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"From GeoVisualization to visual-analytics: methodologies and techniques for human-information discourse"

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From GeoVisualization to visual-analytics: methodologies and techniques for human-information discourse

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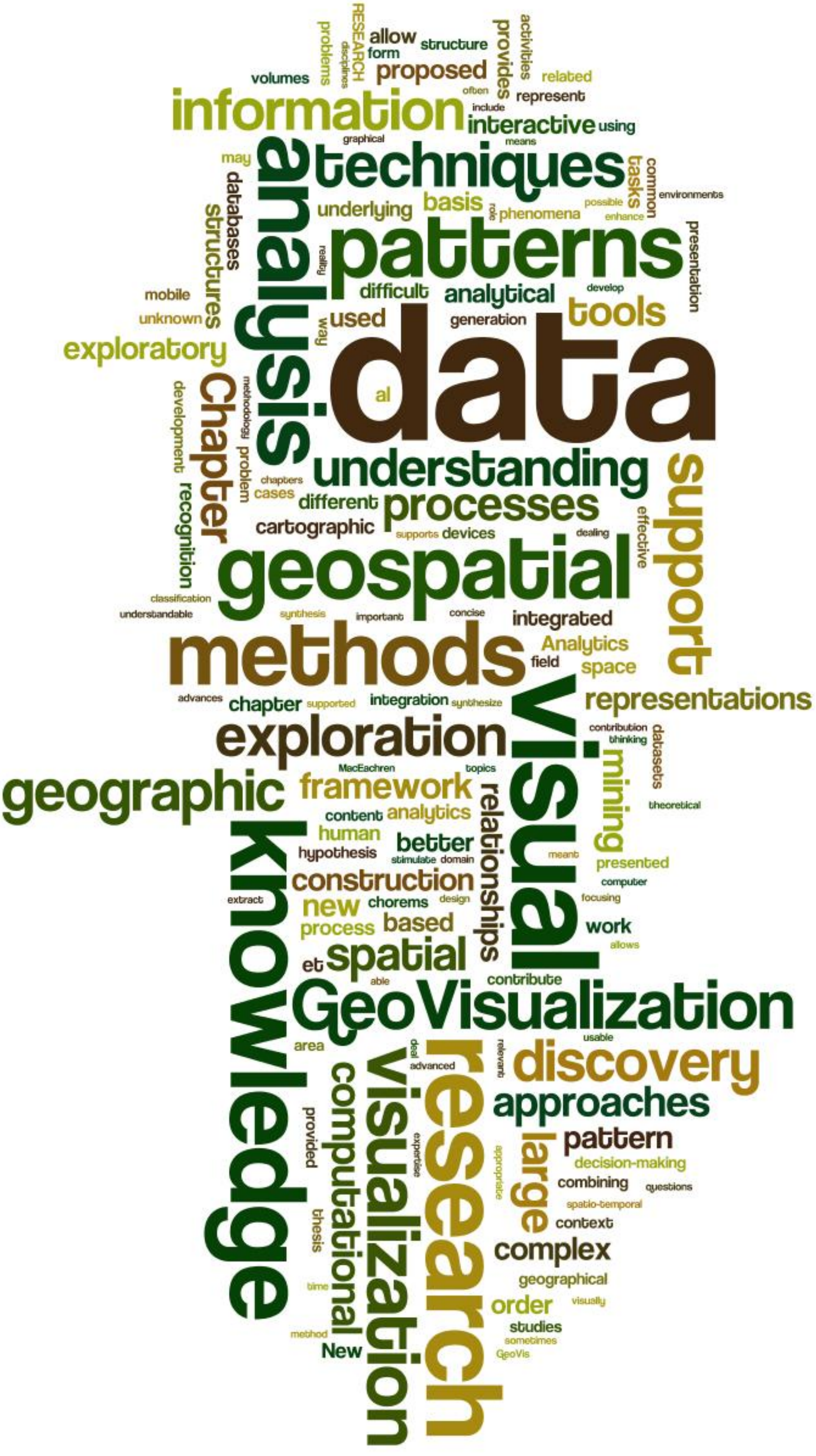
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CHAPTER 1
INTRODUCTION

Recent estimates suggest that 80% of all digital data generated today include geospatial referencing (e.g., geographic coordinates, addresses, postal codes, etc.) (MacEachren and Kraak 2001). Indeed, most researchers agree that the geographic component represents an ubiquitous factor which both is an integral part of a territory and contributes to acquire knowledge about its phenomena. This awareness has a direct implication on studies conducted within the general domain of Earth and Environmental Science, where a parameter involved in the analytical methods is now focused on place and space. As a matter of fact, researchers from those disciplines have recognized that in order to turn large heterogeneous data volumes into information, the challenge is to develop methods capable to understand patterns and relationships in geographic space along with their change over time or processes that are responsible for them. To achieve this goal, human vision and domain expertise can be exploited together with computational tools. In particular, a visual representation and computing may contribute to better motivate pattern recognition and hypothesis generation, thus allowing better understanding of structures and processes, and supporting knowledge construction.

The aforementioned activities fall in the area of GeoVisual Analytics (or geospatial visual analytics). Geovisual Analytics belongs to the GeoVisualization research field and deals with problems involving geographical space and various objects, events, phenomena, and processes populating it. It benefits from the integration of different disciplines. In fact, the adoption of visual interactive methods from GeoVisualization, and their integration with new possibilities offered by computational techniques, set the basis for effective support to data exploration and decision-making processes, due to the capability of combining geospatial information with “human vision and domain expertise” [28], [64].

1.1. PROBLEM AND MOTIVATION

The increasing volumes of geospatial data presents a difficult challenge in the exploration of patterns and relationships. With such large volumes of data, common geospatial analysis techniques are often limited in revealing patterns and relationships, a process necessary for understanding underlying structure and related real world processes.

New interactive visualization tools are being envisaged to deal with large datasets in order to synthesize information and perform complex analytical tasks. Along this line, our research efforts have been focusing on new cartographic approaches which could support daily analysts’ work by producing synthesis and presentation of discovered patterns in a concise and understandable way (Openshaw 1997). In order to decide the class to which the pattern belongs, common classification or pattern recognition methods are used to compare the unknown pattern with all known reference patterns, on the basis of some criteria for the similarity degree. These techniques are difficult to apply in the case of unknown data, as it is not obvious what mechanisms or rules are behind data of interest. New approaches in exploratory geospatial data analysis and visualization are needed to effectively extract patterns and relationships, and represent such data in a visual form that can better stimulate exploration, pattern recognition and hypothesis generation, as well as allow better understanding of structures and processes and support knowledge construction.

1.2. RESEARCH GOALS

The objective of our research is to give support to decision makers when facing problems which require rapid solutions in spite of the complexity of scenarios under investigation. In order to achieve this goal our studies have been focused on GeoVisualization and GeoVisual Analytics research field, which play a relevant role in this scope, because they exploit results from several disciplines, such as exploratory data analysis and GIScience, to provide expert users with highly interactive tools by which they can both visually synthesize information from large datasets and perform complex analytical tasks.

The research we are carrying out along this line is meant to develop software applications capable both to build an immediate overview of a scenario and to explore elements featuring it. To this aim, we are defining methodologies and techniques which embed key aspects from different disciplines, such as augmented reality and location-based services. Their integration is targeted to realize advanced tools where the geographic component role is primary and is meant to contribute to a human-information discourse.

1.3. METHODOLOGY AND TECHNIQUES FOR HUMAN INFORMATION DISCOURSE

To address the abovementioned research issues, a methodology is proposed. It includes a paradigm for visual representation and navigation along with Geovisualization techniques aiming at experimenting it in different domains.

Moreover, a theoretical basis has been defined for enhancing the role of visual metaphors by associating them with a composite structure capable to store different levels of summarized data. This enhancement is intended to offer alternative and different views of the data and stimulate the visual thinking process characteristic of visual exploration. Moreover, it aims to support advanced analytical tasks through the use of appropriately specified operators.

1.4. RELEVANCE OF THIS RESEARCH

The results of this research are new and they are relevant to perform analytical tasks and discovery knowledge from geographical databases. It advances the technological solutions for the wider scope of Geographic Information and provides sample cases, which document knowledge discovery from spatial databases by using GeoVisualization methods in that context. As a matter of fact, by applying such methods this research supports the process of planning and makes it a tool for human information discourse.

This could be considered a preliminary work for building models and provides a relevant contribution to the development of advanced spatial analysis applications that can be exploited also through mobile devices. In particular, given the mobile device pervasiveness they could help decision makers handle emergency situations and crisis evolution by on site tools.

1.5. STRUCTURE OF THE THESIS

To carry out the research goals set out above, a research plan was implemented. These activities are reported in the different chapters of the dissertation, as follows.

Chapter 1: Introduction - This chapter provides an introduction to the scope of the research, the research problem, the relevance of the topic, the context, the objectives, and the research questions.

Chapter 2: This Chapter is meant to introduce the context of this dissertation, which is based on several topics, namely GIScience, Geoinformation, Visual Analytics and GeoVisualization, Decision-Making and Knowledge Discovery.

Chapter 3: This Chapter emphasizes how each specific result has a proper collocation within the whole management process of geospatial data.

Chapter 4: This chapter contains detail on how chorems are able to visually summarize database content. A definition and a classification of chorems, meant both to homogenize chorem construction and usage and to provide a usable framework for computer systems, is provided.

Chapter 5: A technique to enhance user’s navigation activities with mobile devices using augmented reality is proposed.

Chapter 6: Link2U, an integrated solution for mobile devices which combines the potential of augmented reality with the ability to “communicate” of the social network is presented.

Chapter 7: An approach for presentation of personalized *ads* on mobile devices, based on a user model that takes into account user’s interests over time is illustrated.

Chapter 8: We propose a GeoVis method based on a recent InfoVis technique, known as Tag Cloud, which combines tag.

Chapter 9: This section summarizes the content of this thesis, highlighting the contribution research and discusses possible scenarios for the future work.

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CHAPTER 2

DEFINITION OF CONCEPTS

This chapter is targeted to recall fundamentals of topics belonging to the wide scope of this dissertation. Moreover, it traces a link among the key concepts of the involved topics in order to both help understand how the research evolves and provides an overview about the whole research field on Geographic Information. To this aim, in the following the state of play and some basic results on specific topics are discussed, namely GIScience, Geoinformation, Geovisual Analytics and GeoVisualization, Decision-Making and Knowledge Discovery.

2.1. OVERVIEW OF RELATED CONCEPTS

The scope of this research includes several disciplines. Figure 2.1 suggests an organization of their basic concepts around the proposed research area. It indicates the extent of this research in a light gray circle and the core scope with a gray circle. Core concepts and fields are illustrated which involve GIScience, Geoinformation, Visual Analytics and GeoVisualization, Decision-Making and Knowledge Discovery. Individual concepts are arranged around these core fields. The boundary between these fields is fuzzy and is indicated by a dashed line.

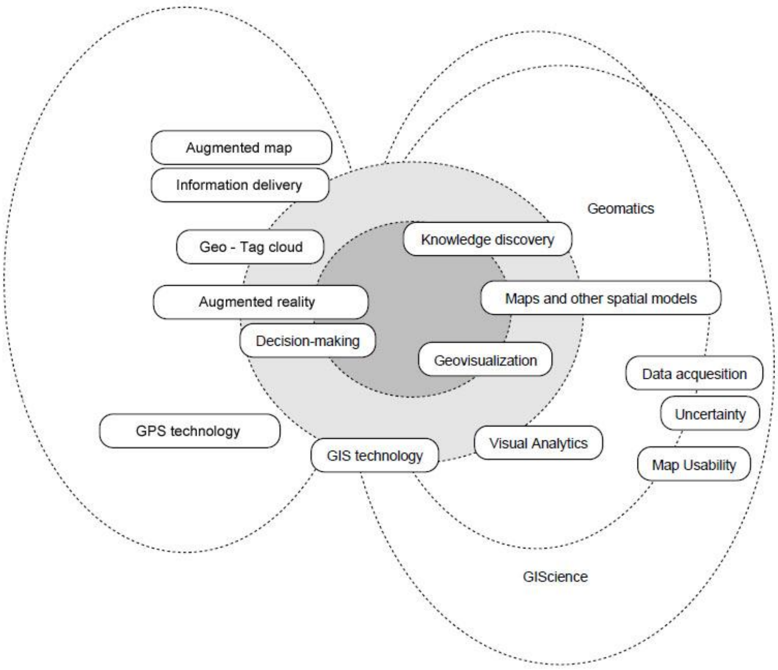


Fig 2.1 Organization of concepts around the proposed research areas

Within this general overview, specific concepts are identified and elaborated. The wide fields of knowledge discovery and decision-making are not included as separate fields, they are integrated as important supporting concepts.

The research starts from Geographic Information Science (or GIScience) that is the science behind the GIS technology. An initial definition by Goodchild describes GIScience as a "science which deals with generic issues that surround the use of GIS technology, impede its successful implementation, or emerge from an understanding of its potential capabilities" (Goodchild, 1992). A full definition of GIScience was provided in a report on a workshop held in January 1999 at the National Science Foundation on Geographic Information Science: "Geographic Information Science (GIScience) is the basic research field that seeks to redefine geographic concepts and their use in the context of geographic information systems. GIScience also examines the impacts of GIS on individuals and society, and the influences of society on GIS. GIScience re-examines some of the most fundamental themes in traditional spatially oriented fields such as geography, cartography, and geodesy, while incorporating more recent developments in cognitive and information science. It also overlaps with and draws from more specialized research fields such as computer science, statistics, mathematics, and psychology, and contributes to progress in those fields. Based on this definition it is a multidisciplinary field, which includes many disciplines that have traditionally researched geographic information technologies (like cartography, remote sensing, geodesy, surveying, photogrammetry, and image processing) and disciplines that have traditionally researched digital technology and information, in general (e.g., computer science, particularly: databases, pattern recognition, computational geometry, image processing, , information science)." (Mark, 2000)

Furthermore finally, GIScience takes into account disciplines that have traditionally investigated the Earth, particularly its surface, with regard to the earth itself or with regard to humans (e.g., biology, ecology, biogeography, environmental science, geography etc.). These are all sciences that are potential users of GIS. All these disciplines have traditionally studied the nature of human understanding and its interactions with machines.

Regarding the difference between the terms spatial and geographic, it might be suggested that geographic has to do with the earth, including its two-dimensional surface and its three-dimensional atmosphere, oceans, sub-surface. Spatial has to do with any multi-dimensional frame (e.g., engineering drawings are referenced to a mechanical object or architectural drawings are referenced to a building). Within this framework, geographic is a subset of spatial, the terms are often used interchangeably. In the literature geographic is also referred as geospatial.

The following subsections briefly introduce methodologies and techniques defined for the visual representation and analysis of geospatial data. However, an initial discussion focused on the spatial data complexity is given, in order to explain why specific approaches are necessary for geospatial data design and management.

2.2. Complexity of geospatial data

To convey valuable information, data must be prearranged, transformed and presented in a way that gives meaning and makes them useful. To facilitate the transfer of knowledge, patterns and meanings of the information must be assimilated. Creative manipulation of data is therefore necessary to assist our understanding (Hodge and Janelle 2000). Cognitive research suggests that, by using an experimental component such as interaction, inspection, evaluation, contemplation or interpretation, meaning and deep understanding can be constructed. Rules are often generated from these processes to form intellectual skills used in problem solving, and are applied to achieve a solution to a novel situation, based on a combination of previously learned rules (Gagné 1977). This process of encoding and subsequently entering the encoded information into longterm memory is a central and critical event in the acquisition of knowledge. Information must therefore be organized or transformed into a form that is semantic or meaningful.

Information derived from geospatial data can be considered as a different type of information, due to their intrinsic structure (location, attributes and time), the semantics, and the geographic scale used (MacEachren and Kraak 2001). These characteristics are significant in geographic space and can be organized in association with geographic positions in a natural and intuitive way (maps). Complexity in geospatial data analysis arises also from the large volumes of data, underlying relationships, and the nature of geographic problems (Openshaw 2000; Miller and Han 2001; Gahegan and Brodaric 2002). The process of geospatial data handling consists of methods and techniques used to collect and analyze data and explore insight related to the dataset in order to solve particular problems. Usually, maps are the results of this process and are used to give a visual representation of an existing phenomenon. This role of maps has changed and expanded (Kraak 2000) owing to the technological capacities for data acquisition and data processing, and the sophisticated nature of new visual representation techniques. Today, with the huge volume of data, static non-interactive maps do not satisfy the fundamental demands of exploratory data analysis (Andrienko et al. 2000). However, the many alternative interactive forms of maps which are now available and the use of dynamic links mean it can still play a key role in exploring geospatial data (Kraak 2000).

2.3. Representation and visualization of large geospatial data

A new form of visual representation for geographic data originated from the visualization field, which attempts to give a response to the increasing needs of users. There is a constant search for better visualization tools to allow users to benefit from geospatial analysis results, and to support the decision-making process.

Visualization is the use of computer-supported interactive visual representations of data to intensify cognition (Card et al. 1999), acquisition or use of knowledge. The cognitive support underlined in this definition is provided in six ways, by:

1. increasing the memory and processing resources available to the users,
2. reducing the search for information,
3. using visual representations to enhance the detection of patterns,
4. enabling perceptual influence operations,
5. using perceptual attention mechanisms for monitoring,
6. encoding information in a manipulable medium.

Visualization allows data and information to be explored graphically, in order to gain the understanding, insight or knowledge from complex multidimensional datasets (McCormick et al. 1987), necessary for decision-making, problem solving and explanation tasks. Visualization could also enhance the understanding of complexity, retaining user's participation through computational steering to improve the overall effectiveness of data analysis.

2.3.1. Information Visualization

Information visualization is the interdisciplinary study of "the visual representation of large-scale collections of non-numerical information, such as files and lines of code in software systems, library and bibliographic databases, networks of relations on the internet, and so forth [49]. The aim of this discipline is to enable complex systems to be better understood, better decisions to be made, and information to be discovered that might otherwise remain unknown (Card et al. 1999). Users looking at large amounts of complex data can quickly find the information they need; navigate and interact with data more easily; recognize patterns and trends; discover errors in the data; easily identify minimum and maximum values, and clusters; and obtain a better understanding of the underlying structure and processes. This is possible, for example, by grouping or visually relating information in order to reduce the search for data, or by aggregating data in order that they may be revealed through clustering or common visual properties. In general, representations used in information visualization often apply geographic metaphors to structure human-computer interaction, and are commonly referred to as spatializations or information spaces (Fabrikant 2001). This approach has then two fundamentally related aspects: structural modeling and graphical representation (Chen 1999). The structural modeling intends to detect, extract and simplify underlying relationships, whereas the graphical representation is meant to transform an initial representation of a structure into a graphical one, so that the structure can be visually examined and interacted with.

Information visualization is concerned with the design, development, and application of computer generated interactive graphical representations of information. This often implies that information visualization primarily deals with abstract, nonspatial data. Transforming such nonspatial data to intuitive and meaningful graphical representations is therefore of fundamental importance to the field. The transformation is also a creative process in which designers assign new meanings into graphical patterns. Like art, information visualization aims to communicate complex ideas to its audience and inspire its users for new connections. Like science, information visualization must present information and associated patterns rigorously, accurately, and faithfully. A common question is the relationship between information visualization and scientific visualization. A simple answer is that they are unique in terms of their corresponding research communities. They do overlap, but largely differ. Here are some questions that might further clarify the scope of information visualization. First, is the original data numerical? Graphical depictions of quantitative information are often seen in the fields of data visualization, statistical graphics, and cartography. For example, is a plot of daily temperatures of a city for the last 2 years qualified as information visualization? The answer to this question may depend on another question: how easy or straightforward is it for someone to produce the plot? A key point to differentiate information visualization from data visualization and scientific visualization is down to the presence or absence of data in quantitative forms and how easy one can transform them to quantitative forms. This is why researchers emphasize the ability to represent nonvisual data in information visualization. Second, if the data is not spatial or quantitative in nature, what does it take to transform it to something that is spatial and visual? This step involves visual design and the development of computer algorithms. It is this step that clearly distinguishes information visualization from its nearest neighbors such as quantitative data visualization. In a more formal terms, this step can be found in an earlier taxonomy of information visualization, which models the process of information visualization in terms of data transformation, visualization transformation, and visual mapping transformation. Data transformation turns raw data into mathematical forms. Visualization transformation establishes a visual–spatial model of the data. Visual mapping transformation determines the appearance of the visual–spatial model to the user. On the other hand, if the data is quantitative in nature, researchers and designers are in a better position to capitalize on this valuable given connection. The connection between scientific and artistic aspects of information visualization is discussed in terms of functional information visualization and aesthetic information visualization. The primary role of functional information visualization is to communicate a message to the user, whereas the goal of aesthetic information visualization is to present a subjective impression of a data set by eliciting a visceral or emotive response from the user.

Finally, as for data, while scientific visualization is applied to scientific data, information visualization is often applied to abstract data. Scientific data are often physically based (the human body, the earth, molecules, etc.), whereas abstract data are non-physical information and may not have obvious spatial mapping (financial data, business information, collections of documents, and abstract conceptions).

2.3.2. GeoVisualization

Visualization in scientific computing emerged from the computer science field along with fields such as scientific visualization and information visualization. Information visualization is documented as having the potential to enable both better understanding of complex systems and discovery of information that might otherwise remain unknown, thus facilitating better decisions (Card et al. 1999). Cartographic research efforts in visualization have been extended to meet other research activities in information science disciplines. This recognition was advanced by the creation in 1995 of a Commission on Visualization (later known as the Commission on Visualization and Virtual Environments) belonging the International Cartography Association (ICA) (MacEachren and Kraak 2001). The research goal of this commission is to cope with the increasing volume of geospatial data by developing theory and practice that facilitate knowledge construction through the visual exploration and analysis of geospatial data. In addition, emphasis is focused on the visual tools necessary to support knowledge retrieval, synthesis and use (MacEachren and Kraak 2001). GeoVisualization (visualization applied to geospatial data) can be considered as the core discipline for understanding complex phenomena and processes, and structures and relationships in complex geospatial datasets. It integrates perspectives on the representation and analysis of geospatial data with recent developments in scientific and information visualization, exploratory data analysis (EDA), GIS, cartography and image analysis (Kraak 2000). GeoVisualization also includes the use of a number of techniques for exploring data, answering questions, generating hypotheses, developing solutions and constructing knowledge. Such a visual exploration of geospatial data (Kraak 1998) can be useful for displaying patterns with interaction and dynamics in order to achieve better decision-making.

Human vision and domain expertise are powerful tools that together with computational tools make it possible to turn large heterogeneous data volumes into information (interpreted data) and, subsequently, into knowledge (understanding derived from integrating information). Visualizing the world through geospatial data has been a cartographic concern for centuries. Still, the ICA recognized a need, in 1993, for a special effort to link cartographic research activities in visualization with those in other information science disciplines, particularly those prompted by the U.S. National Science Foundation (McCormick et al., 1987). The goals of ICA have been to develop both theory and practice to facilitate knowledge construction through visual exploration and analysis of geospatial data, along with the visual tools needed to enable subsequent knowledge retrieval, synthesis, and use. Over the past decade, methods and tools for visualization in support of science have advanced rapidly with demonstrated successes in various areas. In addition, a new discipline of Information Visualization has begun to emerge, with a focus on visualization of non-numerical information (Card et al., 1999). Still, visualization is not being taken advantage of to exploit the full potential of geospatial data. Many core challenges being faced in the natural and social sciences have an inherent complexity and inter-disciplinary nature.

Geovisualization has the potential to provide 'windows' into the complexity of phenomena and processes involved, through innovative scene construction, virtual environments (VEs), and collaboration, thus prompting insight into the structures and relationships contained within these complex, linked datasets (Alan M. MacEachren and Menno-Jan Kraak, 2001). Current visualization methods and tools have not been designed to deal with the unique geospatial characteristics of data critical to these problems nor to take full advantage of georeferencing as a mechanism for fusing data from diverse sources. Geospatial data and the geospatial information resulting from them are essentially different from other kinds of data and information in at least three ways.

First, geospatial data are inherently structured in two (latitude and longitude), three (position above or below the Earth's surface), or four (time) dimensions, while often unstructured in others with no set relationship among non-spatial variables. Thus, distances and directions among entities and locations have real meaning in geographic space. The inherent structure can be exploited to enable efficient data access with very large databases. That same spatial structure poses problems for traditional statistically based methods of analysis (used either alone or in conjunction with visualization, i.e., problems of spatial autocorrelation). Thus, different approaches must be developed for integrated visual-computational analysis of these data.

Second, many objects in geospatial databases have meaningful and useful names that can be taken advantage of in both database access and analysis. As with inherent structure of geospatial data, however, the match between geographic names and objects is complex and varies in explicitness. Geographic names for human constructed objects (e.g., county, road) have precise matches with location in the world while those for natural objects (e.g., mountain, flood plain) often do not.

Third, geographic scale is a critical but complex issue, with different geospatial datasets often containing emergent behavior at different scales. To capture scale-dependent phenomena and processes, geospatial data are typically collected at multiple scales, with fundamental differences in entities and their semantic structure across scales. For example, things defined as objects at one scale (e.g., residential buildings or a thunderstorm event) may be conceptualized as fields at another (e.g., a land use zone or an average precipitation surface), or not represented at all. While multi-scale data integration and analysis is a common problem in science, the diversity in kinds of phenomena brought together in geospatial analysis (for example, modeled climate data, aggregate demographic statistics, highway and river networks, soil classifications, quantitative and qualitative field survey data, satellite remote sensing) makes geospatial scale issues particularly challenging

2.4. Extract Information from complex geospatial data

Take out information from large geospatial data is a major issue in GIScience research. Many efforts across such disciplines as machine learning, statistics, and database and information visualization have underlined different aspects of exploratory analysis and knowledge discovery (Gahegan 2001) for uncovering structure within geospatial data and producing hypotheses with which to explain the patterns (Agrawal et al. 1993; Gahegan and Takatsuka 1999; MacEachren et al. 1999). Several techniques are used, including artificial intelligence (AI) and machine learning techniques (Openshaw and Openshaw 1997; Openshaw 2000; Gahegan 2000a). AI is a domain of computer science dealing with the automation of intelligent behavior for solving complex tasks. The experts define the field as "the study and design of intelligent agents" where an intelligent agent is a system that perceives its environment and takes actions that maximize its chances of success [Poole, Mackworth & Goebel 1998]. AI is an inclusive term for several areas of computing that attempt to mimic processes that humans carry out without much conscious thought (Mallach 1994). Major areas covered by artificial intelligence include artificial neural networks, robotics, machine vision, speech recognition, interpreting sentences in natural languages, and expert systems. In GIScience, there are many complex tasks related to data processing and manipulation for which a number of applications of artificial intelligence have been used. Expert systems or rule-based knowledge engineering systems have been used to design geoinformation systems (Openshaw 1997) to automate either highly skilled tasks such as map generation and name placement on maps in cartography, or rules for selecting good locations in complex planning situations. Neural networks are also applied in various areas of geoinformation science, including mapping, data classification and prediction.

In the following subsections the attention is focused on two research themes which, although originated from a different context, have recently acquired a relevant role for the domain of geographic applications, namely Visual Analytics and Knowledge Discovery & Decision-Making.

2.4.1. Geovisual analytics

Geovisual Analytics is an emerging interdisciplinary field that integrates perspectives from Visual Analytics, grounded in Information and Scientific Visualization, and Geographic Information Science, growing particularly on work in geovisualization, geospatial semantics and knowledge management, geo-computation and spatial analysis. We can define Geovisual Analytics as a new paradigm for how information technologies can be used to process complex geospatial information to facilitate decision making, problem solving, and insight into geographical situations. Geovisual Analytics can be used for situation awareness, supporting collaboration, decision making, and evaluating the analytical process itself. Nowadays there are a lot of Geovisual Analytics tools that help to identify significant geospatial information, data, and knowledge by supporting analytical processes that join innate human abilities of vision and cognition with computer-based visual interfaces. They are specifically designed to provide support for analytical reasoning and provide flexible connections to relevant data and supporting knowledge (Tomaszewski et al 2007).

Frequently, the activities that Geovisual Analytics is directed toward involve recognizing relevant information in huge datasets that make what is relevant difficult to determine by using traditional techniques. Geovisual Analytics is an increasingly important tool for activities ranging from counter-terrorism and crisis management, through environmental science, to strategic business decision making.

Conceptually, Geovisual Analytics system design efforts can build from the following guidelines for visual analytics generally, as outlined in Thomas and Cook (2005):

- Use sense making, cognition, and perception foundations for tools that support reasoning for complex tasks
- Address issues of analytical scale and the interplay between complexity and urgency that dictates and determines the scale
- Synthesize different types of information from different sources into unified representations to find meaning
- Integrate views of large-scale information spaces, coordinated views of information in context, and overviews and details
- Leverage innate human abilities to reason about time and space

Geovisual Analytics investigation requires tools that are highly interactive and support exploration (Allendoerfer et al., 2005), that work with end-users previous experience and mental models, and that allow for evidence to be assessed and hypotheses to be easily evaluated. Thus far, Geovisual Analytics tool development has focused on information analysis relevant to domains such public health threat analysis (Proulx et al., 2006) and historical geography of fragmentary archival documents (Figure 2.2) (Weaver et al., 2006).

Fig 2.2 The 'Hotels Viz', a Geovisual Analytics application built in the Improvise interactive visualization construction system (Weaver, 2004). Users can explore spatial and temporal aspects in past travel behavior based on historical registry entries from historic hotels.

The ultimate end goal of Geovisual Analytics investigation is the dissemination of results to decision makers who need a succinct communication of the interpretations made by an analyst or group of analysts. Geovisual Analytics tools must support visual outputs that can be used as artifacts of persuasion in whatever medium is used to convey the story (Gershon and Page, 2001).

In this thesis, GeoVisual Analytics techniques combine methods from knowledge discovery and interactive visualization in an integrated framework to facilitate decision makers in their knowledge creation and sense making process. These GeoVisual Analytics techniques aims at utilizing the strength of

a) knowledge discovery which allows for fast analysis of spatio-temporal data and pattern recognition,

b) interactive geovisualization which represents data in a way that affords seeing and interacting and enable thought processes to translate from data to information, and

c) the human's knowledge, assessment and reasoning potential that helps to refine and organize information more appropriately in an analytic discourse.

