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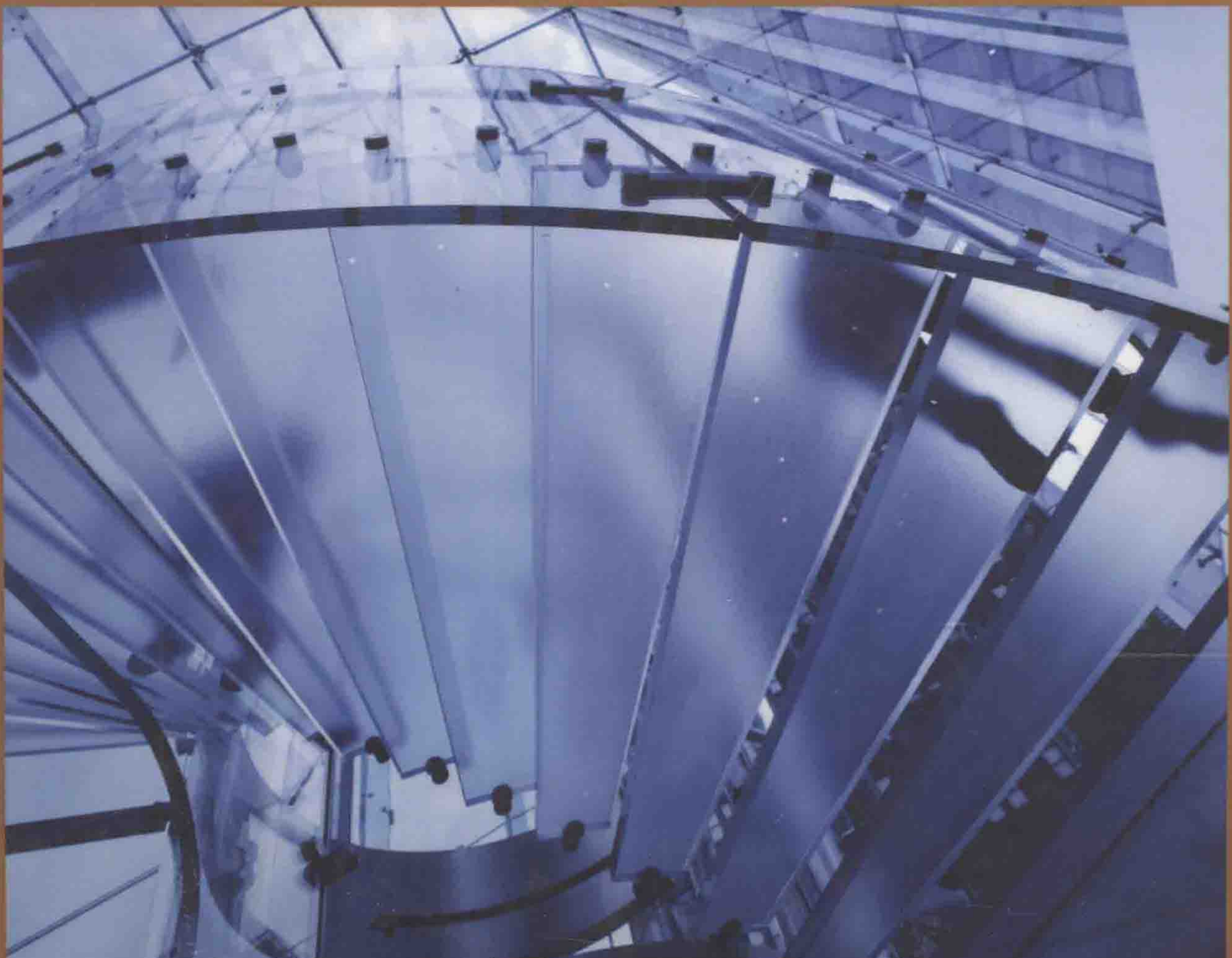
Geospatial Web Services

Advances in Information Interoperability



Peisheng Zhao & Liping Di

Geospatial Web Services:

Advances in Information Interoperability

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Foreword

Two decades ago geospatial Web services, the subject of this book, would have been almost impossible to imagine. The first Web browser was still three years away, and while the Internet was among the most successful of the various competing electronic networks, it was by no means as dominant as it became five years later. Geospatial services were provided by geographic information system (GIS) software operating on stand-alone Unix machines or on minicomputers and delivered over local-area networks. The notion that one day it would be possible to invoke services from remote machines using simple interfaces would have seemed like an impossible dream.

