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Geographic Information Systems

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INTRODUCTION

One of the main challenges of the 21st century are caused by the large amount of geospatial information through a GIS. Throughout time there have been many attempts to define Geographic Information Systems (GIS). Yet there is no consensus on define it and restrict it to one definition is limited. In the acronym - Geographic Information Systems - the geographic refers to the Earth's surface and near-surface, therefore, all human production and activity, and non-human are possible spatialization in GIS.

GIS is recognized as an analytical and decision-making tool with many uses in different fields. Likewise it is used in many industries plus commercial, education or government. It is powerful for

- Land administration,
- Statistical mapping,
- Transport,
- Network and environment management,
- Remote sensing images,
- Water/waste management,
- Maintenance and management of public lighting,
- Regional and urban planning,
- Tourism planning,
- Healthcare planning, and in
- Crime and security management.

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In broad terms GIS is a special class of information systems that keep track not only of events, activities, and things, but also their location. Computerization has opened a vast new potential in the way people communicate, analyze our surroundings and take decisions. The available data represent layers of the real world that can be stored, processed and presented later to answer future needs (Bernhardsen, 2002).

In the process of acquisition, processing and spatial representation there is the involvement of a multiplicity of inputs and outputs that can be managed on databases, which invariably seek analytical and graphical spatial embodiments. In the graphical display, vector or raster elements can be chosen, depending on the degree of specificity of the database and the type of expected results.

These databases can be collected at different scales and using a plurality of data types, including population census, aerial photography or satellite imagery. It allows to address multiple operating phases of the planning management process in a multiscale perspective with the challenge to meet more effective and efficient solutions. Due to this, nowadays it is frequently used as a spatial decision support system (SDSS) (Crossland, 2005).

Well-designed GIS should be able to provide a good computer system, because traditional GIS are intended to users operating on local servers. Traditionally GIS includes hardware and software. The hardware are the physical parts of the computer itself and associated peripherals (e.g., plotters and printers); and the software is interoperable, supporting the many data formats (in the infrastructure life cycle) and implementation may be custom-designed for an organization.

Even so a GIS can have two types of groups typically called as "GIS carries" and "GIS users", which are respectively responsible for the management and analysis. The heart of GIS technology is the ability to conduct spatial analysis, overlay data and integrate other solution and systems. Geoprocessing operations facilitate to link or merge data, spatial characteristics of data; search for particular characteristics or features in an area, update data quickly and cheaply and model data assess alternatives (maps, graphs, address lists, reports and summary statistics) tailored to meet particular needs.

Nonetheless GIS feature a number of operational advantages and have allowed the proliferation of new fields of endeavor in open access systems across multiple forms of acquisition, management, interpretation and spatial information analysis. This can be seen in the first item of the present paper where the background and GIS starting point is explored. The main goal of this paper is to underwrite the concept of GIS evolution and to identify new paths to accommodate recent scientific approaches with extensive range of application possibilities.

THEORETICAL BACKGROUND: THE STARTING POINT

GIS is the advent of a new stage of cartography. The evolution of this type of system is relatively recent, between the 50s and 60s of the XX century, but knowledge and technology have grown rapidly recently. The emergence of technological systems with computerized cartographic application arose from the need of the resolution of certain military problems and public administration domains. Many contributors and diverse influences concerning concepts and principles, data and issues of spatial infrastructure, software vendors, application areas, allowed a cohesive growth (Figure 1). GIS organizational structure is as diverse well as the multitude of roots from which it originated multitude of proprietary and public domain GIS software packages (Hendriks, 2005). Nowadays, applicability of this type of systems widened for commercial, non-profit and academic areas.

