Meeting Geospatial Information Needs Through GIS

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Abstract

Advances in computer and networking technologies are impacting the quality and quantity of information accessible to society. Information retrieval systems provide a methodology and toolset for organizing and retrieving information in ways that improves meeting the information needs of societies. Geospatial information is a specific type of information that is gaining increased attention and importance. Geographic information systems is the convergence of various technological advancements starting in the mid 20th century. Geographic information systems is a kind of information retrieval system for geospatial information. It is important for librarians and information scientists to understand this rapidly evolving technology so they can learn how to best meet the geospatial information needs of their communities. Researchers interested in library and information science have examined how geographic information systems can benefit academic and research libraries, inform the research and development of geographic information retrieval, and shape the future of the GeoWeb. Geographic information systems are a unique and powerful tool that librarians and information scientists can use to meet the geospatial information needs of their communities.

Introduction

Societies are seeing dramatic advances in computer and networking technologies. These advances impact the quality and quantity of information that is accessible to society. As societies become more interconnected through computer and networking technologies there is an increased need to search, find, and evaluate existing and future information. Technological advancements of the 20th century have enabled librarians and information scientists to better serve their communities by providing more efficient storage, maintenance, and retrieval of the specific information their communities seek. With the development of electronic (or automated) information retrieval systems (IRS), librarians and information scientists can more easily provide access to information to help modern society navigate the vast ocean of information available to the world.

Among the tidal waves of information hitting modern societies, geospatial information (also referred to as spatial or geographic information), is a specific type of information that is receiving increased attention due to its importance and value. Geospatial information is information associated with a specific location on earth. Everything that happens on earth happens somewhere. Throughout history technology has enabled societies to capture and record geospatial information for the purpose of better describing the world and their place in the world. Babylonians from 2300 B.C. used clay tablets to map their known world. Greeks made discoveries about the spherical nature of earth including roughly calculating the circumference of the earth. Romans were one of the first known civilizations to create a map depicting a road network. During the period termed the Renaissance explorers constructed maps to help survey new lands and places throughout the world. Geospatial information is an essential part of societies today. For example, geospatial information helps people navigate on transportation systems using receivers that communicate with global positioning satellites (GPS) orbiting the earth. It also helps to assist governments, businesses, and landowners in decision-making processes about commerce and resource management. And furthermore aids individuals in sharing social information about their lives with families, friends, and colleagues. Geospatial information is manifest in common pieces of data such as a zip code, a house or business address, administrative civil boundaries (e.g. states counties, and metropolitan areas), geotagged[1] photos or social media messages, and latitude/longitude coordinates used in GPS receivers.

From traditional cartography and mapping on clay tablets to remotely sensed data of the earth using aerial photography, methods have been developed to help create, maintain, retrieve, analyze, and share geospatial information. Advancements in computer technologies starting in the mid 20th century enabled the development of geographic informations systems. A geographic information system is a collection of components designed to create, manage, store, and retrieve geospatial information that are shared through spatial analysis and visualization. Studying about geographic information systems leads to better understanding of this information retrieval system and its value in searching and finding geospatial information. Understanding geographic information systems and geospatial information retrieval enables librarians and information scientists to better meet the needs of their specific communities. By examining the use of GIS in library services, geographic information retrieval, and the overlap of geospatial information and the World Wide Web, one comes to understand that geographic information systems have an important role in the 21st century library.