How far we have come in two short decades. Geospatial Web services are proliferating rapidly, and are familiar to almost anyone blessed with a high-speed Internet connection from a home computer, laptop, or third-generation phone. We rely on such services to find our way in strange cities, to locate businesses, to make hotel reservations, and a myriad of other daily tasks. Moreover most if not all of the more sophisticated GIS operations needed by planners, researchers, resource managers, utility companies, and virtually every other occupation of the 21st Century are also available from industrial-strength GIS servers.

This book comes at an appropriate time, and fills a niche that has emerged recently in the GIS bookshelf. It describes applications of geospatial Web services to many areas of human activity, from research on global environmental change to the planning of transit systems and to emergency management. The core concepts of Web portals, service-oriented architectures, and spatial data infrastructures are covered, and the book identifies and examines some of the fundamental issues, including the granularity of functions, semantics, and the standardization of functionality.

The book will be invaluable to anyone working in this rapidly developing area. Geospatial Web services are an increasingly important part of the education of any GIS professional, but often too new to be treated in any depth in the standard curricula and textbooks. The book will also be an excellent text for more specialized courses, at the upper undergraduate or graduate levels, and as reading matter for practitioners.

The editors and authors are to be congratulated for bringing together such a powerful collection, and for having the foresight to see the potential of this field. Much remains to be done, however, and the field is still in its infancy. It is still difficult, for example, to achieve the holy grail of the spatial join, because so many forms of uncertainty pervade geospatial data. We still do not have a clear, standard taxonomy or ontology of spatial functions, making a mockery of efforts to build systems for search and discovery of geospatial Web services. And while we have many technologies for supporting various aspects of geospatial Web services, it is still difficult for a novice to navigate through the numerous standards and software alternatives. We can be confident, however, that many of these issues will be resolved in time if the research community addresses them with imagination and vigor, and that the task of building a practical, operational application of chained geospatial Web services will become easier with time.

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Michael F. Goodchild *is Professor of Geography at the University of California, Santa Barbara, and Director of UCSB's Center for Spatial Studies. He received his BA degree from Cambridge University in Physics in 1965 and his PhD in geography from McMaster University in 1969. He was elected member of the National Academy of Sciences and Foreign Member of the Royal Society of Canada in 2002, member of the American Academy of Arts and Sciences in 2006, and Foreign Fellow of the Royal Society in 2010; and in 2007 he received the Prix Vautrin Lud. He was editor of Geographical Analysis between 1987 and 1990 and editor of the Methods, Models, and Geographic Information Sciences section of the Annals of the Association of American Geographers from 2000 to 2006. He serves on the editorial boards of ten other journals and book series, and has published over 15 books and 400 articles. He was Chair of the National Research Council's Mapping Science Committee from 1997 to 1999, and currently chairs the Advisory Committee on Social, Behavioral, and Economic Sciences of the National Science Foundation. His current research interests center on geographic information science, spatial analysis, and uncertainty in geographic data.*

Preface

W3C defines a Web service as a software system designed to use standard protocols to support interoperable machine-to-machine interactions (publication, discovery, access, and orchestration) over a network. As Web services technology has matured in recent years, a new scalable Service-Oriented Architecture (SOA) is emerging as the basis for distributed computing and large networks of collaborating applications. Meanwhile, an increasing amount of geospatial content and capabilities are available online as Web services. This increase significantly enhances the ability of users to collect, analyze and derive geospatial data, information, and knowledge. Geospatial Web services are designed to use Web service technology to deal with spatial information over the network. They provide a promising approach to interoperability for distributed heterogeneous geospatial data and applications. SOA and geospatial Web services are changing the way in which spatial information applications and systems are designed, developed, and deployed. Therefore, the field of geospatial Web services is emerging as one of the most desirable research areas of geospatial information.