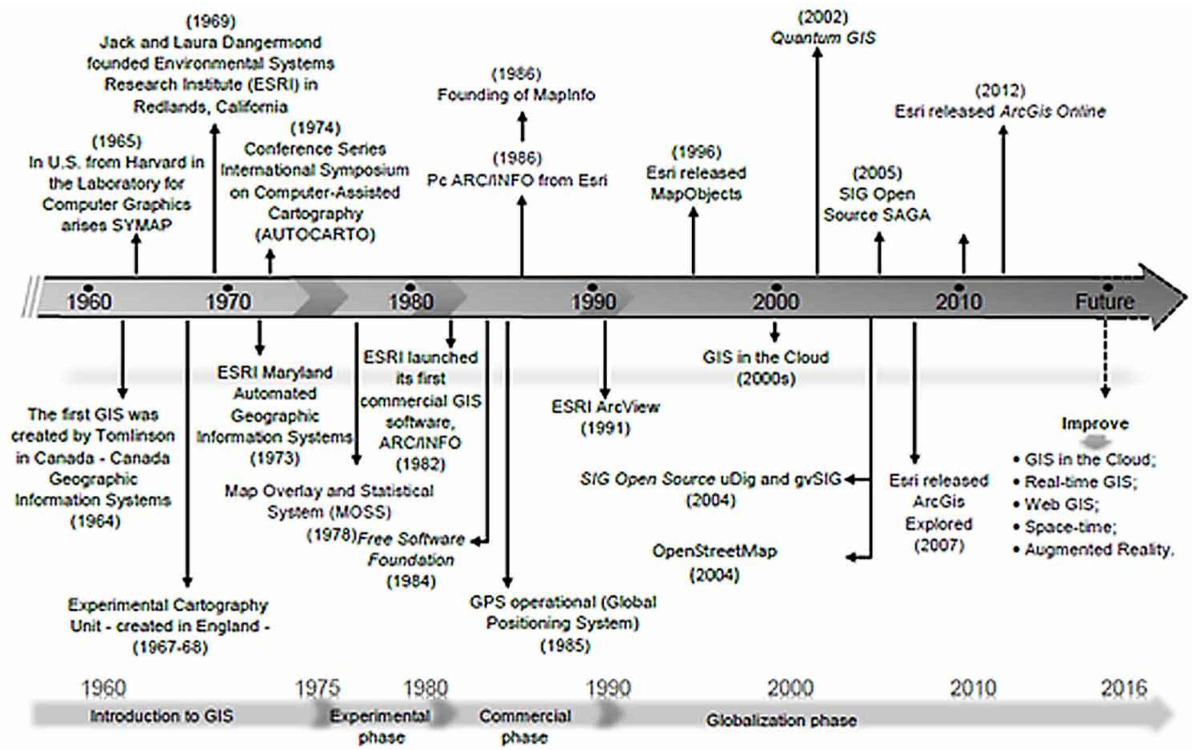
The mid 1960s witnessed the initial development of GIS in combining spatially referenced data, spatial data models and visualization. The actual roots of GIS are complex and difficult to determine (Miller & Goodchild, 2015).

Most authorities cite the Canada Geographic Information System (CGIS), designed around 1964, with a project led by Tomlinson (Bruno & Giannikos, 2015; Mordechai et al., 2008; Tomlinson, 1967). The objective was to obtain means for summaries and tabulations of areas of land from the Canada Land Inventory. For the registration of this lands, was made a massive federal-provincial effort to assess the utilization and potential of the Canadian land base. CGIS arose from the need to answer the challenges to measure accurately the areas of irregular geographic patches of homogeneous utilization and to overlay/compare different themes (Goodchild, 2006).

The period of the 1970s was characterized by rapid evolution, and ability of computer mapping automatic using data format and the solution of a wide range of technical issues. In the 1980s, democratization of access to computer allowed expand use of GIS. These innovations led to the first commercial viability of GIS, started to become popular as a standard computer application in government departments, universities, and private corporations. Accordingly, the ability to select, sort, extract, classify and display geographic data on the basis of complex topological and statistical criteria was available to users (Goodchild, 2006; Pourabbas, 2014).

The 1990s saw map analysis and modeling advances in GIS, and these systems became real management information tools as computing power increased. During this decade, the Open

Figure 1. Timeline of major GIS events, Source: Authors' own elaboration



GIS Consortium (OGC), aimed at developing publicly available geoprocessing specific actions, was founded. OGC is an international industry consortium, including government agencies and universities.

In 2000, the advent of web 2.0 and, more recently, the Web 3.0 (the semantic web) allow the Open Source GIS growth. Open source is a software that allows code source access to be open and free to distribute and modify. Nowadays it is possible for programmers to add new functions very rapidly and cheaply due to recent GIS advances. Mobile and internet devices, cloud computing, NoSQL databases, Semantic Web, Web services offer new ways of accessing, analyzing, and elaborating geospatial information in both real-world and virtual spaces, both for open source and commercial GIS (Pourabbas, 2014).

