Ramanathan Sugumaran
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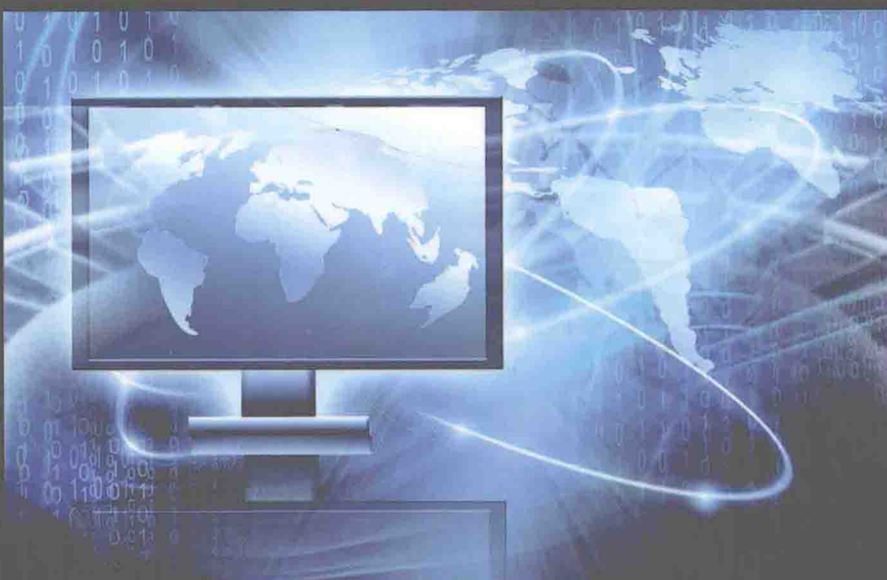
Spatial Decision Support Systems

Principles and Practices



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Dedicated to Grandpa …

Foreword

Geographic information systems (GIS) have been under continuous development for several decades. By now, they are both well known and widely used, and have become integral elements of information technology applications in a wide variety of domains. In its simplest form, GIS software enables users to address a variety of questions that have two root forms: what are the attributes associated with a place and which places have one or more specified attribute(s)? Such systems are particularly helpful when they are used to obtain results for simple queries or to address structured problems that have a well-defined solution process that can be specified and followed as a sequence of steps.

But many problems, particularly those that have a contested public policy component, are neither well structured nor clearly defined. In such cases, different interest groups may not only fail to agree on a solution process for a problem, they may fail to agree on fundamental aspects of its formulation. Consequently, there is no prescriptive process that can be followed to yield a solution. Spatial decision support systems (SDSS) are designed and implemented to address this class of semistructured problems with advanced analytical tools that help people explore a problem, learn about it, and use the information gained to arrive at improved decisions.

This timely book begins with coverage of basic geospatial data handling concepts, methods, and materials. It places the development of SDSS concepts within a historical framework of development and treats important system components with a level of detail that is appropriate for students who may have different backgrounds or be at different stages of intellectual development. Coverage then moves on to demonstrate how these components can be assembled into flexible collections that are used to address particular types of applications. It is here, with the illustration of different component assemblages, that the book coheres by demonstrating how an SDSS can be implemented in the form of a traditional desktop system or using distributed, web-based services. This is done in a way that should prove instructive to both students and their teachers.

I sincerely hope that you enjoy reading and learning from this book and that it will lead you to contribute new insights. I came away from it wishing that the book had been available to me many years ago when I was beginning to struggle with the SDSS concepts that now seem rather straightforward after having read these chapters.

Marc P. Armstrong
Professor and Chair, Department of Geography, The University of Iowa

Preface

Spatial decision support systems (SDSS) are designed to help decision makers solve complex spatially related problems and provide a framework for integrating (a) analytical and spatial modeling capabilities, (b) spatial and nonspatial data management, (c) domain knowledge, (d) spatial display capabilities, and (e) reporting capabilities. The use of SDSS in academic and business communities is increasing. For example, businesses are using sophisticated SDSS to analyze customer information for marketing, customer relationship management, and generating business intelligence to gain competitive advantage. Organizations are also using SDSS for traditional problems such as determining plant locations, where typically only ZIP code information is used. There is also growing interest from planners and managers of resource assessment, environmental analysis, geological exploration, remote sensing, business analyses, soil science, public health, and hazard analysis in developing spatial models and SDSS to support managerial decision making. As the use of SDSS proliferates, there is a great demand for SDSS-related publications, especially books that could be used for training students as well as professionals.