The term geospatial Web service involves not only service technology, but also domain-specific conceptual, methodological, technical, and managerial issues. Such issues include new geospatial SOA frameworks for building cutting-edge interoperable geospatial applications, the basic knowledge and recent progress of standards for interoperable geospatial Web services, the techniques for design, development, deployment, and operation of geospatial Web services, the mechanisms of geospatial Web service registration and discovery, the theories and applications of the geospatial Semantic Web, and the models, methods, languages, and tools of geospatial Web service orchestration. This book provides comprehensive and in-depth academic descriptions, empirical research findings and applications, and future challenges and emerging trends for geospatial Web services.

This book is organized in seven (7) distinct sections, each addressing a state-of-art topic in geospatial Web services: Standards, Design and Implementation, Registry and Discovery, the Semantic Web, Distributed Computing, Workflows, and Applications.

Interoperability is achieved by using standards. Section I explores geospatial interoperability standards. The Open Geospatial Consortium (OGC), a non-profit, international, voluntary consensus standards organization, has developed a set of specifications aimed at the full integration of "geo-enabled" Web services into mainstream computing to make complex spatial information and services interoperable and useful with all kinds of applications. The OGC Web service specifications have been widely accepted by the geospatial communities. Some of them are becoming International Organization for Standardization (ISO) standards. As seen in Chapter 1, Carl Reed introduces the background of the OGC Web services and provides information on the OGC Reference Model and the importance of reference architecture for the successful deployment of applications using OGC and related standards. This chapter highlights the

OGC Web service architecture and relevant key OGC Web services standards. It also discusses planned work on the OGC Web services standards baseline as well as reflections on the impact of current technology trends, such as the mobile internet and cloud computing.

Designing and implementing a geospatial Web service with high performance and better reliability presents developers and architects with an interesting set of problems. Approaching service development armed with just the underlying technologies, such as SOAP and WSDL, is not sufficient. Design issues and patterns related to the geospatial domain must also be studied. Section II, which consists of chapters 2-4, discusses several basic aspects of service design and implementation that facilitate building a better geospatial Web service.

Choices relating to granularity affect service interfaces, data storage and organization, and XML format design. Chapter 2, authored by Elias Ioup and John Sample, highlights the importance of analyzing usage and performance requirements when choosing granularity in the design of a geospatial Web service and provides common examples that explore the different approaches to granularity which are available.

Use of geospatial Web services in mission-critical applications and business processes nonetheless raises important quality concerns. Chapter 3, authored by Richard Onchaga Moses, identifies and elaborates quality concerns and uses data quality and quality of service to define a quality model for geospatial Web services. An ontology framework that explores ontologies to provide a consistent set of concepts to unambiguously define and reason about the quality of geospatial Web services is presented. The chapter also proposes domain middleware to facilitate efficient and cost-effective quality-aware chaining of geospatial web services.

Enabling the commercial use of geospatial Web services in an on demand and ad-hoc fashion highly depends on the efficient mechanisms of security and licensing. Chapter 4, authored by Bastian Schäffer and Rüdiger Gartmann, presents an approach that goes beyond classical Role-Based Access Control models to support ad-hoc license agreements directly in process, without any prior offline negotiated agreements being necessary between service provider and service user for on-demand access. In particular, this chapter focuses on state-of-the-art interface specifications from OGC and defines generic security extensions that are applicable to all OGC standards based on OGC Web Service Common. The static model with trust relationships between the different components of the architecture in heterogeneous security domains as well the dynamic structure is studied.

As the number and variety of geospatial Web services has increased rapidly, registration and discovery of a service, which involves domain knowledge, service metadata, and service interfaces, is becoming a major problem. A catalog service acts as an important "directory" role in SOA: service providers register the service availability by using meta-information, thereby allowing service consumers to discover the desired services by querying meta-information. Section III, which consists of chapters 5 and 6, discusses how to use catalog services to facilitate the registry and discovery of geospatial Web services.