Despite the progress made during the twenty-first century, there are numerous challenges still lay ahead for geospatial sciences in various fields as shown in Table 1 (Yue et al., 2013).

DATA ANALYSIS AND TREATMENT SYSTEMS

Common citizens are constantly interacting with spatial dimension. Thereby, a GIS can be defined as a computer system operated by people, which comprises different aspects to be efficiently oper-

Table 1. The challenges for geospatial sciences for types of data intensity

Intensity	Description
Data	Collect of a multitude of data from space by day and accumulation at a similarly high rate.
Processing	Intensive modes of processing information in different spatiotemporal spectra.
Competition	Action of a multitude of end users accessing parallel to information (reception of a large number of users simultaneously are possible, because of development of the several services (*e.g.,* Google Maps and Bing Maps).
Spatiotemporal	Set of spatial and temporal dimension. It can be distinguished into two types of information – dynamic or static.

Source: (Adapted from Yue et al., 2013.)

ated. Firstly, a GIS have the hardware, software and data components. Those multidimensional components can be articulated to give us the basis to develop spatial analysis. However human interaction is crucial to develop a conceptual model approach, plan, operate and analyze the information. Nowadays a GIS can be very helpful to different enterprises size, organizations and persons where geographic patterns can be modelled and predicted. Spatial/Geographical data is representing real world through layers or objects where spatial position is crucial. Typically geographical data have descriptive or spatial information (Faiz & Krichen, 2012). It can be used to represent discrete data, typically through a vector-based representation (points, line polygons), or as a continuous data through a cell-based or raster mode that uses a matrix representation.

The most interesting part of a GIS project is the Spatial analysis (Heywood et al., 2011). It is related with the capability to visual analysis of maps and imagery, computational analysis of geographic patterns, finding optimum routes, site selection, and advanced predictive modeling (ESRI, 2013:6). The world is complex, but the exponential growth of technologies, such as Global Position Systems (GPS), real time-sensors or GIS made possible there simplification (ESRI, 2013). GIS are efficient tools for recording, exploiting, analyzing and displaying geographical data that can be applied in:

- Transportation,
- Health, environmental,
- Urbanism,
- Political activities,
- Water/waste management,
- Geomarketing,
- Security,
- Tourism,
- Viticulture/enology,
- Education or
- Crime.

This broad kind of applications covering private and public sectors are growing exponentially. Open-source and proprietary software development have been contributing to this development due to its recent growth and attention.

Aside the raster and vector in spatial modelling more recently three and four-dimensional data is being investigated (Lin et al., 2013). Virtual Geographic Environments (VGEs) interest are growing faster in last years. It is characterized as being a bridge between the three scientific requirements of Geographic Information Science: multi-dimensional visualization, dynamic phenomenon simulation, and public participation (Lin et al., 2013).

GIS TRENDS

Currently, the key trends that face in GIS concerns are geospatial web, GIS in the cloud, space-time GIS, augmented reality and real-time GIS. Web-based in GIS combines information systems and geographic web technology (Chakraborty et al., 2015). Web GIS is a paradigm shift from a model based on national governments as major players in the production of geospatial data to one based on the collaboration between citizens and private institutions (Goodchild et al., 2007; Grossner et al., 2008). The enhanced participation of different actors in the generation of geospatial data, it is increasingly difficult to distinguish the producers and users (Budhathoki & Nedovic-Budic, 2008), mainly due to the free software and open source tools availability (Crampton, 2009). Due to the opening of the GIS world to a multitude of actors involved in the mapping data and Web GIS tools, refers to ads to meet end-user needs (Elwood, 2009). GIS based on the web are accessible not just from a computer but also on different multiple devices, including laptops, smartphones or tablets (Chakraborty, 2015).