Description and Brief History

Geographic information systems (GIS) has many definitions depending on the intended purpose and use of the system[2]. GIS can be broadly defined as any integrated collection of computer software and data used to capture, store, modify, analyze, and retrieve geospatial information. GIS is commonly comprised of six main components: hardware, software, data, procedures, the human user, and networks. Hardware refers to the computing devices that are used to run the various sets of GIS tasks and actions. This includes desktop computers, laptops, web servers, mobile phones, and tablets. The software is the set of computer instructions running on one or more devices that provides a digital interface for running GIS tasks and actions on computing devices. Examples include the web browser, desktop and server applications, or mobile apps. Data within a GIS refers to the digital representation of geographic features and attributes that GIS software encodes and decodes. The data is non-spatial tabular data tied to spatial data georeferenced to locations on earth. Spatial data can be represented in the from of vector features (points, lines, and polygons) or raster formats (rectangular grid storing data values for each position in the grid). Vector and raster data can be stored on disk in file-based formats or as items in a database. Procedures in GIS are the guidelines and rules put in place by an organization developing or implementing GIS. The people or users of GIS use the hardware, software, data, procedures, and networks to create, modify, update, and store GIS data and analyses. Communication and information sharing over computing and internet (and intranet) networks provides a backbone to the utility of GIS (Longley, Goodchild, Maguire, & Rhind, 2005, p. 18-24).

GIS has roots in spatial analysis used within the discipline of geography. Its development is multi-disciplinary in nature combining areas of cartography and mapping with statistical analysis and computer science. Various projects in the 1960s spurred development of the first real GIS. Canada's Department of Forestry and Rural Development developed "a computer-based information system for the storage and manipulation of map-based land data" (Tomlinson, 1968). This first GIS system allowed cartographic themes to be mapped digitally and overlaid with other different thematic layers (Tomlinson, 1968, p. 202). These geographic overlays allowed for finding spatial patterns between seemingly disparate datasets. Work done by the United States Bureau of the Census for the 1970 census to create digital records of all streets in the United States as well as the ODYSSEY GIS developed by Harvard University's Laboratory for Computer Graphics and Spatial Analysis[3] spurred further development of GIS as a platform for geospatial information collection, manipulation, analysis, and visualization (Longley et al., 2005, p.17). The 1980s saw the formation of software companies and systems building on the earlier research from the previous two decades. GIS evolved from purely research-driven technology to the business market. The lowering of hardware and software costs while increasing computing power pushed the limits and abilities of computer technologies to more efficiently answer geospatial information questions.

Literature Review

Martindale (2004) lamented that there was not enough literature about GIS within library and information science. Since the creation of GIS in the 1960s (Tomlinson, 1968) there has been substantial literature written about GIS mainly from the fields of geography and computer science (Sweetkind-Singer, & Williams, 2001). Since 1990 there has been an increase in literature written about GIS from authors in the field of library and information science (Michalec, & Welsh, 2007). Research and literature by librarians and information scientists cover various aspects of GIS and how it can meet the needs of information seekers. Researchers note the growing role of GIS in information management and visualization (Barnes, 2013; Chapman, & Essic, 2011; Sedighi, 2012; Johnston, & Jensen, 2009; Shawa, 2006; Xia, 2005). GIS is described in literature as a decision and planning support system that handles digital geographic data by combining non-spatial attribute information with spatial data (Ahonen-Rainio, 2005; Chapman, & Essic, 2011; Sedighi, 2012; French, 2001; Xia, 2005). A common dynamic identified in research literature about GIS is how to support advanced or expert GIS users while also helping meet the needs of the casual user with less GIS expertise (Chapman, & Essic, 2011; French, 2001; Morris, 2006; Sweetkind-Singer, & Williams, 2001). GIS is also identified as a multidisciplinary technology utilized by various user communities in a wide range of study areas (e.g. history, economics, meteorology, biology, geology, sociology, geography, business, marketing, and political science) that fits nicely within the multidisciplinary nature of libraries (Chapman, & Essic, 2011; Dodsworth, & Nicholson, 2012; Martindale, 2004; Mountrakis, Agouris, & Stefanidis, 2005; Sweetkind-Singer, & Williams, 2001).