Chapter 5, authored by Manil Maskey et al., presents a service registry compliant with the OGC Catalog Service for Web (CSW). It is developed as part of an OGC-sponsored interoperability experiment involving the ocean sciences community. A standards-compliant registry for this endeavor eliminates the need for discovering the services from ad-hoc registries and opens up avenues for the development of automated tools. The implemented catalog service supports OGC Sensor Observation Services (SOS) and additional functionality to minimize requirements on service providers and maximize the robustness of the registry.

One of great challenges in Spatial Data Infrastructures (SDI) is the provision of semantics for high precision searching for the underlying data and services. Chapter 6, authored by Fabio Gomes de

Andrade et al., introduces a distributed catalog service that uses ontologies to describe the underlying information to provide a more accurate search. The proposed catalog service that is able to rewrite and propagate queries to other distributed catalogs allows the catalog services in different SDIs to cooperate and exchange information directly with each other without the traditional problems imposed by a centralized architecture.

The lack of semantics in Web services makes it impossible to implement reliable and large-scale interoperation by computer programs or agents. With Semantic Web technologies, geospatial ontologies can capture the semantic network of the geospatial world. Intelligent applications can then take advantage of these built-in geospatial reasoning capabilities for achieving semantic interoperability. Section IV, which consists of chapters 7-10, discusses the infrastructure, interoperability, and application of the geospatial Semantic Web.

Sven Schade, in Chapter 7, introduces the VIsionary Semantic service Infrastructure with ONtologies (VISION) to depict required components and highlight the most important services of geospatial semantics. Model-as-a-Service (MaaS) is introduced as a central concept for encapsulating geospatial environmental models as services. The German-funded GDI-GRID project is discussed to illustrate the examples of MaaS, the need for different types of ontologies, interoperability challenges arising, and potential uses of grid technology.

Chapter 8, authored by Zhong-Ren Peng et al., shows how to take advantage of geospatial semantic Web services to provide a unique approach to address semantic heterogeneity, through a case study of transportation road networks and transit networks for a transit trip planning system. This approach takes advantages of ontology to provide semantic definitions for geospatial data, and uses spatial query functions of OGC Web Feature Service (WFS) for spatial data searches and relational database search functions for non-spatial data queries. The results show that this approach is more efficient than conventional methods of converting all data into ontology instances, as it avoids the costs and consistency problems of data replication.

The Linked Data enables data providers to use the existing links, tags and annotations to help users connect to other related geospatial data. Carlos Granell et al., in chapter 9, propose a Linked Data approach to SDI and suggest it as a way to combine SDI with Volunteered Geographic Information (VGI). This chapter details different implementing strategies, gives examples, and argues for the benefits of this method, while at the same time trying to outline possible fallbacks. The approach presented is a way towards a single shared information space.

A geospatial portal is a gateway of distributed geospatial data, tools and services. Ontology and semantics play an increasingly important role in geospatial portals due to the demand of interoperability. Chapter 10, authored by Naijun Zhou, provides an updated overview of geospatial portals followed by detailed discussion on how the ontological and semantic technologies are incorporated into geospatial portals. Three recent research and practice of geospatial portals are briefly introduced as the case studies of service-oriented portals.

Many geospatial applications involve not only distributed heterogeneous data, but also special processing capabilities available at remote sites. With the advances in network bandwidth, computing platforms and the standardization of Geospatial Web Services, it is possible to implement distributed geospatial computing over the Web. Section V, which consists of chapters 11 and 12, discusses the current state-of-the-art of approaches to distributed geospatial computing.

Enalbing geospatial processing over the Web is a key aspect of the requirements for distributed computing. Chapter 11, authored by Theodor Foerster, explores the current state-of-the-art approach to distributed geoprocessing. This chapter discusses the OGC Web Processing Service, workflows, Quality of Service, and legacy system integration. It uses two scenarios to introduce related concepts and demonstrates different applications for distributed geoprocessing.