The opening of the source code and the use of free software aims to contribute to greater openness to collective voluntary participation in the use, study and modification of the software (Chakraborty et al., 2015). In the beginning of the 21st century started an innovative and leading geolocation-based service of crowdsourcing at a massive scale named as Open Street Map project (OSM). This project improves Volunteered Geographical Information' and aims to create a free digital map of the world. Those collaborative platforms are empowering citizens to create a global patchwork of geographic information (Goodchild, 2007; Mordechai Haklay, 2010). The international non for profit Open Geospatial Consortium was founded in 1994. It is an international voluntary organization that led the standards development process for geospatial and location services (Haklay et al., 2008). Among the three most relevant standards OGC include: Web Feature Service (WFS), Web Map Service (WMS) and Web Coverage Service (WCS) (Giuliani et al., 2016; Parker & Dominguez, 2015).

This new forms of utilisation of GIS on the web environment using a distributed and asynchronous requires a client-server architecture (C/S). This is characterized by a client request of a service, such as mapping, decision analysis, data processing or storage data while the server provide the service (Mekonnen & Gorsevski, 2015). Web GIS exits benefited by providing the best agents solutions to problems that traditional GIS (Chang & Park, 2006). More recently Web-GIS has become to a cloud GIS, based in model of "Software as a Service" (SaaS) (Kerski, 2015).

Cloud computing are increasingly widespread and make possible to run cloud applications in a shared data center accessed by internet. The emergence of GIS in the cloud solved the problems associated to the increase of precision and spatial-temporal scope of information. In general, there are an accumulation of multitude data records and this dataset has varied at a daily rate (Hey, 2012) and allows network access to a set of configurable data (servers, storage, applications and services) (Yang et al., 2011). The recent emergence cloud GIS provides the ability to build a GIS service enabled for use in the cloud and can be made to scale up or down according to user needs. GIS cloud is equipped with new models of maintenance and use of geospatial data for a variety of users and to solve computing problems (Yu et al., 2014). This service provides users the ability to act in the manner of 'pay-as-you-go'. This mechanism of action has been a dream for several decades and has recently become a reality (Armbrust et al., 2010).

The cloud GIS has several characteristics namely: (i) it is not necessary to provide a software installation; (ii) not to use the computer's internal space for data storage; (iii) enable a collaborative action between different actors (flexibility); (iv) adapting services to demand and actual charge; (v) enhancing greater interoperability between various source code; (vi) decrease the time taken by decision-makers to implement processes of deliberation and (vii) the implementation of the entire system in a top-down scale (Armbrust et al., 2010; Blower, 2010; Yu et al., 2014). Cloud computing is a powerful technology that enables greater profitability in energy consumption and economic resources (Buyya et al., 2009; Lee & Chen, 2010; Marston et al., 2011). It perform massive-scale and complex computing and eliminate the need of maintain software, hardware or dedicated space (Assunção et al., 2015; Hashem et al., 2015).

Associated to this is the massive growth of generated data scale and volume which is challenging and time demanding tasks to ensure data processing, analysis and store (Hashem et al., 2015). Concerning to this Big Data concept is emerging and specified the four Vs, namely,

- Volume of data,
- Variety of data collectors,
- Velocity of data transfers, and
- Value process of discovering huge hidden values from large datasets (Gantz & Reinsel, 2011; Hashem et al., 2015).

The advancement of these technologies can enable the construction of spatial data infrastructures (SDI) and cyberinfrastructures (Schäffer et al., 2010; Yang et al., 2010). Some public cloud computing platforms are already available, including Microsoft Azure, Google App Engine or Amazon EC2. In any case a cloud can be public or private. The public cloud is available to the public while the private cloud is only used within an organization.

Cloud computing includes multiple domains, such as energy and mineral sciences, weather, traffic and simulation management systems, landscape ecology, water management, disaster management or human and environmental health (Yang et al., 2013). According to these authors the main obstacles to the success of cloud GIS are associated with policy, management, acquisition and operational requirements. Forward-looking multiple threads are identified:

- Cumulative advances for interdisciplinary approach, abreast of progress in geoscience and digital earth;
- Cloud interoperability based on standards (OGC, OGF, NIST, ISO, IEEE) and through a systemic architecture;
- Integration of innovative interaction systems for viewing and access;
- Real-time simulation for decision support;
- Security levels set to a deployed computer with a platform with distribution of certain information and the collaboration by integrating multiple platforms, and in view of the scope of science for the citizen, technology to crowdsourcing, dynamic events and challenges of education.