Geospatial services in libraries are not new (Barnes, 2013; Martindale, 2004). GIS is popular among the university research community (Chapman, & Essic, 2011; Dodsworth, & Nicholson, 2012; Martindale, 2004; Sweetkind-Singer, & Williams, 2001). Since each academic or special library is unique with their own set of needs and challenges, GIS should be carefully evaluated before implementing in a library (Barnes, 2013; Martindale, 2004; Sweetkind-Singer, & Williams, 2001). Research also covers various other topics related to using GIS within libraries. There are various ways libraries can implement GIS for use by their researching community (Barnes, 2013; Bishop, & Johnston, 2013; Brisaboa, Luaces, Places, & Seco, 2010; Dodsworth, & Nicholson, 2012; Sedighi, 2012; French, 2001; Johnston, & Jensen, 2009; Morris, 2006; Shawa, 2006; Sweetkind-Singer, & Williams, 2001; Xia, 2005). GIS can be used to help index existing and new items in a library collection that contain geospatial information (Bordogna, Ghisalberti, & Psaila, 2012; Brisaboa et al., 2010; Dodsworth, & Nicholson, 2012; Sedighi, 2012; Johnston, & Jensen, 2009; Palacio, Cabanac, & Sallaberry, 2010). Libraries can use GIS to map the actual location of the item on library shelves helping patrons locate items more quickly (Xia, 2005). GIS can also be used as an analysis and visualization tool to help visually represent a library's collection in the form of maps, charts, and tables. (Sedighi, 2012; Johnston, & Jensen, 2009). Some researchers state that library and information science degrees should offer introductions to GIS within their coursework to help peak future library and information science professionals' interest in GIS (Bishop, & Johnston, 2013; Bishop, Grubesic, Prasertong, 2013; Martindale, 2004). Research has mentioned a past GIS Literacy Project initiated by the Association of Research Libraries (ARL) in 1992. This literacy project helped libraries learn about and implement GIS for their user community (French, 2001; Martindale, 2004).

A new frontier in the merging of GIS and library and information science is geographic information retrieval (GIR). Information retrieval (IR) is the retrieval of information that meets one’s information needs. A major part of IR includes indexing information from an item’s content itself or from the metadata that describes the item’s content so that it can be queried against as needed (Palacio et al., 2010, p. 92). GIR is IR focused on retrieving geospatial information. GIR tasks are to parse, measure similarity, and retrieve relevant documents from a collection that contains relevant geospatial information based on the user's information query (Palacio et al., 2010, p. 94). In GIR a GIS provides the ability to search spatially using geospatial information within the information query. It also searches for non-spatial attribute information that are tied to geographic features (Sedighi, 2012). Another aspect of GIR research focuses on better retrieval of relevant geospatial information. This is done by responding accurately to fuzzy or more natural language geospatial queries. This includes researching machine-learning ontology to help improve extracting, indexing, storing, and retrieving geospatial information from documents in a collection (Ahonen-Rainio, 2005; Bordogna et al., 2012; Borges, Davis, Laender, & Medeiros, 2011; Brisaboa et al., 2010; Lutz, & Klien, 2006, Mountrakis et al.2004; Mountain, & MacFarlane, 2007; Wiegand, & Garcia, 2007). Using geospatial filters to narrow down the search criteria for a geospatial query and ranking results geographically, especially using a mobile device, is also a major topic discussed in GIR literature (Mountain, & MacFarlane, 2007).

GIS research within library and information science also focuses on searching for and discovering items containing geospatial information on the World Wide Web (Bishop et al., 2013; Dodsworth, & Nicholson, 2012; Palacio et al., 2010). Some literature studies the influence and use of web-based GIS solutions including web mashups, geo-hacking, Google Maps, and Google Earth (Dodsworth, & Nicholson, 2012; Johnston, & Jensen, 2009; Morris, 2006). Researchers also studied the role of metadata to help evaluate and identify suitable geospatial information on the World Wide Web (Ahonen-Rainio, 2005; Bishop et al., 2013; Chapman, & Essic, 2011). GIS web services are a potential solution for effectively disseminating on the World

Wide Web geospatial information cataloged by a library (Johnston, & Jensen, 2009; Lutz, & Klien, 2006; Morris, 2006; Shawa, 2006; Sweetkind-Singer, & Williams, 2001).

