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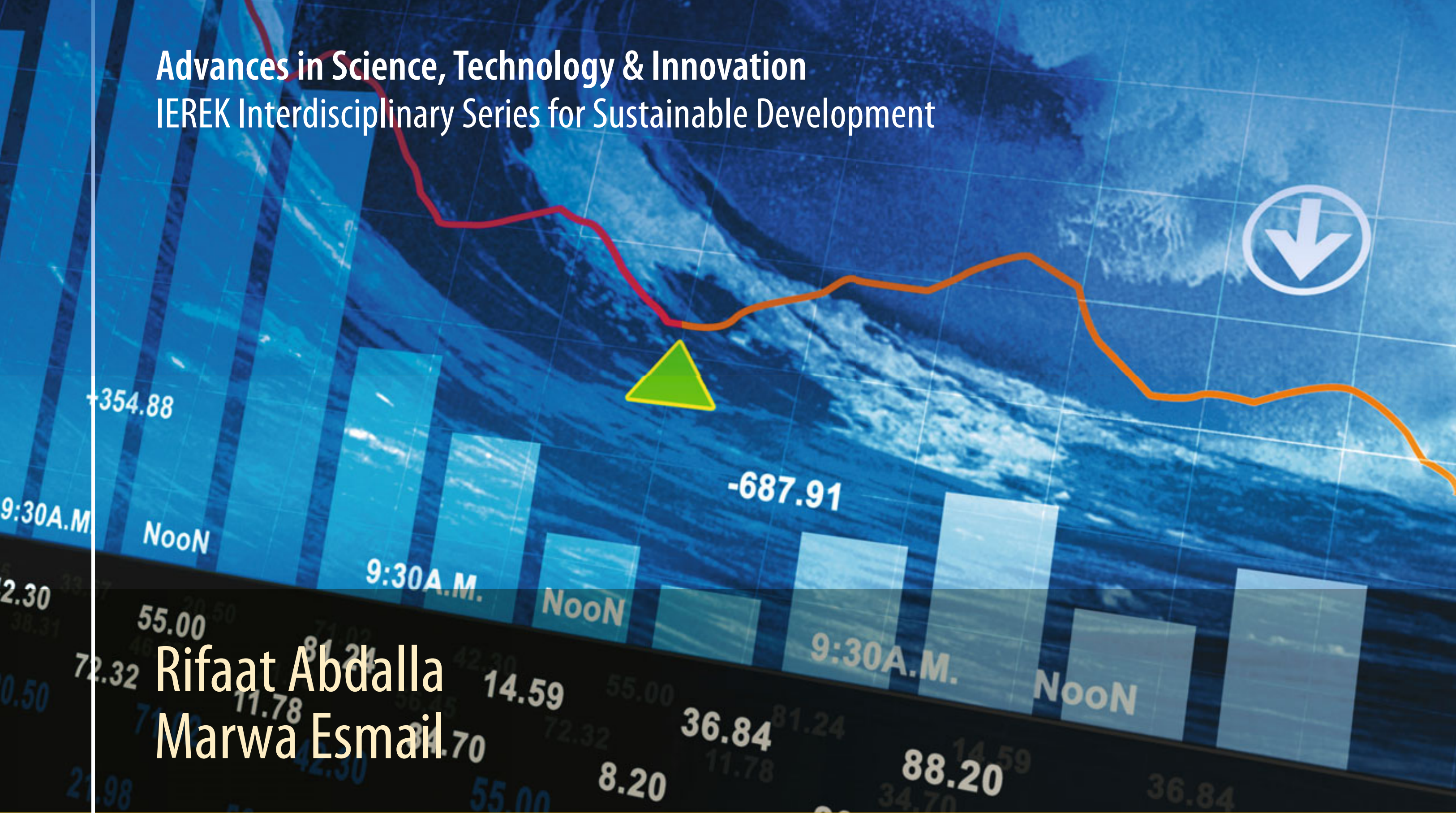

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WebGIS for Disaster Management and Emergency Response

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WebGIS for Disaster Management and Emergency Response

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Mother: Your care has always been an inspirational force for us.

Preface

The application of WebGIS for Disaster Management and Emergency Response provide mechanisms for planning, response and mitigation of the impact of disaster scenarios at the local, regional or national levels. WebGIS for Disaster Management and Emergency Response provides a dynamic link in connecting operational level emergency management practitioners, with planners and decision-makers. The needed timely solutions that support reach to the desired level of effectiveness in protecting life and property. The abundant capability of WebGIS in the way that it provides the ability of freely exchanging geospatial information related to catastrophic events as well as providing remediation solution is enormous. WebGIS links decision-makers and stakeholders with field operators to provide simultaneous information access and decision support to all involved in Disaster Management operations at different level, regardless of the jurisdictions and level of authority. In addition, it allows for a multi-tier decision-making process that incorporates all associated factors, whether it be socioeconomic, or demographic factors. The outstanding multidimensional visualization capability of WebGIS provide means for accessing multiple data sources in real-time.

This book provide strong technologically flavored presentation for the usability of WebGIS for Disaster Management and Emergency Response. It is written in a way that it can provide direct access to the information and knowledge needed with least technical expertise and for wide range of user communities, dealing with the expanded horizon of the inter-disciplinary scope of Disaster Management and Emergency Response. The book is touching on the foundations of GIS, Web Mapping, Artificial Inelegance, Immersive Environments and Cloud Computing, in order to cover all the aspects of Information Technology wide spectrum.

In ten chapters, this book introduces Disaster and Emergency Management Science in the first chapter. The second chapter presents on the basic Concept of Disaster Management and Emergency Response, while the third chapter provides some technical foundations on of WebGIS and the various aspects associated with systems components. The forth chapter introduces the foundations of WebGIS systems and various settings and archectures, associated with WebGIS systems. Techniques and applications of WebGIS to selected Disaster Management scenarios is introduced in the fifth chapter and the basics of Artificial Intelligence utilization in disaster and emergency management are introduced. The seventh chapter discusses Cloud Computing and WebGIS for Disaster and Emergency Management, and the eighth chapter introduces the scope of immersive environments and WebGIS for disaster and emergency management. The ninth chapter highlights the role of Public Participation WebGIS for Disaster and Emergency Management, with some discussion on mobile apps and social media and a means for fast communication that the public can use to share information with decision-makers. Including the concept of crowd sourcing data collection and sharing. The last chapter presents WebGIS decision support capabilities and how it is effective at different levels of decision-making and decision-support for disaster and emergency management.

The authors hope that this effort will bring some value to disaster management and emergency management community, by presenting the scope of utilization of WebGIS with a complete coverage that provides the necessary background for non-technical or less technical professionals and decision-makers that are using WebGIS in their day-to-day activities.

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Dr. Rifaat Abdalla is Associate Professor in the Department of Earth Sciences, College of Science, Sultan Qaboos University. He is specialized in GeoInformatics with focus on WebGIS Applications and Remote Sensing Modeling. Dr. Rifaat Abdalla is a Certified GIS Professional (GISP) and Professional Geoscientist (P.Geo.) from Ontario, Canada. He was with King Abdulaziz University, Jeddah for five years prior joining Sultan Qaboos University in 2017. Dr. Abdalla worked in Oil Industry in Qatar and in UK and was teaching at York University and Ryerson University in Canada. His research interests include Hydrography and Marine Applications for GIS; Modeling and Simulation; Mobile Handheld GIS Visualization; and Disaster Management and Emergency Response Mapping. Dr. Abdalla is a recipient of several prestigious international awards, including the American Society for Photogrammetry and Remote Sensing (ASPRS) PE&RS Best Scientific Paper by ESRI.

Marwa Esmail is a computer scientist, graduated from Faculty of Computer and Information System, Cairo University, with specialization in Information Systems and Decision-Support. Marwa is progressing academic researcher. She has published many research papers and three books in the field of Information Systems, Security and Artificial Intelligence in Arabic language. She has participated in several international conferences. Marwa Esmail has research interests in Introduction to IT for beginners, Big Data and Cyber Security. She is an expert in GIS and the use of Open Source by means of IT frameworks, including Artificial Intelligence and Cloud Computing. Currently, she is working on developing access to different techniques useful in solving many spatial problems and obstacles.

Abbreviations

ADRC	Asian Disaster Reduction Center
AI	Artificial Intelligence
ANN	Artificial Neural Network
DSS	Decision Support System
ES	Expert System
ESRI	Environmental Systems Research Institute
GIS	Geographic Information Systems
MR	Mixed Reality
NRC	National Research Council
NSDI	National Spatial Data Infrastructure
OGC	Open Geospatial Consortium
RS	Remote Sensing
SDLC	Systems Development Life Cycle
SDSS	Spatial Decision Support Systems
UNITAR	United Nations Institute for Training and Research
UNOSAT	United Nations Operational Satellite Applications
VR	Virtual Reality

1 Introduction to Disaster and Emergency Management Science

Introduction

GIS applications in disaster management are progressively turning into a necessary component of disaster and emergency management activities in many parts of the world. The time considerations are extremely critical in emergency management operations. Emergency managers are required to take significant decisions, promptly to provide fast response to extreme situations. The spatial dimension of geospatial data makes it exceptionally critical for decision-makers in the different phases of emergency management operations. It is important for policymakers to have the right information at the ideal time to permit them to react, arrange, or moderate catastrophes. The temporal nature of disasters does not allow emergency managers to gather the critical data, in a timely manner, in many situations. As such, more often, pre-arranged disaster management scenarios are utilized (Becerra-Fernandez et al. 2008). GIS technology is capable of filling up the gap of perception and investigation of simulating emergency scenarios showing various situations and their temporal attributes. This permits disaster managers to have access to sufficient data stored in spatial databases and exhibited in PC-created maps or intuitive models (Miura et al. 2007). GIS can be exceptionally useful to make well-thought counterdisaster response patterns, which can address the overall population. It is a helpful tool in disaster management planning, tabletop activities, and a fundamental element of Emergency Operations Centers (EOCs) (ESRI 1999). GIS gives a component to perception and demonstrating of primary data in different levels of details and for various regions after a disaster strikes. This provides a user-driven approach, which envelops the phases of disaster management, to bolster the procedure of improved primary leadership and builds the level of inclusion of every group of workforce-related exercises and systematic methods (Smirnov et al. 2006).

Disaster and Emergency Management as an Interdisciplinary Science

1. The ability of different government departments at the local, provincial, and federal level to share their data for emergency management.
2. The need for data standards that help with the sharing of data and information.
3. Prioritizing and organizing the "need-to-know" levels, as these relate to emergency management.
4. Information access rights during emergencies and the extent to which this conflicts with privacy regulations.
5. Clear definition for the scope of jurisdictional data and information access.
6. Available Emergency Operations Centers.
7. Clear plans for resource integration during emergency situations. These plans must include the following considerations:
    1. Risk and threads assessment.
    2. What-if scenario modeling.
    3. Maintaining situational awareness.
    4. Allocation of resources and documenting disruptions.
    5. Alerting and notification of communities.
    6. Minimizing vital service disruptions during the response stage.

Although the present WebGIS systems contribute to advanced spatial analysis capabilities, yet new methodologies for investigation, representation, and integration are required to offer additional means for support to urban disaster and emergency management community. The co-locality of an impact because of a series of events may require more progressed spatial analysis answers for giving details about the extent of damage, the cost of harm, the distribution of vulnerable population, the indicators of vulnerability, and the mean for a response. This raises some

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issues with data, and information frameworks of interoperability are essential in giving an available pre-arrangement through spatial analysis. Complex situations such as health-related emergencies are more cumbersome to analyze spatially because of the issues identified with private access to patient's data, and also the difficulty of covering various scales of events in the limited temporal time frame.

Overview of the Role of IT in Disaster and Emergency Management

Disasters are dynamic processes (Alexander 1993) and, by their very nature, are spatially oriented (Waugh 2000). According to Montoya-Morales (2002), most current tools that are used for disaster management focus on the temporal component of the four phases of disaster management, leaving an obvious gap in dealing with the spatial element. The emphasis on the spatial dimension makes GIS technologies ideal for simulating the complex spatial relationships among critical infrastructures (i.e., their interdependencies) while still being able to integrate other modeling tools. Nash et al. (2005) showed that temporal GIS can effectively combine both the temporal and the spatial dimensions. Several studies (including Briggs 2005; Dietzel et al. 2005; Giardino et al. 2004; Gupta and Singh 2005; Abdalla et al. 2006; Laben 2002) outlined the importance of addressing the spatiotemporal effects related to disaster management. These studies have tried to establish an efficient and advanced information system that can accommodate multiple events with the aid of GIS.

The Role of Spatial Technology in Risk and Disaster Management

Risk arises out of uncertainty. It is an inherent part of existence and is the chance of something happening because of a hazard or a disaster, which will affect community and environment.

Risk is the probability or chance that hazard posed. The hazard is a inescapable part of life (Smith 1996). The hazard is the potential; disaster is the actual event (Drabek 1997). Disaster is the result of a hazard affecting a community (Blanchard 1999). Disaster is a source of danger whose evaluation encompasses three elements: risk of personal harm, risk of property, and risk of environmental damage and the acceptability of the level degree of risk (Kovach 1995; Smith 1996). Natural or environmental disaster has the advantages of including both natural and man-made dimensions, such as lithosphere disasters (landslide, subsidence, earthquake), atmospheric disasters (rain, lighting, temperature), hydrosphere disasters (flooding, coastal erosion), biologic disasters (forest fires and wildfire), and technological disasters (oil spills, transport accidents, and failures of constructions), which causes substantial damage/pollute or injury/death to civilian property or persons. The risk is the probability or chance that the hazard posed. Consequently, it can be reduced by primarily preparing a suitable risk management. Risk management is important in protecting community and environment safety, providing better information to make decisions, enabling better asset management and monitory, and improving the perception of community for risks.

Disaster estimating is the foundation in urban risk management that the main aim of risk management is to estimate and predict the loss for the areas which possibly would suffer from disaster with the help of many means of spatial information technique, as well as to analyze the cost, which is possibly produced in the course of carrying the control schemes for disaster protection into execution. Those historical and real-time information can be been gathered by remote sensing, photogrammetric and aerial photographs for determining zones of slope instability, Earth-observing satellite images for mapping and monitoring of different disasters, meteo-satellites for weather conditions and flood hazards prediction and monitoring, radar satellite for hazard monitoring, or other methods and then be handled in Geographic Information System (GIS). It can provide important basis for the selection of the control schemes in each decision-making stage.

Risk management is a process consisting of well-defined steps, which, when taken in sequence, support better decision-making by contributing to a greater insight into risks and their impacts (Sai Global 2003). The first step in the risk management process is focused on the environment to establish the boundaries in which risks are managed, guide decisions on managing risks, and develop risk evaluation criteria. The second step involves identifying the risks which arise from aspects of the environment that will be established from previous step to develop a complete inventory of the risks and what each involves, by selecting suitable techniques to identify potential risks and examining sources of possible risks which pose a major threat to community. Assessing and analyzing the impact of the risks represent the third step, which involves deciding on the relationship between the likelihood (frequency or probability) and the consequences (the impacts) of the risks that be identified. The level of risk should be analyzed in relation to what are currently done to control that risk. Control measures decrease the level of risk, but there may be sufficient risk remaining for the risk to be considered with others. Risk evaluation will be clarified in the following as the activity of risk managing and its outcomes, the degree of control over the risk, the potential and actual losses which may arise from the risk, and the benefits and opportunities presented by the risk. The next step is to treat the risks that be decided as unacceptable by identifying the options which could be used to treat the risks, selecting the best option in terms of its feasibility and cost-effectiveness, preparing a risk treatment plan, and implementing the risk treatment plan.

Disaster risk management is the systematic management of administrative decisions, organization, operational skills and abilities to implement policies, strategies, and coping capacities of the society or individuals to lessen the impacts of natural and related environmental and technological hazards (Strand et al. 2003). Spatial technology makes easier to explore the world and the neighborhood you live in, share knowledge, find opportunities, and make informed decisions. The development of spatial technologies has been driven by the need for better decision-making. Early innovators were motivated by the belief that experts in a wide variety of fields could make better decisions if they had better tools for analyzing and visualizing geographic data (Harrison 2004).

Disaster risk management system addresses the three distinct phases of pre-disaster planning, i.e., early warning, during disaster activities (= response), and post-disaster (includes recovery, relief, rescue, and rehabilitation) (Narain 2003). Early warning in the disaster context implies the means by which a potential danger is detected or forecast and an alert is issued. There are three abilities which constitute the basis of early warning. The first, largely technical ability is to identify a potential risk, or the likelihood of occurrence of a hazardous phenomenon that threatens a vulnerable population. The second ability is that of identifying accurately the vulnerability of a population to whom a warning needs to be directed. The third ability, which requires considerable social and cultural awareness, is communication of information to specific recipients about the threat in sufficient time and with a sufficient clarity so that they take action to avert negative consequences. Establishment of a disaster early warning system requires the development of both local and national risk information capabilities and use of relevant technological applications for rapid and improved warnings.

The spatial technology has the ability to make assessment, estimation of landslide hazard region by creating thematic maps and overlapping them to produce final hazard map that leads to instability in the region by classifying the region to three categories: low, medium, and high risk.