2.4.2. Knowledge Discovery & Decision-Making

In the broader framework of modern thought an early formulation of knowledge was put forward by Descartes to relate "knowledge" to "models". It defined "real knowledge" as concerned with spatiality or extension, in the sense that what could be scientifically known was restricted to what could be called "things", meaning it can be seen (perhaps with the help of instruments) and measured. The world was divided into "thinking substances"--the phenomena of mind--and "extended substances"--the phenomena of bodies or matter, with extension, shape and dimensions. Due to knowledge, humans can solve many problems by using "common sense". Domain-specific knowledge is in the mind of an "expert" because of perception, learning and reasoning, but it can be difficult to communicate and use it. Increasingly, humans use computer technology to store existing knowledge in databases, digital libraries and on the web. Peuquet (2002) examined the background of spatial knowledge and its relation to the nature of space and time. She links the long tradition of human thought about space and time to the GIScience.

Regarding knowledge acquisition she distinguishes between the cycles from the cognitive perspective and from the scientific perspective shown in Figure 2.3. Peuquet suggests that, "In the scientific context theories are formulated via filtering the data to select those observations considered relevant or "interesting". This selection tends to reveal patterns or consistencies in an observed phenomenon.

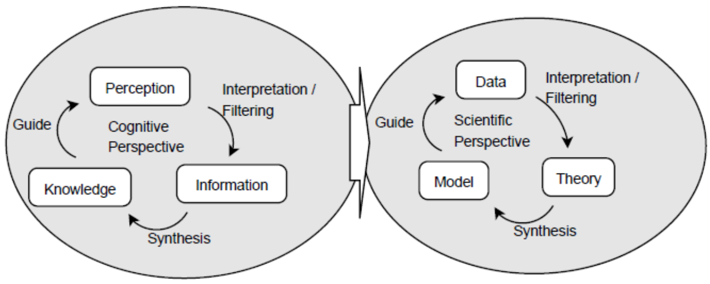


Figure 2.3. Cycles of knowledge acquisition from the cognitive perspective and from the scientific perspective, based on Peuquet (Peuquet, 2002)

Situations where decisions should be taken can be related to different levels of tasks such as mapping, monitoring, management and specific problem solving. When geospatial data are involved, it is recognized that the use of maps and visual representations derived from geospatial analysis operations leads to decisions (Kraak et al. 1995).

Information visualization techniques are increasingly used in combination with other data analysis techniques. Recent works in knowledge discovery in databases (KDD) have provided a window for geographic knowledge discovery. Data mining, knowledge discovery and visualization methods are often combined to try to understand structures and patterns in complex geographic data (MacEachren et al. 1999; Wachowicz 2000; Gahegan et al. 2001). One way to integrate the KDD framework in geospatial data exploration is to combine the computational analysis methods with visual analysis in a process that can support exploratory and knowledge discovery tasks.

Decision making is one of the main goals of geospatial data analysis. It requires a series of steps in order to evaluate possible alternatives and decide upon specific actions. Malczewski (1999) suggested three phases in the geospatial decision-making process:

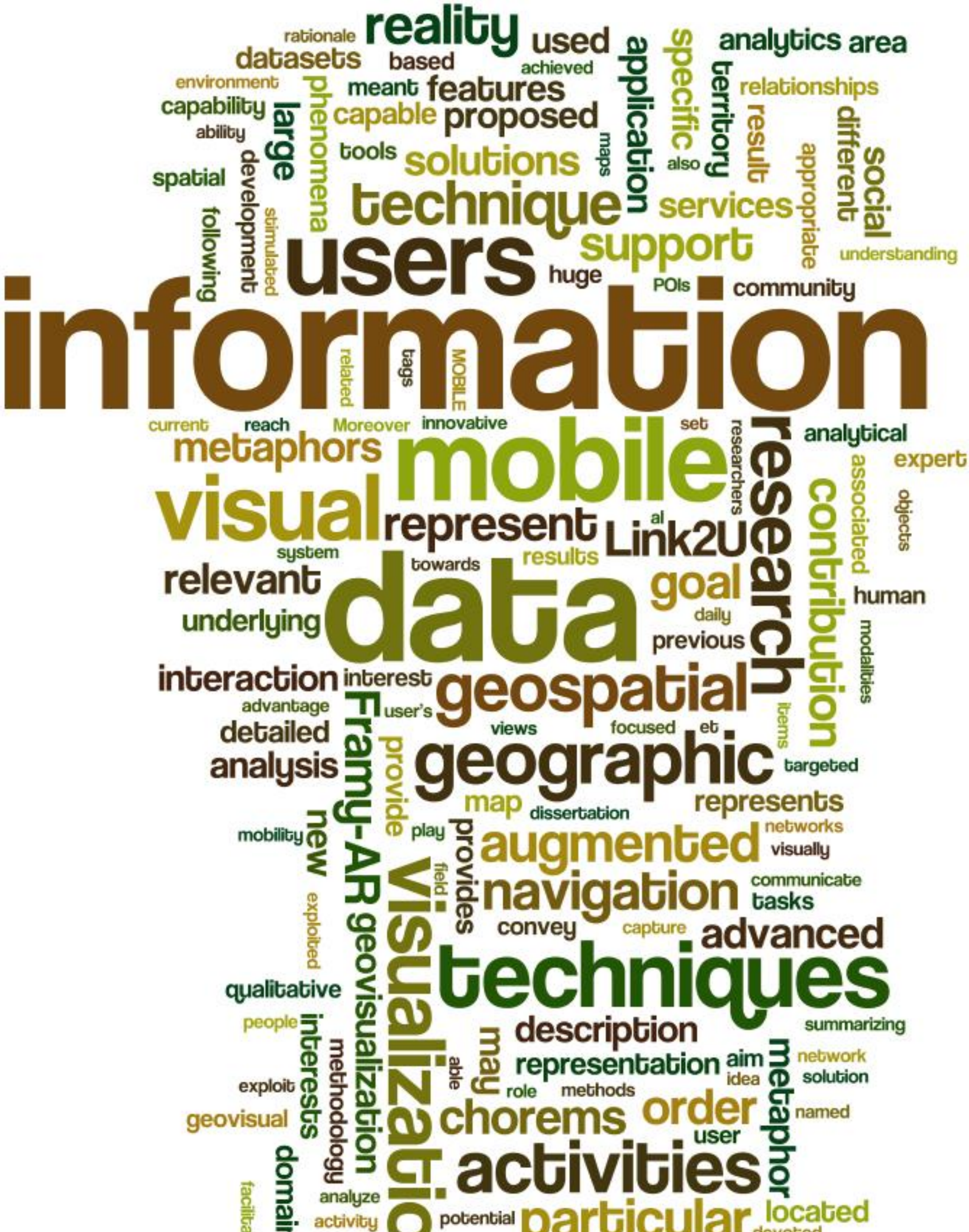
- Intelligence (searching for conditions calling for a decision)

- Design (finding and evaluating decision alternatives)

- Choice (choosing between decision alternatives).

The first phase of the process (intelligence) is devoted to retrieve appropriate information. This phase is particularly important and requires the transformation of appropriate data into relevant information for finding, evaluating and choosing decision alternatives, in a way that effectively facilitates knowledge acquisition. The process of automatically searching large volumes of data for patterns is known as Knowledge discovery. Two basic topics can be considered for this goal, namely what kind of data is searched and in what form the result of the search is represented. The knowledge obtained through the process may become additional data that can be used for further usage and discovery.

The last two phases of the decision-making process (design and choice) may be attributed in certain conditions to human intelligence or other support tools helping the decision making process.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summarizing
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Chapter

CHAPTER 3

ANALYZING LARGE GEOSPATIAL DATASETS

In the last decades, researchers from many disciplines have tried to facilitate people's use of computers and provide ways for scientists to make sense of the huge amounts of data they can manage. However, the inconsistency and the disorder which typically exist in huge volumes of data may compromise their analysis, which is a crucial task in many application domains and essential for decision makers and analysts [75]. Moreover, when a large amount of data is available, activities such as synthesizing information, discovering hidden information, deriving insight from it and performing specific analytical tasks may result time-consuming and expensive, because large and rich databases easily overwhelm mainstream geospatial analysis techniques oriented towards the extraction of information from small and homogeneous datasets (Gahegan et al. 2001; Miller and Han 2001). As a consequence, this awareness by the GeoVisualization community has stimulated researchers from different disciplines to interact in order to devote their efforts towards the design of effective visualization environments for analyzing large geospatial datasets.

Some methods recalled in this dissertation, devoted to make sense of the huge amounts of data, can be used both to extract features from complex data and represent them by applying appropriate visualization techniques capable to derive information in a way that allows better understanding of the underlying structures and processes [37], [34], [35], [38]. These techniques originate from the InfoVis research field where the recent attention of researchers has been encouraged by the necessity to support humans in solving problems through highly interactive visualization tools able to both synthesize information from large datasets and perform complex analytical tasks. To this aim, information spaces may play a relevant role by offering visual representations of data that bring the properties of human perception to bear (Card et al. 1999). In fact, spatial metaphors are often used to facilitate the representation and understanding of information in such spaces (Fabrikant et al. 2002).

The idea that, when dealing with scenarios describing complex issues, visual representations may provide useful support in locating facts and new patterns, has also inspired our research whose aim is twofold. We are investigating the definition of cartographic solutions for geospatial data, capable to better represent geographic information extracted from (spatial) database contents, referring both to static objects and dynamic phenomena. Then, we aim to extend the applicability of these solutions by embedding them within a complete process ranging from visualization to analysis of geospatial information. In order to reach this goal, several issues have being faced which overlap and affect each other. Among the others, to improve *visual experience of interfaces* organized to display and synthesize large amounts of data, our research aims to support users' daily activities by means of solutions which also include principles of human-computer interaction and usability. Moreover, specific objectives embrace providing appropriate tools and interfaces that facilitate the development of problem solutions by combining the potential of augmented reality with the ability to visually analyze and present spatial data. Finally, data exploration represents an additional relevant goal of our research which is targeted to provide expert users with compact and interactive user interfaces able to manage large numbers of items extracted from huge datasets, and therefore contribute to enhance the understanding of geographic processes and knowledge construction.

In the following, a description of results of our research is presented in terms of methods and techniques originated by investigating both the geovisualization field and the visual analytics domain. In particular, the goal of this chapter is to describe my contribution and highlight how each specific result has a proper collocation within the whole management process of geospatial data. These results represent the juxtaposition of theory and methods along with development activities which have led to the realization of effective tools for expert users which take advantage of novel technologies, such as augmented reality, Global Positioning System (GPS) and synthesis techniques that create visual screens of information.

3.1. Enhancing mobile users' capabilities through customized GeoVisualization techniques

The pervasive nature of mobile devices has stimulated developers to realize applications useful for human daily activities, whose interests are focused on supporting users and improving their life style through immediate and light solutions. In particular, the availability of pervasive integrated tools capable to send, receive and handle information has encouraged the development of advanced solutions in several application domains, ranging from cultural heritage to environmental protection, to emergency management to entertainment and edutainment.

Within this scenario, the goal of the research we are carrying out is meant to design and develop advanced user interfaces to support users' exploration activities. In particular, we aim at providing users with services where mobility comes into play. This is the case for user's navigation services, where advanced functionalities are devoted to capture a qualitative global view of a scenario, by simplifying the detection of relevant elements.

The following subsections introduce my contribution to these research activities, namely an innovative paradigm for human-(geo)information discourse which integrates different modalities of visualization and navigation with visual metaphors associated with both geospatial data and their aggregations / syntheses. In particular, the result consists of interactive views of a scenario each visualizing complementary information in terms of maps, geospatial data, and information. The proposed paradigm has been exploited as a basis for advanced navigation techniques, named Framy-Augmented Reality (Framy-AR, for short) and Link2U, which incorporate novel technologies and human-computer/GIS interaction criteria. In general, they combine the pervasiveness of mobile devices, the visual metaphor capability to convey information, and criteria derived from usability studies, in order to define a new modality for navigating and accessing geospatial data. In particular, given the previous features, Framy-AR adds them the augmented reality potentiality, and Link2U takes advantage of the ability to "communicate" of the social network.

3.1.1. Framy-AR: beyond the Screen Map Exploration

Our previous work in the area of mobile interaction was aiming to overcome screen limitations of mobile devices by representing, through a qualitative metaphor, the geographic distribution of elements located outside the visible space. In [6-7] an innovative visualization technique, named Framy, has been introduced which exploits an interaction metaphor for picture frames to provide hints about off-screen objects. The idea is to visualize a frame along the border of the device screen, where the colour intensity of each frame portion represents a visual summary of data located besides the visualized map area. By embedding Framy within a mobile application, an appropriate tradeoff is achieved between the zoom level needed to visualize the required features on a map and the amount of information which can be provided through a mobile application.

Framy-AR represents my current contribution to this research activity. Framy-AR is meant to both capture relevant features of a geographic space and convey such an information through the functionality of an augmented reality environment to enhance user's navigation activities with mobile devices. In Framy-AR a semi-transparent coloured strip is used to summarize information on Points of Interest (POIs) located inside the camera visual cone, and augmented reality techniques are used to emphasize those POIs in the current field-of-view. A customizable multimodal interface which includes visual, audio and tactile interaction modes characterizes the system, in order to fully exploit the communication potentials of current mobile technology.

The main advantage users may gain by Framy-AR is that they can immediately obtain hints about objects located around them, independently of the visualization modality they are adopting. This represents one of the most sought-after goals of a system targeted to support users' navigation and here it is achieved by defining a geovisualization technique where a geospatial data representation is included within a real scenario enriched by a visual metaphor associated with heterogeneous information.

Chapter 4 provides for a detailed description of the Framy-AR visualization technique.

3.1.2. Link2U: Connecting Social Network Users through Mobile Interfaces

Traditionally, social networks have focused on building online communities of people who communicate and share interests and/or activities. The technological revolution determined by the advent of ubiquitous IP networks combined with the advanced features of mobile interfaces has motivated a gradual transformation of social networks and of the services they provide towards mobile social communities. The most tangible effect of such a revolution is that social network users are now able to connect everywhere and anytime through handheld devices. It has therefore become paramount to study new interaction techniques that suitably exploit mobile technology to convey contextual information about both the physical environment surrounding a user and the (mobile) virtual community characterizing it.

Link2U represents an integrated solution for geo-communities on mobile devices which combines the potential of augmented reality with the ability to "communicate" of the social network. The rationale behind it is to meet mobile users' requirements of continuously acquiring information about the surrounding environment, essential for their activities. My contribution to this research has been focused on advanced modalities of geo-localization, location based services (LBS) and augmented reality techniques. In particular, by combining the potentials of mobile devices with the augmented reality capability to convey information of interest, the users' requirement of mobility services to improve their activities inside a wide community of people has been satisfied. This result has been achieved by adopting the idea of complementary views of a scenario enhanced by visual metaphors meant to represent synthesized information and preserve relationships among items of different views, thus guaranteeing the interactivity.

Chapter 5 provides for a detailed description of the Link2U visualization and navigation technique.

3.2. Building a Human-(Geo)information discourse through GeoVisual Analytics techniques

The previous visualization and navigation techniques represent the contribution of this dissertation to the geovisualization field. Users may benefit from Framy-AR, Link2U and every possible new solution which adopts the proposed approach to support their daily activities of representation of relevant information concerned a territory investigated through a user-centred view.

One of the most interesting properties of the above techniques results from the integration of visual metaphors and different modalities of visualization and navigation. It consists of the capability to preserve the link between a metaphor and data associated to it, while navigating a scenario. This property has been then exploited as starting point for the development of a geovisual analytics technique, the goal we are carrying on in order to complete the human-(geo)information discourse in a seamless manner.

The goal of this Section is to introduce my contribution to this research activity. It is based on the previous geovisualization techniques and exploit them to define a new data-entry methodology useful to access data underlying geospatial information. In order to reach this goal, the proposed visual metaphors, defined to represent data and phenomena of interconnected scenarios, have been syntactically and semantically extended by associating them with both a hierarchical structure and syntheses / aggregations of atomic data. Such an enhancement has allowed for the definition of a geovisual analytics methodology that can be used to investigate cause/effect relationships of phenomena of interest by accessing underlying data. In particular, the spatial manipulation of metaphors and the application of specific operators allow to invoke appropriate analysis functions in order to semantically and visually integrate quantitative, qualitative and cognitive aspects of a domain of interest.

The proposed geovisual analytics methodology has been experimented by including three different visualization techniques, namely maps of chorems, clouds of tags and Link2U. In the following, my contribution to this research activity is described and each following subsection is devoted to describe how the proposed methodology has been properly instantiated within specific domains in order to support analytical tasks.

3.2.1. Accessing Spatial Data through Chorematic Maps

Chorems are metaphors capable to visually represent geographic database content. In particular, they illustrate a territory in a schematized way, by summarizing items of interest and phenomena related to them [41].

The well-established capability of map of chorems to synthesize and represent relevant information of a territory has stimulated our research to investigate how the rationale behind this geovisualization technique could be exploited to assign chorems an enhanced role and achieve further advances. My contribution to this investigation has been to study how chorems could be used as an innovative means for database-entry, thus increasing the role they can play in geographic domains, from a cartographic solution to a visual analysis tool. To reach this goal, both structure and semantics of chorems has been enriched and a set of operators has been defined meant to both analyze a specific phenomenon and query the underlying data by which it has been determined. Thus, realizing an application which uses chorems both for visualizing and analyzing a territory and its phenomena implies to obtain a tool capable to completely support expert users' and decision makers' activities.

Chapter 6 provides for a detailed description of geovisual analytics applied to maps of chorems.

3.2.2. Delivering Advertisements on Mobile Devices

Advertising is a rapidly growing sector where potentialities of mobile devices are defining new solutions for the geomarketing policies. In particular, customized delivery of advertisements (ads, for short) on mobile devices is recognized to be a promising approach to overcome limits of traditional and digital media and capture users’ interests in certain domains [84], [114].

The geovisualization technique Link2U, described in chapter 5, has been adopted to build a system for delivering personalized ads on mobile devices, based on a user model that takes into account user’s interests over time. The purpose is to create a community of people, who receive information on sales promotions targeted to shops that have an agreement, directly on their mobile device, also by using advanced techniques of geo-localization and augmented reality. As a result, services where mobility comes into maybe then provided through the Link2U visualization and navigation technique, such as geographic distribution of POIs and traceability of users' movements within a given area. Moreover, each metaphor representing both users, paths and sites is associated with a rich set of structural and semantic information, useful when an analysis function is requested. These functionalities allow expert users to perform analytical tasks and recognize possible relationships between user's interests and potential products.

Chapter 7 provides for a detailed description of these results.

3.2.3. TagaMap: Visually analyzing Geographical Information through Tag Clouds

In this dissertation, a GeoVisual Analytics technique is introduced, named TagaMap, which is based on a recent InfoVis technique, known as Tag Cloud. Clouds of tags summarize the content of a text by a set of differently-sized/coloured keywords. The method I propose adopts the Tag Cloud rationale and extends it by exploiting techniques for summarizing datasets and simplifying their geographic representation, such as cartograms [49] and chorems [80]. Starting from a geographic dataset, the proposed method extracts relevant information about a geographic area by counting and/or summarizing data, and generates a simplified map containing a georeferenced cloud of tags, located within the geographic area which original data are related to. The resulting representation is a sensible map which both conveys to the users qualitative and quantitative features related to the dimension, and their relationships with territory, and allows them both to access underlying geospatial data and then analyze them through semantic and geographic operations.

Chapter 8 provides for a detailed description of TagaMap.


Framy-AR
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CHAPTER 4

AUGMENTED MAP NAVIGATION THROUGH CUSTOMIZABLE MOBILE INTERFACES

The interest toward mobile applications useful for human daily activities is leading researchers to new challenges, embracing the adoption of suitable technology, the identification of efficient and effective algorithmic solutions and the design of usable and powerful user interfaces.

The system described in this Chapter [35], Framy-Augmented Reality (Framy-AR, for short), is meant to support users' exploration activities including the fruition of navigation services. Framy-AR suitably combines the benefits of the Framy visualization technique [92] with those of the augmented reality (AR) to enhance user’s navigation activities with mobile devices. In the new combined visualization method a semi-transparent colored strip is used to summarize information on POIs located inside the camera’s visive cone, while the augmented reality techniques are used to emphasize those points in the current field-of-view. A customizable interface characterizes the system, thanks to the definition of a new technique for computing the best user-adaptive pedestrian route. In particular, the support to the pedestrian navigation is achieved by considering specific features of the pathway under exploration weighting them against user’s profile. Moreover, in order to fully exploit the communication potentials of current mobile technology, a multimodal interface has been designed, which includes visual, audio and tactile interaction modes.

The remainder of the Chapter is organized as follows. In Section 4.1 related work is discussed. Section 4.2 briefly recalls salient aspects of the original Framy visualization technique and shows the new Framy-AR multimodal technique. In Section 4.3 the customization model of Framy-AR is described. Section 4.4 presents a working example which illustrates the Framy-AR functionality.

4.1. RELATED WORK

A valuable work in the area of mobile GIS accessibility has been carried out by Yairi and Igi, who followed a universal design approach to develop their Mobility Support GIS targeted to a variety of pedestrians including elderly, disabled, pregnant, and infant users [67]. The routes in their system are represented by lines and nodes. Lines are associated with attribute data of barrier/barrier-free features often found on sidewalks, while nodes are points indicating a link with lines carrying different attributes. The gained know-how is proposed as useful guidelines for the development of pedestrian oriented accessible GIS.

An interesting application targeted at physically disabled users was presented in [71]. The authors describe a Web GIS providing impaired people with pedestrian routes. Each route is divided into segments, so that each segment has homogeneous characteristics. The overall characteristics of a route are determined by taking into account the difficulties of each obstacle as well as psychological factors related to the specific user. Obstacles are mapped onto a database and a weight is assigned to each of them, so that users can plan the route and analyze the obstacles carefully. This approach turned out to be appropriate for a mobility support GIS, thus we have decided to apply a similar technique for the customization model of Framy-AR, which also retains the distinction between discrete and continuous obstacles. Moreover, in Framy-AR weights depend on both user’s ability, her/his interest in the target destination and degree of disability. Finally, the addition of the tactile and auditory interaction modalities makes our system also suitable for visually impaired users.

Recently, growing attention is being devoted by researchers to the adoption of AR techniques for mobile devices, as a means both to guide users and assist them in the recognition of objects [16], [62], [19].

The AR technique embedded in Framy-AR is based on both user's position and sensors providing orientation on mobile devices. It was partially inspired by the pedestrian navigation system presented in [16], where the user is capable to see the POIs superimposed on the captured video image, and s/he can recognize their location outside the view limits of the camera. The same technique is adopted in Framy-AR, better targeting the use of the original Framy orientation technique to all kinds of mobile pedestrian users.

In [34] the authors exploit technologies related to AR and geo-localization to provide visually impaired users with pedestrian routes. The equipment used for this purpose consists of a wearable computer, a microphone and a headphone. While outdoor user's position is provided by a GPS receiver, the indoor position is retrieved through the ultrasonic receivers. Similarly, our prototype uses a GPS receiver in outdoor areas, while it uses a WI-FI hotspot triangulation technique for indoor areas. Finally, the system is smart-phone based.

Also inspired by the benefits of AR, it is worth mentioning the system presented in [62]. The authors propose a walking guide on mobile devices presented as a sequence of “augmented photographs”. Geo-tagged photographs are retrieved from a database and are automatically augmented with navigational instructions.

Finally, a domain-specific AR application is described in [19]. The authors propose a software for mobile devices capable of recognizing cataloged objects in a museum. The technique is based on user's position and image recognition algorithms.

4.2. The *Framy-AR* multimodal technique

The Framy visualization technique is explicitly targeted to enhance geographic information visualization on small-sized displays. The rationale behind Framy is to display a semi-transparent colored frame along the border of the device screen to provide information clues about different sectors inside or outside the screen. For a given query, the color intensity of each frame portion is proportional to the number of resulting objects located in the corresponding map. Thus, the frame may indicate both the distance and the direction of specific POIs. It may also represent the amount of POIs located toward a specific direction. In general, the frame portion color intensity represents a summary of data located besides the screen border. Moreover, the number of frame portions can be interactively increased so as to refine the query results, indicating, e.g., the direction where certain objects can be found. More details can be found in [85].

Framy-AR represents a project which merges the concepts introduced with Framy into an AR environment to improve the perception of the objects or objects properties on a mobile application characterized by a strong geographic component.

Recent advances in technology have encouraged Information technology (IT) researchers to investigate innovative multimodal interfaces and interaction paradigms, able to exploit the increased technological power as explained in [48]. In Framy-AR, users may benefit from two different visualization modalities, namely Basic and Augmented. The former corresponds to the basic two-dimensional view, the latter exploits augmented reality features to improve users’ sensory perception of the context. Users can switch between the Basic Mode and the Augmented Mode by laying down and drawing up the device (see figure 4.1).

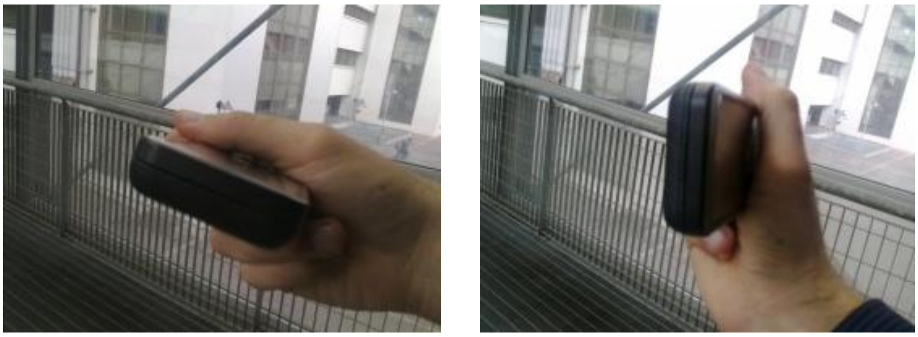
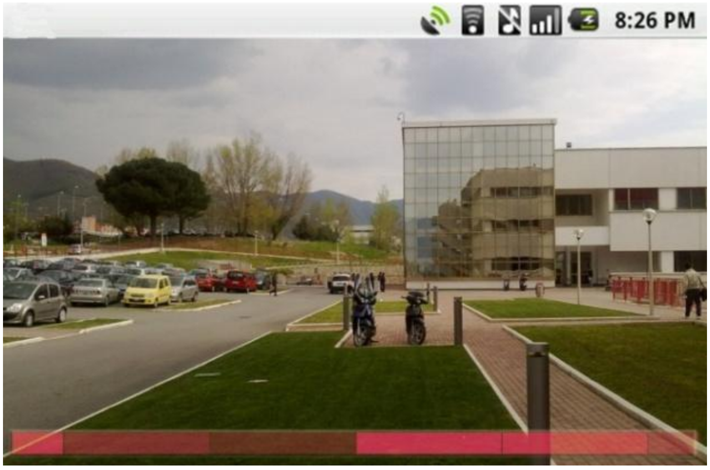
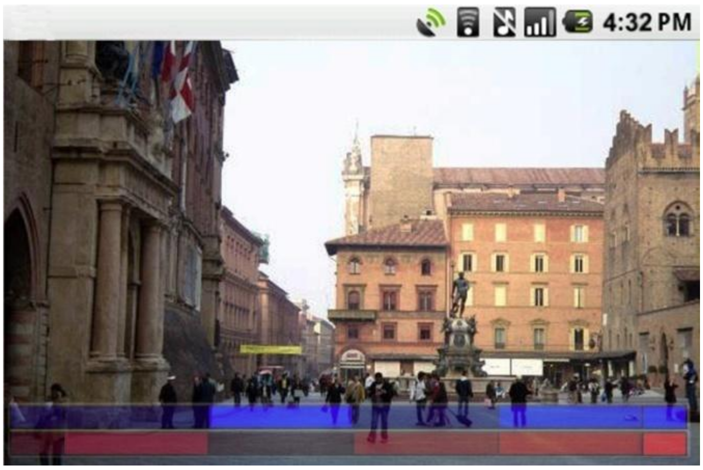


Fig. 4.1 Device positions for Basic Mode and Augmented Mode

By the Basic Mode the information is presented by physically inscribing a colored frame all around the border of the screen, in the Augmented Mode the information is described and visualized by means of a strip depicted on the bottom of the display. Figures 4.2(a) and 4.2(b) represent two scenarios captured by the Augmented Mode visualization.



(a)



(b)

Fig. 4.2 (a) and (b) two Framy-AR scenarios in the Augmented Mode.

The idea behind Framy-AR is to divide the space around the user into n sectors $S_1,\ldots, S_n$ of equal width, namely 360°/n. Figure 4.3 shows such a subdivision by using n = 16. The surrounding physical environment is augmented by a semi-transparent colored strip which is divided into the corresponding n portions $C_1,\ldots,$

C_n. Once the user poses a query, the color intensity[1] of each C_i, is modified on the basis of the value of an aggregate function, such as sum and count, applied on a property of the objects located in S_i. Thus, the color intensity may be expressed as

$$intensity(C_i) = f(g((S_i)) \text{ for each } i \in \{1, \ldots, n\} \qquad (1)$$

where *f* is a monotonic function and *g* is a function which aggregates a numeric value starting from a set of spatial data.

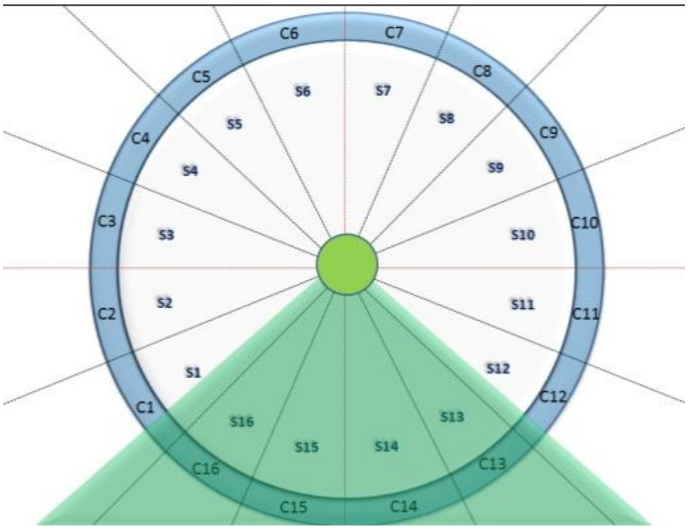


Fig. 4.3 An example of screen subdivision accomplished by Framy and the corresponding user's visual cone

Being in the Augmented Mode, a user will see sectors of the surrounding environment which are being captured within the camera visual cone, and projections of the corresponding strip portions on the vertical plane of the display, meant to convey information about objects lying in the focused sectors. The user's view will dynamically change as s/he turns the camera around.

In Figure 4.2(a), we applied the sum aggregate function on POIs located in the University of Salerno (Italy). It is possible to notice that most POIs are located on the right.

