Supreme Court to review the decision. Although a lengthy discussion of the judicial hierarchy may seem extraneous in a work on forensic GIS, it is important to establish the implications of decisions. It should now be clear that district courts only hear certain types of cases, while an appeals court is a much more powerful entity that sets legal precedent and policy after reviewing select cases, typically dealing with constitutional liberties.

2.2 Admissibility of Evidence

With few exceptions, the progression of a legal case will follow the strict guidelines of rules and codes developed from numerous court decisions (Cohen 2008). All federal courts adhere to the rules for admissibility adopted by the US Supreme Court and published in the Federal Rules of Evidence (FRE).[4] FRE Rule 1101 specifies which courts, judges, cases, and proceedings are required to adhere to the FRE, as well as the only three exceptions (a preliminary question of fact governing admissibility, grand-jury proceedings, and miscellaneous proceedings such as issuing an arrest warrant). The purpose of the FRE, as stated in Rule 102, is to "administer every proceeding fairly, eliminate unjustifiable expense and delay, and promote the development of evidence law, to the end of ascertaining the truth and securing a just determination." State court systems adhere to similar sets of published rules (e.g., Rules of Civil Procedures) based on the FRE (Onsrud 1992). The current edition of FRE contains 68 rules.

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[3] See also http://www.uscourts.gov/uscourts/rules/appellate-procedure.pdf

[4] Federal Rules of Evidence. Amended 01 December 2012. Available at http://www.uscourts.gov/uscourts/rules/rules-evidence.pdf. Accessed 20 September 2013.

In theory, evidence which is relevant and not excluded by any of the FRE is admissible (Levi et al. 2013). Evidence may be admissible as either scientific evidence or demonstrative evidence. Scientific evidence is substantive evidence having probative value in and of itself, while demonstrative evidence is meant to clarify or illustrate testimony and has no probative value (Dischinger and Wallace 2005; Pratt 2001). Presented to prove or disprove a matter at issue in court, scientific (substantive) evidence comes in the form of testimonial evidence (e.g., oral testimony), documentary evidence (e.g., written testimony), or real evidence (e.g., a physical object) (Pratt 2001). Demonstrative evidence comes in the form of illustrative evidence (e.g., photographs) and actual evidence (e.g., confiscated items). Since scientific evidence has independent probative value, it becomes part of the formal record which may be examined by a deliberating jury. The jury is then able to review the facts revealed through the scientific evidence to aid in determination of guilt or innocence and liability (Bird 2001). In contrast, demonstrative evidence is rarely available during deliberations since it has no probative value.

Both scientific evidence and demonstrative evidence must be deemed relevant, authentic, and accurate and reliable (commonly referred to as foundation) in order to be admissible (Markowitz 2002; Dischinger and Wallace 2005). Depending upon the manner in which they are used, geospatial technologies can provide scientific evidence, demonstrative evidence, or both. When spatial data is merely used to illustrate and clarify testimony, it is admissible as demonstrative evidence (i.e., illustrative evidence). However, when used to prove the existence of a fact (e.g., a GPS tracking log) or as the basis of an expert opinion or conclusion, spatial data becomes scientific (Pratt 2001). Admitting spatial data as scientific evidence in a trial is more difficult than admission as demonstrative evidence and is largely dependent on having an expert witness testify about the facts (e.g., authenticity and accuracy) of the data (Dischinger and Wallace 2005). However, spatial data gathered from geospatial technologies may be granted greater admissible probative value when there is minimal human interaction with the data, such as raw satellite images (Krouse et al. 2000).

Spatial data generated from geospatial technologies, such as GIS, GPS, and remotely sensed data, are considered computer-generated data as well as digital data since computer technology is used to create the data which is stored digitally. Pratt (2001) referred to CGE as an abbreviation applicable to computer-generated evidence (also referred to as computer-generated exhibits), a broad term encompassing any use of computers in producing evidence for litigation. The Committee on Identifying the Needs of the Forensic Sciences Community (2009) referred to digital data as the digital evidence (e.g., photographs, call logs, and location records of a device) that could be gathered, processed, or interpreted from digital devices, such as desktop and laptop computers, cell phones, digital cameras, GPS devices, portable media players (e.g., IPods), etc.

Although Chap. 1 characterized spatial data as digital data, it is worthwhile to make a distinction between spatial data and the computer-generated end product derived from spatial data (generated by geospatial technologies) that may ultimately be admitted into court. For example, digital maps would be considered digital data representations of reality, whereas animated maps may be considered computer-generated data. Additional examples could include models which combine spatial