Spatial information technlogy provides a tool that supports researching natural disaster risk management programs like flooding, forest fire, and landslides. Flooding disaster management provides a quick response to the rapid onset of disaster by Flood Early Warning System and Flood Monitoring and Mitigation, hence the use of NOAA AVHRR and GMS data in order to better mitigate and manage disasters.

Spatial information technology is useful in dealing with natural hazards to support increased coordination among multiple programs of risk management by examining the application of these technologies to the task of identifying, analyzing, assessing, treating, and monitoring. The spatial technology can be used for provision of rapid and continuous data for flood forecasting and environmental monitoring, for landslide hazard zoning and assessment, and for forest fire fighting and monitoring.

Geomatics Contribution to Disaster Management

Global natural disasters cause billions of dollars in infrastructure damages, unexpected disruption to socioeconomic activities, and the tragic loss of human lives each year (Fritz and Okal 2008). Remote-sensing techniques and GIS and GNSS tools are frequently used in applications for disaster management in pre- and post-disaster activities. Pre-disaster applications are associated with mitigation and preparedness efforts. Mitigation refers to activities that reduce the vulnerability of societies to the impacts of a disaster, while preparedness refers to activities that facilitate preparation for responding to a disaster when it occurs (Mansourian 2005). Post-disaster applications are associated with response and recovery efforts. Response is related to the immediate and short-term effects of a disaster, while recovery refers to activities that restore communities to pre-disaster conditions, such as reconstruction (Mansourian 2005).

Applications associated with mitigation and preparedness efforts are usually associated with landslide and flood disaster prevention, as part of land use planning studies and/or the identification of vulnerable areas. GIS techniques are commonly used to analyze remote-sensing information, permitting process comprehension and the identification of standards and relationships between variables. In addition, geological, geomorphologic and climatologically information may be combined with risk assessments to provide important planning subsides.

To evaluate areas vulnerable to landslides, methodologies that involve the use of GIS and remote sensing and that have been proposed in recent decades usually analyze land cover maps developed through the classification of satellite images with other map information, such as topography, geology, and geomorphology. Apart from the different geographical areas studied, the differences between landslide studies are usually derived from the model proposed to combine the information in the GIS, the method used to assign the weights for each information layer, the type of satellite image used, and the method used to classify the satellite images. In Lee and Choi (2004), the weights of evidence model (a Bayesian probability model) was used to choose variables (maps) and respective weights. In Gorsevski and Jankowski (2008), the use of rough set theory to accommodate the complex geographical characteristics of landslide susceptibility and to determine rules relating to landslide conditioning factors and landslide events was explored. A multivariate logistic regression model was used in Pradha (2010) to combine variables in the GIS and SPOT and Landsat TM satellite images to map land cover.

GPS technology has been frequently applied in natural disasters and in the monitoring of geophysical phenomena, mainly landslides, which require the application of a different type of GPS technique (Hastaoglu and Sanli 2009). The integration of GIS, remote-sensing, and GNSS data may facilitate the comprehension of climate-related disasters, the identification of slope instabilities (regional scale), an understanding of the geological and geomorphologic controlling factors of seismicity, and the effects of earthquakes on ground structure and infrastructure. All of this information facilitates the compilation of databases on natural disasters and supports humanitarian relief and disaster management activities (Giardino et al. 2012). Although these are good examples of the applicability of GIS, remote-sensing, and GNSS techniques, it is important to demonstrate that the methodologies and information can be shared to achieve results. In addition, the technical staff of risk and disaster management centers must be trained, and the methodologies must be adapted to each specific case.

Frameworks for Disaster Management

The concept of disaster management can refer to the framework defining the policies and guidelines an organization sets up for how to act when a disaster occurs. It can also refer to the actual implementations of such a framework and the activities put into practice for preventing and responding to disasters.

The Sendai Framework for Disaster Risk Reduction was established in March 2015 by the United Nations (UN) and is a non-binding agreement for UN member nations. It is meant to provide guidelines at local, national, regional, and international levels for understanding and reducing risk. The agreement also points at the importance for all levels of society to invest in and enhance frameworks for disaster management. The overall goal being a "substantial reduction of disaster risk and losses in lives, livelihoods, and health and in the economic, physical, social, cultural, and environmental assets of persons, businesses, communities, and countries" (UNISDR 2016).

The United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) is the primary UN organization designated for promoting space-based information in disaster management. The organization is directly bound to the Sendai Framework and is responsible for providing support to countries based on the priorities expressed by the framework. It structures the efforts in disaster management in three main categories: response, rehabilitation, and recovery. These three phases describe efforts being put into action once a disaster has struck and is part of a much wider concept called disaster risk reduction where also preparedness is included (UN-SPIDER 2016).

For disaster management set up by the IFRC, it recognizes that for disaster management to be successful, it has to incorporate preparedness, response, and recovery phases. Preparedness often refers to all the measures taken *before* the event. It might be actions taken on a national level, by a community or an organization to prepare for a disastrous event or to predict such events with the goal of minimizing its effects. Response and recovery on the other hand are actions taken *after* the disaster has occurred (IFRC 2016b).

The Spatiotemporal Dimension in Disaster Management and Emergency Response

The first representation of geographic space for use with a computer is generally attributed to Tobler (1959) who created what is called computer maps in the late 1950s. The 1960s witnessed the development of the first GIS systems in Canada and the USA (Longley et al. 2001). The first operational GIS was designed by Environment Canada in 1968 in order to handle the natural resources inventory (Peuquet 2002). A major development in temporal capabilities of geographic data models and GIS began in the late 1980s with the groundbreaking work of Langran and Christman (1988). According to Peuquet (2001), there were a number of efforts to build geographic databases and prototype systems specifically intended for space–time data by the early 1990s.

A temporal GIS (i.e., "typical" GIS) neglects both the dynamics of natural processes as well as the dependencies resulting from these dynamics (Christakos et al. 2002). Disaster management requires a clear understanding of the physical mechanisms and processes underlying a given disaster scenario. Temporal GIS combines scientific modeling with information technology in order to derive knowledge about phenomena that occur in the spatiotemporal domain and to satisfy particular user needs in an efficient way (Christakos et al. 2002). A GIS always represents the space. Representation of time in addition to the space in a GIS is challenging (Peuquet 2001). The following sections outline the history, approaches, and research issues pertain to temporal GIS.

Many research efforts, including Briggs (2005), Dietzel et al. (2005), Giardino et al. (2004), Gupta and Singh (2005), Erharuyi and Fairbairn (2003), and Goodchild et al. (1993), have outlined the importance of addressing the spatiotemporal aspects of disaster management. Langran (1992) listed five approaches for presenting temporal GIS, which are:

1. 4D modeling: This provides an additional cartographic dimension for representing time.
2. Temporal boundaries of objects: This presents past events as a spatial time series.
3. Space–time cubes: This is a three-dimensional cube that represents one temporal and two spatial dimensions.
4. Sequence snapshots: This is a sequence of "time slice snapshot." The character of each time slice is captured separately.
5. Space–time composites: This is presented by flattening the 3D space–time cube into a two-dimensional space.

Given the time-critical nature of most disasters, it is not unexpected that temporal GIS functions are potentially very important in disaster management scenarios where GIS is implemented. Typically, these functions provide disaster management decision-makers with a wealth of knowledge about historical events, the current situation, event development, and prediction capabilities about what the situation would look like in the future. Langran (1992) lists six major temporal functions. Table 1.1 explains these five functions.

There is substantial number of temporal GIS models that have been developed and used by many researchers. Mennis and Fountain (2001) propose an approach to integrate historical scenarios in GIS using relational databases time-normalization techniques. Sperry et al. (2001) proposed an object-oriented database model that utilizes a lineage metadata model for the management of the evolution of geographical objects and the generation of historical queries. Allen et al. (1995) proposed a generic model for explicitly representing causal links within a spatiotemporal GIS using an object-oriented approach. Elawad et al. (2005) used GIS-based time series analyses to show the change in flood spatial extent over time (i.e., the Qu'Appelle River, Saskatchewan and the Red River, Manitoba, respectively). Particular techniques, like distance decay and interpolation, as shown by Longley et al. (2001) are very effective in providing continuous interpolation based on the weight of adjacent cells over time. One of the limitations with spatiotemporal models is that they require continuous update and modification.

Most of the early research on the temporal capabilities in geographic data models has focused on incorporating the temporal domain. Peuquet (2002) indicate that there is a need for theoretically sound and practically efficient methods of spatiotemporal analysis and mapping. Temporal GIS research has tended to focus on representing a single history through a series of "temporal states" (Nash et al. 2005). Peuquet and Niu (1995) indicate that the GIS limitations of the effective utilization of change dynamics processing time have received substantial attention. Given the increasingly urgent need to better understand dynamic processes involved with disaster management, many researchers, including Le Menach et al. (2005), Mennis et al. (2000), Peuquet (1988), Peuquet (2005), Renger et al. (2002), have continuously worked toward advancing the temporal aspects of GIS. Wang et al. (2005) indicate that there is still work required in order to achieve the satisfactory integration of environmental models with GIS in order to facilitate effective decision-making processes. Ellis (1999) discusses specific research issues in specific areas. Some of these issues are discussed by including structure and representation of space and time and graphical user interfaces for visualization of GIS temporal models.

Functional Capabilities of GIS in Disaster Management and Emergency Response

The work reported by Abdalla and Tao (2005) is among the very few studies that have highlighted the contribution of GIS in the new field of infrastructure interdependency. There are many GIS analytical techniques that are useful for infrastructure interdependency modeling. In this section, the utility of these techniques for addressing particular issues

Table 1.1 Six major temporal GIS functions (after Langran 1992)

Function	Description
Inventory	Store a complete description of the study area, and account for changes in both the physical and world and computer storage
Analysis	Explain, exploit, or forecast the components contained by and the processes at work in a region
Updates	Supersede outdated information with current information
Quality Control	Evaluate whether new data is logically consistent with previous versions and states
Scheduling	Identify or anticipate threshold database states, which trigger predefined system responses
Display	Generate a static or dynamic map, or a tabular summary, of temporal processes at in work in a region

related to infrastructure interdependency research will be highlighted.

Attribute-Based Analysis

The power of GIS stems from its capacity to combine both the spatial attributes and the graphical representation of the feature. There are powerful analytical functions that can be used to model critical infrastructure interdependency. Functions like *Query Within* can provide very useful information about particular sector elements within a specific location. The *Summarize Table* function can provide important information about a specific subset of attributes for a particular location. The *Index Attributes* attribute functions can provide details about indexing critical elements for a particular infrastructure sector unit.

Node-Based Feature Analysis

Node-based feature analysis or point analysis can provide useful information when modeling LBII. Functions like *Distance* can provide actual distance information between different critical infrastructure sectors, or between critical facilities, like hospitals, schools, and others. Point-based analysis can also provide very useful information through *Attribute Analysis;* for instance, point features for emergency medical services can provide many attributes about coverage area, available emergency service capacity, and possible emergency service alternatives at peak times.

Area-Based Analysis

Area-based analysis provides advanced functions for polygon features. Functions like *Dissolve* and *Eliminate* can be used for simulation of "what-if" scenarios. This can provide detailed information about new polygon features that might be created, with respect to areas, neighboring infrastructures, and adjacent facilities. *Clip* operations can be used in conducting polygon-based analysis to show what features might look like in extreme situations. Particular features can also be *Split*. *Buffer* operations can be used as spatial constraints in particular sectors; for example, the user can identify a buffer of a 500 m zone around one or more features.

Network-Based Analysis

Network-based analysis provides a wealth of GIS operations that can be used for modeling infrastructure interdependency. Network operations include line operations such as buffer, which can be used to apply a buffer of a specific distance around a feature on an infrastructure layer. The dissolve operation can be used to unify features (e.g., the dissolve operation can be used to dissolve two line segments into one line). Intersect can be used to perform feature intersection operations; for instance, in simulation modeling this function can be used to provide information about location attributes that might need to be split as a result of intersecting with a particular feature. Optimal Route Finding is very useful in determining the shortest path between two locations. In emergencies, this can be of use when trying to determine the optimal path between facilities and services.

Raster-Based Analysis

Raster-based analysis provides functionality that is of importance when dealing with elevation data and with image analysis. There are a number of 3D analysis functions that are based on raster analysis. These include contouring, which can be used to provide linear elevation features derived from an elevation grid. This function can be of great use in modeling density grids for a particular distribution. Slope and aspect analysis and Hill Shade analysis are also important and provide information, for instance, when dealing with flood analysis. This information can be of great practical importance, since it provides the user with details about the elevation and the terrain.

Advances in the Use of Internet GIS for Disaster Management

Disasters are complex events "concentrated in time and space, in which a community experiences severe damage and disruption of its essential functions, accompanied by widespread human, material, or environmental losses, which often exceed the ability of the community to cope without external assistance" (Smith 2004).

Understanding and managing disasters call for specialized data, data networks, and information processing methods and technologies for GIS, disaster simulation, planning and risk assessment (Newkirk 1993).

The information for and about a disaster is not necessarily readily available ahead of time due to highly dynamic and uncertain conditions (La Porte 1999). However, during and post-disaster reveals high levels of access to pooling and sharing of digital resources, skills, and capabilities through the creation of novel and innovative sociotechnological networks.

The integration of the Internet with GIS applications has been applied to such areas as 3D real-time emergency response (Kwan and Lee 2005), serving maps on the Internet for emergency escape routes (Hardin 1998), and mobile GIS and digital video for urban disaster management (Montoya 2003).

The fast developing Web technology has prompted the scientists, experts, and educators to start developing Web-based decision support tools that allow planners and other government decision-makers to utilize a high-resolution DEM and floodplain-related GIS data layers in making floodplain management decisions. Weather forecasts are based on satellite-captured images, which can be accessed through the Internet. Cyclones, tsunamis, and hurricanes can be seen coming through the satellite images. Movement of high/low-pressure winds can be monitored at five-minute interval to help scientists simulate the future scenario. Forecasting and warning regarding natural disasters can easily be made available on the Internet. When any disaster seems to be occurring at one geographic location, Internet tools help the other locations in the world, where people and property might get affected by the same disaster in due course of time, take precautionary actions. Knowledge of flow rate and speed of an occurring flood helps predict its impact in other downstream areas. Similarly, cyclones, forest fires, and volcano lava flow can be observed and monitored in real time using Internet tools. Thus, the Internet technology has become a vital tool in disaster management through sharing of information. Simonovic and Huang (1999) coined the concept of virtual database (VDB) for the management making use of the Internet technology.

Internet GIS is the network-based geographic information services that can utilize wired or wireless Internet to access geographic information, spatial analysis tools, and GIS Web services and allow for broad dissemination of data and analysis results (Peng and Tsou 2003). The integration of these geospatial tools and datasets that allow for Internet access has become a key factor during and after a disaster event. For example, the disaster of the Indian Ocean tsunami revealed the ability to quickly provide remotely sensed images both before and after the event that showed the extent of damage. This occurred through partnerships between software vendors, Internet service providers, and remote-sensing companies.

Integration of remote sensing with GIS and Web technology makes it an extremely powerful tool to identify indicators of potential disasters. Information sharing through Internet reduces data acquisition time and thus providing efficient way to carry out real-time disaster predictions (floods, earthquake, landslide, tsunami, and hurricane, etc.). Changing land use and assessment of its impact on the system in general within reasonable time frame and with greater degree of accuracy becomes possible with new technology. Investment toward making use of the space technology is worth because improvement in instrumentation and real-time prediction will bring about reduction in disaster damages, better prediction, accurate and timely damage estimation, and improved decision-making in planning stages.

Electronic media are critical to linking the sociophysical world with the symbolic world (Samarajiva 2005). The Internet and mobile technologies have been particularly effective in linking disasters to written accounts, photographs and Web diaries, connecting to a larger audience that can vicariously participate in the disaster. Novel uses of satellite imagery, GIS, and Internet technologies are important in translating disaster information to other audiences.

The intersection of formal and informal social networks creates the ODRC that is increasingly using Internet GIS as another form of communication about the disaster. Internet GIS develops due to the capacity for creative innovation, flexibility, and interactive exchange in the spontaneous sociotechnological networks that develop, access to open-source code, and availability of digital data.

The integration of mapping, Global Positioning Systems, satellite imagery, and interactive geographic information systems provides important opportunities for developing and sharing information and techniques. Other innovative developments take best advantage of online resources. Mashups, the mixing of hybrid Web applications from multiple sources but appearing seamless to end users, combine satellite imagery with maps and geospatial data, providing local information using the open application programming interfaces (APIs), for example, Google Maps and Google Earth (Meraz 2006).

Development of Internet GIS exemplifies its multi- and interdisciplinary nature, integrating computer science, communications, geography, emergency planning, and disaster management. Internet GIS for disasters is composed of the following characteristics:

- Networks
  New, informal, and often unofficial sociotechnological networks form—the ODRC. This sociotechnological network represents the recursive connectivity between people and technology, between centralized groups and individual users, and between private and public sectors (Krippendorff 2006). These networks combine social groups through technological capabilities linking groups of informal Internet bloggers and networks of private companies, governmental agencies, and NGOs. Additionally, ad hoc technical networks have been developed that allow for the intersection between wireless and wired infrastructures, mobile technology, and early reestablishment of Internet and computing facilities after a disaster (Bakht 2004).