When different aggregates of POIs are needed (e.g., hotels and monuments), Framy-AR can separately visualize the colored strips representing each of them, so that the user may summarize information from the displayed strips and make suitable decisions, e.g., the best direction to the target destination.

As an example, in figure 4.2(b) the aggregates of hotels and monuments are considered. Besides taking a glance at the map, the user may want to understand the direction to follow in order to find the easiest-to-reach area where both hotels and monuments lie. In order to derive this summary information, two strips are visualized – red for monuments and blue for hotels, respectively. The user will notice that the lower red strip has the highest color intensity on the right-hand side of the map, and the upper blue strip has the highest intensity on the same side. This indicates that, in response to the request, the user may expect many POIs moving the map focus to the right.

In order to extend the Framy-AR capability to transmit information about the surrounding spatial data, the semitransparent strip can be used to convey information clues both about POIs lying inside the camera's field-of-view cone and those outside it. In this case, this overview can be achieved by exploiting a logarithmic scale (see figure 4.4) which measures the logarithm of a physical quantity instead of the quantity itself. Such a scale has been chosen to give a priority to the elements inside the camera cone.

[1] the intensity corresponds to the saturation index in the Hue-Saturation-Brightness (HSB) model.

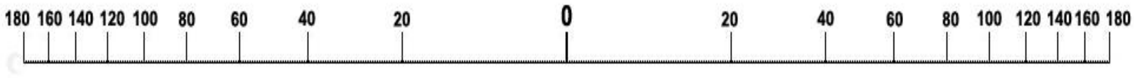


Fig. 4.4 Logarithmic scale for a full view

As shown in Figure 4.4, degrees are displayed on a logarithmic scale from 0 to 180, both on the right and on the left side, and the most significant summarized information comes from the front side through wider intervals.

The trend of intervals can be customized by the user by changing the base of the logarithm which in turn modifies both layout and size of intervals. In Figure 4.5 the logarithm base is set to the default value 10. A user may choose either to represent intervals by using a logarithmic scale or to display only equally sized portions of the circular strip that correspond to the captured sectors.

Fig. 4.5 Augmented Mode with Logarithmic scale

In order to allow the adoption of Framy-AR by individuals with hearing or sight impairments, we have decided to associate sounds and vibrations as additional tips of the device. The idea is that a user can use a device as a detector that identifies objects. When a user moves the device toward the suggested direction, s/he will perceive an increasing frequency of a beep or of the vibration. In particular, given a data distribution, users can hear a sound or feel a vibration whose pitch is synchronized with the color intensity of the corresponding frame portion. Each frame is mapped onto a different signal (sound or vibration) and each frame portion onto a different signal intensity, computed on the basis of the corresponding color intensity thus conveying the same information as the visual counterpart does.

4.3. The customization model

In the area of pedestrian routes calculation it is necessary to take into account possible obstacles to the user based on her/his physical abilitie [71], [67]. Thus, in order to adapt the system to the specific requirements of possibly impaired users, we have enriched the system with a customization model which allows to highlight those sectors which better respond to user's accessibility needs and preferences. To this aim, we have taken into account the accessibility score of each POI *a* belonging to a sector *S* computed on the basis of road conditions conducting the user *u* to that POI and the parameters characterizing *u*. Formally,

$$Score(S,u) = \sum_{a \in S} Score(a,u)$$

where *Score(a, u)* is the score that the model computes for a POI *a*. Basically, our customization model measures the minimum effort that any user has to experience for reaching a given destination. The basis of this model is the length of paths going from the user's location to the destination. These values are successively increased on the basis of the path conditions or decreased on the basis of the user's preferences:

- we penalize a path proportionally to difficulties that users would face by walking along it, while
- we reward the path on the basis of user's specific interests toward the targeted POI.

From a general point of view, penalizations are specifically due to the presence of obstacles that users may find along paths, while rewards are special motivations for the POIs to be reached. Then, the score of each POI may be expressed as the difference of two components:

$$Score(a,u) = w_1 P(a,u) - w_2 R(a,u)$$

where *P(a,u)* is the least penalization to reach *a*, *R(a,u)* is the total rewards, while w_1 and w_2 are the corresponding weights whose values belong to [0, 1] summing up to 1. Each weight specifies the importance of a component in the formula. Basically, if either w_i is set to 0 or 1 the corresponding component should be not considered or it is the only feature considered for the final score computation. In order to balance the significance of *P(a)* and *R(a),* weights may be set to 0,5.

In particular, $P(a,u)$ may be calculated as follows:

$$P(a,u) = \min_{i=1}^{t}(\mathrm{d}(\mathrm{p_i}) + \mathrm{P}(\mathrm{p_i},\mathrm{u}))$$

where $\{p_1, p_2, \ldots, p_t\}$ are the paths the user may follow to reach the POI *a* starting from the her/his location, $P(p_i,u)$ represent the total penalization along the path p_i and $d(p_i)$ is its length.

The final computation of the penalization may be, in turn, divided into two components on the basis of the obstacle typologies that users have to face. To this aim, we have distinguished between discrete and continuous obstacles. The former represent obstacles whose degree of difficulty is independent from the path length (e.g., stairs or holes), the latter are dependent on the path lengths (e.g., dirty or steep roads). In general, we have defined a pair of matrices (*Disability* x *Obstacle*) where the weight associated to each cell corresponds to the total penalty in case of a discrete obstacle, and to the unitary penalty in case of a continuous obstacle.

More formally, let us suppose that:

- the path *p* is divided into *m* segments $\{s_1, s_2, \ldots, s_m\}$ so that each segment contains an instance of either only discrete $\{o_1, o_2, \ldots, o_k\}$ or only continuous $\{o'_1, o'_2, \ldots, o'_l\}$ obstacles, with $m = l+k$.
- the lengths of the segments containing continuous obstacles are $\{d'_1, d'_2, \ldots, d'_l\}$
- the weights of the obstacles along the path are $\{w_1, w_2, \ldots, w_k\}$ and $\{w'_1, w'_2, \ldots, w'_l\}$, and
    - the percentages of user's disability are $\{u_1, u_2, \ldots, u_k\}$ for the discrete obstacles and $\{u'_1, u'_2, \ldots, u'_l\}$ for the continuous obstacles, then

$$P(p,u) = \sum_{i=1}^{k} \mathrm{u_i w_i} + \sum_{i=1}^{l} \mathrm{u'_i w^i_i\, d'_i}$$

On the other hand, the interest in POI *a* could be considered as a further motivation for reaching it. Basically, it could be seen as a reward which should be set against penalties. Rewards are based on two values, which consider a classification of the POI domain *I(a,u)* and the POI characteristics mapped onto user's general interests *Is(a,u),* respectively:

$$R(a,u) = I(a,u) + Is(a,u)$$

Initially, when building a user profile, the system stores the score the user assigns to each domain as well as to its derived subcategories. For our purpose, we have considered a classification of 7 POI categories. As an example, the domain museum has the item subcategories archaeology, sculpture, painting, ecc. Each category is then described by means of a set of terms which are successively used for calculating the similarity with the POI description. When a user *u* registers to the services, she/he is asked to assign an interest value to each general category, and an interest value to each of its subcategories. For every domain, information concerning interests assigned by user to the categories and to their specific item subcategories are stored as vectors. As each POI has a pre-assigned subcategory, selection with respect to this reference is immediate. Each POI *a* is assigned with the score associated with the corresponding specific category in the corresponding user profile. Thus, the interest in a POI *a* of a user *u*, classified as belonging to subcategory $S_{i,j}$, corresponds to the interest assigned to the subcategory $S_{i,j}$ by the user *u*, namely:

$$I(a,u) = S_{i,j}(u)$$

In order to calculate the second part of the reward formula, a similarity value $sim(a, C_i)$ is then computed between the description of the POI *a* and the general categories C_i, by exploiting the cosine similarity formula for the vector space model. In particular, we have used a simple approach where each term weight of the POI description is set to 1 if the normalized term frequency is higher than a given threshold. Consequently, the relevance between a POI a and all general categories of a user model u is computed by using the following formula:

$$Is(a,u) = \frac{\sum_{i=1}^{7} \mathrm{sim}(\mathrm{a}, \mathrm{C_i}) \mathrm{i_i}(u)}{\sum_{i=1}^{7} \mathrm{i_i}(u)}$$

4.4. A WORKING EXAMPLE

Let us suppose that two users u_1 and u_2 have to reach the city town hall from the train station. User u_1 has a partial visual impairment while u_2 has a motor impairment and uses a wheelchair, (Table I). Basically, three paths, p_1, p_2 and p_3, from the starting point are available, the length of p_1 is 100m, p_2 is 160m and p_3 is 200m (see Figure 4.6). Two discrete obstacles are located along path p_1, a continuous obstacle is located along p_2 for the whole length and, finally, no obstacle exists in p_3.

TABLE I. Visual impairments for u_1 and u_2.

	O_1	O_2	O_3	$\%u_1$	$\%u_2$
visual	30	40	0.2	1	0
motor	50	60	0.5	0.1	0.7

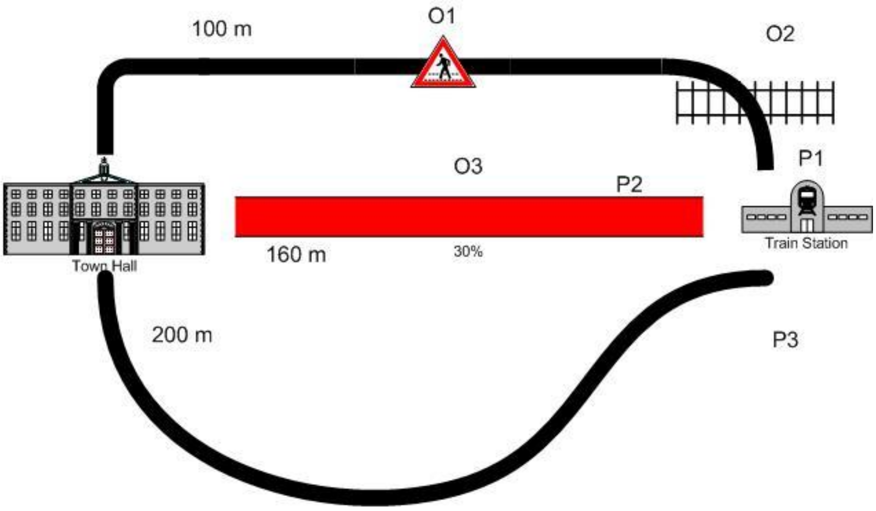


Fig. 4.6 A schematic example of the obstacles located along paths for reaching the town hall from the train station.

$P(Town\ Hall, u_1) = min_{t=1}^{3} P(p_i, u_1)$

Then,

$P(p_1, u_1) = 30 * 1 + 40 * 1 + 30 * 0.1 + 40 * 0.1 = 77$
$P(p_2, u_1) = 0.2 * 50 * 1 + 0.2 * 50 * 0.1 = 11$
$P(p_3, u_1) = 0$

and,

$P(p_1, u_2) = 30 * 0.7 + 40 * 0.7 = 49$
$P(p_2, u_2) = 0.2 * 50 * 0.7 = 7$
$P(p_3, u_2) = 0$

Finally,

$P(Town\ Hall, u_1) = \min\{100 + 77, 160 + 11, 200 + 0\} = 171$
$P(Town\ Hall, u_2) = \min\{100 + 49, 160 + 7, 200 + 0\} = 149$

As a matter of fact, it is possible to notice that even if the shortest path between the train station and the town hall corresponds to p_1, the topology of the obstacles changes the resulting scores. Namely, the impairment of u_1 with the obstacles along p_1 increases its distance of 77 meters which is much more than the 11m calculated along p_2. In the same way, the impairment of u_2 modifies the real distances of p_1 and p_2 by adding increments due to the obstacles, in this case, 49 for p_1 and 7 for p_2. Given this obstacle and the impairment configuration, the path with the shortest calculated distance for u_1 becomes p_2 and the differences between any pair of calculated distances (177, 171, 200) are smaller than the distances without obstacles (100, 160, 200)). On the other hand, p_1 still corresponds to the best desirable path for u_2 because the penalization calculated along p_1 is not sufficient to make p_2 the best path.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access
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clients
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POIs/SNUs
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prototype
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known
applications

CHAPTER 5

CONNECTING SOCIAL NETWORK USERS THROUGH MOBILE INTERFACES

Social networks have focused on building online communities of people who share interests and/or activities. Much research interest towards new ways to communicate and share information has been encouraged by the witnessed success of social network websites, which are regularly used by millions of people. In this chapter we present Link2U, a solution for mobile devices which combines the potential of augmented reality with the ability to "communicate" of the social network. The ultimate aim is to meet mobile users' requirements of continuously acquiring information about the surrounding environment, crucial for their activities. In order to achieve this goal our studies have been especially focused on advanced modalities of geo-localization and on augmented reality techniques. We have in fact decided to combine the potentials of mobile devices with augmented reality features to create a social network that allows members of a group (SNU: Social Network User) to invoke several functionalities, ranging from traditional functions such as messaging, to the calculation of a route on a map and the identification of other SNUs and/or of points of interest (POIs) through the support of augmented reality. Fundamentals of such an approach can be found in [25], [65], [13], where initial solutions are described which combine augmented reality and virtual reality, thus forming the basis for modern research. Moreover, a significant prototype of geo-community for mobile devices is described in [85], where maps are used to represent the users' position. Finally, an example of a guide for mobile devices that involves also community features is proposed in (Carlsson, 2008) [21], where the users can obtain and share information about points of interest shown on the device.

Two applications recently developed, namely Google Latitude [58] and Enkin [15], are representative examples of applications meant to provide intuitive and light navigation systems for mobile devices by suitably exploiting a combination of camera, GPS, and 3D graphics with permanent Internet connection. Latitude is a social network with a worldwide diffusion, which has been introduced by Google as a new concept of mobile social network. When connected, a SNU is allowed to display on a map the position of other members of the group she/he belongs to, and she/he can invoke the calculation of the fastest route to reach them starting from a focus point which corresponds to her/his position. Google Latitude is freely distributed on the latest version of Google Map for mobile devices. Enkin is an augmented reality application for mobile devices which has been validated through a scientific approach. It offers a new concept of pedestrian navigation (handheld navigation concept) based on the augmented reality that combines reality with a typical display of maps. In particular, on the screen and superimposed to video image, the user is capable to see the POIs represented in 3D, and can recognize their location outside the view limits of the camera. From a technological point of view, Enkin takes advantage of the camera eye, the GPS, the compass and the motion sensors to detect the point of view. Moreover, through a little radar view-like frame visualized on the display, Enkin also allows a 2D vision of POIs by using the classic map view.

Our proposal combines benefits coming from both approaches and is based on a geo-localization technique which integrates GPS and WiFi Positioning System (WPS). The latter allows to accurately determine the location of wireless access points (APs) to estimate the physical location of a WiFi enabled device, thus overcoming limits of GPS in terms of coverage and accuracy. Thus, the ultimate goal of our research has been to design and develop an advanced mobile interface able to support users' daily activities, within a mobile social community. As a result, users are provided with services where mobility comes into, such as services that support navigation and location based services (LBS), which may further enhance their activities inside a wide community of people. A prototype of Link2U is being tested at the University of

Salerno, namely Link2U@Unisa. A cross-cultural community has been involved, which includes students and teachers from different faculties. The prototype allows SNUs to determine individual indoor/outdoor positions and calculate the path towards some target POI or some other connected SNU. To build Link2U we exploit a modern mobile device that combines an integrated camera for video-image capture, a Global Position System (GPS) device to detect the position, a compass and motion sensors to detect user's point of view.

The remainder of this Chapter is organized as follows. In Section 5.1 we present the multimodal interaction paradigm adopted in Link2U. To show the human-centered nature of the proposed system, we describe the supported user tasks in terms of Norman's interaction framework [91]. In Section 5.2 we describe the two grouping methods employed by Link2U to allow users to avoid a "sensorial overload" due to the visualization of multiple elements on small device screens. An example of Link2U usage is successively presented in Section 5.3, while technical details about the prototype are described in Section 5.4.

5.1. The Multimodal Interaction Paradigm

Consistently with most social network websites, users in Link2U are split into focused groups, known as contact lists. A SNU may belong to more than one contact list, if he finds it appropriate. The basic tasks he/she may perform within each group, are the context-related visualization of people currently connected, and the route calculation towards a specific target, which can be a POI or another SNU in the group.

As for the contextual information about the virtual group available in the surrounding physical space, each SNU in a list shares a flag which specifies his/her availability status on the network. Thus, people in the group who are presently available on the network, as well as their current location, will be readily visible by the user. In particular two different interactive visualization modalities are provided in Link2U, namely a "Map" mode and a "Live" mode. The former corresponds to the classic two-dimensional map view, where SNUs and POIs are drawn on the map. The Live mode instead exploits augmented reality to improve users' sensory perception about SNUs and POIs located inside the camera visual field and to provide visual clues of those located beyond. Both SNUs and POIs inside the visual field are visualized in a three dimensional environment and are superimposed on the image captured by the camera phone. The visual field has a predefined radius, which can be fixed by the user, on demand.

A SNU can switch between the Map mode and the Live mode by laying down the device or by raising it into vertical position. The two modalities allow to better support SNUs in their everyday activities, alternating the benefits gained from the global view of a two-dimensional map with those of augmented reality. Indeed users may more effectively and efficiently identify contextual services and group users within a social network navigating a map towards the target, and then recognizing POIs/SNUs by simply pointing the phone camera towards the right direction.

As for the route calculation, in Map mode the route is displayed as a 2D polyline, along with a label on the target icon indicating the distance in kilometers between the involved points. Differently, in Live mode the route is displayed as a set of waypoints along with labels that contain a progressive number to reach the next waypoint. A small radar view-like frame visualized on the screen displays the closest waypoints. Once a waypoint has been passed through its color is automatically changed.

The multimodal interaction capabilities offered by Link2U can be described in terms of the well known execution-evaluation cycle defined by Don Norman in [91], as extended in [95], to better characterize multimodal interaction. In Table 1 we describe the two basic interaction tasks of context-related visualization and of route calculation, in terms of the steps characterizing the cycle.

Context-Related Visualization	**Route Calculation**
1.*Establishing the goal*	
The user is willing to receive visual information about the physical and virtual environment surrounding him/her.	The user wants to reach one of the identified POIs/SNUs
2.*Forming the intention*	
The user wishes to locate POIs/SNUs currently available around his/her location.	The user wants to receive visual information about the best route to the target.
3.*Specifying the action sequence*	
The user may exploit two alternative human input modalities, namely Live mode and Map mode to explore the environment.	The user may exploit two alternative human input modalities, namely Live mode and Map mode to compute the route.
4.*Executing the action*	
The user lays down the device and observes the whole map. Then, he/she raises the device into vertical position and slowly turns to explore the surrounding scenario. He alternates between the two modalities.	The user lays down the device and selects the target on the map. He invokes the route calculation function. Then, he/she raises the device into vertical position. He alternates between the two modalities.
5.*Perceiving the system state*	
In Map mode, the user captures the location of POIs within a 2D view. In Live mode, he/she observes POIs/SNUs as visualized in the 3D augmented reality space.	In Map mode, the user perceives the route as a 2D polyline, along with a label on the target icon. In Live mode, he sees a set of waypoints that lead to the target and a small radar view displaying the closest waypoints.
6.*Interpreting the system state*	
The complementary use of the two modalities help the user locate and identify SNUs and/or POIs in a more effective and efficient way.	The complementary use of the two modalities help the user reach the target SNU or POI in a more effective and efficient way.
7.*Evaluating the system state with respect to the goals and the intentions*	
At this stage the user is capable to evaluate whether the localization and identification of SNUs and POIs coming from Link2U allows him/her to effectively interact with the surrounding environment.	At this stage the user is capable to evaluate whether the visualized route has effectively led him/her to the target POI/SNU.

Table 1. The two basic interaction tasks.

Of course, a good mapping should be achieved between the execution and the evaluation phases in order to bridge what Norman calls the gulf of execution (i.e., the distance between user's specification of the action and the actions allowed by the system) and the gulf of evaluation (i.e., the distance between user's perception of the new state and her expectation). We have in fact taken into account this general usability requirement throughout the design process of Link2U. A major contribution towards that goal has been achieved by carefully designing the visualization of groups of users, combining detailed visualization methods with appropriate visual summary methods, as explained below.

5.2. Grouping Methods

In order to avoid confusion due to SNUs crush on the screen, a selected number of them or alternatively a grouping metaphor should be displayed. In this section, we present two grouping methods which allow users to avoid a "sensorial overload" due to the visualization of multiple elements.

The first approach is inspired by the Framy visualization technique [94], which can be used to visually summarize information distributed within an area of interest. The basic idea is to divide the world around the user into sections.

As an instance, Figure 5.1(a) divides the world into 16 sectors (S1-S16). The green triangle located on the bottom shows the camera visual field. Figure 5.1(b) shows an example of visual representation. On the bottom of the screen, the system visualizes an arc, representing the portion of the world bounded by the camera visual field, divided according to the corresponding sectors. The color intensity of each portion is proportional to the number of SNUs located in the corresponding sector.

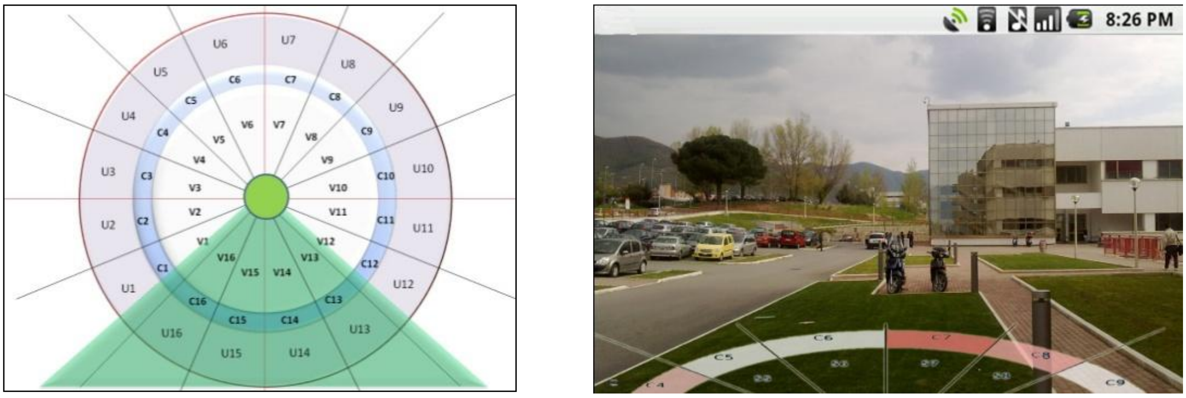
The technique we have adopted for assigning a color and its different intensity degrees to a circle is based on the Hue, Saturation, Value (HSV) model. Starting from this model, we have specified how its components may be calculated in order to determine the color value of each part, namely the HSV value associated with each portion. In particular, we set the Value parameter to 100, thus implying that each part is always associated with the highest color brightness, while the Hue component corresponds to the color assigned to the whole circle.

As for the Saturation index, which corresponds to the color intensity, it is determined on the basis of the number of SNUs located in each sector, that is to say:

$$s_i = (SNUi*100) / SNUTot \qquad (1)$$

where s_i represents the saturation of the i-th sector, SNU_i is the number of SNU in the i-th sector and SNU_{TOT} is total number of SNU within a given buffer.

A further improvement of this technique allows users to disaggregate SNU_s belonging to different contact lists. In this case, each list is associated with a differently colored circle. Each part of the circle is then associated with a different intensity of the chosen color on the basis of the number of SNUs related to that circle.



(a) (b)

Fig. 5.1 (a) Sector division of the region around the user, and (b) an example of the visual representation.

The idea of the second approach is to map meeting places on the basic cartography, such as library, classroom and swimming pool, where SNUs are used to gather. Such places can be detected as Area of SNU Aggregation (ASA) through the  icon. When the SNU number / ASA surface ratio is bigger than a threshold value, the icon evokes the presence of a set of SNUs as shown by the associated label. This approach is exploited in Map mode when the zoom level is within a specific range, and in Live mode when the user position is outside the ASA. Figure 5.2 depicts the visual representation of this visual aggregation technique.

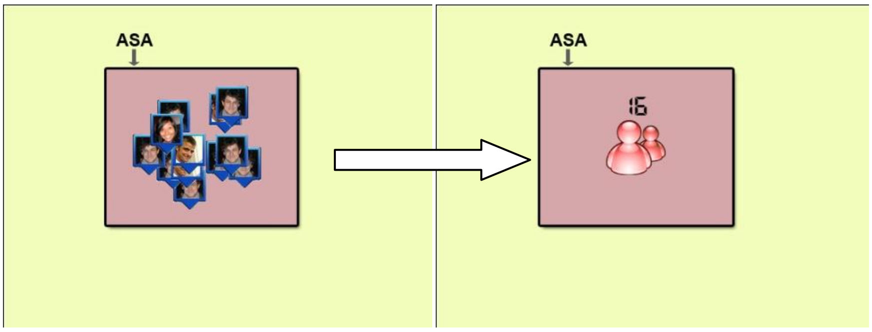


Fig. 5.2 Visual aggregation technique

As a matter of fact, both aggregate methods presented in this section allow to catch a general vision of the world surrounding the user in a easy and intuitive way avoiding the sensorial overloading due to the SNUs crush. In particular, they can be invoked as a sequence of representations which allow users to generalize or detail the content of a given region, depending on the required data. As a matter of fact, they can be applied within two different scenarios in order to extract two different kinds of information. In particular, the aggregation based on circles plays the role of a long distance scanner capable to qualitatively transmit the number of contact list SNUs currently available in given directions. Such an approach can be used when the region of interest is not directly visible through the camera, due to the topology of the region or the distance from the point of view. Differently, in case SNU_s fall within the camera view and are topologically located within an area of interest, they could be aggregated by using the second method. In fact, this latter results more suitable when aggregations are required for delimited regions and can be used to represent a summary of the people who can be found in POIs.

In fact, the two methods may be considered as a sequence of representations which allow users to generalize or detail the content of a given region.

5.3. Scenario

In order to provide an example of the effectiveness of the Link2U approach, a prototype has been realized, namely Link2U@Unisa, and the following scenario of a mapping navigation and social interaction among SNUs has been run.

The scenario is representative of the experiments we have carried out at the Fisciano campus of the University of Salerno. It includes two tasks describing the functionalities offered by Link2U.

In the first task, Monica receives a new student named Davide. Monica does not personally know Davide but she knows he is registered on Link2U community.

In order to accomplish the first task, Monica adds him to her contact list and accesses to Link2U@Unisa in Map mode. The application provides her with a distribution map of the SNUs belonging to her contact list. In this case, the Map mode is useful to obtain a global view of the campus.

Figure 5.3 (a) shows the resulting map where Davide is visualized. In particular, Davide is in the parking area of the swimming-pool and his status is free. Monica asks the system to calculate the route towards Davide.

Fig. 5.3 (a) Map mode visualization of Davide's position. (b) Live mode representation of Davide's position

Monica reaches the car park and switches to Live mode. This helps her to recognize Davide, as shown in Figure 5.3 (b).

In the second task, Enzo is located at the main entrance of the campus and wishes to reach a meeting for foreign students organized in a contact list. In order to carry out this task, Enzo looks on the device in Live mode and takes a look at the distribution of the people of the foreign contact list (see Figure 5.4 a). In this case, he enables the aggregation method based on colors and recognizes that the most numerous group is located on the right-hand side, thus deciding to follow that direction.

After 200 meters he is in the center of the campus and decides to switch the system to visualize aggregates by ASA (see Figure 5.4b). He finds out that a crush of foreign students is located in the library and decides to reach the building. A relevant functionality within task 2 is represented by the route calculation. Such a service may be invoked by both modalities according to user's purpose, such as car navigation and pedestrian exploration. Once invoked this functionality in Map mode, Monica obtains the route towards Davide and starts navigation

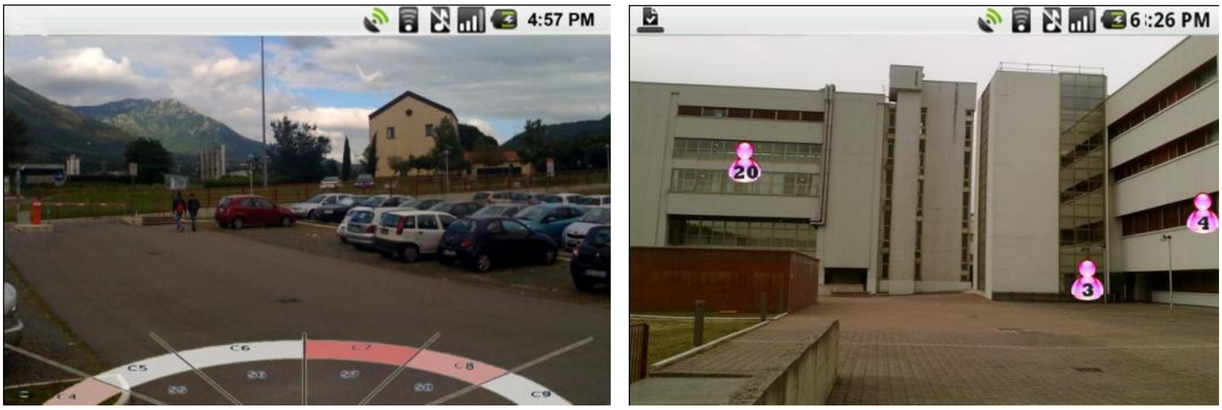


Fig. 5.4 (a) Aggregates of foreign people based on color gradients in live mode, (b) aggregates of foreign people based on ASA

5.4. Link2U@Unisa

Link2U@Unisa is an initial version of a prototype realized in order to validate some of the functionalities underling the approach previously described.

In the following subsections we present the software frameworks used to develop the application on mobile device and illustrate the underlying architecture both in terms of system network and client application.

5.4.1 The System Network

The architecture of the system is client-server based, where the server is responsible for coordinating and updating the positions of the various clients. SNU personal data are stored in the database A in Figure 5.5.

In our case, the server works as a broadcast node, receives information from clients related to their position and their ID, and rebroadcasts such information to all clients. The client represents the SNUs currently connected to the network, recovers their position to make them known to the server and collects information related to other SNUs from the server.

The update of a SNU position is delegated to a server that receives the new position and sends it to all SNUs. When the position of a SNU moves significantly from the last recorded position, its device registers the new location and sends it to the server.

As shown in Figure 5.5, the localization of a client is obtained through two methods. The former corresponds to the classical localization through the GPS standard. The latter calculates the position through the triangulation of the WiFi hotspot signals.