It is evident from the previous examples that there is tremendous interest in the design and deployment of SDSS in various domains. Research on SDSS is also on the rise, which is evidenced by the number of conferences discussing this topic as well as special issues of journals. In addition, there are an increasing number of professional training courses that aim to discuss the fundamentals of SDSS and their applications. With this increased interest and development of SDSS, there is a great need for a comprehensive book that covers the fundamentals of SDSS as well as advanced design concepts for building SDSS. However, currently no such book is available for students, planners and managers, and the research community. Most of the existing materials on SDSS are book chapters, conference proceedings, and journal articles. Many of these are domain or application specific and do not provide a comprehensive treatment of SDSS. In addition to research by the academic community, there have been a number of important developments from vendors and the practitioner community. Hence, there is tremendous opportunity and need for a comprehensive book on SDSS. The primary goal of the authors is to provide a thorough overview concerning the current state of the art in SDSS technology and their application from an interdisciplinary perspective.

The collection in this book consists of four major parts, each addressing different topic areas in SDSS. Part 1, consisting of Chapters 1 and 2, primarily presents an introduction to SDSS and the evolution of SDSS.

Chapter 1 provides an introduction to the importance of spatial decision making and discusses how SDSS supports the spatial decision-making process. The purpose of Chapter 2 is to detail the evolution of SDSS from decision science and geographical information science perspectives.

Part 2 covers the different components of SDSS. Chapter 3 focuses on the spatial database management and spatial analysis capabilities of geographical information science (GIS) software. Chapter 4 focuses on the other components of SDSS, including the model base, user interface, stakeholders, and knowledge components. The focus of Part 3 is the design and implementation of SDSS. Chapter 5 provides an overview of the range of existing SDSS software configurations and covers software that can be used to construct new SDSS. Chapter 6 investigates techniques and technologies for building new SDSS while Chapters 7 and 8 provide examples of desktop and Web-based SDSS development and implementation. In the final part, Chapter 9 provides an overview of SDSS applications from various domains or disciplines with numerous detailed case studies provided. Chapter 10 addresses both technical and organizational challenges that affect the success or failure of SDSS uptake. The chapter concludes by documenting some of the likely future directions of SDSS.

The intended audiences for this book are students as well as professionals working in all decision and geosciences application domains including, but not limited to, resource assessment, environmental analysis and assessment, geological exploration, remote sensing, business analyses, soil science, public health, and hazard analysis. This book will also be of interest to researchers, planners, and managers involved in urban and regional planning. This book will be suitable for teaching at different levels. It will be easy for instructors to adopt because of the organization of its content, which starts with a basic introduction and progresses to advanced step-by-step implementation of SDSS. It also includes creative projects and exercises that instructors can use in introductory or graduate-level courses. This book can also be used by professional trainers that offer short training courses on various aspects of SDSS and their application.

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Secondly, we acknowledge our debt of gratitude to the University of Northern Iowa GeoInformatics Training, Research, Education, and Extension Center (GeoTREE) staff and students. Particularly we would like to thank Scott Larson, Matt Voss, Alexander Savelyev, and Associate Director for the GeoTREE Center Dr. Andrey Petrov for their critical editing of and valuable content suggestions for the book. This book has benefitted greatly from the efforts of these individuals who contributed advice, gave feedback on materials, or helped in testing different software. We have learnt much from discussion and debates with these contributors. The SDSS examples in Chapters 7 and 8 were developed by a number of current and former GeoTREE Center staff. The ArcGIS-based desktop SDSS from Chapter 7 and the ArcGIS Server-based example from Chapter 8 were developed by Dr. Yanli Zhang, currently an Assistant Professor of Water Resources/Spatial Science in the Arthur Temple College of Forestry and Agriculture at Stephen F. Austin State University. The Microsoft Excel Spreadsheet-based AHP SDSS example and the SpreadsheetSDSS Plug-in discussed in Chapter 7 were developed by Dossay Oryspayv. Alexander Savelyev is the primary developer of the OpenSDSS software, which was described in Chapter 7, with contributions from Dossay Oryspayv. Jonathan Voss developed the web-based SDSS using open-source technology described in Chapter 8. Dmitry Ershov developed the web-interface for the SDSS web-portal described in Chapter 9. Matt Clover carried out literature searches and collated many of the articles that were recorded in the SDSS database. Many individuals helped us in administrative matters and in editing, proofreading, and preparation. Our special thanks go to Scott Larson, Jane Gillen (former GeoTREE Administrative Assistant), and Holly Bokelmen for proofreading the manuscript, organizing references, and formatting figures and tables. Thanks also to University of Northern