- Data
  GIS analysis converts raw data (e.g., satellite image) into usable and relevant information. Specific, accurate, and targeted information on local conditions have the potential to be provided to workers and victims in a timely fashion. Satellite imagery is made available and processed via licensure arrangements and networks to provide information. Information may include evacuation routes, shelters, or locations of evacuees. Satellite imagery can depict the geographic extent of the damage and extent of damages done to the built environment, depending on availability, cloud cover, and resolution coupled with GIS overlays of roads, buildings, and infrastructure.

- Delivery
  Data development of products is accomplished via innovative licensing structures with software vendors and data providers as well as GIS users. Downloadable data is available from data providers and widely distributed to aid workers, emergency responders, and decision-makers. During emergencies, software vendors have worked closely with emergency responders to develop necessary data for the emergency event. Due to the hierarchical response of disaster response and the traditional channels for information use and dissemination, not all of this information is necessarily made available to the general public. The ODRC has created Mashups, Web Pages, wikis, and blogs to link people to information sources and provide information in the form of maps.

- Product
  Numerous products have been developed from Internet GIS: multifunctional databases, open-source GIS applications, and specific software applications, services running on the Internet, information, and maps. Integrated and relational databases are the backbone of Internet GIS. Internet GIS for disasters provides technology-based enhancements to further develop multifunctional databases (Montoya 2003). Open-source code is critical to the ODRC for the development of online GIS products for disasters because the user too can change, use, improve, and redistribute the software. In times of emergency and disaster, this ability is particularly important for innovative solutions and applications. Open-source software can be free and can be easily customized to meet a variety of end user requirements. Additionally, the Open Geospatial Consortium, made up of companies, government agencies, and universities, support interoperability across platforms, software, and data types to enhance functionality.

- Interactivity
  Interactive capabilities allow for querying of and adding to databases. Some Web Pages have created interactive capabilities, such as the ability to download or add data. Exactly how Internet GIS is being used as an interactive medium is critical to understand for future use of disaster management systems (Paul 2001).

- Connectivity
  Embedded in this discussion is the assumption that people have access to the Internet. Connectivity is a crucial aspect of Internet GIS, specifically of Internet access generally (Laituri 2003). Other types of connectivity are also important: the extent of support for sharing, exchange and access of data, information and products as well as creating greater connectivity and interaction between the various tiers of the ODRC.

Disaster Management Decision-Making Process

Taking Canada as example, the emergency management system is hierarchical, as summarized in Chap. 1. Response to an emergency typically occurs at the community level. Provincial emergency management offices provide communities with assistance during a major emergency by deploying a community officer (or other members of the provincial emergency response team) to the emergency operations center(s) of the affected community.

For example, local emergency may require collaborative efforts between local, provincial, and federal governments. At the provincial level, most Canadian provinces and territories have local legislation that defines roles and responsibilities and how legal authority is ordered during emergencies at the provincial level. Nevertheless, practical steps involving the decision-making process itself vary between provinces.

Disaster Management Stakeholders

The complexity of the disaster management decision-making process makes it difficult for a single organization to handle it by itself. It is not uncommon, especially in an interdisciplinary field like disaster management, for decision-making to involve an interdepartmental component (e.g., policy, operations, engineering, and command control), which requires expertise in a variety of backgrounds. Etkin et al. (2004) suggest that policies and measures that are available but not sufficiently used can substantially reduce the damage caused by extreme natural events. Economic losses from disasters may be very long-lived, and recovery may be slow. This clearly illustrates the wide involvement of disaster management stakeholders in the disaster management processes.

Decision-making and support tools aided by case studies and scenario development simulations are key research areas in this new field (Traudeu 2004). Risk to a particular infrastructure sector cannot be effectively estimated without complete conceptualization of vulnerabilities and hazards surrounding it (Chang et al. 2002). Research in infrastructure interdependency has evolved very recently as a branch of disaster and emergency management. Following events such as the power blackout of August 2003 in parts of Ontario and the SARS outbreak of 2003 in Toronto, the importance of addressing key questions regarding infrastructure interdependency was recognized.

Summary

Geospatial information technologies, such as geographic information systems (GIS), satellite remote sensing, and crowdsourcing, are important disaster risk management technologies. Geospatial information technology could contribute to pre-disaster activities for disaster risk management. Reviews of geospatial information technologies and how they can be applied in pre- and post-disaster situations will help identify schemes that are more effective.

Internet GIS for disaster management reveals the power of intersecting networks to create new organizational and networking arrangements for addressing disaster and valuing the role of "people as sensors"—to collect information about their locality and disseminate to those in need. It reveals the relationship between geography, communication, and technology. However, disaster management that includes Internet GIS must include an evaluation that demonstrates its utility and success.

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2 Basic Concept of Disaster Management and Emergency Response

Introduction

International Federation of Red Cross and Red Crescent Societies (IFRC) refers to a disaster as "a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using its own resources".

Disasters can be caused by nature and originate from events such as flooding, landslide, cyclones, tsunamis etc. The occurrence of such an event itself does not imply a disaster but when it affects areas where the community is not prepared to withstand the impact of the event, a disaster often follows.

Disaster can also originate from human activities, such as terrorist attacks and wars or from technical failures such as nuclear meltdowns or accidents (Mansourian et al. 2005).

Stallings (2002) indicated that there are no specific research methods that are unique to the field of disaster management. For many years the effects, impacts and issues pertaining to protection from disasters have been the focus of many researchers including Levy and Gopalakrishnan (2005), Murthy (2004), Palm et al. (1990), Schneid and Collins (2001), Steeler (1991), Tierney et al. (2001), Wisner (1995). According to Quarantelli (1995) and Rubin (2000), modern disasters are complex and diverse phenomena with a greater potential for adverse impact. McEntire (2002) indicated that precisely defining the disaster is one of the first issues that stems from research. Many researchers, including Britton (1986), Dynes (1970), and Streeter (1991), have struggled to define disaster. Although disasters have the common result of leaving behind devastation and loss, there is no precise definition for the term "disaster". The bottom line in disaster management is that loss of life and property should be eliminated or minimized, basic needs should be ensured, and business continuity should be secured. The basic requirements of disaster management can be achieved only by interdisciplinary efforts.

Hazard and Risk in the Disaster Management Context

From 1990 to 2005, 6.4% of the population in Canada was evacuated due to disasters resulting from natural hazards. The ability to address risk is a key element in disaster management. Aven (2003) indicates that we need to identify and categorize risk to provide decision support concerning choice of arrangements and measures. Defining risk and hazard as technical terms from a disaster management perspective is crucial. According to McEntire (2002) and Godschalk (1991), incorporating all hazards in the disaster management and planning process is a key strength when addressing disaster management from a Comprehensive Emergency Management (CEM) perspective. This allows hazard and vulnerability to be viewed as a summation of a variety of conditions that define physical and social exposures, disaster resilience, prevent mitigation or preparedness, and post-event response.

A natural hazard can evolve to become a disaster when it affects a human population that is exposed and vulnerable. Figure 2.1 shows the process of the evolution of a disaster and human reaction in each stage. As shown in Figure, human reaction can be negative in the form of vulnerability, or it can be positive in the form of ability to cope with disaster. Based on the process of evolution of hazard, risk assessment methodologies become a key factor in disaster management operations. Ferrier and Haque (2003) have proposed a standard framework for risk assessment for application by a diverse range of decision-makers. Their proposed framework is based on numerical quantitative vulnerability estimation and by assigning a graduate score to particular hazards based on their historical occurrence. The Ferrier and Haque (2003) methodologies aresimilar to the standard methodology adopted by the province of Ontario, which is known as the Hazard Identification and Risk Assessment Methodology (HIRA) Emergency Management Ontario "EMO". According to the HIRA protocol, a

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vulnerability grid can be established based on a standard score that is assigned to hazards in each community, based on historical records and community vulnerability. Hartmann et al. (2004) introduce a new Internet-based disaster response management concept based on dissemination of spatial information to mobile devices. Through this concept, they have integrated risk assessment into disaster response management and provided a strategy to prevent communities from flood inundation impact.

A standardized community-based risk assessment protocol was developed by Emergency Management Australia "EMA" (2002). This framework is based on six major elements, as shown in 2 and discussed below:

1. Risk Context: The first phase is related to the establishment of risk context. In this phase, issues are related to the problem at hand and to the approach of solving it are examined.
2. Hazard Vulnerability: The second phase involves identifying risks in terms of hazard and vulnerability.
3. Risk Analysis: The third phase in this process is—'risk analysis'. In this phase, tools of problem analysis, like "modeling process", are used to analyze risks associated with the problem identified in phase one.
4. Risk Evaluation: The fourth phase is "risk evaluation", in which risks are prioritized and compared against risk evaluation criteria. Risk thresholds are also established in this phase.
5. Communication: The last phase in this process deals with treating risks according to the result of the evaluation. Results obtained from the risk evaluation phase will be communicated to the concerned communities to allow them to implement the disaster management plan (Fig. 2.2).

Disaster Management Cycle

In recent thinking, human adjustment to disasters takes place through a cyclical process. Carter (1991), Killian (2002), and Mileti (1999) have discussed the disaster management cycle as a model that is used to define the process of managing disasters. This model classifies activities into two stages: pre- and post-disaster stages. From an implementation perspective, the disaster management process can be divided into two levels: operational and decision-making (Mileti 1999). The disaster management cycle involves four major phases: preparedness, response, recovery, and mitigation. The activities in these four phases are shown in Fig. 2.3 and are described as follows:

1. **Preparedness**: In this phase, all efforts are focused on understanding needs and addressing the situation in case one or more disasters strike.
2. **Response**: This is the most crucial phase in the disaster management cycle, whereby all efforts are allocated toward providing timely relief.

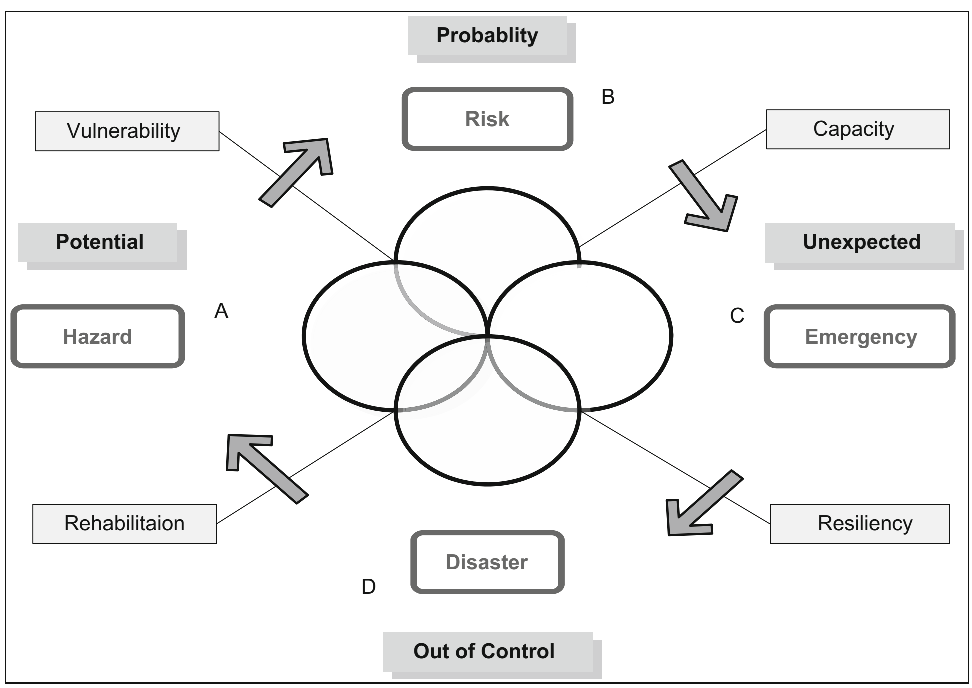

Fig. 2.1 Stages in the evolution of a disaster. **a** Hazard. **b** Risk. **c** Emergency; and **d** Disaster

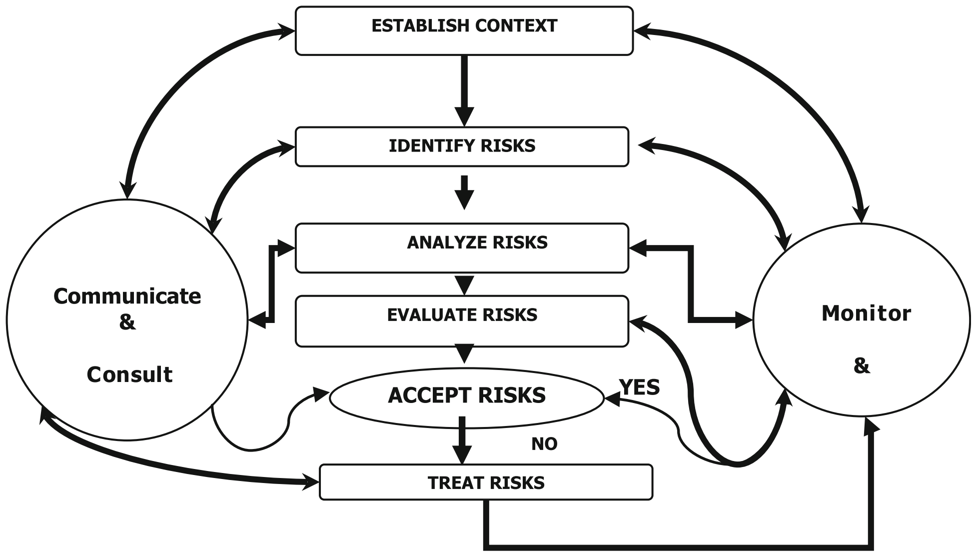

Fig. 2.2 Fundamental elements of the risk assessment process (after EMA 2002)

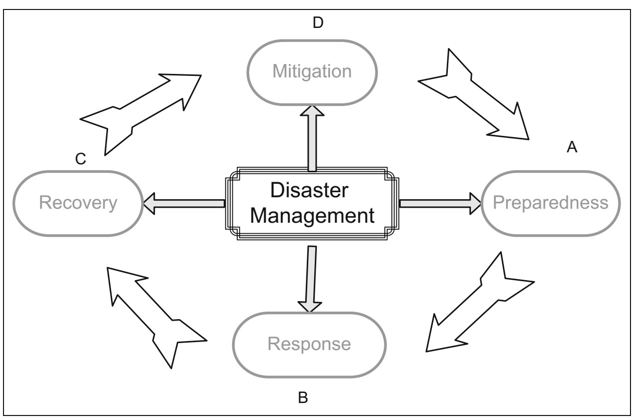

Fig. 2.3 Disaster management cycle. **a** Preparedness. **b** Response. **c** Recovery; and **d** Mitigation (modified from Carter 1991)

3. **Recovery**: This "back to normal phase" involves interdisciplinary effort to address not only the physical aspects of disaster recovery, but also psychological and social aspects. International efforts may be involved in this phase.
4. **Mitigation**: This phase deals with causes and impacts, with the aim of better dealing with disasters in the future. This phase is comprised of two sub-categories. The first is structured mitigation, which involves engineering work to prevent and mitigate disasters. Structural mitigation measures try to keep hazards away from people and buildings or to strengthen buildings and infrastructure to cope with hazards. Levees, dams, and channel diversions are examples of structural mitigation (Mileti 1999). The second is non-structural mitigation, which involves wide interdisciplinary efforts that are aimed at determining vulnerabilities and threats in order to efficiently handle these. For instance policy, education, awareness, and building codes are all examples of non-structural mitigation.

Alexander (1993) has listed seven temporal phases of disasters that are of importance in the process of disaster management. These phases are:

(a) **The Incubation Period**: This entails monitoring of particular phenomena prior to a disaster; for instance rainfall, water surface elevation, and flow velocity can be monitored prior to a flood.
(b) **The Disaster Impact Property versus Time**: For example, various flood levels will have different impacts, thus different levels of damage, based on the location of the affected area.
(c) **Brief Unmitigated Crisis Period**: This refers to the brief time span during which mitigation efforts are paused. This includes the time after particular events when the mitigation efforts are being planned for.
(d) **Search and Rescue**: The time during which search and rescue operations are carried out.
(e) **Fundamental Repair**: Time for repairing basic services for fundamental necessities, for instance, relief efforts.
(f) **Restoration-Extension of "Fundamental Repair,"** whereby reconstruction of key services continues.
(g) **Developmental Reconstruction**: Repairs and reconstructions are finalized.

These temporal aspects are very important when discussing the role of GIS in disaster management.

Comprehensive Emergency Management (CEM)

Comprehensive Emergency Management (CEM) is a concept that ensures that all aspects of anticipating, minimizing the risks from, preparing for, and recovering from an emergency are systematically addressed. There is no country, no community, and no person immune to the impact of disasters. According to Mileti (1999), many disaster losses are predictable, which make them to a certain extent manageable. Effective disaster management processes help to reduce devastation and high costs from disasters. This chapter will first examine disasters by exploring the big picture of the disaster management process by focusing on the elements of CEM. Secondly, this chapter will provide in-depth detail about critical infrastructure interdependency. Third, this chapter will also discuss issues related to temporal GIS and GIS interoperability with emphasis on disaster management applications.