Discussion

One of the main applications of GIS within the field of library and information science is GIS library services. How to successfully integrate GIS with an existing academic or special library is a common question being researched. The ARL initiated a project in 1992 to promote GIS literacy and help research libraries meet their current geospatial information needs. In turn, libraries were assisted in preparing for future geospatial needs and requirements. Careful planning using existing library support mechanisms was crucial in identifying the best ways for a research library to implement GIS services (French, 2001, p. 47). Examples of libraries integrating GIS into their existing library services serve as valuable reference points for better understanding the best approach for use of GIS in a library. Shawa (2006) showed how GIS was used in Princeton University to scan print maps, add the digital maps into their library collection, and make these digital map scans available to access over online. The Stanford University Library integrated GIS into their array of library services to provide a centralized GIS for use by patrons of all academic disciplines served by the library (Sweetkind-Singer, & Williams, 2001). These examples are evidence pointing towards an academic or research library creating and maintaining its own GIS department to better meet the geospatial information needs of the library's community (Sedighi, 2012; Shawa, 2006; Sweetkind-Singer, & Williams, 2001). The multidisciplinary use of GIS by all academic disciplines places the library in a strong position to centrally maintain and support GIS services for the university.

Libraries are also using GIS to make their catalogs geospatially aware. Geographic references stored in existing MARC records can be used to search and visually display items in a library collection using a map (Johnston, & Jensen, 2009). Dodsworth and Nicholson (2012) describe in their research how GIS software has "helped libraries revitalize their collections as well as assist in transferring spatial information literacy skills to academic students and faculty (p. 112). Xia (2005) showed how GIS can be used as a way for better locating items within an academic or research library. Mapping the physical shelf location of an item and displaying that information in the library's OPAC results could prove effective to help patron's more quickly locate items in a research library's large and sprawling collection. With careful planning and implementation GIS can be successfully integrated within a library's system to better support the geospatial information needs of their patrons. There is a clear need for more training in GIS to help librarians and information scientists improve their skills in GIS and discover the best ways to implement GIS library services (Bishop, & Johnston, 2013; Martindale, 2004). Limitations of existing library MARC records to link to geospatial information available online is one hurdle academic and research libraries face in trying to best use GIS for their patrons (Johnston, & Jensen, 2009, p. 129).

A current development of GIS within library and information science is GIR. Research in GIR centers improve accuracy of geospatial information retrieval. This can be reached in various ways. Bordogna et al. (2011) demonstrated using a fuzzy approach to indexing geospatial information for later retrieval since geographic names and locations can be ambiguous, synonymous, or change over time (p. 123). Improving GIR accuracy can also be achieved by making the GIR understand more natural language queries using ontologies. These ontologies make it possible for the information user to use more complex geospatial queries in a more user-friendly way (Lutz, & Klien, 2006, p. 256-257). Wiegand and García (2007) propose a task-based or semantic approach for automating the finding and indexing of geospatial information. This approach more clearly defines relationships between geospatial information by using ontologies and "adds a level of organization to help target search over the multitude of geospatial data and types of data that exist" (Wiegand, & Garcia, 2007, p. 370). Such a system helps improve the effectiveness of retrieving geospatial information. Borges et al. (2011) also propose an ontology-based approach for automatically extracting geospatial information. These ontology-based approaches for extracting and indexing geospatial information using GIS and GIR help to improve the accuracy of searches for geospatial information. While impressive development has occurred in GIR, there remains needed areas of research to ensure users' geospatial information needs are met in the most accurate, efficient way possible. Continued research about GIR will help to enable more intuitive mechanisms for retrieving geospatial information like browsing and searching for information using a map interface instead of a text-based interface using keywords only (Chapman, & Essic, 2011, p. 15). Future research and work can also help improve precision and recall in a GIS (Brisaboa et al., 2010) and in developing ways to support more complex, natural language queries for geospatial information (Borges et al., 2011; Lutz, & Klien, 2006).