Another type of evolution in GIS is linked of framework of Hägerstrand (space-time model). In this context, the space-time studies the individual patterns, considering the various constraints in a particular spatial-temporal environment (Hägerstraand, 1970; Hägerstrand, 1989). There have been a number of efforts to ensure the incorporation of concepts in a GIS (e.g., Goodchild, 2013; Miller, 1991; Neutens et al., 2007; Shaw & Yu, 2009). This system presents a three dimensional orthogonal structure that consists of the union between two spatial dimensions and a temporal dimension. The spatial dimensions, structured 2D scale, represent the location of individuals, while the dimension of time represents the timing of the individual movement in a spatiotemporal system (Miller, 2004).

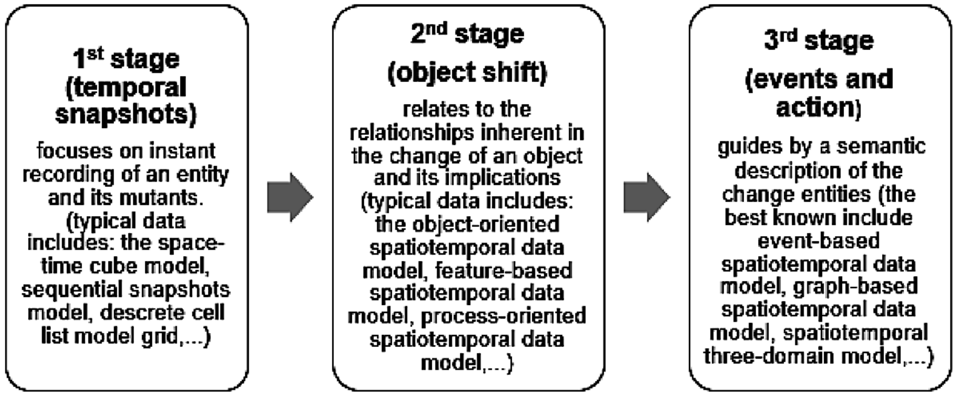
Several variables can represent the characteristics of the daily activity of an individual: location, time, duration, sequence and frequency of the type of activities (Ren & Kwan, 2009). It must be associated with at least one activity. Distinguished two types of activities: the movable and stationary activity. Mobile activity refers to a local motion toward another, while the stationary activity leads to a fixed location. Representation in Hägerstrand system is done in two ways: by vertical line segment when it comes to a stationary activity and a sloping straight line when there is movement toward a certain place (Chen et al., 2011).

In recent years, attempts have been incremented to store and manage the activities of an individual based on their spatial and temporal characteristics (Chen et al., 2013; Wang & Cheng, 2001). This type of analysis has been mainly used in studies that assess individual accessibility (e.g., Delafontaine et al., 2011; Kwan, 1998; Miller, 1999; Neutens, 2015; Neutens et al., 2007). These studies demonstrate that the considerations of space-time contribute to the presentation of more complex models and real human activities (Shaw & Yu, 2009).

Real-Time GIS model was assumed as a new paradigm of information science to capture the real characteristics of human undertakings (Hey, 2012) and transforming historical changed data to real-time data (Gong et al., 2015). The authors divided the model into three stages: temporal snapshots (1st stage), object-shift (2nd stage) and events and action (3rd stage) (Figure 2).

Real-Time GIS analyses have also sought to incorporate collaborative functions. These types

Figure 2. Three stages of real-time models
Source: (Adapted from Gong et al., 2015).



of tools can be differentiated into several types, namely:

- The same time - same place;
- Same time - different location;
- Different time - same place;
- Different time - different location (Sun & Li, 2015).

The Real-Time Collaborative Geographic Information System (RCGIS) enables analysis of interactions in agile and flexible systems, equipped with collaborative principles.

The unpreceded growth of geographically referenced information combined with recent digital augmentation reality (AR) of places growth will become increasingly important in the future (Graham et al., 2013). AR had its recognition in 1992, when Caudell and Mizzel developed works for Boeing and designed a digital transport display in the head, so as to enable a framework of airplane schemes (Yew et al., 2016). Yet, the concept of AR is much older. This was used during the period of World War II with a project developed with the presentation of information on the windshield of the camera. In this statement, there must be a relationship between reality and the information made available in digital media. To this end, there must be a technological device (smartphone or other wireless equipment), tracking and computer software. AR is summarized in three distinct properties:

1. Combination of real and virtual objects in the real world;
2. Run interactively in real time; and
3. Registration of real and virtual objects and their connection (Azuma, 1997).