Freeman et al. (2003) indicate that the complexity of interaction between human and natural environments make the need for addressing the causes of disaster losses a very important issue. A comprehensive emergency management system is composed of the interaction of the institutions, financial mechanisms, regulations, and policies that constitute a country's approach to disaster risk management (Carter 1991).

Principles and Practices in Disaster Management

Disasters can significantly affect human health and seriously disrupt the functioning of society. They cause widespread human, material, or environmental losses that exceed local capacity to respond, and call for external assistance (UNSDR 2009). These events can be categorized as natural, human-induced, and complex.

Disaster relief is an interdisciplinary field dealing with the organizational processes that help prepare for and carry out all emergency functions necessary to prevent, prepare for, respond to, and recover from emergencies and disasters caused by all hazards, whether natural, technological, or human-made.

Emergency preparedness includes 4 phases: mitigation or prevention, preparedness, response, and recovery. Periods of normalcy are the best times to develop disaster preparedness plans.

Pre-disaster planning can maximize the results of the international assistance and decrease the human and material tolls of inevitable disasters.

Disaster management involves 4 interconnected phases: mitigation, preparedness, response, and recovery. Mitigation, considered the cornerstone of emergency management, includes any action aimed at minimizing the impact of a potential disaster, such as construction of dams or levees, vulnerability assessments, and public normal periods, before disaster strikes, are the best times for systematic vulnerability assessments, preventive measures, and preparedness activities. Some, but not all, countries have made good use of such opportunities (Wisner and Adams 2002).

The successful foundation for disaster risk management lies in clearly identifying and understanding the level of exposure and vulnerability to a community and its assets against particular hazards. Accepted definitions of these three key concepts are:

- Hazard
  A source of potential harm or a situation with a potential to cause loss.
- Exposure
  The elements within a given area that have been, or could be, subject to the impact of a particular hazard. Exposure is also sometimes referred to as the elements at risk.
- Vulnerability
  The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

Prevention and mitigation strategies should work toward reducing the financial and social costs to communities over time, improving the built environment, and reducing the impact on, and damage to, the environment. Investment in disaster risk prevention and reduction enhances the economic, social, health, and cultural resilience of people, communities, countries and their assets, as well as the environment.

Disaster Recovery

Recovery activities involve restoring services to the public and returning the affected community to pre-disaster conditions. That recovery phase, by far the longest, starts as soon as the immediate threat to human life has subsided. Due consideration must be given to when, where, and how to rebuild, mindful of not reproducing the unsafe conditions that may have existed before the disaster.

Disaster Management Structures

The management and coordination structures are:

- Disaster management groups

That operates at local, district and state levels and is responsible for the planning, organization, coordination, and implementation of all measures to mitigate/prevent, prepare for, respond to, and recover from disaster events.

- Coordination centers

At local, district and state levels that support disaster management groups in coordinating information, resources, and services necessary for disaster operations.

- Disaster management plans

Developed to ensure appropriate disaster prevention, preparedness, response and recovery at local, district and state levels.

- Functional lead agencies

Through which the disaster management functions and responsibilities of the state government are managed and coordinated.

- Hazard-specific primary agencies

Responsible for the management and coordination of combating specific hazards.

- Specific-purpose committees

Either permanent or temporary, established under the authority of disaster management groups for specific purposes relating to disaster management.

Emergency management principles help us translate doctrine into a set of agreed-upon ways this profession will operate.

Principle 1: Comprehensiveness

Emergency managers must consider disaster possibilities, taking into account:

- All hazards.
- All phases of emergency management.
- All stakeholders.
- All impacts.

Principle 2: Progressiveness

Emergency managers must:

- Anticipate future disasters
- Take protective, preventive, and preparatory measures to build disaster-resistant and disaster-resilient communities.

Principle 3: Integration

Emergency managers must ensure unity of effort among all levels of government and all elements of a community.

Principle 4: Collaboration

Emergency managers must create and sustain broad and sincere relationships among individuals and organizations to:

- Encourage trust.
- Advocate a team atmosphere.
- Build consensus.
- Facilitate communication.

Principle 5: Coordination

Emergency managers must synchronize the activities of all relevant stakeholders to achieve a common purpose.

Principle 6: Flexibility

Emergency managers must use creative and innovative approaches in solving disaster challenges.

Principle 7: Professionalism

Emergency managers must value a science- and knowledge-based approach based on:

- Education.
- Training.
- Experience.
- Ethical practice.
- Public stewardship.
- Continuous improvement.

The Difference Between Disaster and Emergency

Disaster and Emergency are two different things, they are sometimes confused, but they are often related.

Disaster is defined as a sudden calamitous event bringing great damage, loss, or destruction; a sudden or great misfortune or failure. A disaster will likely affect more people and/or will have more devastating consequences than that of an emergency. A disaster can be widespread from regional level and upto the national and international levels. A disaster does not have to be preceded by an emergency. A disaster may come on quickly and without warning.

Examples of a disaster may be the consequences of severe weather such as a hurricane, tornado, or flooding. An economic meltdown followed by a rapid devaluation of currency would be considered a disaster, affecting countless millions of people.

Emergency is defined as an unforeseen combination of circumstances or the resulting state that calls for immediate action; an urgent need for assistance or relief. An emergency can turn into a disaster while a disaster is inherently an emergency situation, if noticed ahead of time. Not all bad results of an emergency will reach the level of disaster. An emergency is a situation that requires immediate attention, a situation that could lead to disaster if left alone or unattended.

Examples of Emergency

It is winter and you are traveling in your vehicle through the snowy mountains on the way to your destination. You are not on the main roads, and you swerve to avoid a deer which suddenly leaped out from the side of the road. You skid off the road down a moderate embankment, you've been injured, and you know that they won't be able to see you from up on the road. It is an emergency.

Mechanisms for Regulating Disaster and Emergency Management

Disaster risk management (DRM) refers to the systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster. This term is an extension of the more general term "risk management" to address the specific issue of disaster risks. DRM aims to avoid, lessen or transfer the adverse effects of hazards through activities and measures for prevention, mitigation and preparedness.

Disaster risk management (DRM) Law refers, for the purposes of this report, to a country's national law (or identified ensemble of laws) that establishes responsibilities, priorities and institutional frameworks specifically for DRM, regardless of the exact terminology used in the law's title, or its translation.

Disaster risk management system or arrangements refers to the legal, policy, administrative, and institutional frameworks established within a country for coordinated and systematic DRM.

Disaster risk reduction (DRR) refers to the concept and practice of reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.

There are many different ways of reducing risk through policies and regulations, and DRR structures and systems can be built up incrementally. Within the overall DRR structure, a variety of policies, regulations, and procedures can be used to address particular kinds of risk and hazard. They include:

Disaster Risk Reduction (DRR) policy, planning, priorities and political commitment:

- Political consensus on the importance of DRR.
- DRR a policy priority at all levels of government.
- National DRR policy, strategy and implementation plan, with clear vision, priorities, targets, and benchmarks.
- Local government DRR policies, strategies, and implementation plans in place
- Official (national and local) policy and strategy of support to community-based disaster risk management (CBDRM).
- Local-level official understanding of, and support for, community vision.

Legal and regulatory systems:

- Relevant and enabling legislation, regulations, codes, etc., addressing and supporting DRR, at national and local levels.
- Jurisdictions and responsibilities for DRR at all levels defined in legislation, regulations, by-laws, etc.
- Mechanisms for compliance and enforcement of laws, regulations, codes, etc., and penalties for non-compliance defined in laws and regulations.
- Legal and regulatory system underpinned by guarantees of relevant rights: to safety, to equitable assistance, to be listened to and consulted.
- Land use regulations, building codes and other laws and regulations relating to DRR enforced locally.

Integration with development policies and planning:

- Government (all levels) takes a holistic and integrated approach to DRR, located within wider development

context and linked to development planning across different sectors.
- DRR incorporated into or linked to other national development plans and donor-supported country programs.
- Routine integration of DRR into development planning and sectoral policies (poverty eradication, social protection, sustainable development, climate change adaptation, desertification, natural resource management, health, education, etc.).
- Formal development planning and implementation processes required to incorporate DRR elements (e.g. hazard, vulnerability and risk analysis, mitigation plans).
- Multi-sectoral institutional platforms for promoting DRR.
- Local planning policies, regulations, and decision-making systems take disaster risk into account.

Integration with emergency response and recovery:

- National policy framework requires DRR to be incorporated into design and implementation of disaster response and recovery.
- Policy, planning, and operational links between emergency management, DRR and development structures.
- Risk reduction incorporated into official (and internationally supported and implemented) post-disaster reconstruction plans and actions.

Institutional mechanisms, capacities and structures; allocation of responsibilities:

- Supportive political, administrative, and financial environment for CBDRM and community-based development.
- Institutional mandates and responsibilities for DRR clearly defined. Inter-institutional or coordinating mechanisms exist, with clearly designated responsibilities.
- Focal point at national level with authority and resources to coordinate all related bodies involved in disaster management and DRR.
- Human, technical, material, and financial resources for DRR adequate to meet defined institutional roles and responsibilities (including budgetary allocation specifically to DRR at national and local levels).
- Devolution of responsibility (and resources) for DRR planning and implementation to local government levels and communities, as far as possible, backed up by provision of specialist expertise and resources to support local decision-making, planning, and management of disasters.
- Committed and effective community outreach services (DRR and related services, e.g., health care).

Partnerships

- DRR identified as responsibility of all sectors of society (public, private, civil), with appropriate inter-sectoral and coordinating mechanisms.
- Long-term civil society, NGO, private sector and community participation and inter-sectoral partnerships for DRR and emergency response.
- Links with regional and global institutions and their DRR initiatives.

Accountability and community participation:

- Basic rights of people formally recognized by national and local government (and civil society organizations): to safety, to equitable vulnerability reduction and relief assistance, to be listened to and consulted (implies responsibility to guarantee these rights where appropriate).
- Effective quality control or audit mechanisms for official structures, systems, etc., in place and applied.
- Government consults civil society, NGOs, private sector, and communities.
- Popular participation in policy development and implementation; political space, and mechanisms allowing citizens to contribute to decision-making.
- Engineering and construction measures. These comprise design standards, building codes, and performance specifications. They ensure that engineered structures can stand up to particular hazards and forces.
- Planning regulations. These can be used to prevent the use of hazardous areas (such as floodplains or unstable hillsides) for housing or commercial development and to keep hazardous industrial activities away from population centers. Many urban plans involve land zoning of this kind. Planning should also ensure that public facilities (hospitals, emergency services, schools, water and power supplies, telephone exchanges, transport infrastructure) are kept away from hazardous zones as far as possible, and that they are not over-concentrated in a few places. For the same reason, regulations may restrict population density in a given area. Ensuring escape and access routes, creation of open spaces as areas of refuge, separation of buildings to reduce fire risk and creation of green or wooded areas to assist drainage are among other risk-reducing measures governed by planning regulations.
- Citizen demands for action to reduce disaster risk.

- Legal measures. In addition to formal disaster management legislation, the law can be used in many other ways to provide appropriate penalties and incentives.
- Financial and economic measures. Financial incentives such as the provision of grants, "soft" loans or tax breaks to companies, communities, and individuals can be used to encourage investment in safer construction and mitigation measures, including location in safer areas.

Early warning system (EWS) refers to the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities, and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.

Principles for implementing Disaster Risk Reduction

- Effective disaster risk reduction requires community participation.
- States have the primary responsibility for implementing measures to reduce disaster risk.
- Disaster risk reduction must be integrated into development activities.
- A multi-hazard approach can improve effectiveness.
- Capacity development is a central strategy for reducing risk.
- Decentralize responsibility for disaster risk reduction.
- Public–private partnerships are an important tool for disaster risk reduction.
- Disaster risk reduction needs to be customized to a particular setting.

Bylaws

Bylaws must be maintained and followed by emergency managment organizations to develop and implement emergency plans and other preparedness, response and recovery measures for emergencies and disasters, provide a comprehensive emergency management framework to develop, coordinate and manage emergency planning, preparedness, response, and recovery.

Acts

The Act enacted to make the activities about disaster management coordinated, object-oriented and strengthened and to formulate rules to build up infrastructure of effective disaster management to fight all types of disaster, whereas it is expedient and necessary to mitigate overall disaster, conduct post-disaster rescue and rehabilitation program with more skill, provide emergency humanitarian aid to vulnerable community by bringing the harmful effect of disaster to a tolerable level through adopting disaster risk reduction programs and to enact rules to create effective disaster management infrastructure to fight disaster to make the activities of concerned public and private organizations more coordinated, object-oriented and strengthened to face the disasters.

Disaster relief acts are legislative tools the government can use to provide regulated aid in the event of a disaster.

Legislations

A key component of the comprehensive disaster management approach is having appropriate legislation in place. Disaster management legislations provide for an effective decision-making process. By taking Canada as an example, the legislations pertaining to emergency management in Canada are not new. In 1985, two major legislations were approved; these are the Emergencies Act and the Emergency Preparedness Act. The Emergencies Act has defined a national emergency as "an urgent and critical situation of a temporary nature, that (a) seriously endangers the lives, health or safety of Canadians and is of such proportion or nature as to exceed the capacity or authority of a province to deal with it, or (b) seriously threatens the ability of the government of Canada to preserve the sovereignty, security, and territorial integrity of Canada."

Following the terrorist attacks of September 11, 2001, significant moves were initiated in order to improve emergency management legislation and to impose more control on the process of managing emergencies in Canada. As a result, a comprehensive review of emergency management activities in Canada was conducted. The Anti-Terrorism Act was passed in 2001. Since then, the Public Safety Act, which was proposed in 2002, has given particular emphases on enhancing the ability of the Government of Canada to provide a secure environment and establishing tighter controls over hazardous substances.

The Anti-Terrorism Act of 2001 and Public Safety Act of 2002, along with the Emergency Management Act of 1985 and Emergency Preparedness Act of 1985, have contributed significantly to the enhancement of Canada's emergency management protocols. The last stage of Canada's post-September 11, 2001 emergency management program enhancement was the transformation of the Office of Critical Infrastructure Protection and Emergency Preparedness (OCIPEP) into being the core of the new ministry of Public Safety and Emergency Preparedness (PSEPC) late in 2003.

Global Disaster Management Initiatives

The subject of disaster and risk reduction draws its relevance from earlier contributions and previous practices in the disaster management fields, where traditionally the focus has been on preparedness for response. Before proceeding further though, it is important to establish a common understanding of the basic tenets of disaster reduction that this review addresses.

Principles:

- Risk assessment is a required step for the adoption of adequate and successful disaster reduction policies and measures.
- Disaster prevention and preparedness are of primary importance in reducing the need for disaster relief.
- Disaster prevention and preparedness should be considered integral aspects of development policy and planning at national, regional, bilateral, multilateral, and international levels.
- The development and strengthening of capacities to prevent, reduce, and mitigate disasters is a top priority area to be addressed so as to provide a strong basis for follow-up activities to the IDNDR.
- Early warnings of impending disasters and their effective dissemination are key factors to successful disaster prevention and preparedness.
- Preventive measures are most effective when they involve participation at all levels from the local community through the national government to the regional and international level.
- Vulnerability can be reduced by the application of proper design and patterns of development focused on target groups by appropriate education and training of the whole community.
- The international community accepts the need to share the necessary technology to prevent, reduce, and mitigate disaster.
- Environmental protection as a component of sustainable development consistent with poverty alleviation is imperative in the prevention and mitigation of natural disasters.
- Each country bears the primary responsibility for protecting its people, infrastructure, and other national assets from the impact of natural disasters. The international community should demonstrate strong political determination required to make efficient use of existing resources, including financial, scientific and technological means, in the field of natural disaster reduction.

United Nations International Strategy for Disaster Reduction (UNISDR)

The UN Office for Disaster Risk Reduction (UNISDR) was established in 1999 to facilitate the implementation of the International Strategy for Disaster Reduction (ISDR). It was created to be the focal point in the United Nations system for the coordination of disaster risk reduction, and ensures synergies among the relevant activities of United Nations agencies and regional organizations, and related activities in socioeconomic and humanitarian fields.

UNISDR's vision is anchored on the four priorities for action set out in the Sendai Framework: understanding disaster risk, strengthening disaster risk governance to manage disaster risk, investing in disaster risk reduction for resilience, and enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation, and reconstruction.

UNISDR coordinates international efforts in Disaster Risk Reduction (DRR) and guide, monitor as well as report regularly on the progress of the implementation of the Sendai Framework for Disaster Risk Reduction, following the Hyogo Framework for Action. It convenes the biennial Global Platform on Disaster Risk Reduction with leaders and decision-makers to advance risk reduction policies and supports the establishment of regional, national, and thematic platforms.

UNISDR informs and connects people by providing practical services and tools such as the risk reduction Web site Prevention Web, terminology, publications on good practices, country profiles, and the Global Assessment Report on Disaster Risk Reduction which is an authoritative biennial analysis of global disaster risks, and trends.