The technology works by sniffing for the surrounding WiFi networks, then measuring signal strength and comparing those results with a database. This implies that a service provider would need to conduct periodic sweeps of an area to catalog the WiFi hotspots that populate the database B. It is worth to note that the client connection is not really required, i.e., the client only scans the hotspots to measure relevant factors used for the database lookup. The location accuracy is proportional to the number of hotspots present in the area around the device.

The client collects data related to the signal strength and its SSID, and transmits them to the server, which in turn calculates the position of client according to the data contained in the database and sends an “Update Position” to all clients.

The GeoServices block embeds two servers which offer external functionalities targeted at generic users, thus reducing the computational work load on the mobile devices. The block communicates via HTTP with the clients, no intermediate node is needed.

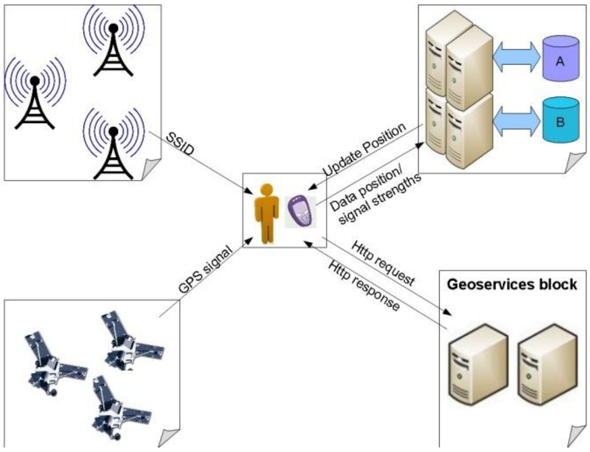


Fig. 5.5 Hardware architecture

In the next Section we exemplify the usage of Link2U through a scenario where the advanced functionality is illustrated.

5.4.2. The Client

The client application has been developed on a G1 HTC DREAM that incorporates the needed hardware along with a Linux embedded system (Android [6]) which allows great freedom in the development of applications.

From a technological point of view, the HTC Dream combines an integrated camera for the video-image capture, a GPS device to detect the position, a compass and motion sensors to detect the user point of view. Moreover, WiFi allows to identify user's position with a good accuracy inside the area not covered by GPS signal. This is possible through a technique of triangulation of the access point positions. Obviously, this service can be offered only within WiFi covered areas, where positions of access points are known.

Android includes a set of core libraries that provides most of the functionality available in the core libraries of the Java programming language. It provides applications with access to the location services supported by the device through the classes in the android.location package. The central component of the location framework is the LocationManager system service, which provides an API to determine location.

The access of a map is provided by MapView that displays a map with data obtained from the Google Maps service. MapView captures key-presses and touch gestures to pan and zoom the map automatically, including handling network requests for additional maps tiles. It also provides users with all of the UI elements necessary for the map control. The applications can also draw a number of Overlay types on top of the map. In general, the MapView class provides a wrapper around the Google Maps API [59].

Android also supplies 3D libraries, an implementation based on OpenGL ES 1.0 APIs. The libraries use either hardware for 3D acceleration (where available) or the included highly optimized 3D software rasterizer.

Link2U@Unisa uses LocationManager for identifying the current position when the GPS signal is accessible, otherwise it exploits the WiFi hotspot triangulation technique.

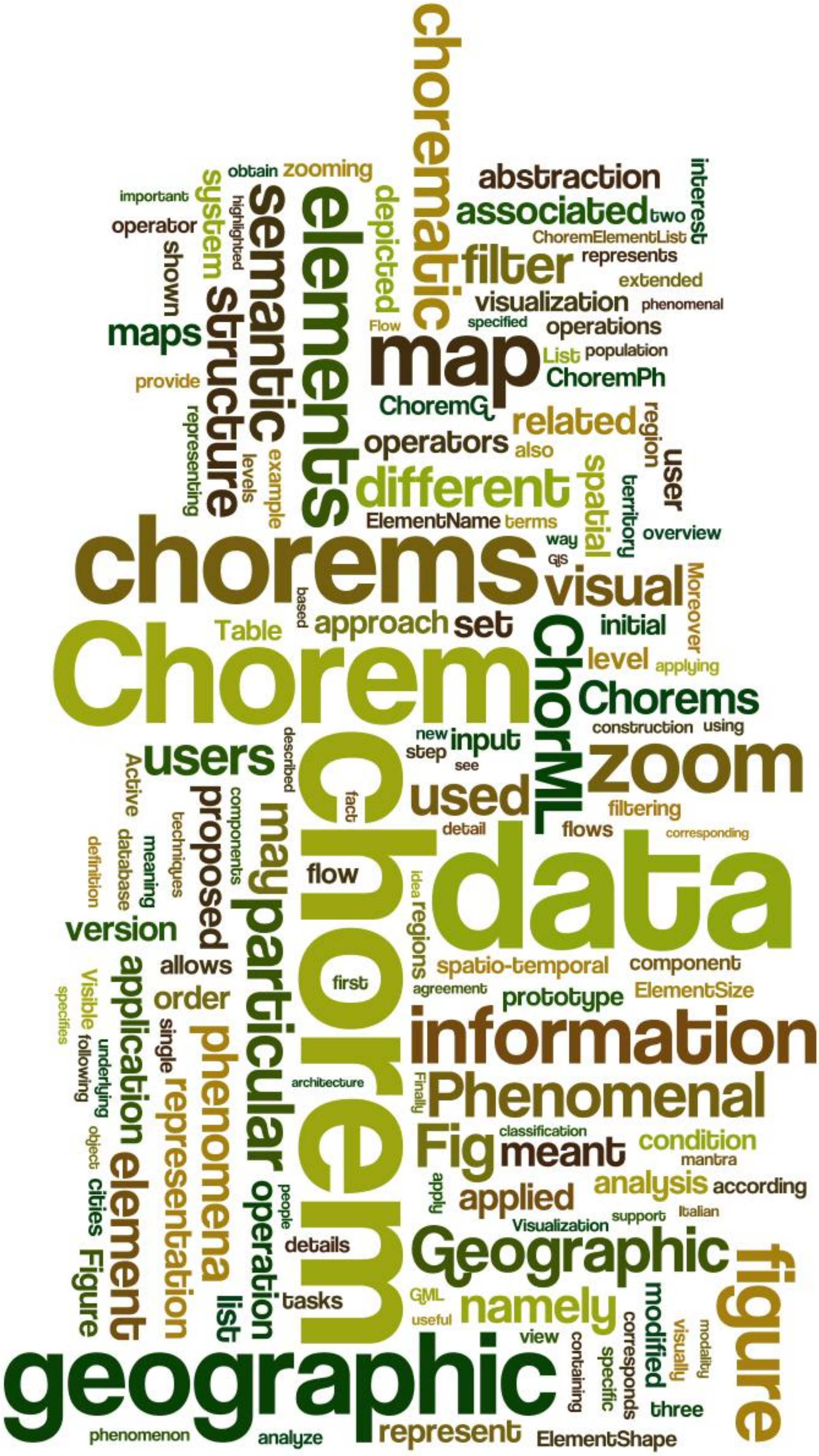
The Map mode uses the MapView framework to view data either on a street plan or on a satellite image. The Live Mode displays data in a 3D environment by using the OpenGL ES and superimposes them on video-captured by camera.

Typically mobile devices have some computational limits that can slow down the application performances. To overcome such limits we exploit some Web Services, thanks to the Internet permanent connection of the device. In particular, for outdoor navigation a route from a user to a POI/SNU is provided by the GPX Driving Direction [61]. As for the indoor mobility, an ad hoc campus cartography and a service have been realized. However, both services receive two couples of coordinates representing source and target points, calculate the path between them and transmit it in GPX format (the GPS Exchange Format)[60]. GPX is a light-weight XML data format for GPS data interchange between applications and Web services on the Internet, such as waypoints, routes and tracks. In Map mode a route is designed according to the list of waypoints in the GPX file.

In Live mode, more information is necessary, namely the height of points. Due to the low accuracy of the height detected with the GPS, it can be achieved through the geo-service GeoNames [56]. Finally, by sending the coordinates of each point belonging to the waypoint list the corresponding heights computed at sea level are obtained.

The initial results of our research have strengthened our choices and have formed the basis for the proposal described in this Chapter. The previous scenario based on the above implementation illustrates how the expressiveness of the visualization technique has notably enhanced the user's navigation and provision of services, making the application more effective and intuitive.

In the future, we plan to improve the prototype in order to both automate its behavior in reply to some stimuli, such as ambient brightness, user's mobility and screen shape, and better satisfy users' requirements on the basis of feedback obtained through a usability study meant to improve the application embedding Link2U.



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CHAPTER 6

A CHOREM-BASED APPROACH FOR VISUALLY ANALYZING SPATIAL DATA

Recent literature and advances in specific domains demonstrate that when dealing with scenarios describing complex issues, such as political, economic and demographic problems, visual representations may provide useful support in locating facts and new patterns. This idea has inspired our research on the definition of cartographic solutions able to better represent geographic information extracted from (spatial) database contents, referring both to static objects and dynamic phenomena. Initial outcomes of this research can be found in [43] where early results of an international project are described, which proposed a solution based on the concept of chorem. The project was launched among three research institutions, namely Institut National des Sciences Appliqués (INSA) of Lyon (France), Dipartimento di Matematica e Informatica (DMI), University of Salerno (Italy) and Tecnologico de Monterrey, Campus de Puebla (Mexico).

First introduced by the French geographer Brunet, chorems represent a schematic territory representation which eliminates details not useful to the map comprehension [8]. An example of such a visual metaphor is given in Figure 6.1, where three maps containing chorems referring to the island of Corse are depicted [18]. In particular, Figure 6.1(a) shows the transhumance between summer and winter pastures, Figure 6.1(b) shows how the wind influences ecosystems and Figure 6.1(c) shows agricultural specialities.

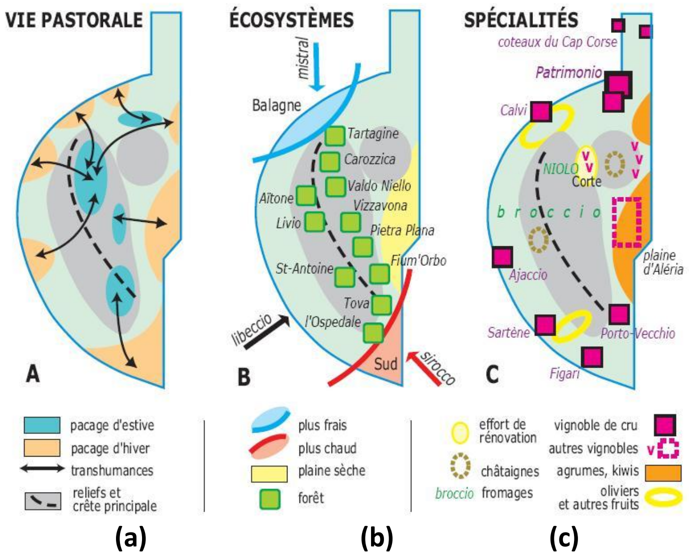


Fig. 6.1 Maps containing chorems about the island of Corse, France.

The potentials of chorems has been initially discussed by Laurini et al. in [80], who listed different roles that chorems may play in supporting expert users in daily activities. The authors argued that chorems can be used to represent geographic knowledge, to visually summarize database contents and finally to underlie the creation of a novel entry system for geographic databases. In [31] a survey on the use of chorems in the community of geographers has been presented, which highlighted the lack of a rigorous approach for chorem creation and composition and the consequent proliferation of ad hoc solutions, in some cases failing in conveying the information they were meant to [8], [10], [22]. In spite of their wide diffusion, no standard structure was available at the time the international project started.

In order to bridge this gap, a definition and a classification of chorems as visual syntheses of geographic database content were first provided in [43], to homogenize chorem construction and usage and to provide a usable framework for computer systems. In particular, the prototype for chorem map generation and results obtained from it were encouraging and represented the starting point for further processing tasks aiming at deriving spatial analysis data, and supporting expert users in decision-making, thus helping them face the complexity of the adopted applications and get rapid and exhaustive responses in critical situations. In fact, as pointed out by Andrienko et al. [1], in many activities, it is essential to support the analyst with means which summarize the outcomes of his work and help him present them in a way that the ultimate users may easily understand the derived knowledge. With this observation in mind, our approach is then meant to support those people, who may need to take rapid decisions even with little expertise in spatial analysis. In particular, the goal of the current research has been to enhance the role that a chorem map may play in geographic domains, by exploiting its synthesis capability also for querying and accessing data of interest when they are visually summarized as a set of chorems on a map.

A preliminary idea has been introduced in [33] where we have proposed to exploit the salient aspects of chorems also to understand the causes of a given phenomenon. Indeed, the strong simplification and the expressive enough summary may be used either to catch a thematic global view of a territory and its phenomena or to investigate and analyze such phenomena by accessing data characterizing them.

To develop this idea, we have first extended the semantics associated with the chorem concept by including information about its construction process in terms of initial data source and intermediate steps. This allows us to investigate phenomena of interest by visually manipulating chorems and applying a set of given spatial operators on them. In particular, we have adopted the Visual Information-Seeking mantra stated by Ben Shneiderman, namely Overview, Zoom and Filter, Details on Demand [101] and the Visual Analytics Mantra presented in [75] Analyze First - Show the Important - Zoom, Filter and Analyze Further - Details on Demand, and assigned these operations a specific behavior. This approach then combines GeoVisualization and interaction techniques [87], [100], [103], [115] to represent and examine well identified spatio-temporal phenomena in an innovative manner. Users may acquire information from the underlying database by interacting with maps of chorems which visually summarize its content. Each interaction task assumes a context-sensitive meaning and invokes a proper functionality among the ones specified in agreement with the Visual Information-Seeking mantra.

A point of distinction of the proposed GeoVisualization system against existing solutions is that the adopted visualization technique relies on the joint representation of a simplified map and an expressive synthesis of spatio-temporal phenomena of interest.

Finally, we have also introduced an extension of the ChorML language, initially introduced to store information about chorems. The enhanced version we propose is the basis for the prototype where the operators have been experimented. In particular, they have been used to exemplify some visual analytics tasks useful to illustrate how the chorem-based approach guarantees simple and immediate solutions for

This Chapter is organized as follows. Section 6.2 discusses some related work. Section 6.3 recalls preliminaries on chorems, such as the chorem structure and classification, the architecture of the system meant to extract and visualize chorems and the Chorem Markup Language (ChorML) meant to store information about chorems. Section 6.4 introduces the set of operators targeted to access and analyse spatial data through the chorem manipulation. In Section 6.5, an extended version of ChorML and a specification of operators based on this language are presented. Finally, the usage of an initial system prototype is described, by illustrating the specified functionalities applied to a chorem map.

6.1. Related Work

Our approach, which is conceived to analyze and visualize huge volumes of geospatial data, summarizes ideas and techniques from the domains of Geovisual Analytics, a particular branch of GeoVisualization, and of Multiscale Information Visualization.

Like other well-known Geovisual Analytics approaches [4], [50], the chorem-based solution combines visual interactive GeoVisualization methods with advanced computational techniques to support data exploration and decision-making processes. However, with respect to existing Geovisual Analytics systems, our environment exploits chorematic maps to represent together the observed phenomenon and the related geographic area, offering, at each detail level, a unified, map-related view of data resulting from information seeking or analysis tasks.

In GeoVisualization and Geovisual Analytics a variety of visualization methods are used to represent geospatial data and/or spatio-temporal phenomena, such as Space-Time Cube [66], Circleview [79], interactive maps [4], treemaps [52], parallel coordinates [55]. Such methods have been often used at the same time, in order to facilitate the interpretation of relevant amount of information, even if in a synthesized form. Although multiple related views may allow users to perform very complex data analysis tasks, the rationale behind our approach is to support rapid decision-making activities that require timely actions to face emergency situations. Our method is not indented to visually mine geospatial data as in [74], [14], but it rather exploits Shneiderman's visual information seeking mantra, to represent well identified spatio-temporal phenomena in a strong synthesis and to allow for the rapid analysis of such phenomena by using such GeoVisualization interaction techniques as filtering and zooming [87], [100], [103], [115].

As for Multiscale Information Visualization (MIV), it consists of techniques meant to help users manipulate information displayed on the screen through different levels of abstraction. Large amounts of data need to be displayed at a high level of abstraction whereas more detailed representations are necessary when the data density decreases. Two different typologies of abstraction are generally performed in MIV, namely, *data abstraction*, which refers to the transformation applied to data before being visually mapped, such as aggregation, filtering, sampling and summarization, and *visual abstraction*, which refers to abstraction gained by transforming the visual representation of the mapped data. In the proposed chorematic framework, we profitably exploit MIV techniques to dynamically change the visual representation of data and present them at different levels of abstraction as the user filters or zoom in on it. Our approach follows MIV principles performing both data abstraction and visual abstraction.

Unlike approaches in Pad series of interfaces, Pad++ [11] and Jazz [12], which used only visual abstraction for semantic zooming, since these Pad systems were developed not as data exploration tools but as alternate desktops, we use the semantic zoom and other operations by applying both data and visual abstraction.

Our idea is analogous to systems like Datasplash [1], the first multiscale visualization system meant on data exploration, based on the construction of multiscale visualization of graphs. However, in our approach data are not organized into a structure of levels with graphs. Our method is in that respect, similar to the approach used in Xmdvtools [50] where they exploit hierarchical clusters for structuring the underlying data in different levels of abstraction.

6.2. Preliminaries

In the last few years, much work has been carried out about chorems. In particular, Del Fatto [34] provides an extensive review about the history of chorem usage. Moreover, in [43] the authors detail how chorems are able to visually summarize database content, providing a definition and a classification of chorems meant both to homogenize chorem construction and usage and to provide a usable framework for computer systems.

This Section is meant to summarize such preliminaries and definitions in order to provide an exhaustive panorama about chorems.

The term chorem derives from the Old Greek word *χώρημα* (read chorema), which means space or territory. According to the definition of the French geographer Roger Brunet [17], a *chorem* is a schematized territory representation, which eliminates any detail not necessary to the map comprehension, or, in other words, it is a kind of synthetic global view of data of interest which emphasizes relevant aspects. In particular, this chorem capability provides decision makers with a means to acquire basic information about the context (what, where and when), as well as deeper semantic aspects (why and what if), useful to support human activity to model, interpret and analyze data of interest. In the literature several uses of the concept of chorem can be found, especially by geographers, who have been using chorems as a communication mean, e.g., to represent spatio-temporal phenomena, usually defining new ad hoc chorems starting from personal knowledge.

6.2.1. Chorem definition and classification

In [41] a study was carried out meant to analyze the extent to which the set of 28 chorems proposed by Brunet (see figure 6.2) is used. Starting from approximately one hundred manually-made maps containing chorems, the authors observed that expert users typically prefer to adopt a minimal set of Brunet's chorems or to generate an ad hoc chorem vocabulary. Moreover, they argued that it is possible to group the most used chorems into two classes, namely chorems with inner geographic properties, which may represent typical geographic elements such as cities, rivers and regions, and chorems which describe phenomena among geographic elements, such as flow and regression. Starting from this analysis, a specification of chorems in terms of components and structure, and a proper classification which takes the chorem meaning into account have been proposed, as follows.

- A *Geographic Pattern* is an interesting bit of knowledge [99] discovered in a geographic database by using functions for extracting relevant unknown information.
- A *Proto-chorems* can be defined as a data item, properly cleaned and organized, on which SQL queries, (spatial) data mining functions or other analysis methods can be applied, in order to discover geographic patterns.

From a semantic point of view a first classification has been proposed in [43], arranging chorems into three main categories, namely:

- Geographic chorems, they represent geographic data with associated simple geometries, such as points, lines, polygons, and objects made up of their combinations, such as networks;
- Phenomenal chorems, they describe spatio-temporal phenomena involving one or several geographic chorems. An initial set of phenomenal chorems consists of three types, namely Flow, Tropism, and Spatial Diffusion. The Flow represents population or object movement between geographic chorems. The Tropism represents an homogeneous attractive or repulsive space, around a geographic chorem. Finally, the

Spatial Diffusion represents a spatial progression or regression, from a geographic chorem towards a specific direction;

- Annotation chorems, they represent map labels or remarks. They can be retrieved from the available data or can be added by designers in order to complete a map.

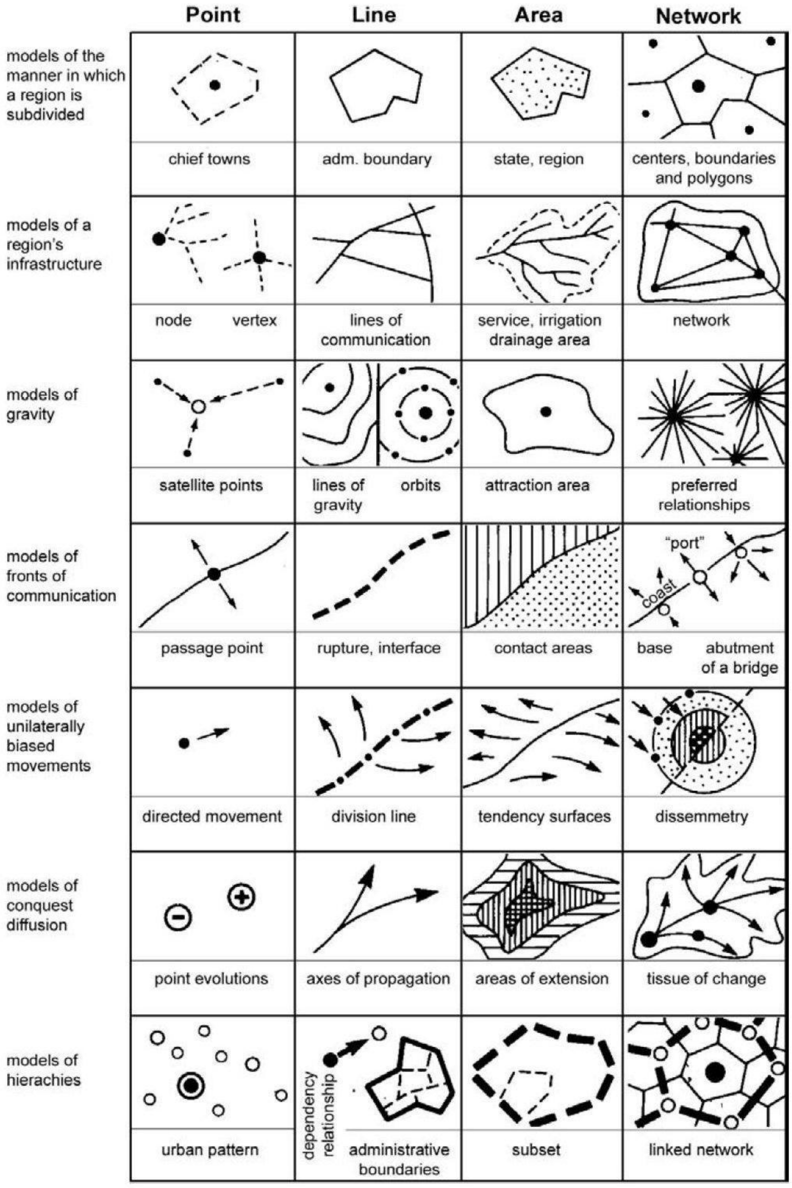


Fig. 6.2 The set of 28 chorems proposed by Brunet [17]

Figure 6.3 depicts the underlying structure of a chorem, which takes into account the complex nature of geographic data/phenomena by visually integrating the iconic and the property components. As for the former, the iconic representation assemblies a graphical component, corresponding to the visual representation, and a meaning, referring to the semantic component. In such a way, users may quickly perceive the meaning associated with data and use them properly. As for the property component of a chorem, it is divided into two parts, a type attribute specifying the category the chorem belongs to, namely geographic, phenomenal or annotation, and a source indicating where and how data could be retrieved (such as the proto-chorem along with functions used to extract the corresponding chorem, a table or a view name, a SQL query or a function). It is worth noting that, in case of a phenomenal chorem, the type attribute also contains information about the geographic chorems which it is related to.

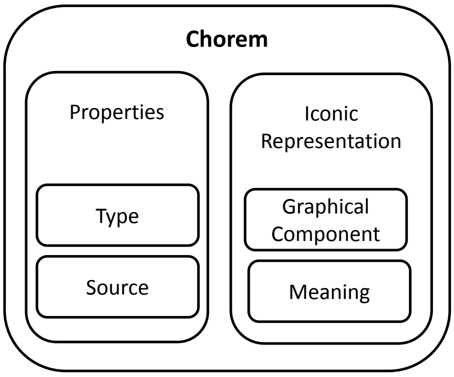
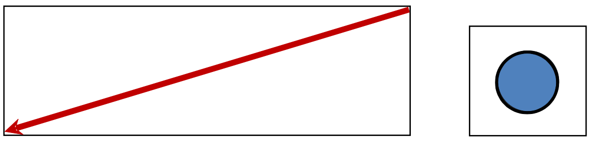


Fig 6.3 The structure of a chorem

Based on this structure, a different classification can be provided which inherits the structural organization typical of the well-established model used in GIS for managing spatial data, namely feature layer, layer and map. In particular, the concept of Chorem element, Chorem and Chorematic Map have been introduced as follows:

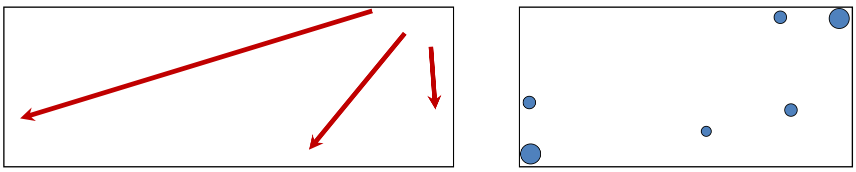
- A *Chorem element* is a basic element that may represent either a single geographic object, such as a city and a region (e.g. a single feature in a GIS data model), or a single phenomenon, such as demographic growth and people displacement, as depicted in figure 6.4.



(a) **(b)**

Fig. 6.4 Chorem Elements representing a single dynamics (a) and a single City (b)

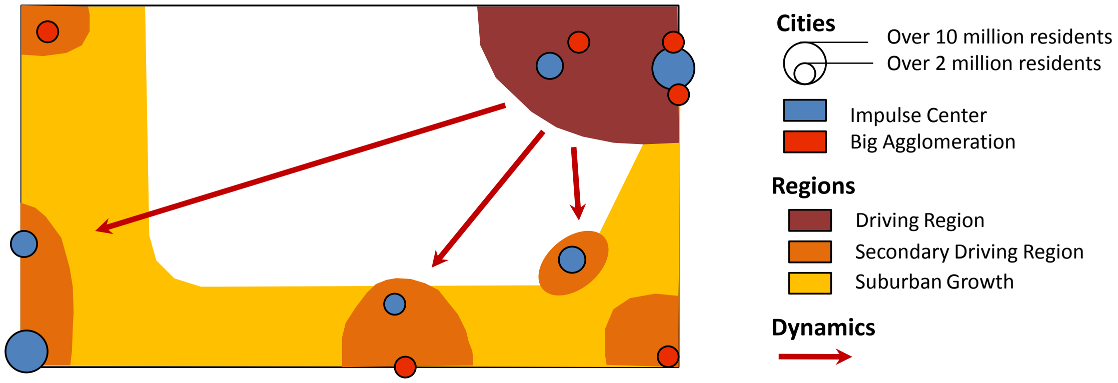
- A *Chorem* is a set of chorem elements of the same typology (e.g. a feature layer in a GIS data model). For instance, a set of the most important USA cities, or a set of the main flows between such cities, as depicted in figure 6.5.



(a) **(b)**

Fig. 6.5 Chorems representing Dynamics (a) and Cities (b)

- A *Chorematic Map* is a set of chorems which schematize data of interest related to a specific place or region (e.g. a map in a GIS data model), as depicted in figure 6.6(a). A legend can be associated with a chorematic map, which explains the meaning of each chorem, as depicted in figure 6.6(b).



(a) (b)

Fig. 6.6 A manually made Chorematic Map (a) about USA and its legend (b) taken from [109]

The above classification emphasizes the relationships existing among a single instance of a chorem, the group which it belongs to, and the whole scenario where different chorems, and consequently different chorem elements are spatially arranged.

6.2.2. The Architecture of the Extraction and Visualization System (ChEViS)

This subsection briefly describes the architecture design of ChEViS (Chorem Extraction and Visualization System), a system for the semi-automatic generation of chorem map which extracts geographic objects and spatio-temporal phenomena from geographic databases and represents them as a map by using chorems.

In Figure 6.7 the ChEViS architecture is illustrated, which consists of two major components, namely the Chorem Extraction System and the Chorem Visualization System. The former is meant to derive and manipulate the information from available geographic datasets, the latter handles such information by assigning it a visual representation in terms of chorem elements, chorems and chorematic maps. Moreover, as shown in Figure 6.7, the system architecture is composed of modules which express functionalities and algorithms coming from different disciplines, from data mining to cartographic generalization. The management and the integration of these various modules raise the complexity of both the system and the process which allow the user to obtain directly from a geographic database a synthesized representation of spatio-temporal phenomena of interest.

The storage of chorem elements and the communication among system components are based on the multi-level language ChorML, summarized in the following subsection.

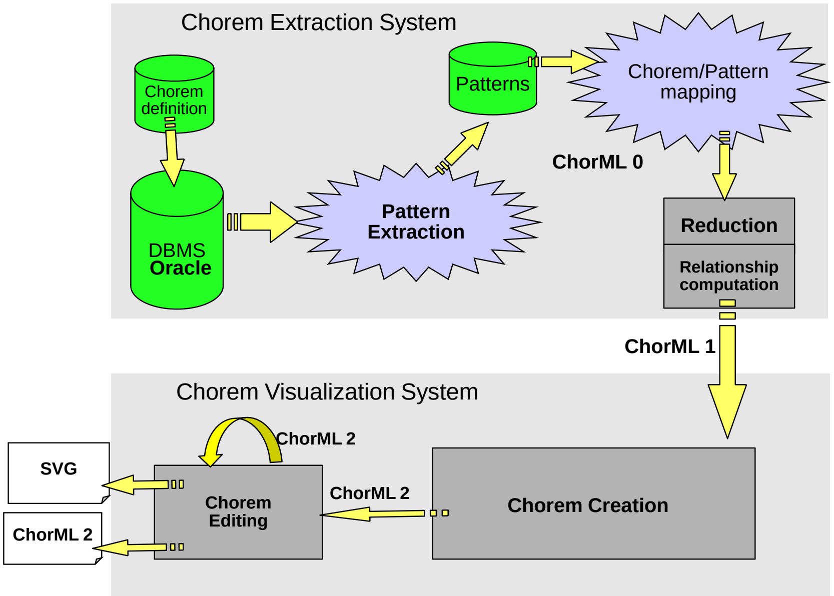


Fig. 6.7 The Chorem extraction and visualization System

6.2.3. ChorML structure

This subection recalls the initial definition of ChorML described in [43], in order to provide the reader with basis to better understand changes we propose later on. The choice of this language derives from the need of a light and interoperable data store / exchange structure which could be consistent with other well-known eXtensible Markup Language (XML) dialects used for storing geographic data, namely Geography Markup Language (GML), and visualizing vector data, namely Scalable Vector Graphics (SVG).