AR is receiving several applications for PC, smartphones, tablet and other devices and will be increasing in the future.

These advances in various types of GIS technologies can create significant digital divides, disadvantaging the poor, ethnic and racial minorities, residents in rural areas, the inhabitants of the global South. The own readiness for open apps coding creates exclusions face to those who can only view and contribute to these features (Elwood, 2009).

FUTURE RESEARCH DIRECTIONS

Information technology and Geographic Science are growing abreast and rapidly. Developments of GIS technology and applications must grow behind the scope of Big Data, Cloud GIS, Real-time GIS and Augmented Reality challenges. For future research, a more rigorous approach should be implemented and guided by technology interoperability, integrated multidisciplinary approach, security, how to benefit and integrate GIS database with citizen-collected data and deeply understand how to collect and analyse real time data. The advent of data needed will be exceeded by the abundance of real time data arising the challenges on how to detach different sources to canvass their quality and include them in spatial analysis. For this more deeply and integrated analysis models are required and at the same time more spread applications will be required to provide the spatial information by multiple technological devices.

CONCLUSION

The expansion and advances of GIS technologies created conditions to proliferate different approaches to work in multiple areas, such as geography, cartography, remote sensing, image processing, education or environmental sciences. This section presents the evolution of GIS from its conception to the present. Moreover, it shows the main challenges posed by multiple skills acquired by the GIS in recent decades, namely presenting a shift from traditionally confined public planning areas to multi collaborate users, from desktop to the web and from real to virtual and augmented reality. In fact, maps have always been used for the removal of political borders, but today the networking capabilities generated conditions for GIS intelligence statement. The development of the web has supported the new challenges associated with GIS, particularly in areas connected with augmented reality, the real-time GIS information, GIS space-time or Cloud GIS. Associated to this arise Big Data challenges and problems to the Geographic Science (GS). The cumulative advances in the relationship between GIS and Web can hence contribute to the expansion of information generated and treated, interoperability between servers and users and networking. Geographic information will reinforce their position in our day's life and for GS those trends will catch much more research than ever.

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KEY TERMS AND DEFINITIONS

Augmented Reality: Augmented Reality (AR) into GIS assures the link between the perception of user and the relationship with the real world. The real world is represented with 2D and 3D virtual information. The computer augments the actual landscape with additional information that can be supported by inserting fields based on GIS applications.

Crowdsourcing: Crowdsourcing is an act of performing a GIS task by a user on a voluntary basis for a set of users. This type of action is based on a bottom-up approach. It is associated with the creation of data through a group dynamic. The crowdsourced data collection is carried out using portable devices (GPS, PC, mobile phones) and the data is synchronized in the central database, accessible and shareable, based on services and maps on the web.

GIS in the Cloud: GIS in the cloud or cloud GIS bases on the integrated web systems. The data generates maps to support the analysis and optimization of real time operations. The cloud integration helps the organization of complex workflows and maintaining extensive geodatabases.

GIS: GIS is a system that permits to visualize, analyze, display and understand the relationships between spatial phenomena. Nowadays, GIS is capable to transform large numbers of data, to analyze and transform momentarily alternate data and generate charts, graphs, summary and descriptive statistics. Among the main key elements to a noble GIS it is noted: computer hardware and software, operational context (people and organizations) and internet service.

Real-Time: Real-time is a term often used to describe the time of execution of a task. This tool helps the users to obtain a frequently monitoring and more efficiently. GIS technology enables the sharing of a series of real-time data. Among the main features is visualization, analysis and understanding of phenomena in reduced timescale.

Pace-Time: Space-time is suggested in Hägerstrand time-geographic framework. Presents and analyses the individual activities in time and space dimensions. In GIS environment results in the spatial representation of the dimension x and y and temporal dimensions of time in hours, minutes or seconds. The space-time patch is used for the implementation of the daily trajectory of the individual in time and space.

Web-Based GIS: Web-based GIS is based on a type of distributed information. This set of technological services is part of a communication structure between the GIS server and the client. Their relationship is expressed through URLs (created by the server) and HTTP (for the customer). Spatial data access, advanced mapping and spatial analysis are the most common type of analysis options in Web-based GIS.