Preface

The need to understand our dynamic and changing planet perhaps has never been more important. However, in order to gather, analyze, and gain knowledge from the complex systems and forces which affect the earth, large amounts of data are required. Even the simple task of answering technologically, the fundamental question, "where am I?" requires the ability to generate, explore, describe, and use vast datasets. The study of Geoinformatics promises to serve the need to explore, to research and enhance humanity's grasp of the world.

This handbook of research provides a comprehensive look at the challenges and discoveries made in this emerging field. It is a collection of informed, pertinent and researched articles on all vital aspects of this field is divided in to 8 sections as follows (1) Spatial Databases, (2) Mapping and Visualization, (3) Analysis, (4) Ontologies, (5) Distributed Geoprocessing, (6) Location-Based Services, (7) Management, and (8) Selected Readings. These sections outline the possibilities and challenges faced in the field and represents areas in which it can expand and become further defined.

Section I addresses one of the fundamental challenges of Geoinformatics. It is rare that a field involves as large a potential dataset as the Earth and as difficult to define and query. However, these chapters explain this topic and provide the framework and analysis of today's methods of over-stepping this obstacle.

Chapter I, "GML as Database – Present and Future" by Jose E. Córcoles and Pascual González, begins the discussion of spatial database by introducing the opportunities presented by treating Geography Markup Language (GML) as a database. This chapter discusses the the need for a query language that is applicable to both the alpha-numeric and the spatial aspects of GML. There are many ways to query XML data; however few of these approaches are applicable to GML databases. This chapter presents ways of overcoming this as well as discussing general concerns, such as how to store GML data.

Chapter II, "Querying GML – A Pressing Need" by Jose E. Córcoles and Pascual González, provides further analysis of the challenge of querying GML data. Córcoles The authors show, in depth, the various methods of querying GML, explaining the results and pitfalls of each. The original methods of querying GML are presented and the four most prevalent methods of querying GML are introduced and dissected. In all, the chapter provides a clear picture of this important developing topic.

Chapter III, "Image Database Indexing Techniques" by Michael Vassilakopoulos, Antonio Corral, Boris Rachev, Irena Valova, & Mariana Stoeva, covers the highly applicable area of image databases, which can be used in a variety of applications for medical to multimedia and educational purposes. This chapter discusses how to query images for the content of additional properties (descriptive information) that have been embedded for each image. For example, identifying feature can be queried to collect data such as which images have been used in the book cover of children's books, or what images depict vivid blue sky, to what cultivation areas reside in polluted atmosphere areas. One can also query by example or sketch, for example, a sample image is chosen or drawn by the user and images similar to this sample

are sought or find data that combines regional data and other sorts of spatial data. This chapter presents a clear description of the potential for these techniques.

Due to the rapid advances in database systems and information technology over the last decade, researchers in information systems, decision science, artificial intelligence (AI), machine learning and data mining communities are facing a new challenge: discovering and driving useful and actionable knowledge from massive data sets. During the last decade, many researchers have also studied how to exploit the synergy in information from multiple sources. **Chapter IV**, "Different Roles and Definitions of Spatial Data Fusion," by Patrik Skogster, explores this phenomenon, defines some of the new terminology and introduces the technologies utilized along with the challenges faced.

"Spatial Data Infrastructures," **Chapter V** by Carlos Granell, Michael Gould, Miguel Ángel Manso, and Miguel Ángel Bernabé, introduces Spatial Data infrastructures and discusses some of the early challenges facing the formulation of a more unified approach. The chapter then treats the various methods of creating an infrastructure primarily within institutions. Improving institutional collaboration and SDI effectiveness are the two main concerns this chapter raises.

Chapter VI, "Geoportals and the GDI Accessibility" by Trias Aditya and Menno-Jan Kraak, discusses making data discoverable and as well as some of the research challenges related to the development of geoportals that enable users to really exploit the GDI potentials. These challenges include taking into account users in designing metadata presentations, enhancing semantic interoperability, and content integration and facilitating geocollaboration.