ChorML is therefore a language derived from XML which has been specified to store information about chorems. It consists of three levels which differ in terms of structure and typology of stored information. In particular, level 0 of ChorML is made up of XML and GML tags. As shown in figure 6.8(a), it supports the chorem extraction by storing information about proto-chorems, origin of data (lineage) and functions applied to them in order to obtain a list of chorems.

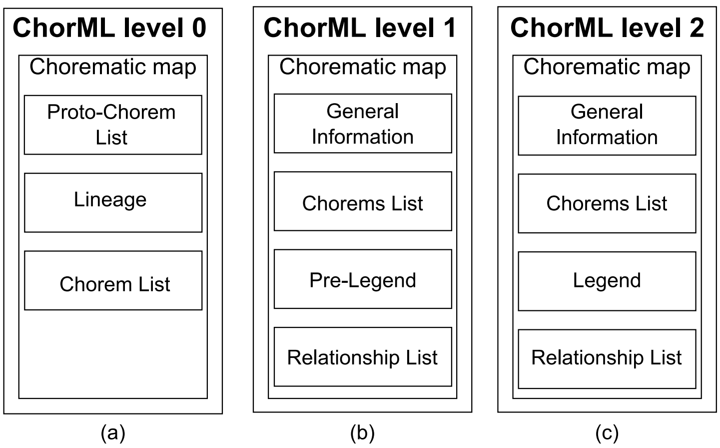


Fig. 6.8 ChorML levels.

Level 1 of ChorML is still a combination of XML and GML tags. It connects the Chorem Extraction and the Chorem Visualization subsystems by specifying the results of the application of (spatial) data mining algorithms. In particular, as depicted in figure 6.8(b), the items of the language are:

- general information containing id, project name, author name, creation date, layout, reference system, original database name, last update;
- the chorem list where geographic data are GML coded;
- pre-legend containing a description of chorems;
- spatial relationships between chorems.

Currently, this level is totally specified by an XML grammar presented in [27] , whereas in [26] a system for generating ChorML starting from a DB extended by Oracle Spatial is described.

Level 2 of ChorML corresponds to XML and SVG tags, useful for visualization tasks. The elements of level 1 and level 2 differ on the coding of geographic components, GML and SVG respectively. Figure 6.8(c) illustrates the level 2 structure. Finally, figure 6.9 shows the structure of ChorML, in terms of chorem list and chorem elements, whereas figure 6.10 illustrates ChorML tags associated with each chorem element.

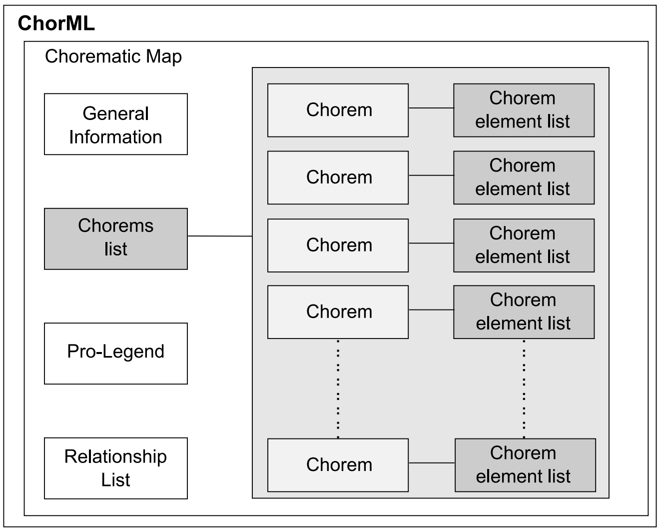


Fig. 6.9 The original structure of ChorML.

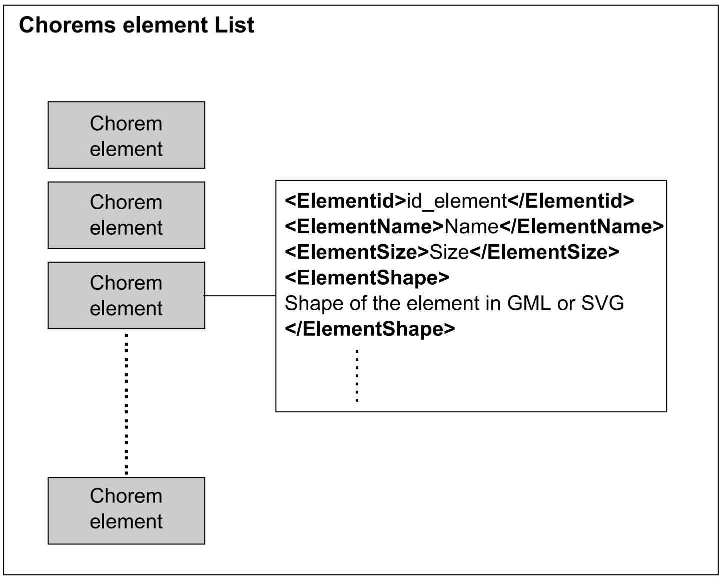


Fig. 6.10 ChorML tags of a Chorem Element.

6.3. Accessing Spatial Data through Chorematic Maps

The idea underlying our approach is based on the Visual Information-Seeking mantra stated by Ben Shneiderman [101] and on Keim's adaptation to the Visual Analytics domain, presented in [75]. Shneiderman's formulation "*Overview first, zoom and filter, then details on demand*", is a well-known visualization paradigm which encompasses several visual design guidelines and provides a general framework for designing information visualization applications [112]. In such a macroscopic versus microscopic approach, the overview task is meant to obtain a global view of a situation featuring a domain of interest. Shneiderman argues that by using it, a user can gain a general idea of the entire collection of data and, at the same time, such an overview can help users control the contents of the detail view [101]. According to Craft and Cairns [29] the "*Overview* provides a general context for understanding the data set; it paints a picture of the whole data entity that the information visualization represents. Significant features can be discerned and selected for further examination".

Keim's adaptation of the mantra, "*Analyze First - Show the Important - Zoom, Filter and Analyze Further - Details on Demand*" points out that solely visual and interactive methods are not appropriate when dealing with the analysis of huge amounts of data. In particular, starting from a huge data collection, it is reasonable to apply first some analysis computations and then provide an overview of the resulting relevant contents, rather than directly providing a complete overview of those data. In that way, the user may interact with a synthesis of the important components of data, thus not running the risk to get lost inside the original data collection.

The synthetic global view offered by chorematic maps exactly results from the application of the *analize first – show the important* step of the extended mantra. Chorematic maps were indeed conceived to provide a schematized representation of a territory and related spatio-temporal phenomena, built upon larger sets of source data, supplied in the form of proto-chorems, and on libraries of geographic patterns. A chorematic map is therefore able to emphasize important aspects of a territory, which are useful for a better comprehension of the described phenomena. In agreement to Shneiderman's theory, the *overview* represented by an initial chorematic map, not only provides users with an immediate synthesis of the mini-world under investigation and capture salient information, but it is also used to locate which part of it to analyze. As a matter of fact, it is always available during subsequent navigation and analysis tasks to help users control the focus of the analysis and easily orient themselves in the map.

As for the *zoom and filter* step of the visual information-seeking mantra, the goal is to focus attention on a reduced portion of the whole space. Zooming and Filtering represent the basic techniques often used in information visualization and in GIS, meant to limit the amount of displayed information, also by applying filtering criteria. According to Shneiderman [101], users usually point the attention on some portion of a collection, thus they need tools which allow them to control the zoom focus and the zoom factor. About this step, Keim *et al.* [75] add the idea that zooming and filtering data is a way to trigger further analysis, which requires visualization of the results in turn. The zoom and filter step needs a more complex interaction with users. In our approach, by zooming and filtering a chorematic map, users may gradually reduce the search space and select a subset of data in agreement with Shneiderman's and Keim's interpretations.

The final step of the paradigm, namely *details on demand*, is meant to obtain detailed information about a particular object or group of objects. Shneiderman states that once the entire collection has been trimmed to a minimal subset, users could easily browse details about either a selected group or a single item, e.g., by clicking on the selected area and getting details in a pop-up window [54]. Moreover, as explained in [63] "Details on Demand stands for techniques that provide more detail on the data set only after the user requested them". Keim *et al.* [75] state that a particular attention is possible for small portions of data when they require a special attention from the analyst, not necessarily at the end of the process. As for the *details on demand* step, our approach allows the user to select and query a chorem element in order to obtain descriptive information related to it.

In the following subsections we describe the operations we propose, meant to realize visual analytics tasks on chorematic maps.

6.3.1. Zooming and filtering a chorematic map

Given the underlying structure of a chorem (see figure 6.3), when specifying a zooming or a filtering operation on a map, it is necessary to distinguish which chorem component is going to be affected, and how it may change. Indeed, each part of a chorem structure can be manipulated and the corresponding result varies in agreement with the role of the involved component. As an example, when more details about the graphical representation of a phenomenon are required, a geographic zooming on the corresponding visual notation should be specified. Differently, when more details about the meaning of a phenomenon are entailed, then a semantic zooming should be invoked, which allows accessing data associated with the source component of the chorem under investigation. A similar distinction can be detected for the filtering operations which can select occurrences of a phenomenon on the basis of either its characteristics or the underlying territory.

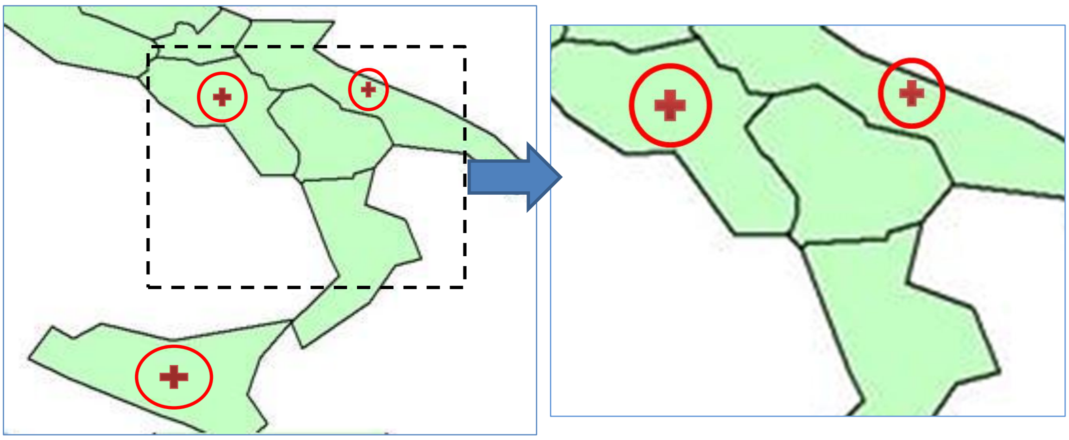
These differences concerning operations and operands led us to define four operators, namely Geographic Zoom, Semantic Zoom, Geographic Filter and Semantic Filter, through which users are able to navigate a chorematic map from an initial overview to a particular detail. In particular, as for the zooming operators, the geographic modality includes the usage of different geographic scales, whereas the semantic modality invokes a thematic aggregation/disaggregation for navigating among different layers of information semantically related. As for the filtering operators, the geographic modality determines which chorem elements have to be selected on the basis of a territory chosen through a spatial condition. The semantic modality selects a subset of chorem elements which satisfy an alphanumeric condition

In order to realize the above operations, the chorem structure depicted in figure 6.3 has been properly extended by embedding information about levels of abstraction inside the Source component featuring the Chorem Properties.

Geographic Zoom

This operation corresponds to the traditional GIS zoom operator, also known as graphical or geometric zoom, which, as defined in [103], "allows the user to specify the scale of magnification and increasing or decreasing the magnification of an image by that scale. This allows the user focus on a specific area and information outside of this area is generally discarded". The geographic zoom operator acts exclusively on the visual aspect of the chorem, by changing the size of the visible details of the involved chorem elements, leaving them unchanged, also in terms of structure.

Figure 6.11 shows the application of the geographic zoom operator on the chorematic map depicted in figure 6.11(a) meant to visualize it at a different scale level (see figure 6.11(b)).



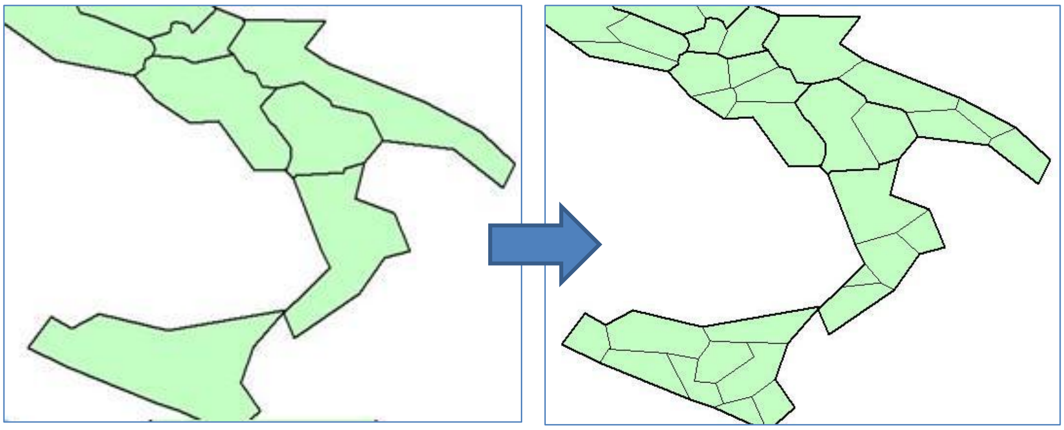
(a) (b)

Fig. 6.11 An example of a geographic zoom.

Semantic Zoom

Semantic Zoom is a well-known technique in Information Visualization research field. According to [87] as a physical zoom changes the size and visible detail of an object, a semantic zoom changes the type and meaning of information displayed by the object. As defined in [115], it is equivalent to "different representations for different spatial scales. When zooming away, instead of seeing a scaled down version of an object, see a different representation. The representation shown depends on the meaning to be imparted." According to our definition, this operation applied to a chorem presents it at a different level of abstraction. In fact, it allows to analyze chorems and chorem elements visualizing them in detail, without affecting the initial map scale and their graphical representation. In particular, by invoking the semantic zoom-in (resp., -out), an initial set of chorem elements may be disaggregated (resp., aggregated) thus allowing the access to a different level of information. Moreover, when a Geographic Chorem is involved, the operation is propagated to the Phenomenal Chorems in relationship with it. In a similar way, when a Phenomenal Chorem is involved, the operation is propagated to the related Geographic Chorems.

figure 6.12 illustrates an example of application of semantic zoom-in to a Geographic Chorem, meant to disaggregate the Region chorem and its chorem elements representing Italian regions. When the operation is applied to the chorem elements of figure 6.12(a), they are simply split up, by showing the level of geographic data abstraction referring to the Province chorem elements (see figure 6.12(b)). This implies both a different source and meaning of data.



(a) (b)

Fig. 6.12 An example of a semantic zoom applied to a Geographic Chorem.

The chorem structure is modified accordingly, by properly substituting the Meaning of the corresponding Iconic Representation component along with the Source of the Property component, as shown in figure 6.13.

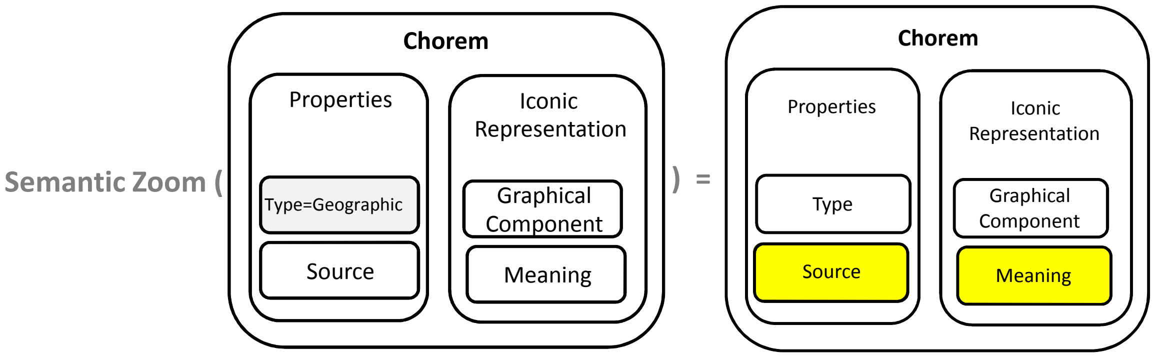
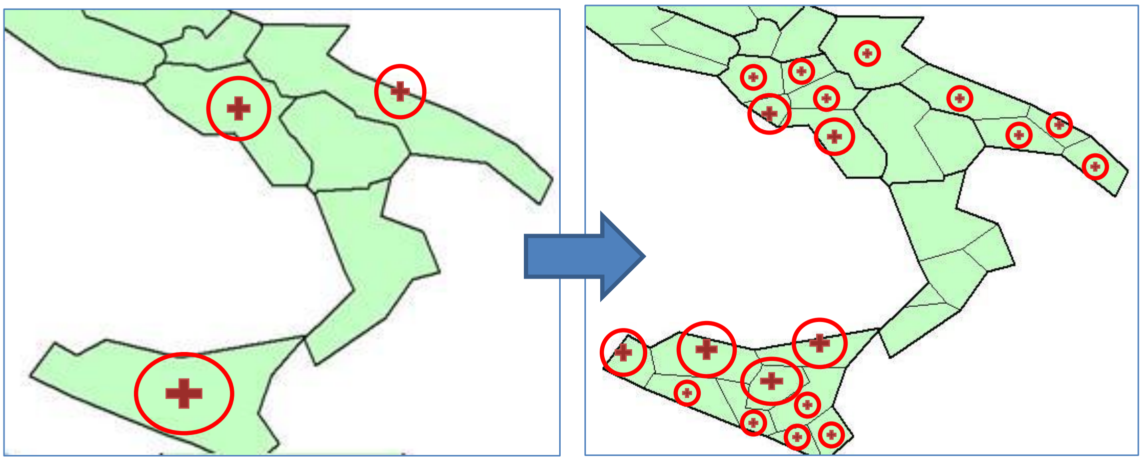


Fig. 6.13 The application of the semantic zoom operator which modifies the Source and the Meaning of a Geographic Chorem.

When a semantic zoom is applied on a Phenomenal Chorem, it is decomposed along with the Geographic Chorems related to it. Figure 6.14(a) depicts several occurrences of the Phenomenal Chorem representing the growth of population in the last 30 years. By zooming on it, the Geographic Chorems related to it are disaggregated and each single phenomenon is decomposed into phenomena in agreement with the derived Geographic Chorems, (see figure 6.14(b)).



(a) (b)

Fig. 6.14 An example of a semantic zoom applied to a Phenomenal Chorem.

In this case, the chorem structure is differently modified, as highlighted in Figure 6.15. In fact, even if the output chorem refers to a different abstraction of the territory, it still corresponds to the initial Phenomenal Chorem, i.e. the growth of population in the last 30 years.

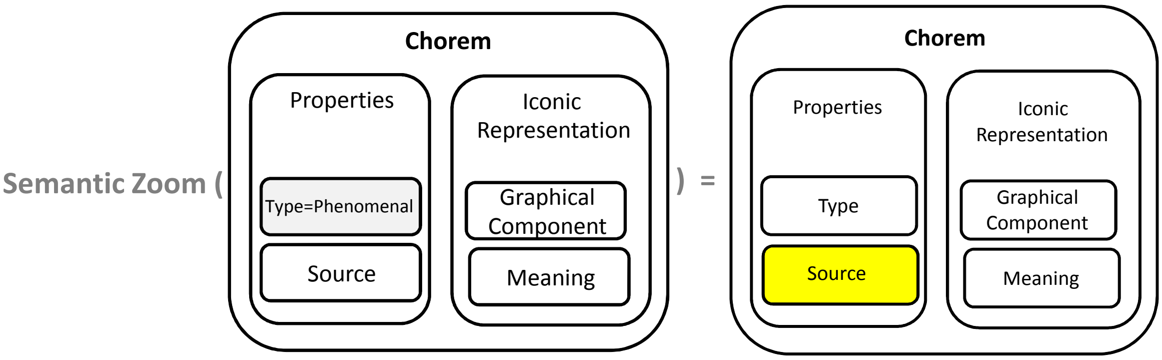


Fig. 6.15. The application of a semantic zoom operator to a Phenomenal Chorem.

GEOGRAPHIC FILTER

This operation allows the user to select Phenomenal Chorems elements by using as spatial filter the Graphical Component of one or more Geographic Chorems elements. Generally, a filter is intended as a tool which satisfies different criteria and conditions. In this case, the condition corresponds to the territory of interest where phenomenal chorems elements have to be analyzed.

Figure 6.16 illustrates how, by applying the filter on specific regions (highlighted in figure 6.16(a)), only the Phenomenal Chorems elements associated with them are visualized, as shown in figure 6.16(b).

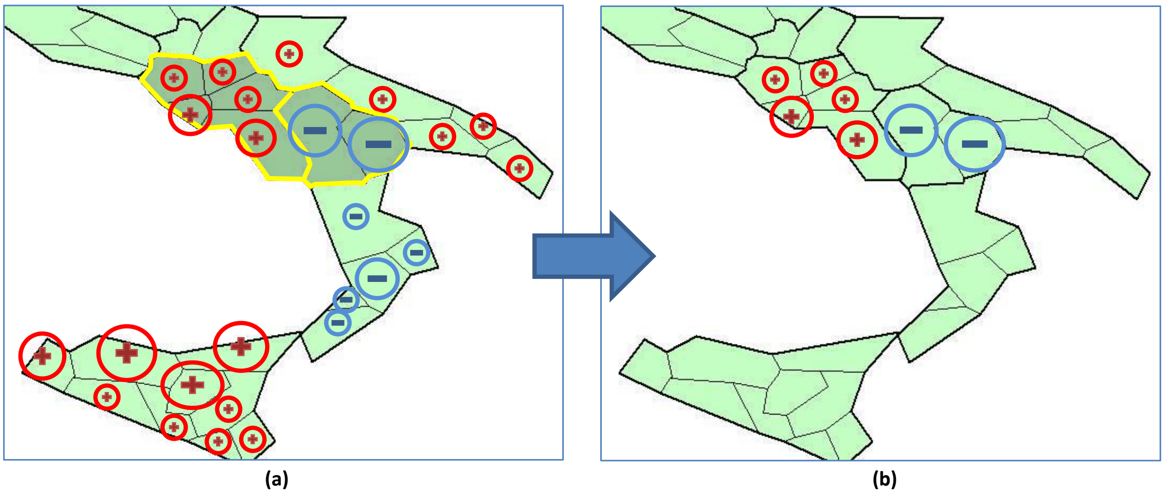


Fig. 6.16. An example of a geographic filter

In figure 6.17 the application of a geographic filter is shown in terms of chorem structure. The input corresponds a Geographic Chorem, namely the chorem on which the condition is applied, and a Geographic Condition, which corresponds to a subset of Geographic Chorem elements used as a condition, belonging to the first parameter. The output of the operation consists of one or more Phenomenal Chorems whose elements satisfy the given condition, thus implying the modification of the Source of the Property component. It is worth to noting that the outputted Phenomenal Chorems are filtered from the initial set of the ones related to the Geographic Chorem in input.

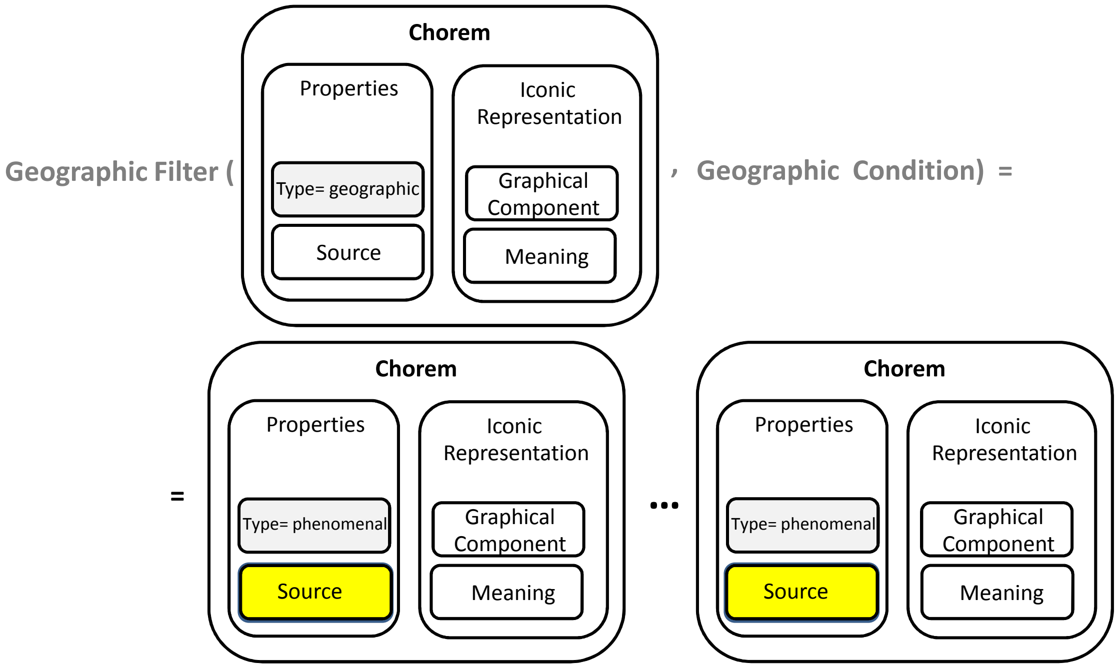


Fig. 6.17. The application of a geographic filter

SEMANTIC FILTER

This operation allows users to filter chorem elements which satisfy a particular condition, by directly operating on the semantics associated to them. Users can select the chorem they need to analyze, and identify the descriptive element on which a threshold or a condition should be applied in order to reduce the set of visualized data.

Figure 6.18 illustrates the application of a semantic filter to a Phenomenal Chorem which represents the growth of population in the last 30 years. In this case, only the Phenomenal Chorem elements which satisfy the given condition (growth > 3%) are shown on the map.

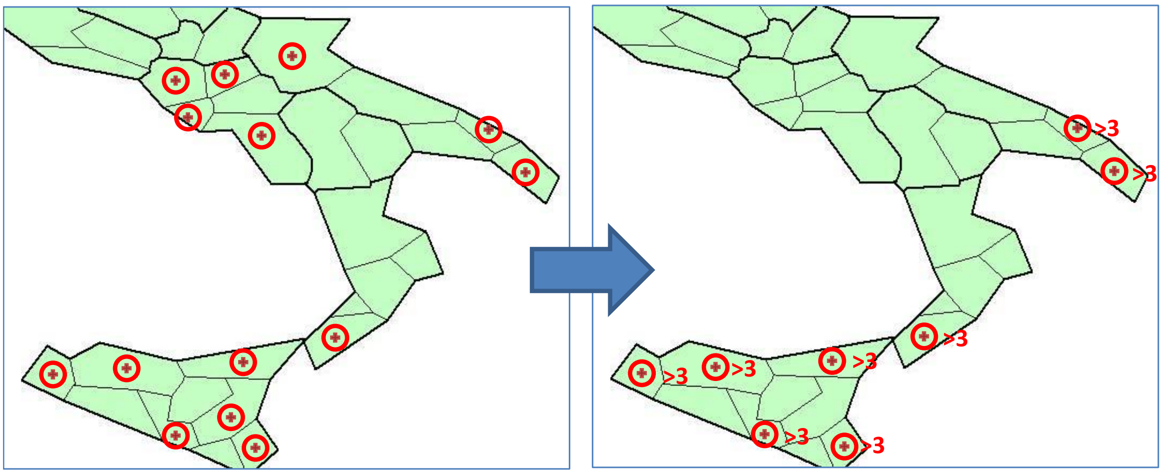


Fig. 6.18. The application of a semantic filter to a Phenomenal Chorem

As highlighted in figure 6.19, the semantic filter operator acts on both the Properties and the Iconic Representation of the chorem structure. In fact, the Graphical Component changes since it embeds the applied condition, the Meaning varies according to the semantics of the output chorem, and finally the Source is modified since it refers to a subset of initial data.

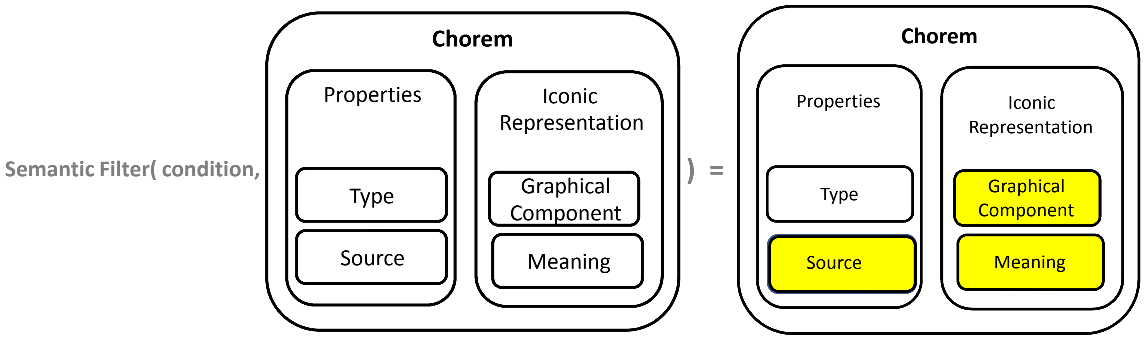


Fig. 6.19. The application of a semantic filter to a Phenomenal Chorem

6.4. Extending ChorML to Perform Visual Analytics Tasks

The set of previous operators can be applied to chorematic maps to perform visual analytics tasks. In particular, each of them allows users to capture a specific aspect of a geographic object as well as a phenomenon, while their proper combinations represent light solutions to derive complex information. These properties are implicitly guaranteed by the nature of chorems and the result of any operator preserves them .