United Nations World Summit on Sustainable Development

The United Nations Conference on Sustainable Development (UNCSD), also known as Rio 2012, Rio+20 (Portuguese pronunciation or Earth Summit 2012 was the third international conference on sustainable development aimed at reconciling the economic and environmental goals of the global community. It was held in Brazil in Rio de Janeiro from 13 to 22 June 2012.

Rio de Janeiro 1992

In 1992, the first conference of its kind, the United Nations Conference on Environment and Development (UNCED), commonly referred to as the Rio Conference or Earth Summit, succeeded in raising public awareness of the need to integrate environment and development. The conference drew 109 heads of states to Rio de Janeiro, Brazil, to address what was dubbed urgent problems of environmental protection and socioeconomic development. The Earth Summit influenced subsequent UN conferences, including Rio+20 and set the global green agenda. "The World Conference on Human Rights" for example, focused on the right of people to a healthy environment and the right to development; controversial demands that had met with resistance from some Member States until the Earth Summit.

Johannesburg 2002

The World Summit on Sustainable Development (WSSD) in Johannesburg, South Africa, noted that "an integrated, multi-hazard, inclusive approach to address vulnerability, risk assessment, and disaster management, including prevention, mitigation, preparedness, response, and recovery, is an essential element of a safer world in the twenty-first century." The Johannesburg Plan of Implementation provided UNISDR and the Inter-Agency Task Force with a concrete set of objectives for integrating and mainstreaming risk reduction into development policies and processes.

United Nations World Conference on Disaster Risk Reduction

Kyoto Protocol 1992 Took Effect 2005

The Kyoto Protocol is an international treaty which extends the 1992 United Nations Framework Convention on Climate Change (UNFCCC) that commits state parties to reduce greenhouse gas emissions, based on the scientific consensus that (part one) global warming is occurring, and (part two) it is extremely likely that human-made CO_2 emissions have predominantly caused it. The Kyoto Protocol was adopted in Kyoto, Japan on December 11, 1997 and entered into force on February 16, 2005.

The Kyoto Protocol implemented the objective of the UNFCCC to fight global warming by reducing greenhouse gas concentrations in the atmosphere to "a level that would prevent dangerous anthropogenic interference with the climate system". The Kyoto Protocol applies to the six greenhouse gases listed in Annex A: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs) per-fluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

The protocol is based on the principle of common but differentiated responsibilities: it acknowledges that individual countries have different capabilities in combating climate change, owing to economic development, and ergo puts the obligation to reduce current emissions on developed countries on the basis that they are historically responsible for the current levels of greenhouse gases in the atmosphere.

Sendai—Japan Framework 2015

UNISDR's current mandate was set down in UN General Assembly Resolution 69/283, adopted in June 2015. It is tasked with supporting the implementation, follow-up, and review of the Sendai Framework for Disaster Risk Reduction 2015–2030, including by fostering coherence with other international instruments, such as the 2030 Agenda for Sustainable Development and its Sustainable Development Goals, as well as the Paris Agreement on climate change. As such, UNISDR champions and supports the integration of disaster risk management across different areas of work of the United Nations and of its Members States as well as among a broad range of key stakeholders, including the private sector and civil society.

Prior to the adoption of the Sendai Framework in March 2015, UNISDR's role had been to support the implementation of the Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters. UNISDR also organizes the Global Platform for Disaster Risk Reduction.

To carry out its mandate, UNISDR's vision is articulated in line with the Sendai Framework, as the "substantial reduction of disaster losses and risk for a sustainable future".

The vision builds on UNISDR's significant track record of expertise and accomplishments under the Hyogo Framework for Action, from 2005 to 2015. These include the successful establishment and leadership of regional and global coordinating and review mechanisms for disaster risk reduction; ongoing support to countries, intergovernmental processes, and key stakeholders, by providing relevant risk information, decision-making support tools and policy guidance; catalyzing multi-stakeholder engagement in disaster risk reduction, including the private sector, parliamentarians and civil society; fostering gender-sensitive disaster risk reduction; and effective global advocacy.

United Nations Space Platform for Disaster Risk Reduction (UNSPIDER)

UN-SPIDER is a program of the United Nations Office for Outer Space Affairs (UNOOSA), with offices in Vienna, Beijing, and Bonn. The Bonn office systematically compiles relevant information on how to use Earth Observation, satellite communication, and satellite navigation for disaster risk management and emergency response. This information is made available on UN-SPIDER's Knowledge Portal. With workshops, technical advisory support and training courses the program facilitates knowledge exchange and capacity building on how to access and use space-based information, especially in developing countries.

Charter for Sharing Space Information to Counterdisaster

The International Charter "Space and Major Disasters" makes space technology available to assist emergency teams on the ground during major disasters. This initiative, created in 1999 by CNES and ESA, now includes 16 space agencies from around the world. The idea was to create a charter through which participants would commit to provide free access to spatial data to countries hit by major disasters, be they man-made or natural. The International Charter "Space and Major Disasters" was born. The two founding members, CNES and ESA, were quickly joined by the Canadian Space Agency (CSA), and then by 14 organizations from countries around the world: India, China, the UK, the USA, Japan, South Korea, Brazil, Germany, etc. This unusual coalition transcends the usual political and economic interests. The charter is open to space agencies and national or international space systems operators. Civil defense and security agencies as well as rescue organizations in one of the participants' countries automatically become authorized users of the charter's services. In order to provide timely assistance to affected populations and rescue teams in the field, charter members ensure permanent vigilance: once the relevance and validity of the request is verified, the objective is to schedule specific imaging operations and transmit the data to relevant personnel and services as quickly as possible.

Summary

This chapter provides discussion on the concepts and terminologies used for disaster management and emergency response. It provides basic background information about disaster management, infrastructure interdependency, temporal GIS, and GIS interoperability. The first section of this chapter focuses on the concept of Comprehensive Emergency Management (CEM) and introduces the process of evolution and the four phases of the disaster management cycle. The second section discusses the concept of infrastructure interdependency. This section highlights the challenges and the complexity associated with identifying and analyzing interdependencies between different critical infrastructure sectors.

This chapter shows that spatially based approaches are potentially powerful in dealing with critical infrastructure interdependency. This is mainly due to their capability to effectively deal with large amounts of data. The third section of this chapter discusses temporal GIS as an effective approach to dealing with dynamic processes such as disasters. The history of temporal GIS, as well as approaches for integrating space and time in GIS are discussed, along with current research issues in temporal GIS. The last section of this chapter discusses GIS interoperability as a means of delivering network-centric disaster management models. The standards and approaches of the OGC interoperability initiative are discussed. In the final portion of the chapter, an overview of the utility of GIS in infrastructure interdependency is also provided.

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3 Technological Foundations of WebGIS

Introduction

Integration of GIS and Internet technology has revolutionized the use and range of geospatial data and its applications in planning and implementation of strategies for a wide range of activities. The combination of GIS and Internet offers great possibilities, such as the interactive access to geospatial data, real-time data integration and transmission, enhancement of the functions of geographic information, and the access to platform-independent GIS analysis tools.

Disasters have an effect on many important economic and social parameters, which are related to a wide spectrum of geosciences. Disaster management system based on GIS Web services is exclusively designed to handle the disaster where disaster can be classified into two categories: the first category is natural disaster such as tsunami, flood, earthquake, cyclone, volcanic eruptions, and the second category is man-made disasters such as fires, stampedes, war and deliberate attacks, industrial accidents, oil spills, and nuclear explosions/radiation. The necessity of the system is many people live in danger because of lack of providing timely help to the affected victims and tardy response of relief works. Disaster management system incorporates with GIS Web services to identify the affected areas and possible routes to reach the location. It is possible to minimize the potential risks by developing early warning strategies, prepare and implement developmental plans to provide resilience to such disasters, mobilize resources, and to help in rehabilitation and post-disaster reconstruction. Space technology plays a crucial role in efficient mitigation of disasters. While communication satellites help in disaster warning, relief mobilization, and support, Earth observation satellites provide required database for pre-disaster preparedness programmed, disaster response, monitoring activities and post-disaster damage assessment, reconstruction, and rehabilitation.

Managing Disasters—Why GIS?

A disaster is defined as an event (happening with or without warning) causing serious disruption to the functioning of a community or a society, means of causing or threatening death, injury or disease, damage to property, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources (DKKV 2002).

Government agencies have been tasked to prepare for a wide range of events when it comes to emergency preparation, planning, and response. Disaster planning, at its core, tends to deal with preparing a response to critical and complicated events with unknown situational variables and unpredictable temporal and spatial constraints. A situation itself can come in the form of natural or man-made disasters that are intended and targeted events or accidental occurrences. Geographic Information Systems (GIS) can be an important tool for the purposes of mitigating damages incurred during disaster events by providing tools and data to be used in a response planning.

GIS functions:
There are many functions for GIS such as spatial data management, display, query, modify, and output.
Disaster management activity is divided into the following phases as: prediction, prevention, mitigation, emergency management, and recovery.

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GIS provides many benefits in disaster management as following: better decision-making, cost saving, improved analysis, effective planning, better communication, and better collaboration.

Role of GIS in Disaster Management:

- Accurate data availability.
- Location of site accurately within least permissible time.
- Accessibility information between source and destination.
- Real-time visualization of area of interest.
- Reduce the time element involved in activities.

GIS Role Use and Value in Emergencies:

Emergency management community of presentation of information in a visual/map format. “A picture is worth a thousand words” is often quoted in justification of GIS. This concept is especially significant in emergency response in which time is extremely critical and numerous factors must be considered. A map provides a quick grasp and understanding of a situation, targets special issues (hot spots, outliers), and provides the means to quickly evaluate those. In addition to the power of a map, the value of GIS as an information integrator, able to bring diverse data together, organized on the basis of location, was presented, a capability that exposed many, heretofore, unrecognized patterns and relationships. The importance and value of access to operational, regularly updated, up-to-date data to decision-making for emergency response were validated.

Geospatial technology is used for the collection, analysis, and visualization of geographic information. In an emergency, up-to-date information is needed for coordination, communication, and efficient decision-making. During a disaster, geospatial technology integrates diverse and disparate data and makes it accessible. Geospatial technology can provide time-critical information to responders and decision-makers and provide powerful visualization in coordinating disaster preparedness, response, and recovery efforts.

Real cases for using GIS in disaster management:

Events of September 11:

The attack on the World Trade Center (WTC) in New York City (NYC) on September 11, 2001, had a dramatic effect on the world in many ways and on the GIS field in very particular ways. The terrorist events demonstrated in unmistakable ways.

The value and utility of GI Science in emergency management.

GIS was reaching a level of maturity in the city at that moment, and the city’s GIS resources were applied fully to the emergency response. In fact, GIS emerged as a significant component of the emergency response and achieved national and international recognition for the contributions made in supporting the response effort. The events of September 11, 2001, and the months following saw GIS become recognized and emerged as a major contributor to emergency management as numerous breakthroughs and successes were achieved in what was, up until then, a nascent role for GIS in the emergency management field.

The events had a significant impact on GIS in EM in NYC and across the world. Consciousness was raised, the value of GIS was proven, numerous lessons were learned and documented, funds and resources were allocated, and a wide range of development activities was undertaken.

Hurricane Katrina:

> Hurricane Katrina affected an area of nearly the size of the UK (230,000 square km); it killed more than 1,700 people, and the total cost of damage is estimated at more than $200 billion dollars. Information management is a crucial component of emergency response. The ability of emergency officials to access information in an accurate and timely manner maximizes the success of the efforts. Since most of the information used in disaster management has a geographic dimension, geotechnologies have a large capacity to contribute to emergency management. The capabilities of geotechnologies to capture, store, analyze, and visualize spatial data in emergency management have been documented in the literature (Cutter 2003; Zlatanova et al. 2006; Carrara and Guzzetti 1996). Paradoxically, in praxis, the convergence of the two fields of geoinformation and emergency management is only rudimentary developed and little work has been undertaken to enhance the integration.

Geographic Information (GI) Science accelerated and enhanced decision-making, in the emergency response after Hurricane Katrina. Since most of the information needed in disaster management has a spatial dimension, geotechnology is a vital source for streamlining response activities. The rapid-response situation after a disaster, however, exposes new challenges in the use of geotechnologies.

During Hurricane Katrina, 70% of the police force in New Orleans were victims, leaving the city with limited law enforcement. Officers from other areas were called in who were not familiar with the city. Geospatial technology was used to create maps that included roads and major infrastructure locations to help guide first responders coming from different areas. Information on things such as water supplies, electricity outages, and baseball fields to land helicopters was needed and supplied to first responders by the use of geospatial technology. After much miscommunication during Katrina, it was apparent that access to centralized data on all levels of government is important. A major disaster typically affects more than one local city. A centralized geospatial database is one way of storing and accessing the data that exists between multiple sources and levels of government.

Concept of WebGIS

Internet-based GIS has been widely recognized in both public and private organizations as a fundamental tool for storage and distribution of data to targeted audiences (Brovelli et al. 2016).

The GIS-based Web portals provide a centralized and uniform interface to access the distributed and heterogeneous resources and data services (Karnatak et al. 2007).

According to (Peng 2001), Internet GIS refers to a network-centric GIS tool that uses the Internet as a primary means of providing access to distributed data and other information, disseminating spatial information, and conducting GIS analysis.

Web-Based GIS Software

The prime concern during any disaster management is the availability of the right spatial information in the right time and the dissemination of this information to all concerned to make right decisions. In this way, distributing geospatial information on a network of information gives a chance to the managers of organizations to easy access to the information about disaster management, any time and anywhere they are. So a stand-alone GIS cannot be useful in this respect, and disaster management needs a network-based GIS with accessing to online data. Therefore, a Web-based GIS has been considered for managing response phase of disaster management. Web-based GIS applications involve a user (the client) who contacts a server for some information.

GIS Web Service

GIS Web services provide direct access to data, eliminating the need to download a dataset and import it into your desktop application, instead using a simple HTTP interface (URL) to access the data. The department uses a variety of service protocols including Web Map Service (WMS), Web Map Tile Service (WMTS), and Web Feature Service (WFS) provided by the Open Geospatial Consortium (OGC) and ESRI Web mapping services.

Web Services for Spatial Data

Web services for spatial data enable using data from servers directly with desktop GIS software, without downloading first data as files to the own computer. In such a way, it is possible to use always up-to-date data easily. All most common commercial and open-source GIS desktop software products support Web standards (MapInfo, ArcGIS, QGIS, and GRASS). Web services are used so that the user connects to the service using a special menu. For connection, user needs to know the server's URL. After connecting to the server, the user gets a list of available map layers. Web services are also easy to use in map applications on Web. Data may be requested also directly with a HTTP GET or POST request.

Most common Web service standards of Open Geospatial Consortium's (OGC) are: Web Map Service (WMS), Web Map Tile Service (WMTS), Web Feature Service (WFS), and Web Coverage Service (WCS).

WMS and WMTS return map image in raster format, WFS data in vector format, and WCS data in raster format. In WMTS, maps are available only in pre-defined scales and size. In WMS, scale and map size can be set without restrictions. WMTS, are faster, because often the map tiles are already ready at the server. For requesting only part of data different filters may be used, for example, BBOX defines the area of interest.

GIS Web Services

The main challenges of geospatial (Shengru and Abdelguerfi 2006) data are:
Geospatial data are in bulk in size; loading the data and map into the client is complex; reload of map and data takes time; geospatial data is highly heterogeneous, and complex geospatial problems need large quantities of geospatial data from multiple sources and locations.

WebGIS Components

The major components of the whole portal are categorized into navigation tools, legend tools, search tools, and other tools such as WMS layer adding tool, layer manager. Features on the map can be identifying using map identify tool.

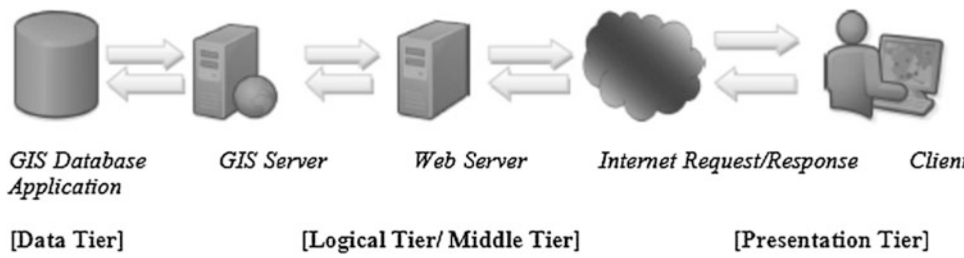

Fig. 3.1 Components of WebGIS-based system (Abdel-Hadi 2012)

Distance measuring tool of map also has been included as part of spatial map analysis tool. Results of map query or area of interest can be printed out along with detail legend using print tool. The size, font type, and map output can be customized using this tool. The map can be produced in various file formats such as PNG, JPEG, GIF, or PDF. Region-specific zoom is made possible using quick zoom tool.

Searching of non-spatial attributes could also be performed by the users. To do this, user first selects a layer and then, fill a from its listed fields/columns. An attribute to be searched is entered in the textbox. Clicking the "Search by Value" will create a pop-up window listing the attribute table matching the search criteria and subsequent zooming in the map and highlighted.