Research about the GeoWeb is another emerging trend in the field of library and information science. The GeoWeb is defined as "a merger between the Web, geospatial technologies, and geographic information" (Bishop et al., 2013). Research in the GeoWeb focuses on issues connected to indexing and discovering geospatial information through the internet on the World Wide Web. A common manifestation of the GeoWeb are geospatial catalogs or geolibraries. Geospatial catalogs have an advantage over traditional library collections because the data is digitally stored and accessible over the World Wide Web. The sequence of digital data can be reordered and manipulated in ways that a physical library collection cannot (Longley et al., 2005, p. 247).

Online portals to geospatial information can be found among governments seeking to provide more transparent access to geospatial information they create and maintain. The United States created The Geospatial Platform to help organize, manage, and share geospatial information with the public that is created by government agencies[4]. The United Kingdom is another example of a government utilizing geolibraries to help share geospatial information with the public by releasing public data generated by governmental departments and other local authorities[5]. Examples of commercial or private sector geolibraries include WeoGeo, ArcGIS.com, and Data Basin[6]. Similar in purpose to the government geolibraries, these commercial libraries exist to help collect, manage, and share geospatial information with the public. These geolibraries provide access to geospatial information that are valuable for librarians and information scientists to meet the geospatial information needs of their communities.

Evaluating geospatial information is another issue facing the GeoWeb that needs the attention of librarians and information scientists. Like non-spatial data on the World Wide Web, geospatial information can be unreliable and inconsistent in how data is collected, described, and formatted (Bishop et al., 2013, p. 297). This poses challenges to accurately searching for and finding needed geospatial information. The lack of controlled keywords and vocabularies for use in filling out geospatial metadata also presents an obstacle searching and discovering the most relevant geospatial information (Chapman, & Essic, 2011, p. 3). Ahonen-Rainio (2005) concludes that despite overall understanding of the importance of metadata, "availability of geospatial metadata is still limited and the resources needed for creating metadata are debated" (p. 61). Chapman and Essic (2011) recommend that libraries identify the most valuable metadata fields for evaluating a dataset's relevance, cleaning up keywords and non-compliant metadata records for geospatial information. They recommend working within the library and information science community to develop "a thesaurus for thematic keywords that fits the specific needs of geospatial resources" (p. 15). Various metadata standards exist on the web that have been used to describe geospatial information[7], but enforcing these standards has proved problematic. With a lack of standard vocabularies to help populate metadata records in these schemas, metadata describing online geospatial information is inaccurate, confusing, and disconnected.

Another area of research related to the emerging trend of the GeoWeb is the development of geospatial web services and tools that enable people to modify and visualize geospatial information through the internet (Bishop et al., 2013, pp. 297-298). Online mapping products like Google Maps, Google Earth, Bing Maps, and OpenStreetMap[8] provide application programming interfaces (APIs). These enable web mashups and geo-hacking where anyone with internet access can combine various geospatial information sources from distributed environments (Morris, 2006, pp. 295-296). These new technologies are enabling a new way for librarians and information scientists to search, find, and retrieve geospatial information. The various Google mapping products are found in some academic and research libraries as a GIS itself, giving users the ability to perform geospatial queries for retrieving needed information.

These online mapping services were also shown to be used among academic libraries in finding, collecting, distributing, and educating about geospatial information and library services (Dodsworth, & Nicholson, 2012, p. 112). Although the GeoWeb accelerated access to greater amounts of geospatial information, challenges still exist in searching geospatial information on the World Wide Web more easily and accurately. Assessing the suitability of geospatial information, interlinking documents and items with geospatial relationships, and evolving the GeoWeb into a true semantic GeoWeb are challenges library and information scientists will face into the future.