Chapter VII, "Real-Time Extraction of the Road Geometry" by Hervé Gontran asserts that, ideally, the information captured by a mobile-mapping system should be processed by real-time algorithmics. This may reduce the need for human intervention to driving the data-collecting platform while ensuring immediate quality control as well as reducing costs and potential errors. This chapter features an incursion into real-time mapping and distributed computer serving real-time mapping, as well as real-time georeferencing.

Section II, "Mapping and Visualization," illustrates some of the real-world applications of Geoinformatics and the common problems encountered. The first chapter in the section, "Cognitive Maps," by Stephen Hirtle reviews the history and nature of cognitive maps, providing reasons why some maps are useful and effective while other models are lacking. The conclusion he draws includes a discussion of the knowledge acquisition, hierarchical structuring, and schematization of geographic knowledge. He then further discusses alternative frameworks for cognitive mapping. Cognitive mapping is proven to be rich source of both empirical findings and theoretical research and important for many areas of geoinformatics.

Chapter IX, "Map Overlay Problem," by Maikel Garma de la Osa and Yissell Arias Sánchez, tackles the problem caused by combining maps or layers of data into a single output map. This process is summarized and explained through section detailing the four state-of-the-art steps for creating a useful output map that conquers the map overlay problem. Vector algorithms and raster algorithms are both treated in this article, which provides a cohesive description of the solutions currently being developed.

In **Chapter X**, "Dealing with 3D Surface Models - Raster and TIN" by Md Mahbubur R. Meenar and John A. Sorrentino, the authors contribute their expertise to the puzzle of digitally portraying a 3D surface both with raster data and a Triangulated Irregular Network (TIN). The six ways of mapping a 3D surface are introduced and these two methods are thoroughly explored and the pros and cons of each are weighed. There are many applications for inquiry, from hydrological modeling and geo-morphology to civil and other engineering. These applications, as well as future trends, are included in this chapter.

"Web Map Servers Data Formats ", **Chapter XI**, by Yurai Núñez-Rodríguez is an introduction to the most typical types of data provided by such servers, which are map images; though some serve as feature

descriptions as well as other properties. Map image formats can be divided into two main classes: raster and vector maps. This chapter shows both formats and the way that they are served on the Web.

Chapter XII, "Overview, Classification and Selection of Map Projections for Geospatial Applications" by Eric Delmelle and Raymond Dezzani, presents a new approach for the general solution of the point-location problem and the particular solution of the point-in-polygon problem (Preparata, 1985) on which they focus their attention. Some of the most efficient solutions for the point-in-polygon problem reduce the solution to a solution of other fundamental problems in computational geometry, such as computing the triangulation of a polygon or computing a trapezoidal partition of a polygon to solve then, in an efficient way, the point-location problem for that trapezoidal partition. Nevertheless, two different methods for solving the point-in-polygon problem have become popular: counting ray-crossings and computing "winding" numbers. Both algorithms lead to solutions with a less-than-attractive cost of O(n), however the first one is significantly better than the second (O'Rourke, 2001). An implementation comparison by Haines (1994) shows the second to be more than twenty times slower.

Section III details the efforts to create an effective method of analyzing terrain and other aspects singular to creating geographical and geological data. One such common problem is addressed in **Chapter XIII**, "About the Point Location Problem." José Poveda and Michael Gould present a new approach for the general solution to the point-location problem and the particular solution to the point-in-polygon problem. Some of the most efficient solutions for the point-in-polygon problem reduce the solution to a solution of other fundamental problems in computational geometry. This chapter explores those solutions and presents a new algorithm to solve this problem.

Chapter XIV, "Classification in GIS using Support Vector Machines" by Alina Lazar and Bradley A. Shellito, addresses the usage of Support Vector Machines (SVM) for classification of remotely sensed data and other spatial data created from Geographic Information Systems (GIS). Variability, noise, and the nonlinear separability property are problems that must be confronted when dealing with spatial data, and SVM have become popular tools for classification and regression as they address most of these problems. This chapter discusses these issues.