The automatic identification of map on mouse cursor moves is made possible using "Auto Identify" widget. The user selects a layer and its corresponding attribute(s), once applied; the user sees the attributes corresponding to the map location when mouse cursor moves.

The addition of WMS layers is also possible on this WebGIS portal. First we host the layers having similar projection through the GeoServer (Kamel and Honda 2006) (Fig. 3.1).

Objective of Disaster Management Internet GIS

Objective of the Geographic Information Systems (GIS) is to make full use of spatial data (data input and output, analyses, storage, and updating) beyond the limits of conventional paper maps. The term "spatial data" refers to data consisting of "geographical data" and "attribute data". Geographical data relates to distribution, locations, and configurations of topographic features (elevations, rivers, etc.) and features of human activities and social environments (railroads, roads and streets, buildings, land use, vegetation, and population), while attribute data consists of attributes (name, class, numerical value, etc.) of such feature items. A GIS has various functions that help users to take decisions and to perform environmental or disaster impact assessments. Such functions include: visualization using selective overlay of spatial data or by legends (classifiers), statistical processing using spatial analysis, extraction (buffering) of disaster-affected areas, and selection of shortest paths. Usually, to use GIS resources, dedicated hardware, software, and databases are necessary. A Web-based GIS has the advantage that it can be devised to enable analysis, display, and acquisition of data using the Internet without requiring the user to install any special GIS software. This is a very important point in the handling of disaster information, because it helps reduce equipment investment and facilitates information sharing.

The accessibility to the Internet varies considerably among Asian Disaster Reduction Center (ADRC) member countries. However, it is certain that Internet user populations will increase in these countries, along with easier access to faster and cheaper connection services. Moreover, the problem of unavailability of fixed telephone lines is steadily diminishing, thanks to the steady development of the satellite Internet connection technology. Thus, Internet GIS resources can be expected to be a more important component of a disaster risk management system in an emergency.

Role of the Internet-Based GIS in Various Phases of Disaster Management

GIS has emerged as a very important tool for effective planning, communication, and training in the various stages of the disaster management cycle. The prime concern during any disaster is the availability of the spatial information, and the dissemination of this information to all concerned.

Fig. 3.2 Phases of disaster management and its activities

Internet-based GIS can play a key role in this aspect by providing cost-effective information at various stages of the disaster life cycle, with a much wider reach.

- Information assessment for disaster management must be closely examined to determine if such databases and GIS products are really meeting the needs of the impacted populations.
- Internet enhances the ability for interactive communication of relevant information quickly and efficiently, provided people have the means to access the technology.
- Different forms of media interact to fuel news stories and information dissemination. The Internet, online media, and blogs work in concert, remixing and amplifying information.
- Synergistic effects from multiple new technologies (mobile phones) are enhancing access to information, as well as how information is disseminated.
- Web sites, wikis, interactive maps, and blogs offer immediate assistance to a community, such as relief efforts, locations of impacted areas, potential dangers, shelter locations, donations, and ways to assist.
- Different types of information can be made rapidly available that depict the geographic extent of the event, and satellite images provide a bird's eye view of the location.
- The power of information and communication technologies is at times not evidenced by their actual performance during a catastrophe. For example, during the Kashmir earthquake of 2005, basic GIS data layers were not available, and processed satellite images revealed little in the way of damage assessments.
- Maps and information needed for the local scale are often not available. This data is location-specific, sensitive to scale, and rarely has adequate coverage of the social landscape.
- Increase the skills in information systems for emergency managers and humanitarian aid workers to better understand the role of data collection and information for emergency management.
- Develop training for community-based emergency data collection for localities. Develop drills for emergency response that include GIS applications, rapid-response assessments, and analysis.
- Develop new methods for geovisualization.
- Develop emergency management GIS applications and curricula to train the next generation of emergency responders. Develop geospatial educational tools for multi-risk assessment.
- Build participatory partnerships and approaches in mapping disaster events.
- Research and develop appropriate temporal and spatial scales for disaster management databases.
- Integration of the GIS and the Internet technology can be used to significantly increase the usage and accessibility of the spatial data, which is a key requirement before, during, and after any disaster.

Table 3.1 Mobile GIS applications and major technologies

Major technologies used for field-based GIS	Major applications used for field-based GIS
Hardware: Pocket PC (WinCE), PDA (Palm OS), Tablet PC (Windows based) **Software**: Mobile GIS/GPS software(ArcPad) (Map extend), onsite **Programming tool**: Java (J2SE or J2ME),Visual Basic, .net compact framework **Wireless communications**: Wi-Fi or cellular phone signals **GPS**: External Bluetooth or cable-linked	• Environmental monitoring and natural resource management • Ecological/geographic research (field data collection) • Utilities maintenance (electric, gas, and water) • Asset management systems • Educational travel • Emergency response and hazard management

– Establish long-term monitoring data collection programs to understand recovery and restoration in an interdisciplinary environment. During the disaster, real-time monitoring and evacuation/rescue need immediate attention. The latest information can be made available through Internet giving a detailed picture of the event tracking, forecast of the affected region, the evacuation plan, and the position/movement of various agencies like military (Fig. 3.2).

Integration of Mobile Telecommunications with Disaster Management Internet GIS

Mobile phone networks can be developed with a smaller initial investment than fixed telephone networks. Therefore, mobile phone networks are rapidly expanding in countries. There are already many successful cases of transmission of early warnings and disaster emergency information using wireless telecommunications technologies such as cell phone short mail services. The ongoing diffusion of broadband connections will influence the way mobile phones are used. It will become more common than it is today to use mobile phones for interactive transmission of image data in addition to text and voice data.

To display GIS data on the small screen of a mobile phone, it will be necessary to develop a new data format different from the existing Internet GIS data formats, as well as a whole new set of data. Therefore, it is likely that mobile phone-based GIS data will first become available for major cities and surrounding areas. It is also important, in terms of cost-effectiveness, to develop cell phone-based GIS networks as a useful multi-purpose urban IT infrastructure not only for disaster reduction, but also for daily social life and tourism (Table 3.1).

Once they become widely used, cell phones bundled with sophisticated digital camera and GPS functions will provide a powerful Internet tool for semi-real-time GIS data sharing between affected areas and disaster management headquarters in disaster emergencies. It is also considered that cell phones will become a useful ubiquitous communications tool for raising disaster preparedness awareness among local populations and promoting "participatory disaster-resistant city planning."

Geospatial Responses to Disasters: The Role of Cyberspace

Disasters reveal the need for integrated solutions that include on-the-ground emergency response informed by geospatial technologies and digital databases. Visualization and spatial applications are critical in pre-, during, and in post-disaster management and response. Increasingly, cyberspace plays a role in geospatial responses to disaster in the following ways: (1) revealing the role of virtual communities in disseminating information via new and innovative means (e.g., mobile phones, mash-ups, crowdsourcing); (2) illuminating the need for interdisciplinary approaches to address disasters where geospatial approaches and technologies are at the forefront; (3) identifying efforts to improve communication through spatial data; and (4) developing long-term strategies for recovery efforts, risk reduction, restoration, and monitoring programs.

Disasters bring us closer via the Internet and the World Wide Web. Online disaster communities, made up of the victims and their families, governments, news outlets, non-governmental organizations, humanitarian aid groups, and an interested public, form in response to cataclysmic events. The online disaster community is global in that it transcends national boundaries in virtual space, solicits aid and intervention, and provides multiple lines of communication and information dissemination via chat rooms, blogs, and help lines. Virtual scales are not measured in terms of distance but by one's relationship to the event: friend, family, disaster responder, aid provider, or government official. However, the disaster occurs in an explicit geographic location with measurable results that are photographed, recorded, and placed online where the physical environment intersects with virtual space.

Effective disaster management and response demand rapid utilization of information and data from many sources. The ability to seamlessly integrate and distribute digital data into spatially explicit forms for rapid assessment and analysis during and after a disaster remains a challenging undertaking. Specialized data, data networks, and information processing methods and technologies are needed in a highly dynamic situation fraught with uncertainty and unpredictability. However, during and post-disaster activities reveal high levels of access to and pooling and sharing of digital resources, skills, and capabilities through the creation of novel and innovative sociotechnological networks.

Researchers have done considerable work in addressing the role of geospatial technologies in disaster response and management. This research includes GIS and public safety, GIScience, and applications for emergency response, disaster recovery networks, vulnerability mapping, and local responses to disaster using GIS. The integration of the Internet with GIS applications has been applied to such areas as 3D real-time emergency response, serving maps on the Internet for emergency escape routes, and mobile GIS and digital video for urban disaster management. Geospatial modeling has been used for such things as determining evacuation routes, tracking hurricanes, and ascertaining refugee populations.

The conceptual basis for disaster prediction and planning is undergoing a shift as evidenced by Susan Cutter et al. in a 2008 paper entitled "A Place-Based Model for Understanding Community Resilience to Natural Disasters." Cutter et al. highlighted the need to focus on resilience and adaptability rather than risk and vulnerability. The January 2010 Cartography and Geographic Information Science is a special issue that focuses on temporal and spatial scales of hazards and disasters, monitoring of long-term recovery, and methods to improve communicating knowledge of these events using spatial data. A suite of research has considered the role of local communities in integrating local knowledge into disaster management activities. The notion of "people as sensors" people collecting information, often spatial information, to aid in the recovery process and posting this information on the Internet for broad dissemination outside the established traditional channels of emergency response is yet another aspect of the intersection of disaster, place, and technology.

In 2007, the National Research Council (NRC) published Successful Response Starts with a Map: Improving Geospatial Support for Disaster Management, written by the Mapping Science Committee. This report describes the state of the art of geospatial data and tools for emergency management and emphasizes the need for improvement on how this data and the tools are used. Mechanisms to increase data sharing, use of satellite images, and Internet services for data provision are among the critical needs to enhance the use of geospatial technologies. The Indonesian tsunami and Hurricane Katrina reveal important advances that occurred via the use of the Internet and GIS. For example, the disaster of the Indonesian tsunami demonstrated the ability to quickly provide remotely sensed images both before and after the event that showed the extent of damage. This occurred through partnerships between software vendors, Internet service providers, and remote-sensing companies. The failure of governmental agencies in the aftermath of Hurricane Katrina resulted in numerous individuals responding via creating maps of donation and emergency aid sites. Creating data-sharing mechanisms in times of emergency response is needed; however, the report cites security as one of the main reasons for the lack of data sharing and for failure in providing data for emergency response. The recommendation by the Mapping Science Committee is to strengthen the National Spatial Data Infrastructure (NSDI) of standard development and clearinghouse construction and to provide the framework for emergency management data needs and coordination.

In 2009, the United Nations Foundation and Vodafone published a report, New Technologies in Emergencies and Conflicts: The Role of Information and Social Networks that describes the new technologies and innovative uses of existing technologies to address crises. The mobile phone, the growth of broadband, and emerging telecommunications, computing, and multimedia are having a profound impact on how, when, and where people communicate. One of the observations reported is the shift to “many to many” forms of communication, such as social networking, from the traditional “one to many” type of communication in the form of radio and television. These communication changes will impact dissemination and delivery of information, as well as develop people-centered approaches focusing on local needs and emergency planning efforts. Geospatial trends are viewed as either top down, where high-resolution satellite images are used to assess infrastructure damage after disasters, or bottom up, where crowdsourcing techniques integrate cell phone broadcasting, social networking, and online maps to pinpoint local crisis conditions.

When disasters have occurred, there has been an informal development of technology and communication that has self-organized during the event to provide coherent, relevant information outside the traditional information providers. The spontaneous response to disaster was particularly acute after Hurricane Katrina in the USA, coupled with Internet and mobile applications outside the traditional structure of information dissemination and emergency management.

These events reinforce emergency management as a community activity that is local yet linked to national-level priorities. However, the issues of appropriate data protocols and validity and authentication of information are not insignificant. Collaboration and coordination between government agencies, humanitarian organizations, and private companies remain problematic due to conflicting missions, data security issues, and inadequate funding of emergency response technologies. There is an international need for a regulatory framework for geospatial tools and communication techniques similar to the call by the NRC for the NSDI.

The integration of mapping, Global Positioning Systems, satellite imagery, and interactive geographic information systems provides important opportunities for developing and sharing information and techniques. “Technological gift giving” during disaster events has resulted in special licensing arrangements, innovative data sharing, and new applications. Mash-ups of the mixing of hybrid Web applications from multiple sources combine satellite imagery with maps and geospatial data to provide local data. This activity capitalizes on researchers’ observations about the need for data collection at finer spatial scales, such as neighborhoods and sub-neighborhoods, to create better disaster management plans. Disasters create space for the establishment of new networks, opportunities for collaboration, and information exchange.

Maps and, increasingly, satellite images are ubiquitous throughout the online disaster landscape. Global and regional consortiums provide technical advice about disaster response, training opportunities for GIS disaster applications, direct access to satellite imagery, technical help in processing digital data, and links to other information portals. Often, the latest satellite images and maps of a recent disaster can be found on these sites. For example, United Nations Institute for Training and Research (UNITAR) Operational Satellite Applications Programme (UNOSAT) provides the international community with geographic information and aims to universalize access to satellite imagery. The Radio and Internet for the Communication of Hydro-meteorological Information for Rural Development (RANET) project uses Internet technology to disseminate early warning information, satellite imagery, weather, and climate data to rural areas. The application of appropriate or best-fit technologies is a critical aspect of GIS and Internet applications due to factors such as bandwidth, literacy levels, and data availability. Cell phone and wireless technology are key factors in countries with inadequate wired infrastructure where interactive maps can be accessed on cell phone screens.

In 2005, Paul Currion wrote about the “first responders of the wired world” in reference to the innovative uses of blogs, message boards, pinpoint maps, mash-ups, and Web portals by technically savvy Internet users to share local information about disasters. While emergencies vary widely in scale, severity, and duration, they are inherently local. Oftentimes, information required from a GIS for immediate emergency response is seemingly simple, not requiring complex analytic procedures but reliable and adequate data. These activities attempt to distribute appropriate, accurate information in a timely fashion and, in some instances, in real time. Multiple disasters have facilitated the formation of volunteer organizations that provide hands-on expertise to develop location-specific GIS applications. These organizations respond to disaster events by developing a list of volunteers and soliciting assistance in response to disasters. For example, GISCorps coordinates short-term, volunteer GIS services to underprivileged communities worldwide. Immediately after the Haitian earthquake, MapAction had a team on the ground to assist in relief coordination through developing maps of relief deliveries.

Summary

Disaster management system using GIS Web services which encompasses will provide effective management of post-disaster management and rehabilitation. By using the system, the isolated areas are identified, and the shortest route will be provided to the authorities to reach the affected places. Moreover, the system can be used by the authorities to take a decision for deployment of rescue team and identifying the mode of transport in case roads are blocked. The proposed system emerges three important emergency services such as police, fire, and medical based on GIS Web service used to provide the required services to the user. The three services may work separately or join together as a composite service. GIS Web services are self-contained, self-described modular component of geospatial application which can be accessed through standard protocols. GIS Web services can be applied to various applications like geomarketing, construction and coordination, e-Governance, natural resources, urban planning, emergency response.

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4 WebGIS Systems and Architectures

Introduction

With the recent advances in broadband and wireless communication technologies as well as the dramatic increase in Internet technology, it is promising to extend further the reach and range of GIS user working in offices and laboratories in the field or at home which would lead to the development of Internet GIS or Web-enabled GIS (Peng and Tsou 2003).

Distributing geospatial information on the Internet is an enforcing factor for information providers. The Internet allows all levels of society to access geospatial information and provides a media for processing georelated information with no location restrictions. Web-based GIS is evolved from different Web maps and client–server architecture to distributed ones. As such, the Internet reshapes all functions of information systems including gathering, storing, retrieving, analyzing, and visualizing data. The high cost of GIS system, the release of system specific databases, and the enormous software developer efforts on upgrading the system are fading with the introduction of Web-based GIS. Moreover, disseminating spatial information on the Internet improves the decision-making processes.

This chapter examines the current WebGIS technologies with emphasis on architectures. Eight state-of-the-art WebGIS products from leading GIS companies have been scientifically assessed. This chapter also proposes a WebGIS development strategies starting from requirement analysis and ending in GIS use and maintenance.

WebGIS Technology

GIS-based Web portals provide a centralized and uniform interface to access the distributed and heterogeneous resources and data services (Karnatak et al. 2007).

Development of the Web and expansion of the Internet provide two key capabilities that can greatly help geoscientists. First, the Web allows visual interaction with data. By setting up a Web server, clients can produce maps. Since the maps and charts are published on the Internet, other clients can view these updates, helping to speed up the evaluation process. Second, because of the near ubiquitous nature of the Internet, the geospatial data can be widely accessible. Clients can work on it from almost any location. Both of these features altars the way geoscientists do their work in the very near future. The combination of easy access to data and visual presentation of it addresses some of the primary difficulties in performing geosciences evaluations (Gillavry 2000).

WebGIS does not require more resources such as powerful computers, extensive training, and expensive site licenses are not required for a site-wide GIS solution (Strand 1998).