The goal of this Section is to exemplify the application of these operators when investigating phenomena represented on a chorematic map. To this end, we have implemented the operations in a prototype developed in agreement with the architecture of the ChEViS Visualization Subsystem. In particular, at present the proposed operators are offered through a stand-alone ChorML-based environment where chorematic maps are input and manipulated by expert users for visual analytics tasks. Due to the underlying architecture compliance, such an environment could be embedded into ChEViS, thus providing a unique environment for producing, visualizing, querying and analysing chorematic maps.

Two subsections follow. The former is devoted to present the extended version of ChorML used in the prototype along with the specification of the proposed operators in the terms of the new ChorML version. The latter is meant to illustrate how the analysis carried out in [43] on the migrating flows of population, can be now improved thanks to the new operators.

6.4.1. The extended version of ChorML

The basic ChorML code stores information exclusively about the visual summary. No information about the initial data source and intermediate steps is available. Then, a revised version of ChorML has been necessary, able to collect both data referring to detected phenomena and functions used for aggregating those data. In particular, it has been necessary to operate during the construction phase of a map by adding ChorML ad hoc information, expressed as a multi-scale structure to store intermediate data processed during the map construction. Moreover, it has been also necessary to store geographic components as geometric primitives whereas the associated alphanumeric data can be derived by specifying dynamic queries used for their aggregation.

Figure 6.20 illustrates the structure we have proposed. A hierarchy tag, containing a list of chorem elements, is used as part of the ChorML tag to create nested chorem elements. Moreover, proper tags for specifying which chorem element is active (for the application of operators) and visible in the hierarchy have been added. This organization corresponds to a multi-scale representation, which allows to access the different levels of aggregation of the original data, a very simple hierarchical organization which highly improves the expressive power of the structure. In fact, once stored, such information may be managed to answer queries that end users pose by spatially manipulating a chorematic map. Selecting a chorem, zooming a portion of it, filtering a region of interest, represent actions which invoke the previously defined operations and which can be realized by parsing the ChorML code and choosing the portion on which to operate.

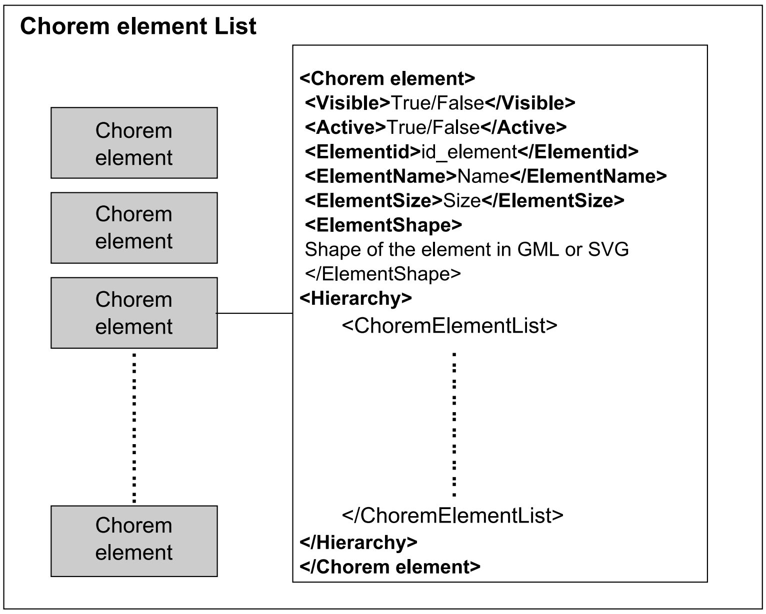


Fig. 6.20. The extended structure of ChorML

Using the above extended version of ChorML it is possible to express geographical hierarchies in a seamless way. As an example, the maps depicted in figure 6.21 represents two different feature layers referring to the same country, In particular, figure 6.21(a) depicting the Italian regions and figure 6.21(b) illustrating the Italian provinces. When representing them through a chorem-based approach, it is possible to derive either two chorematic maps, representing regions and provinces respectively, or a unique chorematic map by using the proposed structure, where the aggregation of provinces within regions is captured. Thus, a two-level geographic hierarchy could be managed which provides for different views of the same geographic area. At the first level, each region is represented by a chorem element. Each chorem element "Region" in turn contains a list of chorem elements which correspond to the provinces belonging to it. Such a list of chorem elements "Province" represents the second level of the geographic hierarchy.

Fig. 6.21. Maps representing the geographic hierarchy of Italian Region (a) and Provinces (b)

The following ChorML code represents a chorem element which stores the region "Basilicata", highlighted in figure 6.21(a), and the corresponding provinces "Potenza" and "Matera", highlighted in figure 6.21(b).

```
<Chorem element>
        <Visible> False</Visible>
        <Active> False</Active>
        <Elementid> element 7</Elementid>
        <ElementName>BASILICATA</ElementName>
        <ElementSize>3</ElementSize>
        <ElementShape>Shape of the element expressed in GML</ElementShape>
        <Hierarchy>
                <ChoremElementList>
                    <Chorem element>
                       <Visible> True</Visible>
                       <Active> True</Active>
                       <Elementid> element 21</Elementid>
                       <ElementName>POTENZA</ElementName>
                       <ElementSize>3</ElementSize>
                       <ElementShape>Shape of the element expressed in GML </ElementShape>
                       <Hierarchy>
                               <ChoremElementList>
                               </ChoremElementList>
                       </Hierarchy>
                    </Chorem element>
                    <Chorem element>
                       <Visible> True</Visible>
                       <Active> False</Active>
                       <Elementid> element 22</Elementid>
                       <ElementName>MATERA</ElementName>
                       <ElementSize>3</ElementSize>
                       <ElementShape>Shape of the element expressed in GML o</ElementShape>
                       <Hierarchy>
                               <ChoremElementList>
                               </ChoremElementList>
                       </Hierarchy>
                   </Chorem element>
                </ChoremElementList>
        </Hierarchy>
</Chorem element>
```

In the following, we describe a specification of the operators proposed in the previous section which can be specified trough the extended version of the ChorML, namely GeographicZoom, SemanticZoom, GeographicFilter and SemanticFilter. It is important to notice that given the substantial difference of definition between Geographic and Phenomenal Chorems, we provide two different definitions of semantic zoom, namely: (1) SemanticZoomG, which is a specification for semantic zoom applied to Geographic Chorems and (2) SemanticZoomPh, which is a specification for semantic zoom applied to Phenomenal Chorems. In contrast, GeographicFilter applies only to Geographic chorems, as GeographicZoom and SemanticFilter can be uniformly applied to both categories.

(1) SemanticZoomG ((ChoremG , [zoomIn/zoomOut]) = (ChoremG', (List(ChoremPh))), where

- *ChoremG*: the input Geographic Chorem.
- *[zoomIn / zoomOut]:* an optional boolean parameter which indicates the zoom modality (i.e., 0 specifies a zoom in, 1 specifies zoom out);
- *ChoremG '*: the *ChoremG* modified according to the zoom operation.
- *(List (ChoremPh)):* a list of Phenomenal Chorems associated to the input Geographic Chorem. This list of Chorems could be empty if no Phenomenal Chorem is associated with the input Geographic Chorem.

(2) SemanticZoomPh ((ChoremPh, x, [zoomIn / zoomOut]) = (ChoremPh' ,ChoremG, (List (ChoremPh))), where

- *ChoremPh*: the input Phenomenal Chorem;
- *x:* a numeric parameter related to the type of the input Phenomenal Chorem which indicates how the chorem element should be explored. In case of a Flow Chorem, it can assume three values, allowing the exploration of the single origin, single destination or both origin and destination of the flow;
- *[zoomIn / zoomOut]*, an optional boolean parameter which indicates the zoom modality ((i.e., 0 specifies a zoom in, 1 specifies zoom out);
- *ChoremPh'*: the *ChoremPh* modified according to the zoom operation;
- *ChoremG*: the Geographical Chorem related to *ChoremPh* modified according to the zoom operation;
- *(List(ChoremPh)):* a list of Phenomenal Chorems associated to *ChoremG* . This list of Chorems could be empty if no Phenomenal Chorems are associated with *ChoremG*.

(3) GeographicZoomG ((Chorem , [zoomIn/zoomOut]) = (Chorem'), where

- *Chorem* indicates the Chorem (Geographic or Phenomenal) on which to apply the zoom.
- *[zoomIn / zoomOut]:* an optional boolean parameter which indicates the zoom modality (i.e., 0 specifies a zoom in, 1 specifies zoom out);
- *Chorem '*: the *ChoremG* modified according to the zoom operation.

(4) *GeographicFilter((List(ChoremElementG)) = (ChoremG, (List(ChoremPh))),* where

- *List (ChoremElementG):* one or more chorem elements of a Geographic Chorem;
- *ChoremG: The* Geographic Chorem which contains the list of chorem elements in input, modified according to the operation;
- *List (ChoremPh)):* a list of phenomenal Chorems associated with visible or selected chorem elements.

(5*) SemanticFilter* ((*Chorem, FilteringElement, Condition, Value) =(Chorem', (List(ChoremElement))),* where

- *Chorem*: indicates the Chorem (Geographic or Phenomenal) on which to apply the filter;
- *FilteringElement*: specifies the descriptive element on which to apply the filter;
- *Condition*: is the condition to apply to the item value, or a mathematical comparison operator: = (Equality), > (greater than), <(less than),> = (greater than or equal), <= (less than or equal), <> (different);
- *Value*: is the descriptive value on which the *Condition* is applied.
- *Chorem'* : the input Chorem (Geographic or Phenomenal) modified according to the operation;
- *List (ChoremElement)* : a list of chorem elements belonging to the input chorem filtered according to the input condition.

6.4.2. THE ANALYSIS OF MIGRATING FLOWS OF POPULATION THROUGH A CHOREMATIC MAP

This subsection presents some examples of interaction tasks, meant to show how users may analyze particular phenomena of interest, by performing appropriate operations on chorematic maps. The initial prototype of the Chorem Visualization System has been modified to support users' interaction on chorematic maps when they carry out analyses on the represented spatio-temporal phenomena. In particular, the prototype modules, which generate the visual representation of chorem elements have been slightly modified in order to fit the new version of ChorML. On the contrary, the algorithms of the previous version still hold, namely:

- a version of the Ramer-Douglas-Peucker [96], [44] algorithm modified for preserving particular topological relationships. It is meant to simplify the shape of geometry associated to the chorems,
- the Forced-Directed Map Labeling algorithm proposed by Ebner et al. [53], used for the resolution of problems deriving from the label placement in a chorematic map,
- a modified version of Tobler's Flow Mapper algorithm proposed by the Center for Spatially Integrated Social Science [108], based on the method suggested by Tobler [110]. It is used for the resolution of problems deriving from the Flow Displaying in the chorematic map.

A new interface module has been also introduced in order to allow users to both navigate a chorematic map and analyze data underlying the chorems through the implementation of the proposed operators. The following figures show the screenshots of the proposed prototype and depict the usage of the previously described operations in a specific domain, namely migrating flows of population in Italy. In particular, this Subsection is focused on the changes occurred in the new version of ChorML code representing the chorematic map, when the operations are executed.

Figure 6.22 shows a chorematic map which corresponds to the overview of the mini-world under investigation. It contains three chorems, Macro-Regions and Most Populated Cities (both Geographic Chorems) and Migrating Flows (a Phenomenal Chorem), containing five macro-region elements, six most populated cities elements and three most significant flows elements, respectively.

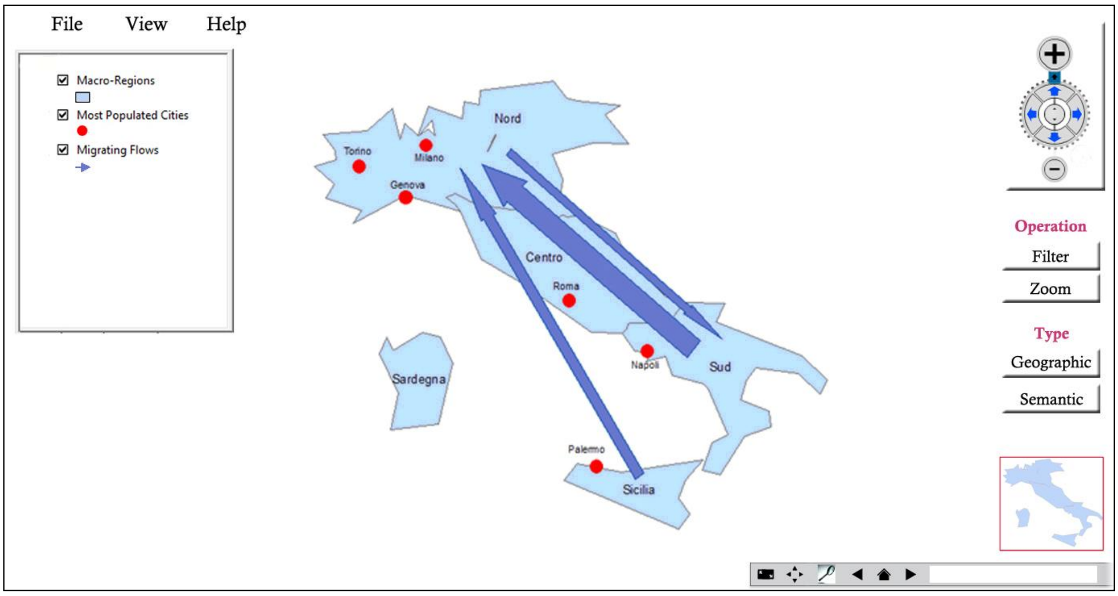


Fig. 6.22 The chorematic map of migrating flows in Italy in 2001

As illustrated in [43], the construction of the chorematic map of figure 6.22 results from a process which started from a geographic database containing demographic data related to the Italian regions and cities in 2001. First, proto-chorems are produced which contain data about cities and regions, as schematized in Table 1 and Table 2, respectively. In particular, in Table 1 data related to cities in terms of city name (CityName), position (Lat,Lon), population (Pop2001), city identifier (Codistat) and shape (Shape), are shown. In Table 2 a matrix is shown, where the *x* value associated with the (*a,b*) pair corresponds to the *x* number of citizens who migrated from the *a* region towards the *b* region. As an example, the (Calabria, Lombardia) = 5308 implies that 5308 citizens migrated from the Calabria region towards the Lombardia region.

CityName	**Lat**	**Lon**	**Pop2001**	**CodIstat**	**Shape**
Agrigento	13,5896	37,3219	54619	084001	Point
Alessandria	8,6200	44,9134	85438	006003	Point
Ancona	13,5110	45,5991	100507	042002	Point
Aosta	7,3177	45,7383	34062	007003	Point
Arezzo	11,8700	43,4733	91589	051002	Point
...	...	...	...	...	...

Table 1. Demographic data related to the Italian cities.

Then, by clustering and summarizing data in Table 1 according to proper functions, data reported in Table 3 have been obtained. In particular, an Oracle Spatial function (the *SDO SAM.SPATIAL CLUSTERS* spatial function) determined five groups of regions, clustered according to the closeness property. Such data synthesize the size of migration between the five recognized macro-regions. Moreover, by applying a threshold of 25000, the three most important flows have been highlighted (see Table 3). Finally, demographic data depicted in Table 2 are used to determine a set of important cities in term of population. A proper threshold is used by the system to determine the 6 most populated cities through a SQL query, by filtering the cities exceeding 500000 residents.

The current approach allows for managing data at different levels of aggregation, even if not planned during the construction task. In the example, to achieve that, original data of Table 1 are stored into ChorML code together with the summarized data reported in Table 3.

Region	Piemonte	V_d_A	Lombardia	Veneto	…
Abruzzo	235	4	792	337	…
Basilicata	377	6	769	166	…
Calabria	2244	167	5308	1083	…
Campania	2648	69	8591	3183	…
Emilia-Romagna	852	55	4168	1953	…
…	…	…	…	…	…

Table 2. Citizen displacements between Italian regions

	North	Center	Sud	Sicilia	Sardinia
North	0	18112	<u>31130</u>	13150	5248
Center	20903	0	10594	2084	1428
Sud	<u>66668</u>	22132	0	2521	847
Sicilia	<u>26489</u>	4172	2483	0	319
Sardinia	6323	1420	588	269	0

Table 3. Displacements between macro-regions

Users may browse the map from a global view to a detailed feature and pose dynamic queries on the interface, in agreement with Shneiderman's mantra. Let us consider the request "Determine the region which received the highest number of migrating people from the South of Italy, disregarding the islands".

By recalling the overview step, five macro-regions and three arrows, representing the most relevant migration flows, can be detected as shown in figure 6.22 In particular, the arrow thickness is visually proportional to the number of people who migrated between the macro-regions.

The zoom and filter step is then useful to determine the most significant flow from the South macro-region towards a specific Northern region. In fact, by invoking a geographic filter, only the two flows depicted in figure 6.23 are visualized, whereas the third one is filtered out.

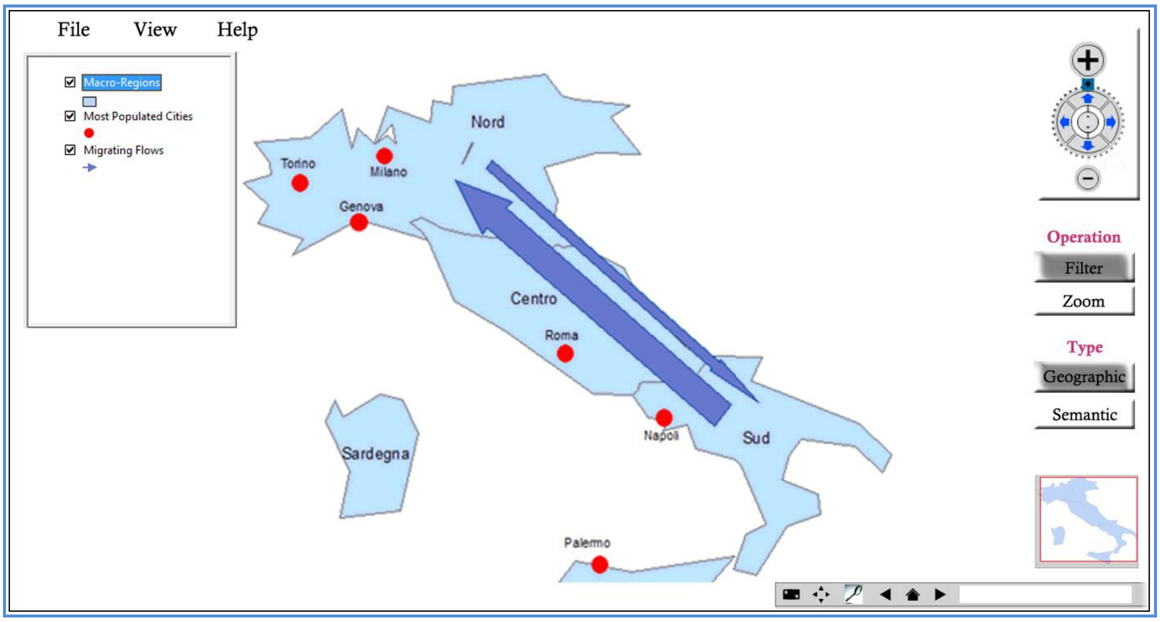


Fig. 6.23. The application of a geographic filter

By applying the definition of geographic filter, the following request is invoked by the system GeographicFilter(North, Center, South, Sardinia). The input parameter of the request is the list of the chorem elements which are fully visualized on the map, namely the macro-regions North, Center, South, Sardinia. The output is described as (Macro-Regions Chorem, (SouthNorthFlow, NorthSouthFlow)). It consists of the output chorem, namely the Macro-Regions chorem, and the list of phenomena related to the input list of chorem elements, namely the two flows obtained, SouthNorthFlow and NorthSouthFlow.

In the following, the representation of ChorML code associated with the flows represented on the map of figure 6.23 is specified.

```
<Chorem>
   <GeneralInformationChorem>
               <Name>MigratingFlow</Name>
               <Type>flow</Type>
               <ChoremID>chorem3</ChoremID>
   </GeneralInformationChorem>
   <ChoremElementList>
               <ChoremElement>
                           <Visible>true</Visible>
                           <Active>true</Active>
                           <ElementID>flow-1</ElementID>
                           <ElementName>North-South Flow</ElementName>
                           <ElementSize>2</ElementSize>
                           <ElementShape />
               </ChoremElement>
```

```
            <ChoremElement>
                        <Visible>true</Visible>
                        <Active>true</Active>
                        <ElementID>flow-2</ElementID>
                        <ElementName>south-north flow</ElementName>
                        <ElementSize>4</ElementSize>
                        <ElementShape />
            </ChoremElement>
  </ChoremElementList>
</Chorem>
```

As an alternative way to visualize data about the most relevant migration flow, the user may apply a semantic filter on the phenomenal chorem depicted in figure 6.23, by selecting the operator to apply and the chorem on which to apply the operator, and by typing the filter condition (>50000). The resulting chorematic map is depicted in figure 6.24.

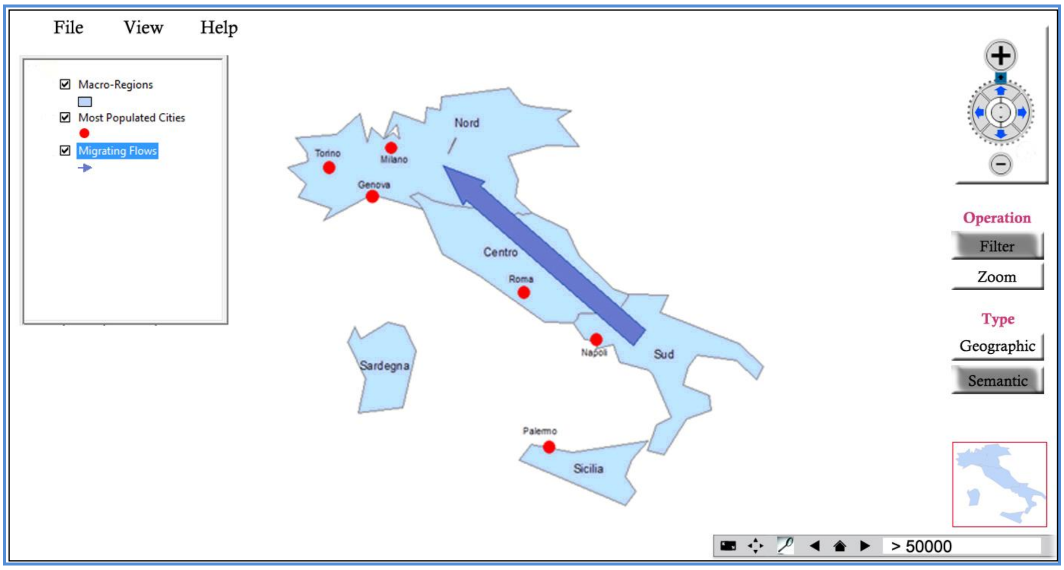


Fig. 6.24. The application of a semantic filter on the Flow Phenomenal Chorem

Moreover, by applying a semantic zoom-in on the destination of the detected flow, the user may decompose it, displaying regions belonging to the macro-region chorem, accordingly.

This operation allows the user to understand how the previous detected flow was created by aggregating components of a lower level of representation, as depicted in figure 6.25.

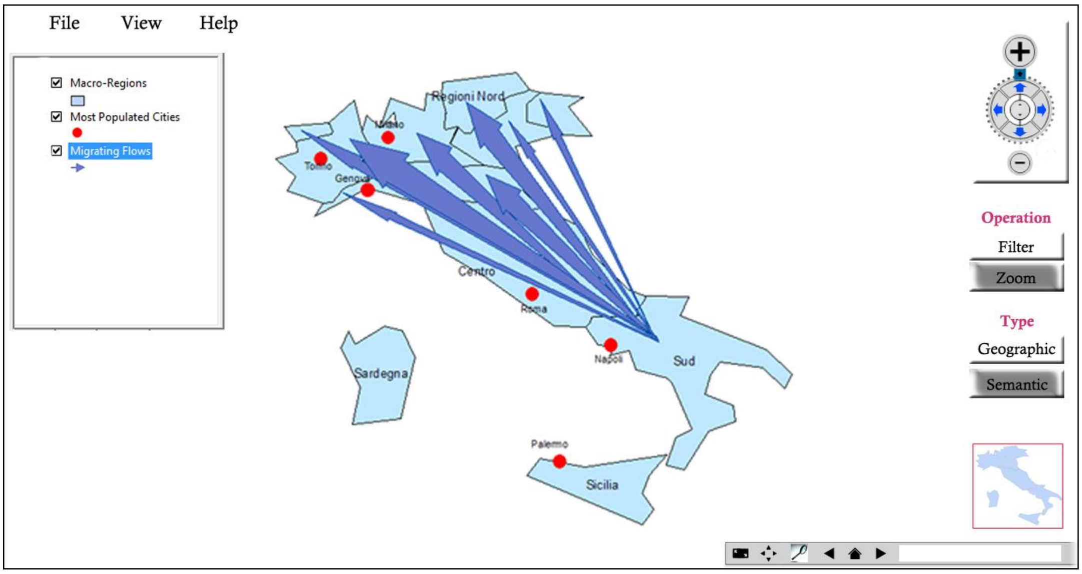


Fig. 6.25. The application of a semantic zoom

Finally, let us suppose that the user aims to visualize the most significant migration flow. He can perform the following tasks. First, a geographic zoom is used in order to gain the focus on a portion of the whole map, as shown in figure 6.26.

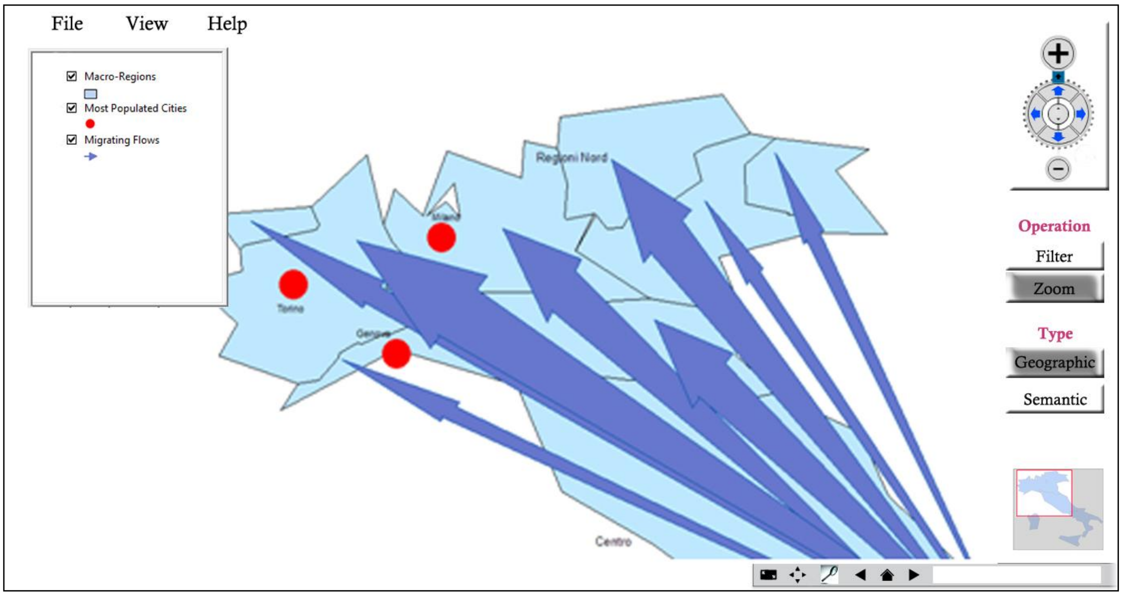


Fig. 6.26. The application of a geographic zoom

Then, by applying again a semantic filter, the most significant flow may be selected. In particular, the user may specify the MAX keyword, obtaining a map which contains only the requested flow, as depicted in figure 6.27. Within a new version of the prototype, currently in progress, this kind of operation will be carried out in a more visual and interactive way, by using a slider control, as suggested in Dynamaps [46].

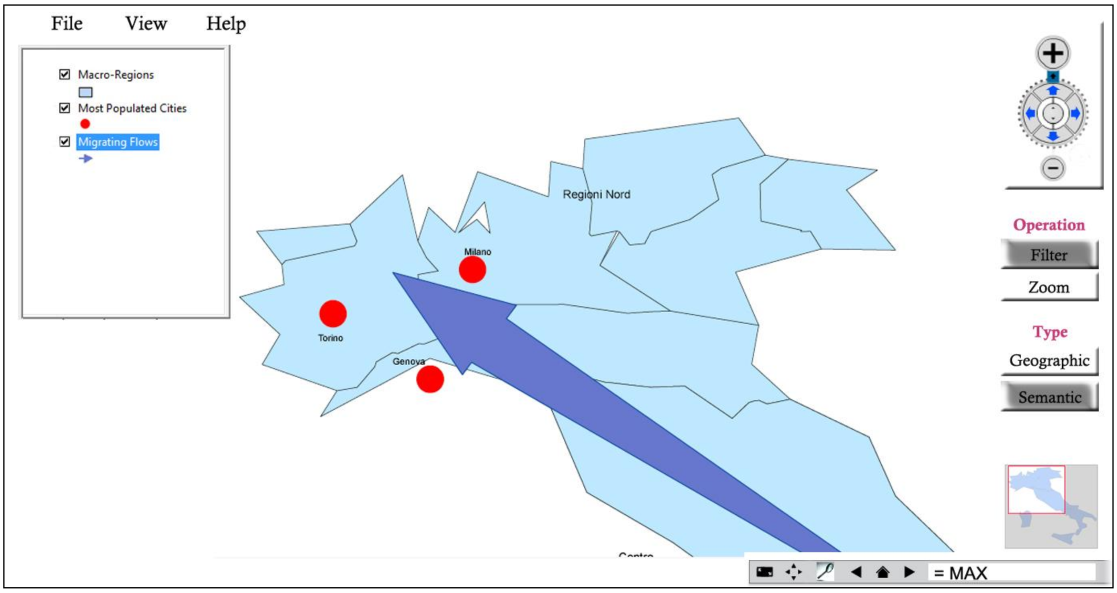


Fig. 6.27. The application of a semantic filter

Finally, the third step of Shneiderman's Mantra, details on demand, may be performed in order to obtain the exact number of people associated with the flow. To do so, the user can zoom out the map in order to obtain an overview of the result, then he can select the info mode and finally he can move over the flow to obtain the exact number of people, namely 568 people, as shown in figure 6.28.