Chapter XV, "Network Modeling" by Kevin M. Curtin, reviews the types of networks modeled in geographic applications and describes the graph theoretic bases underlying network models. It also outlines the implementations of network models in GISystems and the analyses performed with those models. The chapter describes future challenges in network modeling.

Chapter XVI, entitled "Artificial Neural Networks," by Xiaojun Yang, introduces the basic structure of artificial neural networks. It also reviews their major applications in geoinformatics, such as regression analysis, time series prediction and modeling, pattern recognition and image classification, and data processing. These are also used to predict and forecast water resource variables such as algae concentration, nitrogen concentration, runoff, total volume, discharge, or flow, as well as urban predictive modeling.

Chapter XVII, "Spatial Interpolation," Xiaojun Yang discusses concept of spatial interpolation, reviewing some commonly used interpolators that are specifically designed for point data, providing several criteria for selecting an appropriate interpolator. Future research needs and new, emerging applications are also presented.

Chapter XVIII, "Spatio-Temporal Object Modeling" by Bo Huang tackles the issue of spatio-temporal object modeling. Numerous spatio-temporal models have been developed. Huang outlines these and shows how the integration of the spatial and temporal components to create a seamless spatio-temporal data model is a key issue that can improve spatio-temporal data management and analysis immensely.

In **Chapter XIX** entitled "Challenges and Critical Issues for Temporal GIS Research and Technologies", May Yuan discusses the critical issues and major research challenges for conceptual and technological developments in temporal GIS are highlighted. There are many sources for research on

this subject and Yuan provides a valuable summary of the temporal GIS research as well as topics for further development.

Chapter XX, "Rough Sets and Granular Computing in Geospatial Information" by Iftikhar U. Sikder, discusses the various aspects of rough set-based approximation modeling of spatial and conceptual granularity. It outlines the context and applications of rough set theory in representing objects with intermediate boundaries, spatial reasoning, and knowledge discovery. It also provides issues that need to be explored in spatial reasoning, knowledge discovery, and data mining.

In ***Section IV***, "Ontologies," the major issues surrounding the ontological debates implicit in the study of Geoinformatics are discussed. Chapter XXI, "Geospatial and Temporal Semantic Analytics" by Matthew Perry, Amit Sheth, Ismailcem Budak Arpinar, and Farshad Hakimpour, focuses on semantic analytics and knowledge discovery in the geographic information science domain. Semantic analytics applications provide capabilities for analyzing relationships and patterns in semantic metadata. So far, research in this area has concentrated on thematic relationships between entities (e.g., the fact that two glycopeptides participated in the same biological process). However, for many domains and applications, spatial and temporal relationships cannot be overlooked. It also discusses the authors' ongoing work in realizing semantic analytics and discovery in all three dimensions of information: thematic, spatial, and temporal.

Chapter XXII entitled "Geospatial Image Metadata Catalog Services," by Yuqi Bai, Liping Di, Aijun Chen, Yang Liu, and Yaxing Wei, analyzes three open catalog service systems. It reviews the metadata standards, catalog service conceptual schemas and protocols, and the components of catalog service specifications. This chapter also provides conclusions from the review of three public catalog services and the challenges met and created by their approaches.

Chapter XXIII, "Geospatial Semantic Web: Critical Issues" by Peisheng Zhao, Liping Di, Wenli Yang, Genong Yu, and Peng Yue, discusses geospatial ontology and geospatial reasoning in relation to the Geospatial Semantic Web. These two components are the foci that elaborated in the two sections of this chapter. Two application cases are presented to show the syndicated achievements of the Geospatial Semantic Web and a short summary is given at the end.