Transferred Geodata

Except attribute data, a decisive question for using GIS in the Internet is the data format (vector or raster), which is used to transfer data to client. For data transmission to the client, map is converted into no space raster or a suitable vector format. When raster data is transferred, a standard Web browser without extension can be used, since Web browser displays GIF and JPEG. That means the data on the server has to be converted to a raster format. The data volume due to the known image size and the original data on the server is safe as only an image is sent to the client. The disadvantage of using raster data is the lack of comfort of handling and regarding cartographic aspects, like font problem. Moving over an object with mouse cannot highlight single objects. In addition, a server contact is necessary per each request from the client.

Because of low vector data volume, it transmits faster than raster. Vector data is handled by a standard Web browser with extended functionality (e.g., using plug-ins). The user gets more functionality with vector data. For example, single objects can be selected directly or

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highlighted. One more advantage of using vector data is the possibility of local processing; it is not necessary to contact the server per executed browser action. The amount of vector data sent over Web could be three to four times less than the amount of raster data needed for equivalent resolution, resulting in faster response time and greater productivity (Nayak 2000). Disadvantages of vector data are manufacturer dependence as well as changing data volume; the amount of data varies with the selected area. To avoid data redundancy in client side, dynamic generalization must be provided. Distributing vector data may also endanger copyright rules. The choice of transferring data form (vector or raster) varies with applications and the existing infrastructures. Software products, which offer optional transferring of vector or raster data, may provide advantages. They may allow pre-selection with raster data and afterward loading of the actual vector data with the possibility of subsequently local process.

Different consortia are developing future standard formats for transferring data over the Internet. The Open GIS consortium, for example, presents Geography Markup Language (GML). GML shall enable the transport and storage of geographical information in Extensible Markup Language (XML). Geographic information includes both properties and the geometry of geographic features (www.opengis.org). The W3C submits scalable vector graphics (SVG), which is a language for describing two-dimensional vector and mixed vector/raster graphics in XML (www.w3.org).

Interactive Web Maps

There are several technology levels to publish map data on the Web, ranging from sites that simply publish static Web maps to more sophisticated sites which support dynamic maps, interactively customized maps, and multiple computer platforms and operating systems. In terms of WebGIS, the most challenging map is the interactive one. Within the Open GIS consortium, a Special Interest Group (SIG) for WWW Mapping is working on issues of Web-based GIS publishing. This group has recently developed an essential model of interactive portrayal (Fig. 4.1).

This model is a very useful tool to analyze and compare different architectures for Internet Map Servers and other Internet-based GIS applications. Moreover, it is more precise than the common expression, which often leads to misunderstandings. The interactive portrayal model has four tiers:

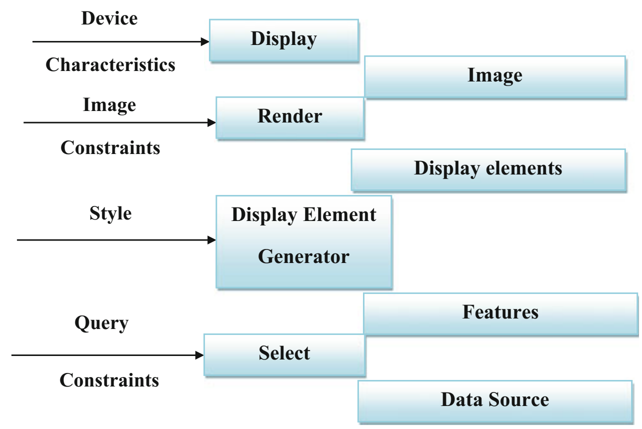

Fig. 4.1 Open GIS model of portrayal workflow

- The selection process retrieves data from a geospatial data source according to query constraints such as a search area or thematic selections.
- The Display Element Generator process turns the selected geospatial data into a sequence of display elements. It attaches styles such as symbols, line styles, fill styles to spatial features; generates annotation from alphanumeric attributes; sorts the display elements in a certain order; and does other graphical processing.
- The render takes the display elements and generates a rendered map. Examples of rendered maps are in-memory display lists, GIF files, or postscript files.
- The display process makes the rendered map visible to the user on a suitable display device.

Between These Four Tiers, There Are Three Different Types of Data

- Features and coverage (e.g., raster data) retrieved from the selection process.
- Display elements generated from the Display Element Generator.
- Images produced by the render.

The next capability for interactive Web maps is to allow users to add new themes to the map from a catalog of available data sources. This can be accomplished by specifying the entire theme, or by querying the spatial or attribute data and returning all those features that satisfy the query criteria (Strand 1998). When maps are comprised of multiple themes, each theme being displayed as a graphical layer in the map image, the displayed map can become too complex to be of value, unless users are allowed to select which themes are displayed.

Internet Map Servers

The Internet Map Server (IMS) applications allow GIS database custodians to easily make their spatial data accessible through a Web browser interface to end users. High-speed corporate intranets make an ideal network for distributing data in this manner, given the fact that bandwidth requirements can be high. Making data available to the entire world is certainly feasible, and any organization that has a public Web site can certainly add an IMS without opening up too many additional security holes.

For a working IMS, software requires two components to function: a geospatial data processing engine that runs on the server side as a service, Servlet or common gateway interface (CGI) application, and processes the raw spatial data into a map; and a standard Web server that manages the incoming requests and replies with the proper map data back to the client-side browser or application window. The end product is either a JPEG or GIF image or vector, which is transmitted back to the client browser or a stream of data that is interpreted by a plug-in to the client browser. IMS that transmits back an image has a limited capability that does not extend much beyond pan, zoom, and basic vector attribute query. The feature streaming IMS requires a downloadable plug-in, but allows for advanced buffer, query, labeling, and subsetting operations to be performed. Some IMS sites offer both a plug-in and a simple HTML version, which is nice for plug-in weary surfers. An overview of the eight most commonly used Internet Map Servers is provided in Table 4.1.

In the Internet Map Servers, product suite contains IMS as out-of-the-box but customizable and expandable tool or IMS as development environment. When deciding for IMS, one should pay attention to the offered data interface to use existing geodata without problems.

WebGIS Architecture

In performing the GIS analysis tasks, WebGIS is similar to the client/server typical three-tier architecture. The geoprocessing is broken down into server-side and client-side tasks. A client typically is a Web browser. The server side consists of a Web server, WebGIS software, and database (Fig. 4.2) (Helali 2001).

This model of network widely exists within enterprises, in which some computers act as servers and others act as clients. Server simply has the proprietary GIS running and adds a client interface at the client side and a middleware at the server side to communicate between the client and the proprietary GIS software.

Recent developments in object-oriented programming make it possible to produce software components and send them to the client before running it in the client machine, such as Java classes, ActiveX components, and plug-ins. This comes out to the thick client GIS. The thick client architecture lets the client machine do the most processing works locally. Both thin and thick client systems have some advantages and drawbacks, but they are not the best solution in terms of taking advantage of network resources.

Thin Client Architecture (Server-Side Applications)

The thin client architecture is used in typical architecture. In a thin client system, the clients only have user interfaces to communicate with the server and display the results. All the processing is done on the server actually as shown in Fig. 4.2. The server computers usually have more power than the client and manage the centralized resources. Besides, the main functionality is on the server side in thin architecture; there is also the possibility for utility programs at the server side to be linked to the server software. Figure 4.3 shows schematic communication between Web browser, Web server, and GIS server. On the Web server side, there are some possibilities to realize the GIS connection to the World Wide Web; CGI, Web Server Application Programming Interface (API), Active Server Page (ASP), Java Server Pages (JSP), and Java servlet. The descriptions of the five possibilities mentioned above are in Helali (2001).

The user on the client side does not need any knowledge about the linkage of the IMS at the server side, but the system administrator or application developers should be familiar with these techniques. This architecture is used in ESRI ArcView IMS, MapObjects IMS, and MapInfo MapXtreme systems.

Major Advantages of This Model Driven From Data Base Centralization Are:

- Central control.
- Easy for data eminence/updating.
- Keep the latest version.
- Generally cheaper.
- Integration possibilities.
- Regarding some cartographic aspects such as font.

Table 4.1 Selected Internet Map Servers

Internet Map Server	Transferred geodata	Platform of IMS	Browser extensions	Data interface
ArcView IMS 1.0a (ESRI)	Raster	UNIX, WIN 9X, NT	HTML, Applet	Shapefiles, Coverage's, SDE Layer, …
MapObjects IMS 2.0 (ESRI)	Raster	WIN 9X, NT	HTML, Applet	Shapefiles, Coverage's, SDE Layer, …
Arc IMS 3.1 (ESRI)	Raster, Vector (Internal ESRI formats)	WIN 98, NT	HTML, Applet	Shapefiles, Coverage's, SDE Layer, …
MapXtreme NT Ver 2.0 (MapInfo)	Raster	WIN NT	HTML, Applet	MapInfo format map, Shapefiles, SDE Layer, Raster format
MapXtreme Java Ver 2.0 (MapInfo)	Raster, Vector	WIN NT, UNIX, …	Applet	MapInfo format map, Shapefiles, SDE Layer, Raster format
MapGuide 4.0 (AutoDesk)	Raster, Vector	WIN NT	Plug-in, ActiveX, Applet	DWG, DXF, DGN, Shapefiles, Coverage's, MapInfo, …
GeoMedia Web Map/Enterprise 3.0 (Intergraph)	Raster, Vector	WIN NT	Plug-in, ActiveX	MGE, Shapefiles, Coverage's, MapInfo, Oracle, Access, …
Map Server 3.5 (Minnesota DNR)	Raster, Vector	WIN 9X, NT, WIN 2K	HTML, Applet	Shapefiles, SDE Layer, Raster format

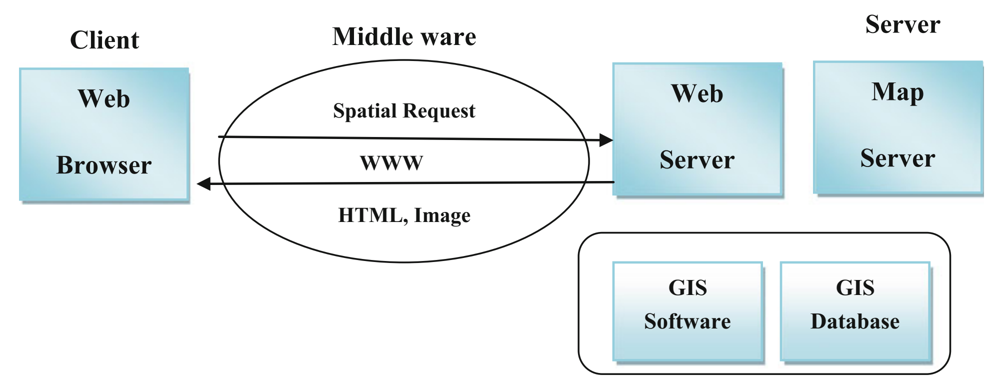

Fig. 4.2 How a typical WebGIS model works

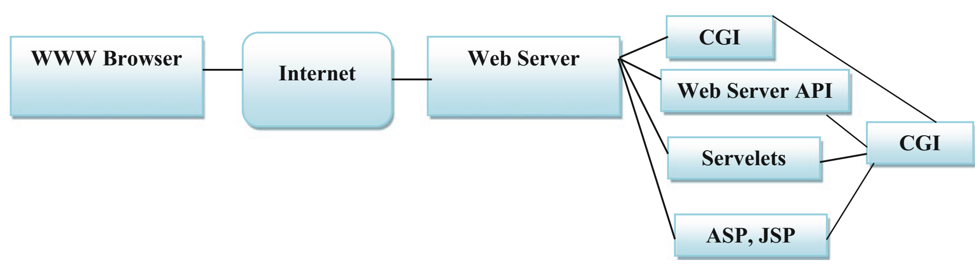

Fig. 4.3 Server-side application

Disadvantages Are:

- Not responsive to local needs: Users have different invokes.
- No local accountability: Accountability needs application in client side.
- Large data volume (size of the database).
- Response time slow: Users use a browser and it takes long time to download new HTML frame.
- Less interactive: In client side, there are limited application and browser abilities.
- Vector data does not appear in client side: Browsers without additional plug-in cannot read vector files.

Thick Client Architecture (Client-Side Applications)

In general, a Web browser can handle HTML documents and embedded raster images in the standard formats. To deal with other data formats like vector data, video clips, or music files, the browser's functionality has to be extended. Using exactly the same client–server communication in thin client architecture, vector files format could not be used. To overcome this problem, most browser applications offer a mechanism that allows third-tier programs to work together with the browser as a plug-in.

The user interface functionality has progressed from simple document fetching to more interactive applications. This progress is as follows: HTML, CGI, using HTML forms and CGI, JavaScript to increase user interface capabilities, Java applets to provide client-side functionality. Currently, user interface capabilities are combined with remote invocations (Fig. 4.4) (Byong-Lyol et al. 1998).

Major Advantages of This Model Are:

- Document/graphics standards are not required.
- Vector data can be used.
- Image quality not restricted to GIF and JPEG.
- Modern interface is possible; it is not restricted to single-click operations.

Disadvantages to Client-Side GIS Are:

- Non-conformance can limits.
- User base.
- Users require to obtain additional software.
- Platform/browser is incompatible.

Medium Client Architecture

For avoiding vector data in client side and reducing problems of previous architectures, medium client is suggested. With using extensions in both client and server sides, clients may have more functionally than thin client architecture. In Fig. 4.5, these four components in interactive map are pictured as services, each with interfaces, which can be invoked by clients of that service.

In other words, if a user's computer contains just the display service, then that user would be said to be using a thin client. If the user's computer additionally contained a render service, then that user would be said to be using a medium client. And finally, if the user's computer also contained the Display Element Generator service, that would indicate the user is using a thick client. After some

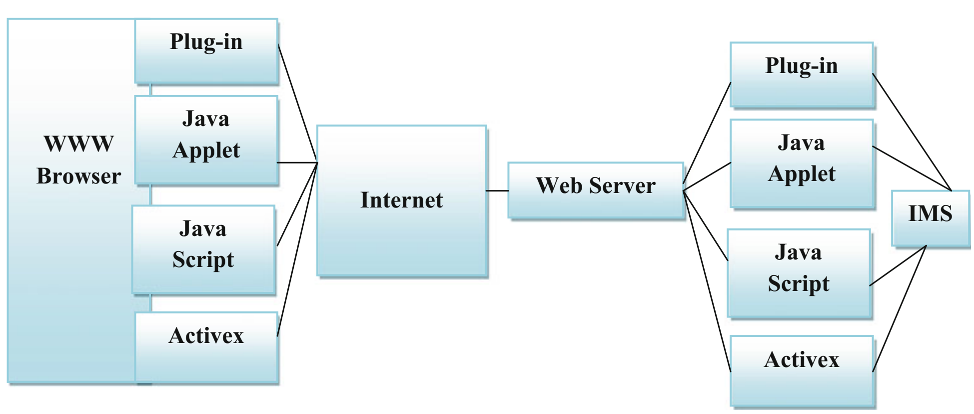

Fig. 4.4 Client-side applications

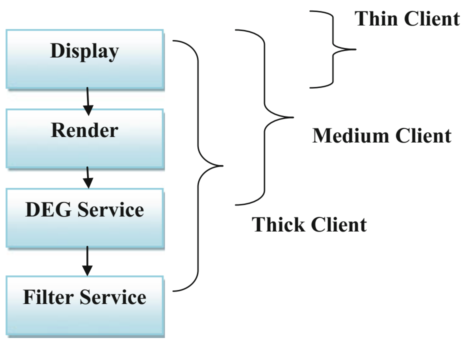

Fig. 4.5 Medium client position in open GIS point of view

consideration, it was decided that while this distinction may be somewhat helpful in describing Web mapping, the terms "thick client" and "thin client" were already encumbered by very imprecise definitions used in marketing literature and were therefore not suitable for continued use in some cases (Doyle 1999).

Distributed Architecture

Recent developments in information technology have resulted in a number of distributed object architectures that provide the framework required for building distributed applications. The framework also supports a large number of servers and applications running concurrently. Many of such frameworks provide natural mechanism for interoperability (Kafatos 1999). For example, Distributed Component Object model architecture in Windows platform and Java Remote Method Invocation (RMI) in Java Virtual Machine (JVM) are the most popular protocols that are used in different cases. These architectures may be applied to GIS to improve the traditional client/server GIS model and develop scalable distributed GIS model. Some attempts have been made in the academic area (Zhang 1998).

The general idea of the distributed GIS service model is that a client program, in either an Internet browser or an independent application, should be able to access the resources distributed in the entire network. The resources here refer to both geodata and geoprocessing components available in the network. The client and the server in this context do not refer to a specific machine. Any machine, when it requests the remote resources during the processing, is a client, and any machine that provides such resources is a server. In a specific program, a client may connect to several servers if needed and a specific machine may be the client at one time and the server at another time. An ideal distributed GIS service model should be a "geodata anywhere, geoprocessing anywhere" model, which means the geodata and geoprocessing tools could be distributed with the largest flexibility virtually anywhere in the network. The geodata and geoprocessing components do not have to be in the same site, but they should be able to cooperate or integrate whenever they are needed to finish a specific task (Yuan 2000).