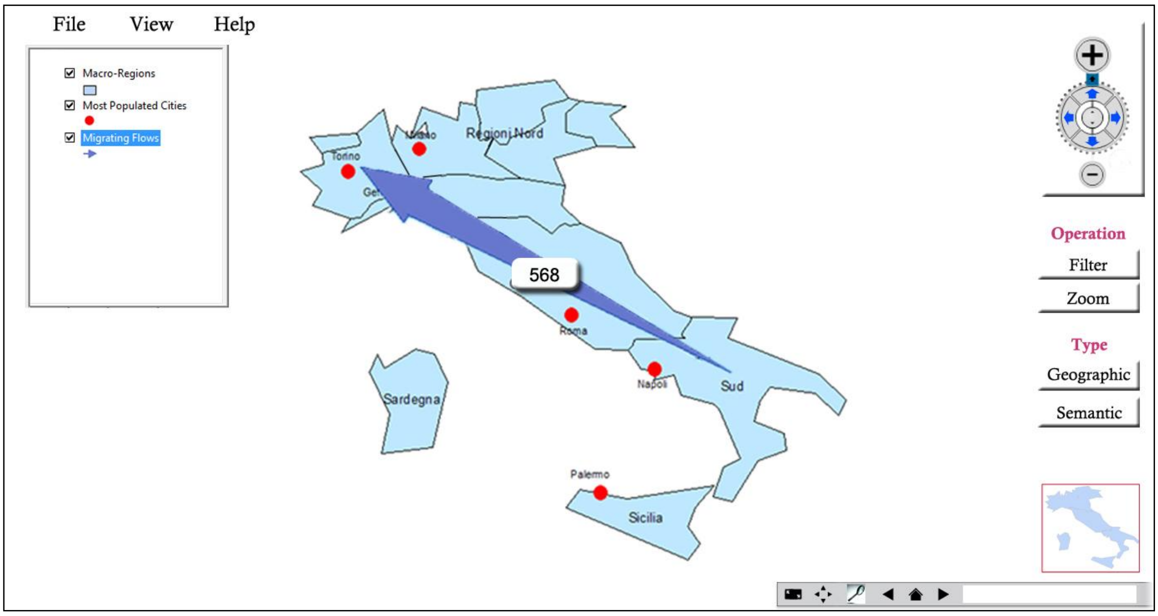


Fig. 6.28. The final result of user's request

The system prototype is currently evolving towards a more complete interactive system which encompasses a larger variety of phenomenal chorems. It will be used in comparative experimental studies meant for the usability assessment, which will evaluate ultimate users' capability to use chorematic maps for quick spatial analysis activities. Also we plan to further investigate cognitive and semiotic aspects of chorems which could enhance users' perception of the conveyed information.

At present, we are designing a mobile version of the prototype. In fact, two main features usually requested by visualization methods of mobile interfaces are implicitly guaranteed by chorems, namely the strong simplification of geographic data and the expressive enough summary of spatio-temporal phenomena. Thus, by exploiting these inner characteristics it will be possible to develop a prototype to allow expert users to perform on-site visual analyses through immediate and light solutions, without losing the communicative efficacy and the capability of investigation, typical of chorematic maps. Moreover, based on such a mobile version, other experimental studies are planned, addressed to verify that the proposed visualization technique is especially suitable for devices which have a limited size and are often used for outdoor spatial analysis activities.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CHAPTER7

GEOMARKETING POLICIES AND AUGMENTED REALITY FOR ADVERTISEMENT DELIVERY ON MOBILE DEVICES.

Mobile computing is an essential part of everyone's daily routine. From checking of business mails while on the go, to visiting social network sites while in the mall or at the airport, and carrying out various kinds of business and transactions, it plays a huge role to draw people together even when physically apart. In particular, the availability of a permanent Internet accessing has created new business opportunities on which agencies and marketers have focused their attention. This capability has transformed modern mobile devices into real personal computers, increasing the ability of building/extending existing applications through the combined use of several technologies such as camera, GPS, 3D graphics and the Internet connection.

Advertising is a developing sector where new solutions for the geomarketing policies are under expansion. Especially, customized delivery of advertisements on mobile devices is a successfully approach to overcome limits of traditional and digital media. However, further attention is still required in order to investigate an adequate tradeoff between the requirements elicited from advertising companies and the degree to which a user may accept to be bothered while performing some tasks.

With respect to conventional advertising, online advertising may benefit from a promising advantage, namely the measurability. Whenever an *ad* is published on the web, several parameters can be measured, such as how many times a page with the *ad* has been seen, how many users have clicked on a suggested link with respect to those who have visited the page, how long a user has been watching a commercial video on the web. Obviously, there are several forms of online advertising and for each of them a proper measure exists, which can be specified according to geomarketing policies. Moreover, mobile phones are extremely personal devices and this makes them a precisely targeted communication channel, improving the effectiveness of advertising campaign. Then, when designing a mobile advertising campaign, it is important both to remember to provide a non-intrusive consumer experience and ensure that advertisements *(ads,* for short) are effectively displayed on the majority of mobile phones, without compatibility problems [95].

This Chapter is meant to present an approach for presentation of personalized ads on mobile devices, based on a user model that takes into account user's interests over time. The aim is to build a community of people, where they write up a profile indicating their commercial interests. By means of this profile, they receive information on sales promotions targeted to certain shops that have an agreement, directly on their mobile device, also by using advanced techniques of geo-localization and augmented reality.

In order to reach this goal, a personalization component of the advertising management system has been designed capable to dynamically create, save and update a user model on the basis of the latest interaction history and on the delivered contents. In particular, our studies have been especially focused on advanced modalities of geo-targeting that allow to control where ads are displayed based on parameters like geographic point coordinates. Moreover, we have decided to combine the potentials of mobile devices with augmented reality features [35] that allow customers to invoke several functionalities, ranging from traditional functions such as obtaining latest news about a product, getting an indication on a map and receiving information on other products of interest.

Technologies underlying the proposed system combine benefits coming from both approaches and are based on a geo-localization technique which integrates GPS and WiFi Positioning System (WPS). WPS allows to accurately determine location of wireless access points (APs) to estimate the physical location of a WiFi enabled device, thus overcoming limits of GPS in terms of coverage and accuracy. As a result, users are provided with services where mobility comes into, such as services that support navigation and location based services (LBS), which may further enhance their activities inside a wide community of people.

The Chapter is organized as follows. In Section 7.1 a system overview is given by illustrating the available visualization modalities. In Section 7.2, the dynamic user model for ads delivery is described. Section 7.3 specifies the system architecture, while Section 7.4 describes the client application.

7.1. SYSTEM OVERVIEW

The system provides an integrated platform of services to promote commercial business that have an agreement. It is a client/server application where service requesters are consumers with a smartphone.

Users logging on a website have to create a personal profile that stores their buy preferences (see Figure 7.1). By using a wizard it is possible to select commercial categories of interest by assigning a score to each item. For our purpose, we considered the classification of 35 product categories adopted by the ebay© platform. As an example, the car domain has the item subcategories sportive, limousine, city car, ecc.. The score is automatically and continuously updated according to some actions taken by the user. A user may change her/his profile to add / delete a category, and update the score. Once the profile is complete, the user may use the client application. Through the mobile device s/he receives real-time advertisements of associated stores according to her/his position and preferences. Augmented reality may contribute to the advertisement delivery.

Fig. 7.1 A user profile

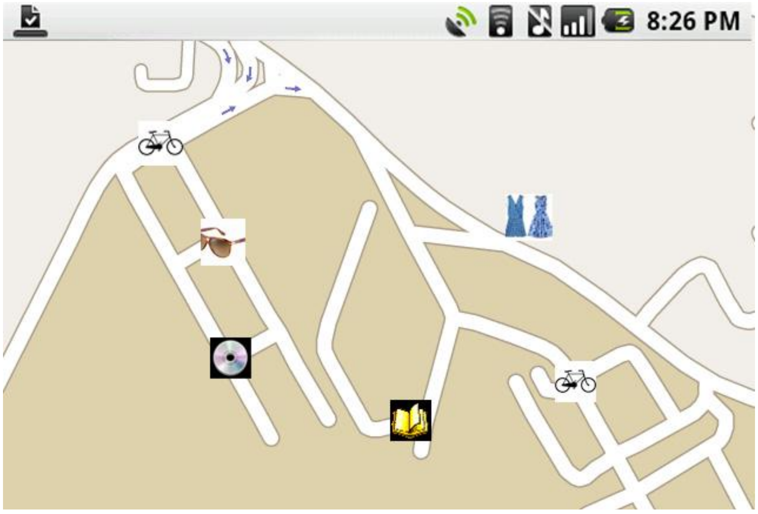


Fig. 7.2 The Map Mode visualization modality

While running the application in Map mode, the user can see all shops having an agreement around her/his current position. In this modality s/he can zoom on a selected shop and can obtain additional information, such as discounts on some products. All data sent to the user are first compared with preferences set in her/his profile thus giving the vendor the possibility to select only information of interest.

Fig. 7.3. The Live Mode visualization modality - Outdoor

While running the application in Live mode (see figure 7.3), the user can exploit augmented reality to improve her/his sensory perception about objects of interest around her/him, captured by the video camera, such as a product shown in a shop window. Figure 7.4 illustrates an indoor use of the Live Mode.

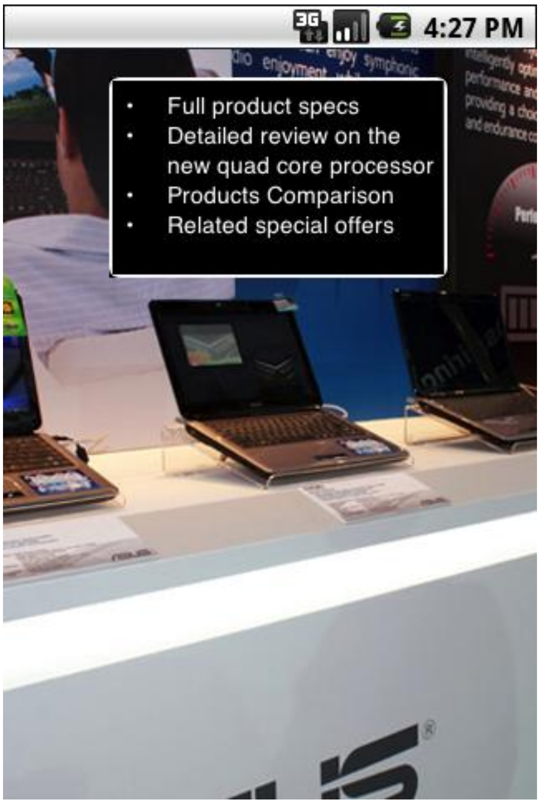


Fig. 7.4 The Live Mode visualization modality - Indoor

In such a modality, when the user points the camera on a specific product the system provides her/him with detailed information and where available, additional information from the Internet, such as reviews from specialized sites, comparison with similar products offered by the shop, additional special offers.

By pointing the camera towards the shopping window, the system provides the user with information about offered products selected according to the user profile. Switching between these modalities depends on a threshold which combines the available number of satellites and WiFi signal strength.

7.2. A DYNAMIC USER MODEL FOR ADS DELIVERY

The *ads* available for the publication on a mobile device through the system prototype are chosen or discarded by associating them with a rank value which both takes into account long-term as well as short-term user interests, and periodically verifies if the dynamically updated ranks satisfy a specific pleasure threshold.

Based on results described in [95], in this Section the dynamic user model is described and it is explained how long-term and short-term interests are computed and then combined to derive a user-oriented rank.

7.2.1. LONG TERM USER INTEREST FRAMEWORKS

Long-terms user interests are modeled with respect to two reference frameworks. The former is based on a classification of domains and the latter is based on *ad* contents mapped onto user's general interests.

As for the first framework, when building a user profile, the system stores for each domain, the score the user assigns to each of its derived subcategories. Such a score is stored as a matrix, where rows correspond to the subcategories and columns corresponds to users (see Table. 1).

CAT	**u_1**	**…**	**u_m**
C_1	val_{11}	…	val_{1m}
…	…	…	…
C_n	val_{n1}	…	val_{nm}

Table 1. User specified scores for CAT item subcategories

As each *ad* has a pre-assigned sub-category, selection with respect to this reference framework is immediate. Each *ad* a is assigned with the score associated with the corresponding specific category in the corresponding user profile. Thus, the relevance of the *ad* a for a user profile u, classified as belonging to subcategory C_i, corresponds to the score assigned to C_i by the user u. Namely:

$$Rel_u(a) = S_{Ci}(u). \qquad (1)$$

A similarity value sim(a, CAT) is then computed between the *ad* a and the general category CAT to which C_i belongs, by exploiting the cosine similarity formula for the vector space model.

Consequently, the relevance between an ad a and all general categories of a user model u is computed by using the next formula:

$$REL_u(a) = \frac{\sum_{i=1}^{35} sim(a,CAT_i)S_{CAT}(u)}{\sum_{i=1}^{35} S_{CAT}(u)} \qquad (2)$$

The second reference framework for long-term interests further specializes user's profile. It is based on a set of user-specified keywords, which are weighted on the basis of their relevance for the user. For each user, these keywords are stored as a term weight vector (k_u), as illustrated in Table 2.

k_u	**k_1**	**…**	**k_t**
U	k_{1u}		k_{tu}

Table 2. User specified scores for keywords

Again, the relevance between the *ad* and the keywords of a user model is given by the similarity cosine of the vector space model:

$$rel_{Ku}(a) = sim\ (a, k_u). \qquad (3)$$

Thus, the long-term interest LT(u,a) of a user u in a given *ad* a can be computed by combining formulas (1) and (3) as follows:

$$LT(u,a) = \frac{w_1 rel_u(a) + w_2 REL_u(a) + w_3 rel_{Ku}(a)}{w_1 + w_2 + w_3},$$

where w_1, w_2, w_3 are the weights representing the importance assigned to the three relevance measures, referred to the specific category, to the general category and to user's keywords, respectively.

In order to dynamically update the long term interests of user profile, each current subcategory is georeferenced and two functions are calculated, namely $diff_s\ (lat_2, lon_2, lat_1, lon_1)$ whose output is the difference in meters between two couples of latitude and longitude coordinates, corresponding to two different user's positions, and $diff_t(timestamp_2, timestamp_1)$ which calculates how long the user stays in the first position. In order to associate a meaningful size to the user's position, a buffer zone is performed inside which movements are not relevant.

A new variable, *ptw* (position-time, weight) is defined by each customer of the system, according to his needs, with the following procedure :

Choosen the desired distance x, in meters

if $diff_s\ (lat_2, lon_2, lat_1, lon_1) \leq x$

then

if $diff_t(timestamp2, timestamp1) \geq 600\ sec$

then

$$ptw = \frac{1}{\sum_1^n S_{Ci}}$$

else

$$ptw = 0$$

Based on the subcategory-location association, the *ptw* value is then added to the proper subcategory, thus dynamically updating its relevance for the user.

Finally, the relevance of a subcategory for a user may be decreased of $1/_{S_{Ci}}$ in case either the user or the system did not update it in the last three months.

The *LT(u,a)* value is successively updated by combining it with a short-term rank which is based on the feedback the user provides during the navigation.

7.2.2 Short term user interest framework

Short-term interests are represented by means of feedback terms. Such terms are obtained from the user-provided feedback over the web documents s/he receives while browsing. That is to say, the user provides positive or negative feedback (f) over the document, and a set of representative terms is extracted from them. This information is processed and the resulting value is a term weight vector (t). By fixing a *p* value, representing the number of the last web documents which should be considered for the short-term value, a similarity degree between an *adv* a and the web document d is defined as follows:

$$r_{ad} = sim(a, t_d),$$

and the current short-term interests of the user u are specified as follows:

$$r^t_{au} = \frac{\sum_{i=1}^{p} f_i r_{adi}}{p}$$

Short-terms interests tend to correspond to temporary information needs whose interest for the user vanishes after the connection session.

By combining long-term and short-term interests, the total relevance between an *ad* a and a user model u is computed by the following formula:

$$Int(u,a) = \frac{w_1 rel_u(a) + w_2 REL_u(a) + w_3 rel_{Ku}(a) + w_4 ST(u,a)}{w_1 + w_2 + w_3 + w_4}$$

where w4 is the weight representing the importance given to the short-term interest in the given user model.

7.3. SYSTEM ARCHITECTURE

The system architecture is based on a client-server paradigm (see figure 7.5). The server receives information from clients, such as user position and time of her/his permanency on a given place.

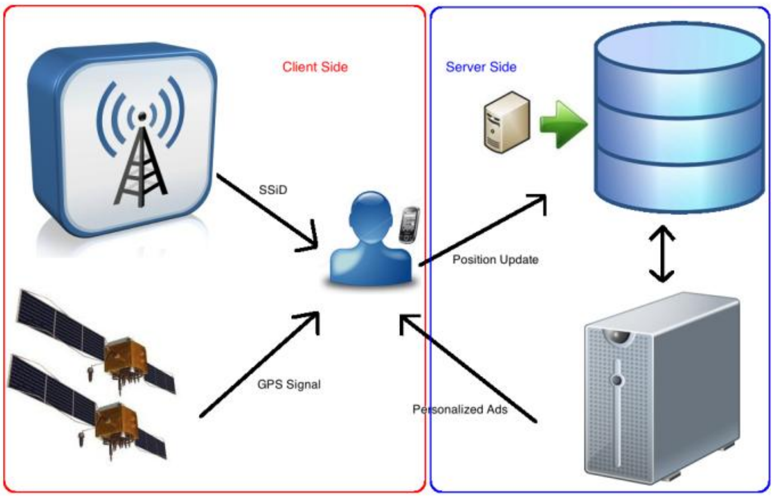


Fig. 7.5 System Architecture

In particular, based on fixed buffer zones, which can be specified by customers in agreement with their needs, the client collects information about current user's activity and, when the position changes significantly, i.e the user has moved to a different buffer zone, a new record is sent to the server. Figure 7.6 illustrates two different user positions captured by the client, and figure 7.7 shows how such data are stored on the server database.

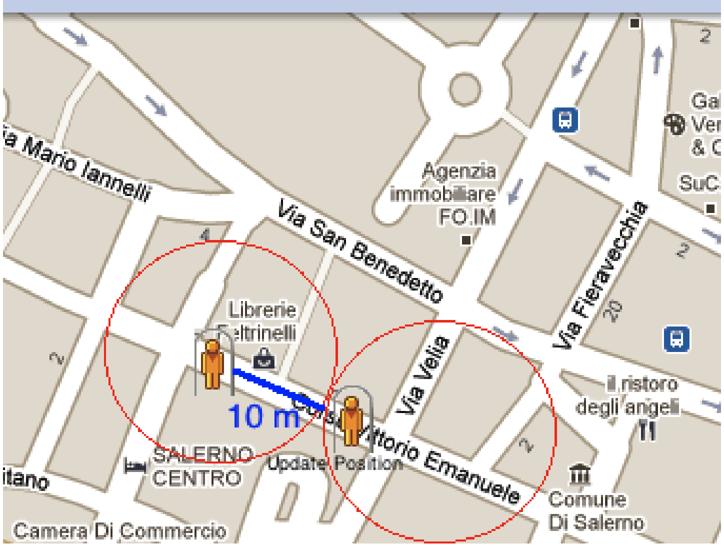


Fig. 7.6 Tracking user position

The user's localization is obtained through two methods. The former corresponds to the classical localization through the GPS standard. The latter calculates the position through the triangulation of the WiFi hotspot signals by sniffing for the surrounding WiFi networks, then measuring signal strength and comparing those results with a threshold. The location accuracy is proportional to the number of hotspots present in the area around the device. The client collects data related to the signal strength and its SSID, and transmits them to the server, which in turn calculates the position of the client according to the data contained in the database.

ID Track	ID User	Latitude	Longitude	Elevation	ID Area
1	1	36.124015°	-115.207160°	678	2
2	1	36.124187°	-115.207801°	678	
3	1	36.124190°	-115.207721°	678	4
4	1	36.124192°	-115.207689°	678	
5	1	36.124185°	-115.207671°	678	22
6	1	36.124183°	-115.207638°	678	22
7	1	36.124184°	-115.207624°	678	
8	1	36.124183°	-115.207591°	678	
9	1	36.124138°	-115.207573°	678	
10	1	36.124117°	-115.207552°	678	
11	1	36.124114°	-115.207502°	678	
12	1	36.124102°	-115.207426°	678	5
13	1	36.124070°	-115.207423°	678	5
14	1	36.124053°	-115.207424°	678	
15	1	36.124026°	-115.207425°	678	

Fig 7.7 Tracking user position on server database

Data stored on the server database are used to make estimations both to dynamically enrich user's profile and provide more detailed hints on products of interest. The user position is updated according to the information sent by the client, that allows the system to understand if the user is moving rapidly or s/he is near a shop having an agreement. Based on the user position and profile the server sends specific commercial *ads*.

7.4. THE CLIENT

The client application has been developed on a device that incorporates a software stack for mobile. In this case, Android platform[7] has been used that includes an operating system, middleware and key applications which allow autonomy in the development of application for mobile.

The Android platform is made up of:

- an hardware reference design which describes the physical characteristics that a device must satisfy to support the software stack;
- a Linux based kernel (2.6 version) for processes, memory management, network stack and driver management;
- a set of Open Source libraries, such as SQLite, WebKit, OpenGL, Open Core;
- a run time environment used for the execution of the applications;
- a framework which provides the applications with all system services, such as telephony or geo-localization.

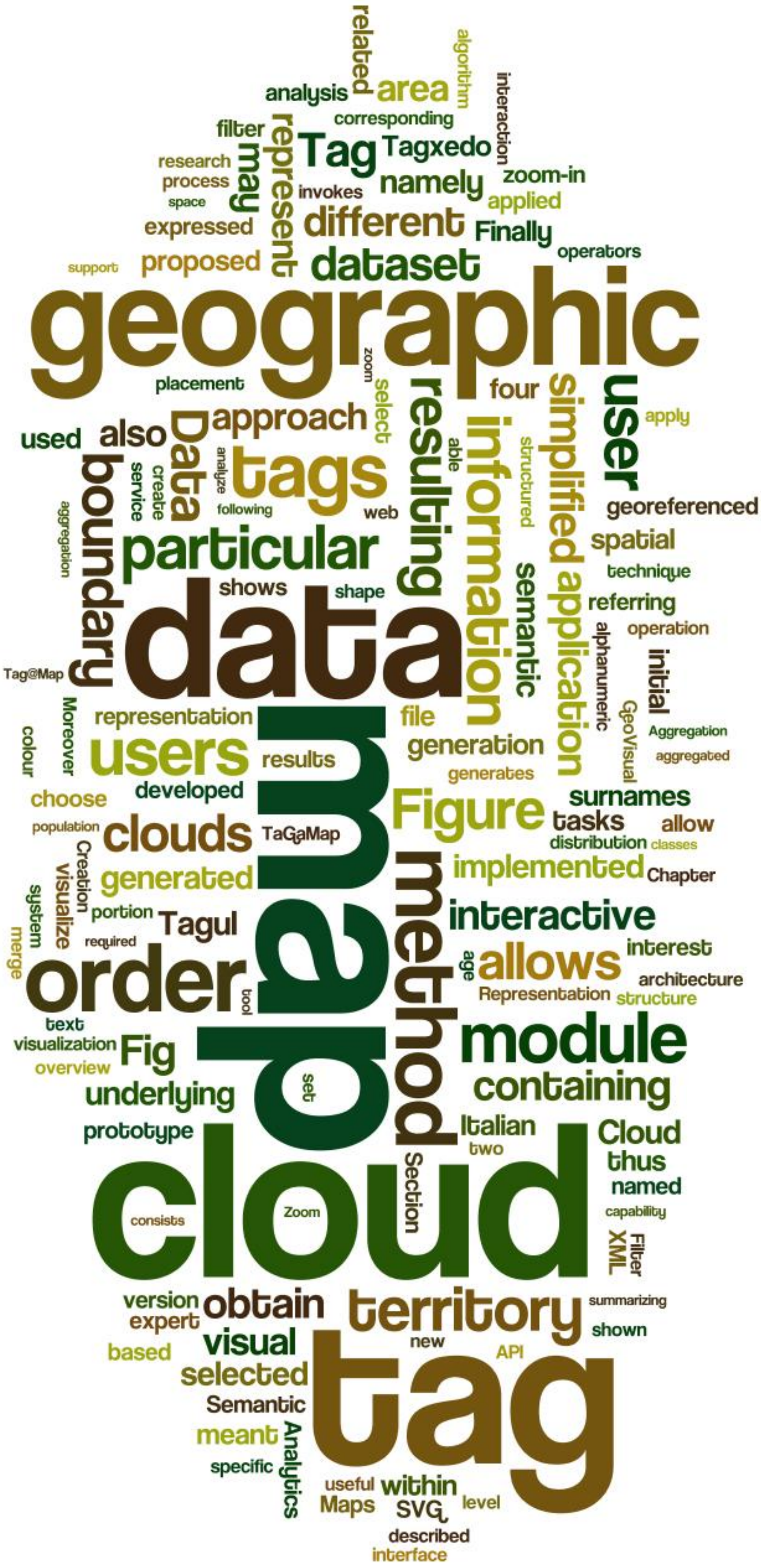
From a technological point of view, the system prototype combines an integrated camera for the video-image capture, a GPS device to detect the position, a compass and motion sensors to detect the user point of view. Moreover, WiFi allows to identify user position with a good accuracy inside the area not covered by GPS signal. This is achieved by using a technique that calculates the position through the triangulation of the WiFi hotspots signal. Obviously, this service can be offered only within WiFi covered areas, where positions of access points are known.

As for the Android framework, it includes a set of core libraries that provide developers with most of the functionality available in the core libraries of the Java programming language. It provides applications with access to the location services, which are supported by the device through the classes in the android.location package. The central component of the location framework is the LocationManager system service, which provides an API to determine location. Android also supplies 3D libraries, an implementation based on OpenGL ES 1.0 APIs. The libraries use either hardware for 3D acceleration (where available) or the included highly optimized 3D software rasterizer. LocationManager is used for identifying the current position when the GPS signal is accessible, otherwise it exploits the WiFi hotspot triangulation technique when users get into a shopping centre.

The access to a map is provided by MapView that displays a map with data obtained by the Google Maps service. MapView captures key-presses and touch gestures to automatically pan and zoom the map, including handling network requests for additional maps tiles. It also provides users with all UI elements necessary for the map control. The applications can also draw a number of Overlay types on top of the map. In general, the MapView class provides a wrapper around the Google Maps API [59]. Android also supplies 3D libraries, an implementation based on OpenGL ES 1.0 APIs. The libraries use either hardware for 3D acceleration (where available) or the included highly optimized 3D software rasterizer.

As for the two visualization modalities, the Map mode uses the MapView framework to view data either on a street plan or on a satellite image. The Live Mode displays data in a 3D environment by using the OpenGL ES and superimposes them on video-captured by camera.

Typically, mobile devices have some computational limits that can slow down the application performances. To overcome such limits some Web Services have been exploited, thanks to the Internet permanent connection of the device. In particular, for outdoor navigation a route is provided by the GPX Driving Direction [61]. As for the indoor mobility, an ad *hoc* cartography and a service have been realized. Both services receive two couples of coordinates representing source and target points, calculate the path between them and transmit it in GPX format (the GPS Exchange Format) [60]. GPX is a light-weight XML data format for GPS data interchange between applications and Web services on the Internet, such as waypoints, routes and tracks.


geographic
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users
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boundary
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representation
file
GeoVisual
Aggregation
aggregated
Moreover
colour
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population
TaGaMap
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distribution
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Chapter
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Tagul
required
interest
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architecture
Representation
structure
tool
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visualization
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CHAPTER 8

ANALYZING GEOGRAPHIC INFORMATION THROUGH TAG CLOUDS

A Tag Cloud is a visual representation typical for text data, used to depict keyword metadata (tags) whose importance is expressed by graphic properties [113]. It is useful for quickly observing the most important / frequent terms of a text, which are arranged with the juxtaposition of different font size and colour.

The goal of this Chapter is to illustrate a GeoVisual Analytics method which combines the tag cloud property to convey information with advanced visual metaphors capable to encapsulate structured and semantic information. In particular, this Chapter consists of two main parts each devoted to illustrate a relevant result in the field of both GeoVisualization and GeoVisual Analytics.

A preliminary result of the research carried out corresponds to a visualization method for spatial data which adopts the Tag Cloud rationale and extends it by exploiting techniques for summarizing datasets and simplifying their geographic representation, such as Cartograms [49] and Chorems [80]. Starting from a geographic dataset, the proposed method extracts relevant information about a geographic area by counting and/or summarizing data, and generates a simplified map containing a georeferenced cloud of tags, located within the geographic area which original data are related to. In order to apply this method, a system prototype, named TaGaMap, has been developed. It assembles results from this initial phase of our research and allows for building a map containing the tag cloud, which represent summarized data extracted from the underlying dataset [37].

The second part of this Chapter is devoted to describe recent advancements achieved along this line. The goal is the definition of a GeoVisual Analytics method which includes the previous approach to visually represent spatial data and adds *ad hoc* functions meant to perform analytical tasks. In order to reach this aim some changes have been required to the algorithm for tag cloud generation and the potential of Web-based visual environments has been taken into account due to their capability to support database querying. The resulting map is interactive, that is to say, its tags along with the georeferenced cloud can be manipulated in order to answer specific users' requests. In particular, semantic and geographic operations have been specified whose aim is to both capture visual and semantic details, and select areas and data of interest.

In order to apply this method, a Web application, named Tag@Map, has been developed. It allows both to build a map containing the tag cloud, represent summarized data extracted from the underlying dataset, and support expert users' interaction to analyze phenomena of interest.

The Chapter is organized as follows. Section 8.1 recalls preliminaries about cloud/tag-based methods. Section 8.2 introduces the proposed geovisualization technique. In Section 8.3, the system architecture is described and the TaGaMap prototype built on it is presented. Section 8.4 described the GeoVisual Analytics technique based on the extended version of the previous method.

8.1. BACKGROUND

Wordle, Tagul and Tagxedo represent the most popular tag cloud generators. Wordle [111] is a web tool which generates tag clouds starting from a website or free form text. The rationale behind its algorithm is to provide a more appealing version of a traditional tag cloud, by trying to fix some typical typographic problems. In fact, the Wordle layout packs words tightly, avoiding overlapped tags. It also exploits the space of a letter O in a larger word by including a tiny word, and provides users with a broad set of visual parameters to play with, namely a large set of typefaces and several pre-created colour schemes. Such a capability breaks away from the pure horizontal alignment of conventional tag clouds, giving the option to place words vertical or even diagonally. Tagul [104] is a web service tool that allows users to create tag clouds, by providing developers with the Tagul API [105], an XML-RPC server that uses HTTPS. A method called 'generateCloud' is invoked with an XML file as input parameter and an SVG cloud file (compressed by ZLIB) is returned. All cloud customizations (shapes, fonts, colours, angles, etc.) may be set in the XML file. The generated cloud file is rendered by a Tagul flash component. Both generated cloud and flash component can be hosted on a website, thus allowing independence from Tagul while serving clouds to website visitors. Tagxedo [106] is a web service tool that lets users to create tag clouds in a very interactive mode. The user may customize the tag cloud by choosing colour, theme, font, orientation, layout. Moreover, s/he may also choose a customized shape (from an image) in order to distribute the cloud on it. Like Tagul, also Tagxedo provides a service to obtain a tag cloud via HTTP request, by adding some parameters (URL, theme, orientation, and basic shape) to the Tagxedo URL. Figure 8.1 shows a tag cloud generated by Tagxedo representing a cloud of common names.