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Authors

Dr. Ramanathan Sugumaran is Professor of Geography and Director of GeoTREE Center at the University of Northern Iowa. He has over nineteen years of research experience in remote sensing, geographic information systems (GIS), Global Positioning Systems (GPS), and spatial decision support systems (SDSS) with applications for natural resources and environmental planning and management. Dr. Sugumaran has served as PI or Co-PI on over $5 million worth of research grants funded by the National Aeronautics and Space Administration (NASA), Raytheon Corp., the National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of Defense (DOD), the U.S. Department of Agriculture (USDA), Missouri Department of Natural Resources (MDNR), the U.S. Department of Transportation (DOT), and the U.S. Fish and Wildlife Service. He has also published numerous journal articles and presented more than one hundred papers at national and international conferences. Dr. Sugumaran has two PhDs—a PhD in geography from the University of Edinburgh in the United Kingdom and one from the University of Baroda, India. For the past ten years, he has developed and taught several courses and advised more than twenty students on their masters theses. Dr. Sugumaran has also been a recipient of several academic awards that include the outstanding graduate faculty teaching award, Outstanding Scholar award, and Veridian Community Engagement Award.

John DeGroote is a GeoInformatics Scientist at the GeoTREE Center at the University of Northern Iowa. He has been actively applying geospatial technologies for environmental and natural resource applications for nine years. He has experience working on a wide range of issues with a diverse set of investigators including hydrologists, soil scientists, ecologists, and economists. He has extensive experience in developing custom GIS and SDSS applications, using programming and database development, for use by researchers and environmental managers. John has authored or co-authored numerous peer-reviewed articles concerning the use of geospatial technologies for a variety of application domains. He has also presented research at numerous national and international conferences.

Abbreviations

AGNPS: Agricultural Non-Point Source Pollution Model
AHP: Analytic Hierarchy Process
AI: artificial intelligence
AML: Arc Macro Language
ANN: artificial neural networks
API: application programming interfaces
AVHRR: Advanced Very High Resolution Radiometer
AvIMS: ArcView Internet Map Server
CA: cellular automata
CAD: computer-aided design
CLIPS: C Language Interface Production System
COM: Component Object Model
CORBA: Common Object Request Broker Architecture
DBMC: database management component
DBMS: database management system
DCOM: Distributed Component Object Model
DDE: Dynamic Data Exchange
DEM: digital elevation model
DLL: dynamic-link libraries
DNR: Department of Natural Resources
DSS: decision support systems
EDSS: environmental decision support systems
EMDS: Ecosystem Management Decision Support
ES: expert systems
ESRI: Environmental Systems Research Institute
FEMA: Federal Emergency Management Agency
GA: genetic algorithms
GADS: geo-data analysis and display system
GDAL: Geospatial Data Abstraction Library
GIS: Geographic Information Systems
GML: Geography Markup Language
GPS: Global Positioning Systems
GRASS: Geographic Resource Analysis Support Systems
GUI: graphical user interface
HSPF: Hydrological Simulation Program-Fortran
ILWIS: Integrated Land and Water Information System
KMC: knowledge management component
KML: Keyhole Markup Language
LiDAR: Light Detection and Ranging

MCA: multi-criteria analysis
MCDA: multi-criteria decision analysis
MCDM: multi-criteria decision making
MCE: multi-criteria evaluation
MMC: model management component
NDVI: Normalized Difference Vegetation Index
NOAA: National Oceanic and Atmospheric Administration
NTF: National Transfer Format
OGC: Open Geospatial Consortium
OLE: Object Linking and Embedding
OWA: ordered weighted averaging
PSS: planning support systems
QGIS: Quantum GIS
RFID: radio frequency identification
RIKS: Research Institute for Knowledge Systems
RMI: remote method invocation
RS: remote sensing
SAGA: System for Automated Geoscientific Analyses
SC: stakeholder component
SDLC: systems development life cycle
SDSS: spatial decision support systems
SML: Spatial Modeler Language
SOAP: Simple Object Access Protocol
SWAT: Soil and Water Assessment Tool
TIGER: Topologically Integrated Geographic Encoding and Reference System
uDig: User-friendly Desktop Internet GIS
UNI: University of Northern Iowa
VPN: virtual private network
WCS: Web Coverage Service
WFS: (OGC) Web Feature Service
WLC: weighted linear combination
WMS: Web Map Service
WSDL: Web Services Description Language
XML: Extensible Markup Language

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