Conclusion

GIS is seeing rapid growth and evolution similar to the changes seen in its underlying computer and network technologies. The increased awareness and use of geospatial information in modern societies presents new opportunities and challenges for librarians and information scientists. Many libraries have exerted tremendous effort to implement GIS within existing academic and research library services. Within academic and research libraries GIS is used to help index existing and new library items. By using the item's geospatial attributes they can be discovered and browsed using cartographic displays. Existing map collections can be digitized and cataloged within GIS to make a library's cartographic collection accessible to a wider audience as well as to the broader online community. The research and development in the use of GIS for GIR will continue to ensure improvement in how geospatial information is indexed and retrieved. The merging of GIS and the World Wide Web provides greater possibilities for creating, discovering, and using geospatial information. As the Web continues to evolve in handling metadata and understanding the relationships between online and connected data, research in GIS and the GeoWeb will help improve the access and reliability of geospatial information available online. While challenges of data quality and accessibility are manifested as the quantity of geospatial information increases, the rapid advancements in GIS technologies offer powerful solutions for librarians and information scientists to find innovative solutions to these challenges and meet the geospatial information needs of societies.

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Footnotes

[1] Geotag is an electronically attached label of a geospatial location on earth to photos, videos, or social media communications.

[2] GIS can be used by different user groups for a wide variety of purposes. In this way GIS has been defined by the groups of people that find them useful. For example, the general public may see GIS as a container of digital maps. Scientists may see GIS as a tool to reveal seemingly invisible patterns or connections that are only seen when analyzed spatially. Decision makers and planners may define GIS as a computerized tool for performing operations on geospatial data that are too tedious, expensive, or inaccurate if accomplished by hand (Longley et al., 2005, p. 16). Because GIS is used in many different ways the definition of GIS can vary relative to how it is being used.

[3] The early efforts of the Harvard Laboratory for Computer Graphics and Spatial Analysis was a perfect demonstration of the multidisciplinary nature of GIS. This research by planners, geographers, cartographers, mathematicians, computer scientists, artists, and landscape architects “converged to rethink thematic mapping, spatial analysis, and what is now called gis” (Chrisman, 2004, p. 1).

[4] The Federal Geographic Data Committee (FGDC) created The Geospatial Platform (http://www.geoplatform.gov/) to collect and manage geospatial information generated by all United States Federal Agencies.

[5] Similar to the U.S. government's efforts to make government data more accessible on Data.gov (http://data.gov) and The Geospatial Platform (http://www.geoplatform.gov), the United Kingdom offers free government data on data.gov.uk (http://data.gov.uk). They provide a map-based search as well for geospatially finding available information within the UK (http://data.gov.uk/data/map-based-search).

[6] These private online geolibraries act as electronic content management systems of governmental and non-governmental geospatial information. ArcGIS Online (http://www.arcgis.com) is a subscription-based portal for creating and managing online maps within organizations. WeoGeo (http://www.weogeo.com) is a collection of free and paid geospatial content that can be discovered using a map-based search interface. Data Basin is a free web portal collection of geospatial information to help scientists and researchers better understand the issues surrounding environmental conservation.

[7] Some common standards that are used by GIS and geospatial information are ISO 19115, Dublin Core, and CSDGM, a standard established by the U.S. Federal Geographic Data Commitee, promoting the creation, use, and sharing of geospatial information.

[8] Online web mapping tools are seeing a surge in development and use. Google has become a major provider of geospatial mapping products (https://maps.google.com, http://www.google.com/earth/). OpenStreetMap (http://www.openstreetmap.org) is an open data mapping product that relies on crowdsourced, voluntary efforts by members of local communities to map geospatial features all over the world. These mapping products power the map data utilized in applications running on a variety of devices and platforms including web sites and mobile devices. Companies like MapBox (https://www.mapbox.com) and CartoDB (https://cartodb.com) are pushing the boundaries for providing tools and interfaces exposing a larger amount of geospatial information on the World Wide Web.