Cloud computing is a new promising computing platform that delivers software, hardware, and infrastructure as services on demand. Gobe Hobnona et al., in chapter 12, examine the potential for offering capabilities of the Geographic Resources Analysis Support System (GRASS) as a service within a cloud computing. The chapter describes a prototype "Cloud" service that adopts the OGC WPS standard.

Individual Geospatial Web services can be assembled into a workflow to represent a more complicated geospatial model and process flow to achieve desired results. The service-oriented workflow is essential for complex geospatial applications and knowledge discovery over the Web. Section VI, which consists of chapters 13 and 14, discusses some advanced aspects of building workflows.

Chapter 13, authored by Peng Yue et al., addresses key research issues for intelligent chaining of geoprocessing services using the Semantic Web. This chapter discusses a set of applicable solutions, including a common data and service environment, semantic descriptions of geoprocessing services, and a general process for intelligent generation of geoprocessing workflows. A proof-of-concept prototype system and some use cases are demonstrated in this chapter to prove the applicability of the presented approach.

Tino Fleuren and Paul Müller, in chapter 14, discuss executing large-scale geospatial workflows in Grid environments. The chapter presents a workflow enactment system that maintains the robustness of centralized control, but is enhanced by distributed components called proxy services that can communicate with each other to allow for efficient coupling between parallel tasks and avoiding of unnecessary data transfers in Grid environments.

An increasing number of geospatial applications are implemented based on Web services. This increase significantly enhances the ability of users to collect, analyze and derive geospatial data, information, and knowledge. Sections VII, which consists of chapters 15-19, discusses some domain applications that highlight the promise of geospatial Web services for information interoperability.

The Global Earth Observation System of Systems (GEOSS) aims to provide comprehensive, coordinated, and sustained observations of the Earth system. George Percivall, in chapter 15, presents an evolutionary development process and reusable architecture methods for applying Web services to a global scale system of systems for Earth observations. The GEOSS architecture, which is organized and documented in the ISO RM-ODP standard, is explored in this chapter.

For the Earth Observation data to be fully utilized, one of the most important aspects is to adopt technologies that will enable users to easily find and obtain needed data in a form that can be readily used with little or no manipulation. Chapter 16, authored by Wenli Yang, examines the potential for operational and scalable delivery of on-demand personalized EO data using the interoperable OGC Web Coverage Service (WCS). The basic aspects of OGC WCS, such as standards, implementation, performance and scalability, and relevant data, are discussed in this chapter.

To confront the ever-growing volume and complexity of disasters, a highly interoperable, loosely coupled, dynamic, geospatially-enabled information platform with comprehensive situational awareness is required. Chapter 17, authored by Ning An et al., discusses how interoperable geospatial Web services, especially the ones standardized by the OGC, have been used in different phases of emergency management. This chapter highlights that a holistic approach with geospatial Web services will create more value for emergency management.

Elena Roglia and Rosa Meo, in chapter 18, outline the architecture and functionalities of a SOA-based system that integrates sensor data transmitted by a fleet of unmanned aircraft for territorial surveillance and protection from natural disasters. This chapter also addresses a service for the annotation of spatial objects of interest to exploit the on-line information sources continuously updated by the social network communities.

The geospatial Web portal is the gateway to integrating news, information, data, and applications from the geosciences communities. Chapter 19, authored by Weiguo Han et al., introduces the GeoBrain Online Analysis System (GeOnAS): an SOA-based geospatial Web portal. This data-rich and service-centric portal provides the standards-based discovery, retrieval, visualization, and analysis of geospatial data and service. It facilitates geoscience research and education around the world and helps decision-makers and analysts work more efficiently and effectively within an SOA runtime environment.

This book provides researchers, scholars, and other professionals with the most advanced research developments, solutions, and implementations of geospatial Web services. It is expected to provide a better understanding of the strategic role of geospatial Web services in a distributed heterogeneous environment and the life cycle of geospatial Web services for building interoperable SOA-based geospatial applications. The book is also expected to be used in advanced courses as supplemental course material on geospatial interoperability, advanced GIS, and e-Science education.

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Standards

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Section 2
Design and Implementation

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