Section V, "Distributed Geoprocessing", explores the ways to decrease the centralization and increase the interchangeability of geoprocessing and, in particular, geospatial data. "Geospatial Web Service Chaining" by Carlos Granell, Michael Gould and Miguel Ángel Esbrí, outlines the highly distributed Web services model in which geospatial data is loosely coupled with the underlying systems used to create and handle them, and geo-processing functionalities are made available as remote, interchangable, interoperable, and specialized geospatial services. The implications and possibilities of chaining these Web services are explored and defined and the future of geospatial Web service chaining is debated.

Chapter XXV is entitled "Multi-agent Systems for Distributed Geospatial Modeling, Simulation and Computing," by Genong (Eugene) Yu, Liping Di, Wenli Yang, Peisheng Zhao, and Peng Yue. Multi-agent system is specialized in studying the collective effects of multiple intelligent agents. An intelligent agent is a computer system with autonomous action in an environment. This technology is especially suitable for studying geospatial phenomena since they are complex in nature and call for intertwined actions from different forces. This chapter describes multi-agent systems and their application in geospatial modeling, simulation, and computing. Geospatial data integration and mining are discussed.

Chapter XXVI, "Towards Automatic Composition of Geospatial Web Services," by Peng Yue, Liping Di, Wenli Yang, Genong Yu, and Peisheng Zhao, explores the wide application of Web service technologies to the geospatial domain, and how they open the challenge for geospatial Web service composition. This chapter introduces techniques for automatic Web service composition and current progress related to the geospatial domain. The key considerations discussed in this chapter offer a guide to the further exploration of this subject.

In **Chapter XXVII**, "Grid Computing and Its Application to Geoinformatics" by Aijun Chen, Liping Di, Yuqi Bai, and Yaxing Wei, grid computing is introduced and applied to geoinfromatics. Grid computing, defined in the mid-1990s, has appeared as a new E-Science Information Technology for addressing the formidable challenges associated with the integration of heterogeneous computing systems and data resources. The many implications for geospatial datasets and, in particular, the Open Geospatial Consortium are analyzed and further applications of this developing technology are presented.

Chapter XXVIII, "Sharing of Distributed Geospatial Data through Grid Technology," by Yaxing Wei, Liping Di, Baohua Zhao, Guangxuan Liao, Aijun Chen, and Yuqi Bai further analyzes the capabilities of grid technology. With the advancement of geoscience, more and more complex geospatial algorithms involving geospatial data from multiple sources and domains are designed. Contrary to their past monolithic design and implementation, current computing trends suggest new geospatial applications will be distributed and used in heterogeneous network environments. The capabilities to efficiently access and share the tremendous amount of distributed geospatial data are crucial to geospatial applications. This chapter discusses the potential to develop those capabilities through grid technology.

Section VI, "Location-Based Services", describes the issues surrounding the ability of geoinformatics to recognize and utilize location. **Chapter XXIX**, "Cognitively Ergonomic Route Directions" by Alexander Klippel, Kai-Florian Richter, and Stefan Hansen, provides an overview of elements of cognitively ergonomic route directions. Cognitive ergonomics, in general, seeks to identify characteristics of cognitive information processing and to formalize these characteristics such that they can be used to improve information systems. For route directions, an increasing number of behavioral studies have, for example, pointed to the following characteristics: the use of landmarks, changing levels of granularity, the qualitative description of spatial relations. It also details these aspects and additionally introduces formal approaches that incorporate them to automatically provide route directions that adhere to principles of cognitive ergonomics.

Chapter XXX, entitled "Multicast over Location-Based Services" by Péter Hegedüs, Mihály Orosz, Gábor Hosszú, and Ferenc Kovács, details the potential found in combining to different technologies. The two basically different technologies, LBSs in mobile communication and the well-elaborated multicast technology are merged in the multicast via LBS solutions. As this chapter demonstrates, this emerging new area has a lot of possibilities, which have not been completely utilized.

Chapter XXXI, "Routing", by Kevin M. Curtin, discusses the formulation of routing problems including the shortest path problems, and will review in detail general vehicle routing problems and the traveling salesman problem. Solution procedures for routing problems are discussed and future trends in routing research are outlined.