Fig. 8.1. A tag cloud of common names generated by Tagxedo [106].

An interesting method, named Tag Maps [72] has been developed to display textual topics linked to a specific location on a map. As shown in Figure 8.2, it summarizes large collections of data and visualizes the corresponding tags associated with a real geographic space. Tag Clouds and Tag Maps share the visualization approach, which consists of differently sized and coloured aggregated tags, while they differ in the extraction and aggregation criteria, namely free form text with respect to structured and georeferenced data.

Fig. 8.2 A Tag Map of London [72].

8.2. Visualizing Data Summaries by Georeferenced Clouds of Tags

In order to develop a method for visualizing geographic information, the Tag Cloud technique and the Tag Maps approach have been revised. They have been combined and extended with the capability of both summarizing datasets and simplifying their geographic representation also by altering their original shape. Moreover, tags have been adopted to express concepts extracted from data sources, and finally, the georeferencing concept underlying Tag Maps has been adapted by associating it with the whole cloud.

The method application results in a simplified map containing a georeferenced cloud of tags, each referring to a different map characteristics. In particular, it counts and summarizes data from a geographic dataset and expresses them through tag clouds within the geographic area which data are related to. It is worth to noticing that the position of each single tag is meaningless, because all of them refer to the geographic boundary, that is, the tag placement is "area based", thus implying a graphic approach for the map layout. As a consequence, two subsequent applications of the method on the same dataset may produce two different clouds. Differently, the tag placement in Tag Maps is "point based", that is, the solution is derived from the label placement, a well-established cartographic approach, which concerns with the prominence of spatially-coincident tags, the real time label placement, and a legible output production [37].

Figure 8.3 depicts a map produced according to the proposed method. It illustrates USA population divided by age classes and gender. In particular, the prominence of each class is expressed by the size, while the colour represents the different types of the same age class, namely male in blue and female in pink.

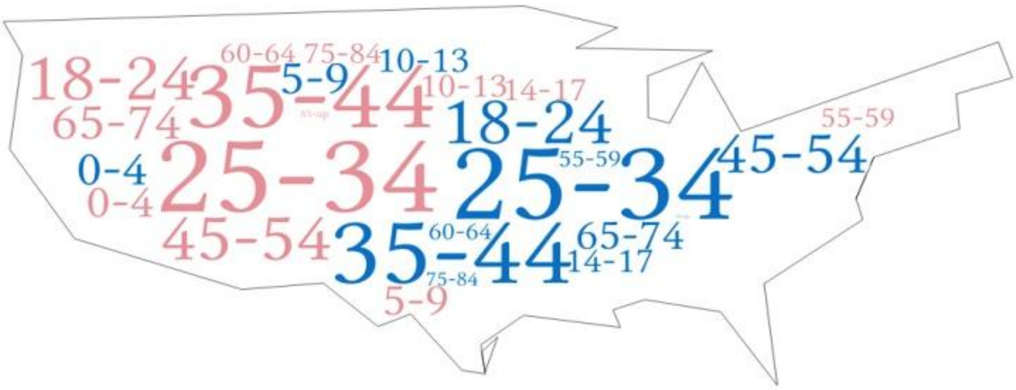

Fig. 8.3 A map obtained by applying the proposed method.

8.3. The System Architecture and the *TaGaMap* Prototype

In order to apply the proposed method a system prototype has been developed based on the architecture consisting of the four following modules. The *Data Selection* module is meant to read data from the geographic dataset and allows users to choose both the geographic map boundary and the alphanumeric data to represent within the map as tag cloud. The *Data Aggregation and Generalization* module is meant both to generalize the map boundary and calculate a weight function useful for the cloud generation. The *Cloud Creation* module has been designed to create the tag cloud, which has to fit in the simplified map boundary. Finally, the *Data Representation* module is able to merge the boundary and the cloud in order to visualize the resulting map.

The initial prototype, named TaGaMap, is focused on data extraction and aggregation, and output visualization, and adopts various techniques to obtain an overview of data distribution and classification. TaGaMap has been implemented by using various technologies, such as Java and PHP as programming language, Java Topology Suite (JTS) as spatial data model and spatial analysis method set, and XML and SVG as exchange and storage means. Figure 8.4 depicts the process generation of a simplified map which represents the USA population partitioned in age classes. The Data Selection module has been implemented as a Java application. It takes as input a geographic dataset, such as an ESRI Shapefile or a Postgres/Postgis table, and allows the user to select both the geographic map boundary and the alphanumeric data to visualize. The Data Aggregation and Generalization module has been implemented to simplify the map boundary, as shown in Figure 8.4(a), by using the well-known Ramer-Douglas-Peucker (RDP) algorithm [51], [96]. It produces the simplified map in XML and SVG format. Moreover, it also allows the user to select the weight function useful to establish the tag dimension. The Cloud Creation module has been implemented as a PHP application to call a remote API (Tagul API [106]) via XML-RPC, which generates the tag cloud. The API takes an XML file as input parameter, containing the derived simplified map boundary and the calculated tag weight function, and returns an SVG file. As shown in Figure 8.4(b), the cloud assumes the shape of the map boundary. Finally, as shown in Figure 8.4(c), the Data Representation module has been implemented to merge the SVG version of the simplified map boundary and the tag cloud in order to derive the resulting map. Such a module is also useful to allow the user to customize the output map by modifying some graphic parameters, such as fonts, colors and angles.

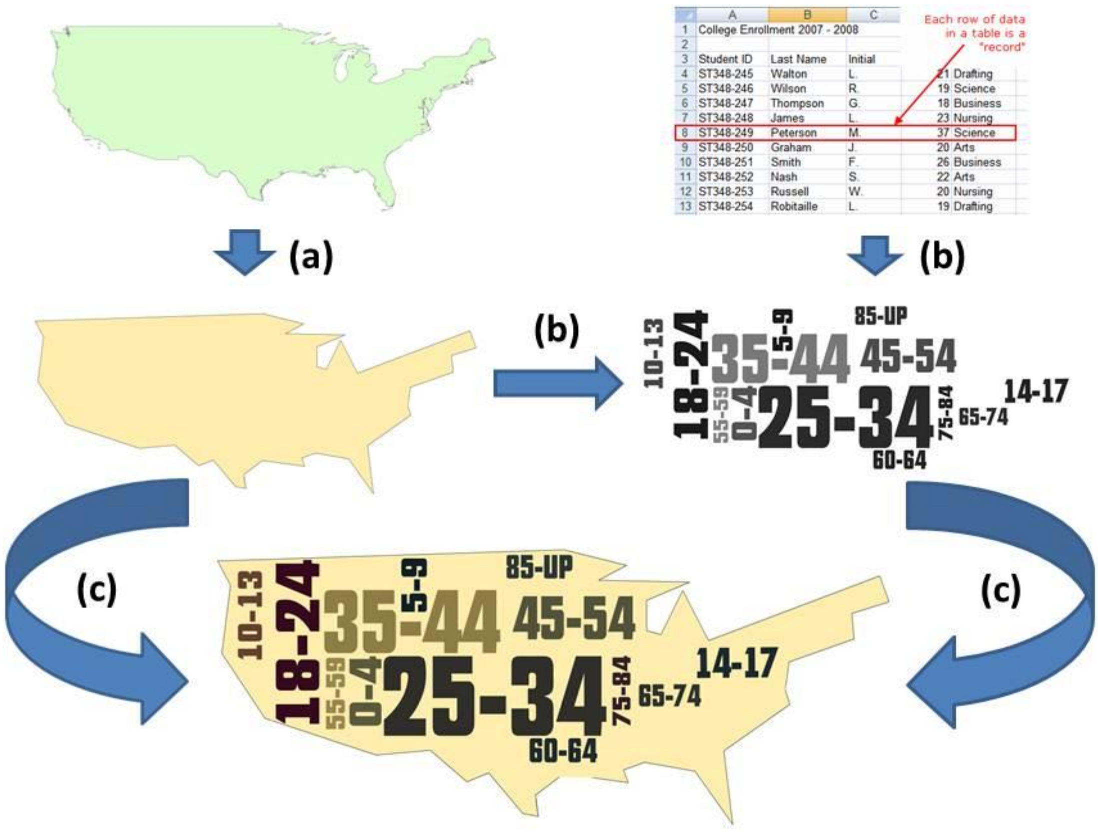

Fig. 8.4 the generation process of a tagged map representing the USA population partitioned in age classes.

8.4. Performing GeoVisual Analytics by Georeferenced Clouds of Tags

Previous results form the basis of the research described in this Section. The goal is to increase the role that a map containing a cloud of tags may play in geographic domains, by assigning it an active role also when analysis tasks are required.

The achievement of the above objective has required the enhancement of the structure underlying a tag, by associating it with a structure capable to organize and store complex data. Thus, starting from a territory and a geographic dataset referring to it, the enhanced visualization technique both elaborates a simplified view of the territory by extracting and aggregating data of interest, and outputs an interactive map which reacts to its direct manipulation.

The observation underlying the current proposal is that tags and chorems may share the composite structure by which successive summaries of data are organized into levels. Indeed, they both represent visual metaphors associated with structured summarized data which can be queried in order to obtain analytical information. Then, the approach based on the Visual Information-Seeking mantra stated by Ben Shneiderman [101] and on Keim's adaptation to the Visual Analytics domain [74], can be efficiently adopted and adapted as follows, in order to transform a map expressed as a tag cloud into a support for expert users to analyze a territory and its phenomena.

The initial overview offered by a map containing a tag cloud offers a schematized representation of the distribution of a phenomenon and can be used as a means to locate which part of it to analyze. By zooming and filtering an interactive map containing tag clouds, users may gradually reduce the search space and select a subset of data.
Once not necessary information has been visually discarded, the final step of the paradigm, namely *details on demand*, is meant to obtain detailed information about a particular element. In our proposal, users may easily browse a portion of a tag cloud and obtain descriptive information related to a selected tag.

In order to build the whole analysis path, we have adopted the visual approach defined in [38] for analytical tasks, and customized the four operators to perform the aforementioned user interactive tasks.

Although chorems and tag clouds differ for the spatio-temporal phenomena they represent, sharing a similar approach for the information visual representation allow us to inherit the meaning of the operators and adapt it to the expected behavior when applied to tag clouds. Moreover, distinguishing geographic and semantic aspects of both tags and clouds also lets us obtain an exact relationship between operators and operands, thus providing users with a well-defined functionality to navigate an interactive map from an initial overview to a particular detail. In particular, while the Geographic Zoom preserves its conventional behavior, the Semantic Zoom invokes a different level of abstraction referring to data of the selected area. It implies that the initial cloud is disaggregated / aggregated and a smaller area is centered and then expressed as a new cloud. Tags related to the new territory are calculated accordingly, thus allowing the access to a different level of information. In order to select predefined areas, the Geographic Filter can be used to apply a spatial filter to a wider territory. In particular, an existing geometry can be used to cut a region of interest, thus requiring only tags belonging to that region. Both scale and level of information detail are unchanged. Finally, the Semantic Filter operation allows users to filter tags which satisfy a condition applied to their semantics.

In order to implement the proposed method and check its applicability, an improved system prototype, named *TaG@Map*, has been developed on the basis of advances applied to the initial version.

8.4.1. The System Architecture and the Tag@Map Prototype

Starting from the TagaMap architecture, it has been extended and adapted to a conventional client-server architecture. The server side embeds a spatial database and an application which elaborates and publishes data in a map format, while the client visualizes the resulting map and allows the interaction by a browser. In order to allow the interaction with different abstraction levels of the same information, data underlying the map have been hierarchically structured.

The aforementioned four modules have been then integrated in the application server side. In particular, the Data Selection module is meant to read and elaborate data from a geographic dataset by allowing expert users to choose the geographic map boundary and the alphanumeric data to represent within the map as tag cloud. The Data Aggregation and Generalization module is meant to both allow expert users to choose the aggregation method and generalize the map boundaries used for the cloud generation. The Cloud Creation module has been designed to create the tag cloud, which has to fit within the simplified map boundaries. Finally, the Data Representation module is able to merge the simplified boundaries and the generated cloud in a hierarchical structure in order to visualize the resulting interactive map.

TaG@Map has been implemented using the same modules and technologies of the original version of TagaMap, except for the Cloud Creation module. In this case we used an *ad hoc* algorithm which frees Tag@Map from an external web service, thus providing an application available for further customization. Finally, the Data Representation module has been implemented as a basic CartoWeb client, able to both visualize the resulting map and allow interactive analysis tasks.

In the following subsection, the previous four operators are exemplified in order to show how they works when embedded into Tag@Map. In particular, some examples of interaction tasks are described by which users are able to navigate data from a general overview to a specific detailed information.

8.4.2. The Analysis of Italian Surnames performed through Tag@map

The following screenshots are taken from a specific scenario, namely the distribution of surnames in Italy.

The generated interactive map is illustrated in Figure 8.5. It shows the distribution of surnames in Italy, where the prominence of each surname is expressed by the font size. By interacting with it, a philology or a linguistic expert user could to speed and simplify his/her research activities about the origins of the populations who inhabit the territory under investigation.

Fig. 8.5 A georeferenced tag cloud for the most popular Italian surnames

As previously stated, the creation of this map results from a process which starts from a geographic database containing demographic data related to the Italian territory. In particular, for each Italian Province the dataset contains the associated surnames, the geographic data, and the data about the Region to which it belongs. Such a user-controlled process aggregates the alphanumeric and geographic data for both Region and the whole Italian territory. The result consists of a value which expresses the frequency of surnames at the national level. In particular, a threshold determined by the user (60 for this map) sets the number of surnames to be displayed, which can be tuned in order to obtain a map with a more or less crowded cloud.

In order to refine the analysis, the interface allows the user to zoom-in the map and obtain data about a small portion of territory by performing two different zoom operations, namely geographic and semantic zoom. In particular, the former allows the user to better visualize tags related to a portion of territory in agreement with the common GIS zoom, without creating a new cloud. Differently, a Semantic Zoom invokes a new cloud generation referring to the portion of territory on which the user focuses. Figure 8.5 shows the Northern Italy on which a geographic zoom-in operator is applied.

Fig. 8.6 A map resulting from a geographic zoom-in operation.

Figure 8.7 shows a map resulting from a semantic zoom-in operator applied on four Italian regions selected by the user, namely Emilia Romagna, Toscana, Marche, Umbria. Data referring to the selected territory have been aggregated and the corresponding tags have been calculated and embedded within the boundary resulting from the merge of the underlying regions.

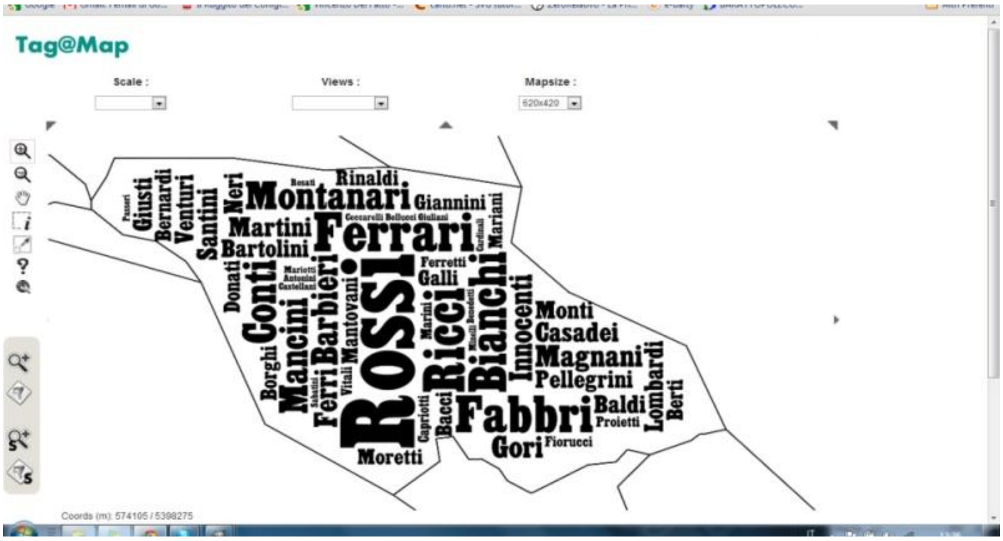

Fig. 8.7 The map resulting from a semantic zoom-in operation on four Italian regions.

A different selection can be performed through a geographic filter. The user can directly choose a given territory among those visualized, and the corresponding tag cloud is generated, accordingly. In this case, by either dragging a selection rectangle on the map or simply pointing on the area of interest, the interface invokes the creation of the cloud corresponding to the selected area. Figure 8.8 shows the application of a geographic filter which generates the tag cloud of the Emilia Romagna region.

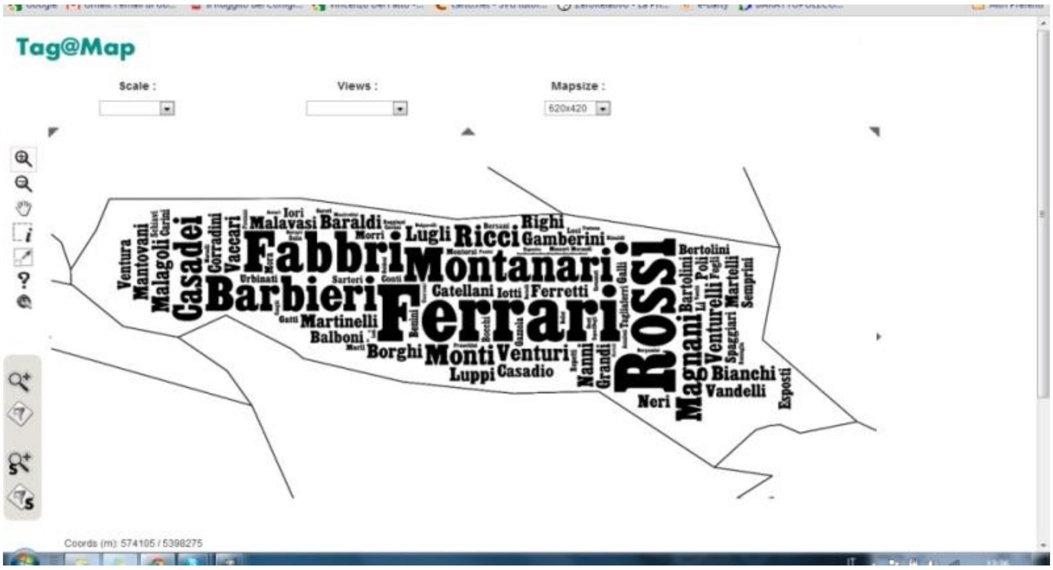

Fig. 8.8 The map resulting from a geographic filter operation.

Finally, the interface allows the user to query the tag cloud in order to obtain details about the selected tag. Figure 8.9 illustrates the pop up menu specifying the number of occurrences of the selected tag. It results from the application of the Semantic Filter on the Ferrari tag, the most frequent surname in Emilia Romagna. By pointing at this tag, the interface invokes a query which performs the requested computation.

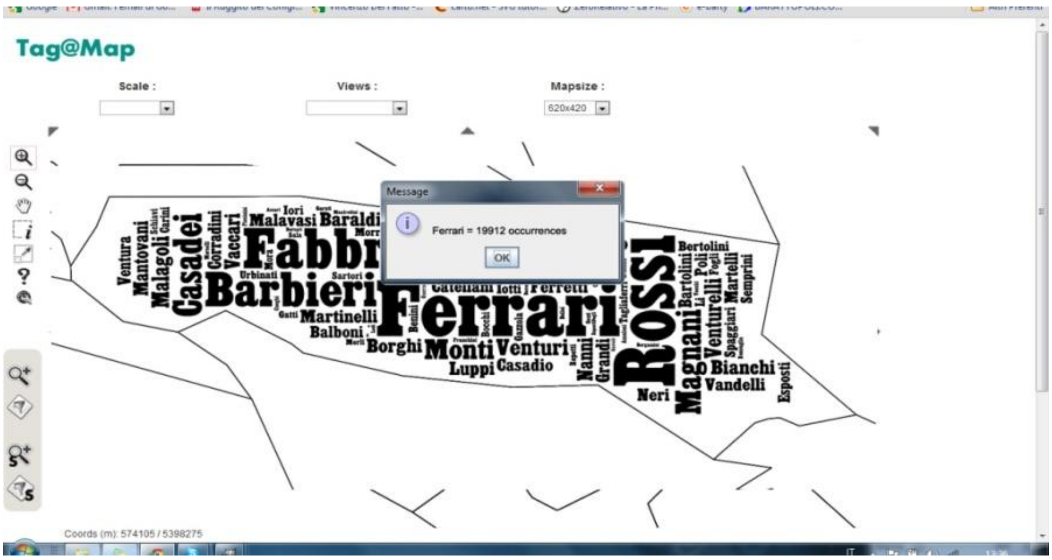

Fig. 8.9. A pop up windows resulting from a Semantic Filter on the map.

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CHAPTER 9

CONCLUSIONS

The main goal of this dissertation has been to contribute to the GeoVisualization and GeoVisual Analytics research field by defining and realizing methods and techniques to improve human-(geo)information discourse. General speaking, contributing to the achievement of this goal means first to investigate potentialities of recent advances in diverse disciplines which have the territory as a common element. Indeed, as they analyze phenomena related to it by different point of views, GeoVisual Analytics researchers should understand how findings may be shared and integrated. A second relevant aspect concerns the combination of alternative graphic representations and geocomputational approach which can be exploited to stimulate the visual thought process, enabling new map forms used as visual thinking and decision-support.

These observations along with the twenty-year experience matured by computer science researchers from the University of Salerno within the visual language and multimedia database field has focused attention on the changing and expanding role of maps in science also useful to face general-purpose issues related to territory. In particular, recent literature demonstrates that studies conducted within the GeoVisualization domain have produced proficient working systems developed with a twofold goal, namely providing users with environments where users can easily view geographic data in many alternative views through visual geospatial displays, and hiding the inner complexity of geospatial data thus overcoming difficulties by unskilled users.

The aim of this Chapter is to draw some conclusions about the work described in this dissertation within the GeoVisualization and GeoVisual Analytics research field. It is organized as follows, a General Discussion Section summaries the contribution to the research and discusses possible scenarios where direct and indirect impact can be generated by adopting the proposed solutions. The subsequent Contribution Section briefly highlights specific methods and techniques proposed. Finally, the Future Work Section discusses some final remarks about the research that we aim to carry out in order to extend and improve functionalities of our systems, and to investigate other possible applications in the geographic information field.

9.1. GENERAL DISCUSSION

Traditional cartography is an essential tool to describe facts and relationships concerning with territory. It associates geographic concepts with graphic symbols which help readers gain an immediate comprehension of represented data. This approach is well-established and decision makers are usually satisfied by its expressiveness when dealing with the cartography of facts.

In this dissertation, two objectives have been pursued. The former has been to design and implement tools for representing and analyzing geospatial objects and phenomena derived from large amounts of data. The latter has been to embed such solutions within advanced navigation systems on mobile devices, where 2D and augmented scenarios are interlinked. These two goals have then shared a common rationale based on following three expected characteristics, namely

- a human-centered approach to GeoVisualization and GeoVisual Analysis,

- visual metaphors capable of representing both simple and complex/composite data in an homogeneous manner, and
- geovisualization methods and tools that can be exploited by Visual Analytics techniques in a seamless way.

The following Section explains how the above aspects have been considered when developing the present contribution.

9.2. Contributions

General speaking, the aim of this dissertations was to support both expert and end users' activities where the geographic component is an important factor. Several solutions have been proposed in literature and their benefits have been investigated.

Our major contribution along this line has been to define an innovative paradigm for human-(geo)information discourse which integrates different modalities of visualization and navigation with visual metaphors associated with both geospatial data and their aggregations / syntheses. These summaries are characterized both by a geographic generalization, which simplifies the shapes of the territory under investigation, and by a semantic generalization, which selects the relevant aspects of spatial and non-spatial attributes of a geographic database. Moreover, the structure associated to visual metaphors has been enhanced in order to store also intermediate steps accomplished during the summarizing process. This implies that the knowledge extracted from a dataset can be analyzed by subsequent levels, from the highest stage strongly connected to the human interpretation to lowest level directly linked to the source data.

This paradigm has been exploited in Framy-AR and Link2U, two geovisualization techniques which combine the pervasiveness of mobile devices, criteria derived from usability studies and the augmented reality potentiality, in order to define a new modality for navigating and accessing geospatial data. In particular, they both provide for display of complementary views whose focus is located on user's position and user's point of view, respectively.

As for the GeoVisual Analytics research field, the capability to preserve the link between a metaphor and data associated to it while navigating a scenario, has been exploited as starting point for the development of a method for accessing data underlying geospatial information. In particular, the enhancement applied to the visual metaphors allows to invoke appropriate analysis operators in order to semantically and visually integrate quantitative, qualitative and cognitive aspects of a domain of interest and investigate cause/effect relationships.

A Chorem-based application, a Link2U-based application for geomarketing policies and the Tag@Map application for georeferenced tag clouds represent three different experimentation of the above method. They all embed the previous paradigm and exploit the multi-level structure associated with the involved visual metaphors. The specified operators help users navigate and investigate phenomena preserving relationships among different point of views of a scenario.

9.3. Future work

As future work we plan to:

1. execute comparative experimental studies in order to evaluate the effectiveness of our approach. In particular, such experiments will be meant to measure expert users' capability in using the GeoVisual Analysis techniques, in order to locate factors generating anomalies, difficult to detect when supported by traditional cartography;
2. investigate the integration of GeoVisual Analysis techniques proposed in this dissertation with a decision support system;
3. extend Tag@Map functionality to generate composite maps involving different but related interactive tag clouds;
4. analyze the results of a study we are carrying out with different categories of users (including elderly people, children and impaired people), meant to evaluate Framy-AR and Link2U against usability and accessibility factors.

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Chapter 2 - Definition of concepts

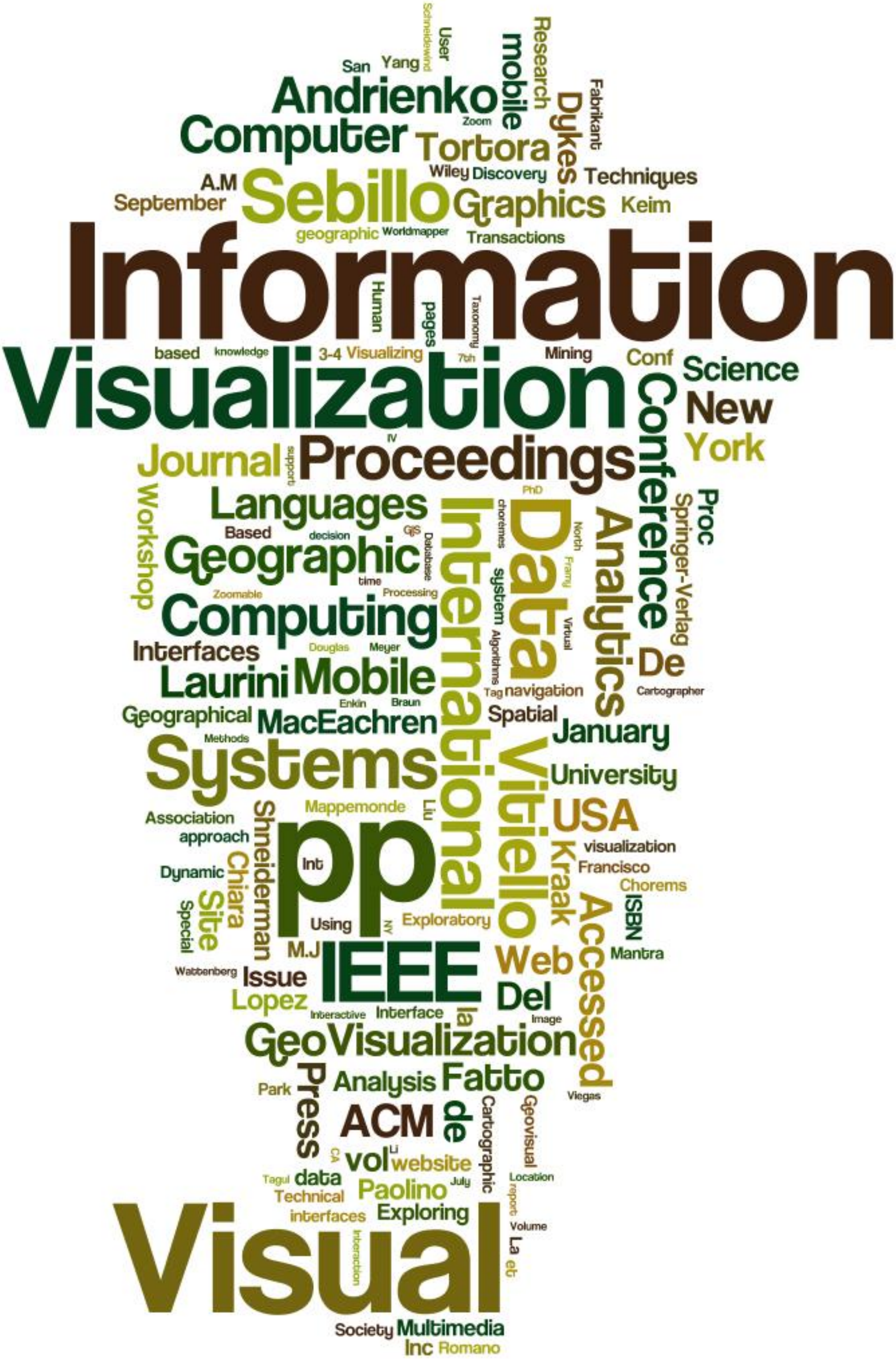
Chapter 4 - Augmented Map navigation through Customizable Mobile Interfaces

Chapter 5 - Connecting Social Network Users through Mobile Interfaces

Chapter 6 - A Chorem-based Approach for Visually Analyzing Spatial Data

Chapter 7 - Geomarketing Policies and Augmented Reality for Advertisement Delivery on Mobile Devices

Chapter 8 - Analyzing Geographic Information through Tag Clouds



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