Chapter XXXII, "Location Privacy" by Matt Duckham, raises a number of issues surrounding the ever-growing capabilities of geoinformatics. Location privacy can be defined as the claim of individuals to determine for themselves when, how, and to what extent information about their geographic location is communicated to others. Location privacy has become an especially important issue in geoinformatics because of the emergence of location-aware computing. This implication of the interaction between these technology and personal rights is explored in this chapter.

Chapter XXXIII "Location-Based Performance Tuning in Mobile Sensor Networks" by Vladimir I. Zadorozhny, considers the location-based approach for performance tuning that significantly facilitates the challenge of utilizing Mobile Sensor Networks. The authors introduce mobile nodes that can be deployed in conjunction with stationary sensor nodes to perform mission critical surveillance and monitoring tasks. It details the past advances in this field and discusses other approaches to this challenge.

In **Chapter XXXIV** entitled "Location-Based Services - A Taxonomy on Theory and Practice" by Henrik Hanke and Alf Neumann, re-emphasizes the term service, including information and functionality, which is offered by LBS applications and consumed by customers and sheds light on the ubiquitous infor-

mation management approach as important foundation for advanced mobile data services. Furthermore, the chapter provides an overview of the essential service concepts and relevant implications, challenges and opportunities that can be derived from the application context of LBS. Finally, a taxonomy on theory and practice is presented that draws the link from the technology to the service.

Chapter XXXV, "Coupling GPS and GIS", by Md Mahbubur R Meenar, John A. Sorrentino, and Sharmin Yesmin, discusses the use of a Global Positioning System (GPS) as a method of collecting locational data for Geographic Information Systems (GIS) and increasing in popularity in the GIS community. GIS data is dynamic – it changes over time, and GPS is an effective way to track those changes (Steede-Terry, 2000).

Chapter XXXVI is entitled "Modern Navigation Systems and Related Spatial Query" by Wei-Shinn Ku, Haojun Wang, and Roger Zimmermann. With the availability and accuracy of satellite-based positioning systems and the growing computational power of mobile devices, recent research and commercial products of navigation systems are focusing on incorporating real-time information for supporting various applications. In addition, for routing purposes, navigation systems implement many algorithms related to path finding (e.g., shortest path search algorithms). This chapter presents the foundation and state-of-the-art development of navigation systems and reviews several spatial query related algorithms.

Chapter XXXVII, "Location Privacy in Automotive Telematics" by Muhammad Usman Iqbal and Samsung Lim presents a background on location privacy and some possible privacy abuses of telematics services. Existing approaches to curb these abuses are investigated as well. The chapter then suggests possible measures to strengthen location privacy, especially highlighting the necessity of building sufficient privacy into new technology to make privacy integral from the start.

Chapter XXXVIII, entitled "Map Matching Algorithms for Intelligent Transport Systems" by Mohammed A. Quddus features an in-depth literature review on map matching algorithms and suggests the future trends in map matching research. It also describes methodologies used in map matching algorithms as well as future trends in the development of map matching algorithms.

Section VII, "Management", discusses the problems and potential associated with developing tools to effectively manage data. The first chapter, **Chapter XXXIX**, "A Package-Based Architecture for Customized GIS" by Andrés Pazos, José Poveda, and Michael Gould summarize the expansion of Geographic Information Systems into the public and private sector discussing the challenges associated with this explosion. This discussion leads to their proposal, which is architecture, named CGIS, which allows the optimum distribution and installation of the GIS application, where each user can customize his/her application interactively. The authors introduce this concept and explore it in this chapter.

Chapter XL, "Virtual Environments for Geospatial Applications," by Magesh Chandramouli and Bo Huang, explores the application of virtual environments to 3D geospatial visualization, animation, and interaction. The authors describe the design and implementation of some 3D models, which offer a good level of user-interaction and animation. This chapter discusses related issues such as the constraints in progressive terrain rendering, geographic data modeling, photo-realism in virtual worlds, and the system performance with relatively larger files.

Geospatial predictive models often require mapping of predefined concepts or categories with various conditioning factors in a given space. **Chapter XLI** "Managing Uncertainty in Geospatial Predictive Models" by Iftikhar U. Sikder, discusses various aspects of uncertainty in predictive modeling by characterizing different typologies of classification uncertainty. The authors argue that understanding uncertainty semantics is a perquisite for efficient handling and management of predictive models.

Chapter XLII, "Geographic Visual Query Languages and Ambiguities Treatment" by Arianna D'Ulizia, Fernando Ferri, and Patrizia Grifoni, briefly reviews the approaches used for the definition of visual querying for spatial databases. The chapter also illustrates problems with ambiguity treatment in

these kinds of visual languages and classifies different languages on the grounds of methodology adopting to resolve the problem of ambiguity is proposed. Lastly, some future perspectives on the growth of visual languages for spatial databases and conclusions are presented.

This handbook of research concludes with a section of selected readings, intended to further enhance and inform the existing content. The first of these chapters, "GeoCache: A Cache for GML Geographical Data" by Lionel Savary, Georges Gardarin, Karine Zeitouni, this chapter introduces a novel cache-based architecture to optimize spatial queries over GML encoded data. A new cache replacement policy is then proposed. It takes into account the containment properties of geographical data and predicates, and allows evicting the most irrelevant values from the cache. Experiences with the GeoCache prototype show the effectiveness of the proposed architecture with the associated replacement policy, compared to existing works.

Chapter XLIV, "Cognitive Mapping and GIS For Community-Based Resource Identification " by Lyn Kathlene, describes and analyzes the effectiveness of two methodological techniques, cognitive mapping and geographical information systems (GIS), for identifying social service resources. It also examines the processes used to integrate hand-drawn map information into geocoded data points and provides recommendations for improving efficiency and precision.

Chapter XLV, "Collaborative Mapping and GIS: An Alternative Geographic Information Framework" by Edward Mac Gillavry, describes the technical and social developments that underpin this revolution in map making. It presents a framework for an alternative geographic information infrastructure that draws from collaborative mapping initiatives and builds on established web technologies. Storing geographic information in machine-readable formats and exchanging geographic information through web services, collaborative mapping may enable the "napsterisation" of geographic information thus providing complementary and alternative geographic information from the products created by national mapping agencies.

Within **Chapter XLVI**, "Semantic Interoperability of Geospatial Services" by Iftikhar U. Sikder and Santosh K. Misra, the authors propose a multi-agent based framework that allows multiple data sources and models to be semantically integrated for spatial modeling in business processing. The chapter reviews the feasibility of ontology-based spatial resource integration options to combine the core spatial reasoning with domain-specific application models. The authors propose an ontology-based framework for semantic level communication of spatial objects and application models and then introduce a multi-agent system (OSIRIS – Ontology-based Spatial Information and Resource Integration Services) to semantically interoperate complex spatial services and integrate them in a meaningful composition.

Chapter XLVII, "Biometric Authentication in Broadband Networks for Location-based Services" by Stelios C. A. Thomopoulos and Nikolaos Argyreas addresses some of the issues associated with the use of biometric ID for user and apparatus authentication over broadband wireless networks (e.g. GPRS, UMTS, WiFi, LANs) and narrow band local networks (e.g., BlueTooth, Zigbee, PANs, BANs).

The concluding chapter of this section, "Design and Implementation Approaches for Location-Based, Tourism-Related Services" by George Kakaletris, Dimitris Varoutas, Dimitris Katsianis, Thomas Sphicopoulos, presents the key concepts, capabilities and considerations of infrastructures and applications targeted to the mobile tourist, covering data and content delivery, positioning, systems' interactions, platforms, protocols, security and privacy as well as business modelling aspects.