The WebGIS pattern has democratized geographic information access and is broadening its reach significantly. It has transformed GIS beyond siloed applications and simplified access by abstracting geographic data into standard spatial services. ESRI has engineered the concept of WebGIS into platform technology that supports simple and smart mapping, powerful analytics, application programming interfaces (APIs), and apps that deliver functionality for mobile devices, the Web, or the desktop. This WebGIS platform empowers a range of users from individuals, workgroups, departments, and even entire organizations.

The platform enables interaction and collaboration between multiple self-contained WebGIS deployments, scaling WebGIS to achieve the concept of a system of systems. We call this pattern distributed GIS. Interactions in distributed GIS revolve around shared items (Web maps, Web scenes, layers, apps, dashboards) with optional automatic replication across multiple GIS systems that leave the data at the source of truth.

Administrators set up their nodes in this network and create the rules of engagement that reflect how the parts of their organization interact, including defined roles that limit what individuals can access, edit, or create. The resulting distributed GIS enables two-way dialogue among multiple entities at a far greater scale than previously envisioned.

The transition from WebGIS to distributed GIS revolves around the importance of identity. Identity allows administrators to preserve role-based permissions that exist in each organization. Users gain portability with access to their apps and maps from wherever they log in. Organizations can leverage roles in configured apps that bring together people and processes to address cross-cutting issues.

WebGIS Development Cycle

Developing a WebGIS is more than simply buying the appropriate hardware and software. Several strategies have been proposed to provide successful implementation (Alesheikh and Helali 2001). The implementation strategies have been scientifically assessed and modified so that the requirement of the TTO project can be met with minimum cost and time. Figure 4.6 shows the WebGIS development cycle, which is described in terms of eight major activities starting with the requirement analysis and ending with ongoing use and maintenance of the WebGIS system.

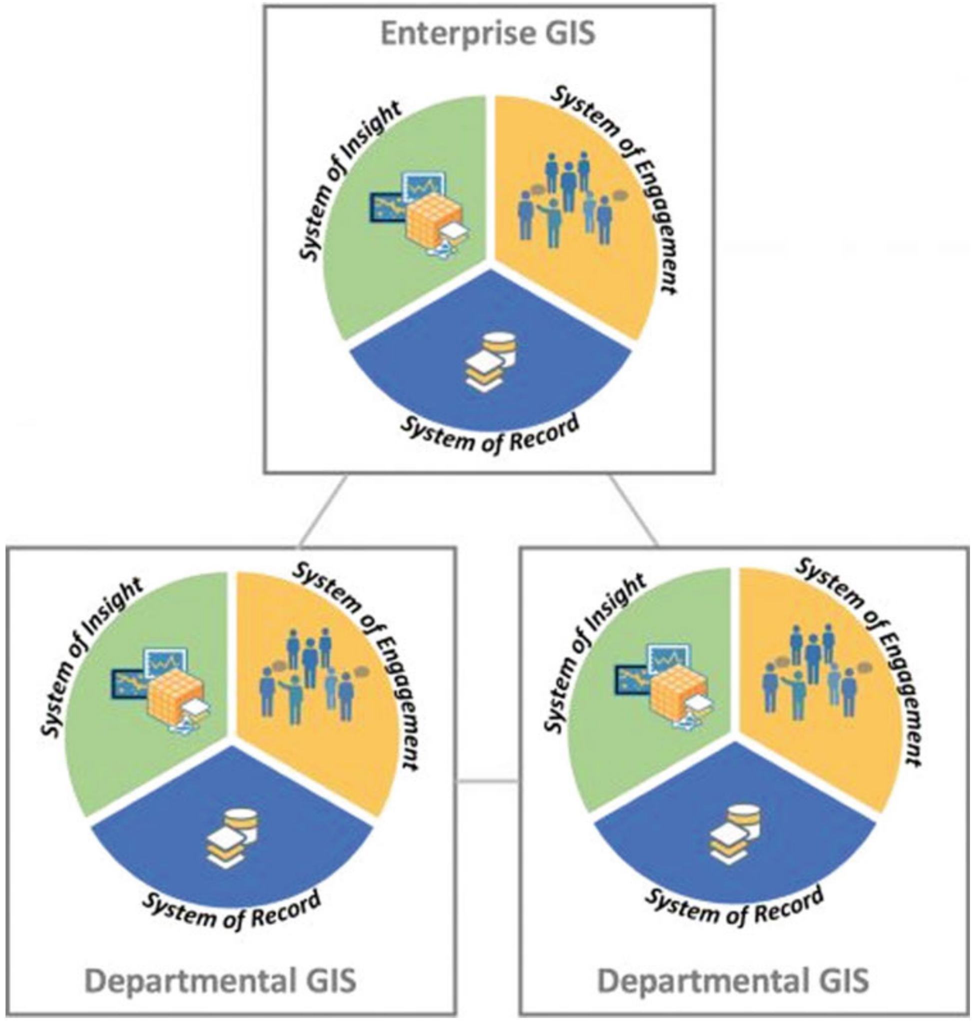

Fig. 4.6 Distributed GIS

Requirement Analysis

The object of the TTO project is to disseminate Iranian road information through the Internet, so that constituents can easily access the data. The requirement analysis step has been performed through interviewing potential users. This step produced two critical pieces of information:

- A list of functions that are needed. The required functions are the basic visualization functions such as pan, zoom, and more advanced functions such as object identification, spatial query, and shortest path. Clients can use these functions to view road information and peripheral constructs such as gas stations and rest areas.
- A master list of available/needed geographic data. TTO has captured several layers of road information using GPS. In this project, only 25 layers of information have been used that include police station, restaurants, gas station, mosques, etc.

The information gained in the requirement analysis activity went directly into the Conceptual GIS Design activity.

Conceptual Design

Once the required data has been identified, the data model that identifies the entities and their relationships were designed. Since the data will be delivered through a central server and clients will have access to raster formats, medium client architecture was chosen providing the users with access to interactive maps.

Survey of Available Software and Hardware

Selecting suitable software is an important step in a successful implementation. Software was evaluated on functionality and performance, and independent of the hardware and operating system. With respect to the required functions, cost, and what has been mentioned in Table 4.1, two software: Arc IMS 3.1 and MapObjects IMS, were selected for further evaluation. WebGIS requires specific hardware configuration. Since the volume of transferred data is huge, the speed of Internet connection is vitally important. Most of the data are sent from Map Server to clients; as such, the send speed has been identified to be more than 128 kbps. Based on a pilot project and the experience gained through similar projects, a dual processor computer with 512 MB RAM has been selected for this project.

Database Design and Construction

The primary purpose of this phase of the WebGIS development process was to specify "how" the WebGIS performs the required applications. Database design involves defining how graphics will be symbolized (i.e., color, weight, size, symbols), how graphics files will be structured, how non-graphic attribute files will be structured, what is the active layer, in what scale shall the layers expose, how GIS products will be presented (e.g., map sheet layouts, report formats), and what management and security restrictions will be imposed on file access. Completing the following activities does this:

- Selecting a source (document, map, digital file, etc.) for each entity and attribute included in the entity–relationship diagram.
- Setting up the actual database design (logical/physical design).
- Defining the procedures for converting data from source media to the database. Since the formats of the data were selected to be ESRI compatible, the needed data were converted to such format.
- Defining procedures for managing and maintaining the database.

Acquisition of GIS Hardware and Software

The database design activity was conducted concurrently with the pilot study and benchmark activities. Actual procedures and the physical database design cannot be completed before specific GIS hardware and software has been selected, while at the same time GIS hardware and software selection cannot be finalized until the selected GIS can be shown to adequately perform the required functions on the data. Thus, these three activities (design, testing, and hardware/software acquisition) have been conducted concurrently and iteratively.

Based on the functional capabilities, vendor support, cost/maintenance fee, and the survey of available hardware/software, those have been purchased, and all necessary renovation of space, wiring, and environmental remodeling has been carried out.

WebGIS System Integration

At this point in the WebGIS development process, the WebGIS hardware and software have been acquired and data conversion is complete. The object of this phase was then to integrate different components of the hardware and software, to test them to make sure they work as expected, and to initiate all procedures necessary to use the GIS.

Application Development

The initial requirement analysis contained some applications of a complex nature. However, the majority of initial applications was straightforward and can be implemented using the basic functionality that is part of the WebGIS software (e.g., display). The more complex applications were not supported by the basic functions of WebGIS but have been programmed. Ease of use, user-friendliness, and reducing the volume of data transfer were the critical issues considered in the development. Figure 4.7 shows the initial user interface that has been programmed using HTML, JavaScript, and Java.

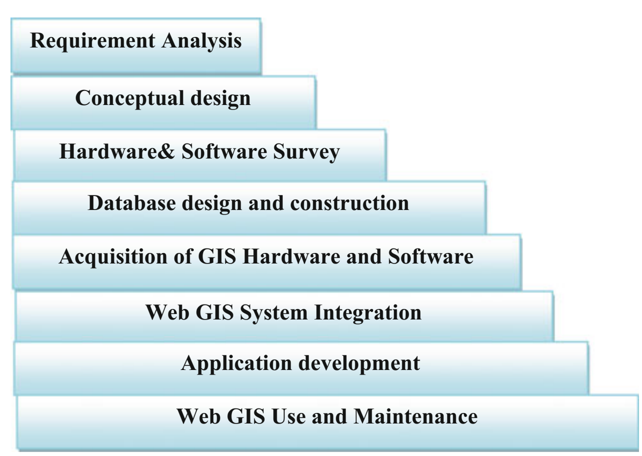

Fig. 4.7 WebGIS development cycle

WebGIS Use and Maintenance

The final step in WebGIS implementation was to put the system to use. With system integration and testing completed and all applications available for use, the system was released to users. Two activities were in place:

- User support and service, in which new applications will be determined, and
- System maintenance (database, hardware, software), in which the WebGIS must run smoothly.

WebGIS Server Components

Database Server

The database server may have a file-based system or Relational Database Management System (RDBMS), or a combination of files and RDBMS. In a typical WebGIS application, the spatial data is organized in RDBMS environment which allows better performance, data security, data consistency, and many more advantages of RDBMS for GIS datasets. Following are well known and famous RDBMS-based database server software solutions available for geospatial datasets (Table 4.2):

GIS or Map Server

Map server or GIS server is a software package or program, which is responsible for rendering the GIS data into Web browser. Since the standard Web servers and browsers support only standard image and data formats like .jpeg, .gif, .txt, .html, .xml, to represent or publish geospatial data in Web-compatible format there is a need of intermediate software components called as a Map Server or GIS server. Today, many of the map server products are available either as commercial product or as open-source/freeware products for map publishing in the Internet environment. The available Map Servers' products are either based on Common Gateway Interface (CGI) or Servlet-based connectors. The important GIS/map server products available at present are shown in Table 4.3.

Application Server

An application server in a GIS environment especially in WebGIS applications is software which provides customized software applications with services like query system, GIS analysis and processing, report generation, data security, and authorizations. Many times the application servers are a part of GIS/map server. In general, the WebGIS application servers are customized by using application programming

Table 4.2 Important GIS database servers with RDBMS support

S. No.	Database server software	Strength	Official Web address	Status
1	PostgreSQL + POSTGIS	Performance and advanced analysis	http://postgis.refractions.net http://www.postgresql.org	Open source (freeware)
2	ArcSDE + Selected RDBMS	Technical support	http://www.esri.com	Commercial
3	Oracle Spatial	Support for Java and store common spatial data types in a native Oracle environment	http://www.oracle.com/technology/products/spatial/index.html	Commercial
4	MySQL	Compatibility with PHP and other open-source s/w	http://www.mysql.com	Open source (freeware)
5	TerraLib	Time series analysis and supported by many RDBMS	http://www.terralib.org/	Open source (freeware)
6	SpatiaLite	Spatial extensions for the open-source SQLite database	http://www.gaia-gis.it/spatialite	Open source (freeware)
7	IBM DB2	Strong error handling	http://www.01.ibm.com/software/data/db2	Commercial

Table 4.3 Important GIS/map server products and their strengths

S. No.	Map/GIS server software	Strength	Official Web address	Status
1	GeoServer	Performance, security, vector support, and OGC Web services	http://www.geoserver.org	Open source (freeware)
2	UMN map server	Performance, raster and vector support	http://www.osgeo.org	Open source (freeware)
3	Arc GIS server	Technical support and GIS processing	http://www.esri.com	Commercial
4	Skyline globe	3D visualization	http://www.skylineglobe.com	Commercial
5	Map guide	Support and quick customization	http://mapguide.osgeo.org	Open source (freeware) and commercial
6	Degree	OGC Web services	http://www.deegree.org	Open source (freeware)
7	ERDAS APOLLO server	Raster support	http://www.erdas.com	Commercial
8	Intergraph geoWeb server	Engineering-based application	http://www.intergraph.com	Commercial

Table 4.4 Important application development environment for WebGIS applications

S. No.	Database server software	Strength	Official Web address	Status
1	Open Layer	AJAX library for accessing geographic data layers of all kinds	http://openlayers.org	Open source (freeware)
2	GeoBase	Geocoding, navigation and route optimization	http://www.geobase.org	Open source (freeware)
3	Geomajas	Aggregation and transformation of GIS data sources	http://www.geomajas.org	Open source (freeware)
4	GeoTools	GIS data creation, editing and processing using Java framework	http://www.geotools.org	Open source (freeware)
5	GDAL/OGR	Compatibility with any development environment	http://www.gdal.org	Open source (freeware)
6	GEOEXT	Rich GUI using Open Layer API	http://www.geoext.org	Open source (freeware)

interface (API like Open Layer), GIS objects, and spatial libraries (e.g., GDAL, OGR, Geotool). Many application servers like JBOSS (java application server) are bundled with GIS servers like ERDAS APOLLO server and available as a single package. The development of application server using open API like Open Layer API, Google API, Yahoo API is becoming very popular in user community due to its easy development and interactive support from user community. The development of application server can be done using Java SDK, .net framework, PHP, JavaScript, etc. (Table 4.4).

Web Server

A Web server is a computer program, which uses the client/server model and the World Wide Web's hypertext transfer protocol (HTTP), and serves the files that form Web pages to Web users (whose computers contain HTTP clients that forward their requests). The primary function of a Web server is to deliver Web pages on the request to clients. This means delivery of HTML documents and any additional content that may be included by a document, such as images, style sheets, and scripts. A user agent, commonly a Web

Table 4.5 Popular Web server products (Hassan and Holt 2000)

Product	Vendor	Web sites hosted	Percent (%)
Apache	Apache	397,867,089	64.91
IIS	Microsoft	88,210,995	14.39
nginx	Igor Sysoev	60,627,200	9.89
GWS	Google	19,394,196	3.16
Resin	Caucho Technology	4,700,000	0.77
lighttpd	lighttpd	N/A	N/A
Sun Java system Web server	Oracle	N/A	N/A

browser or Web crawler, initiates communication by making a request for a specific resource using HTTP, and the server responds with the content of that resource or an error message if unable to do so (Table 4.5).

Summary

This chapter analyzes the current WebGIS architectures and proposes a WebGIS development process; there are some observations as following:

- WebGIS development is more than buying GIS software and hardware. In order to succeed, the implementation phase must be considered as a process rather than a step. The process starts with requirement analysis and ends in WebGIS use and maintenance.
- Requirement analysis will expose the needed functions and consequently the WebGIS architecture. Medium client architecture has been developed for the case study as it optimizes the projects requirements.
- As the data transfer rate is high from server to client, the Internet band must be selected high; moreover, the amount of data dictates a high processor computer.

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5 WebGIS Techniques and Applications

Introduction

A WebGIS is a computer software and hardware configuration that allows the sharing of maps, spatial data, and geographic processing operations throughout one's own network and beyond using common Web communications protocols such as HTTP (Dragićević 2004) and WebSockets. In a WebGIS, resources are often sent from a centralized machine (or "server") upon request. Organizations may choose to implement WebGIS to share computing capabilities and resources across departments on a local intranet, while others may use WebGIS as a vehicle for disseminating information to a worldwide audience (Plewe 1997). In some situations, the public might even be invited to contribute or update data in an online environment.

WebGIS reduces the need for end users to install sophisticated software to work with geographic information, as most operations can be performed in Web browsers or lightweight mobile apps. Thus, the Web offers the potential to lower the GIS learning curve and increase the accessibility and exposure of GIS to the public. Implementing WebGIS on one's own servers requires a substantial investment in hardware, software, and connective infrastructure, as well as the skills to link and configure those components. As a result, new business models are emerging where GIS is sold as a package of services running on cloud architectures.

WebGIS, as the combination of the Web and GIS (Geographic Information Systems), is a new and promising field. It has unlocked the power of GIS and put online maps and geospatial intelligence in the offices/homes of millions and the hands of billions.

Disaster management system based on GIS Web services exclusively designed to handle the disaster such as tsunami, flood, earthquake, cyclone. The necessity of the system is many people lives in danger because of lack of providing timely help to the affected victims and tardy response of relief works. Disaster management system incorporates with GIS Web services to identify the affected areas and possible routes to reach the location.

GIS Web services are self-contained, self-described modular component of geospatial application which can be accessed through standard protocols. GIS Web services can be applied to various applications like geomarketing, construction and coordination, e-Governance, natural resources, urban planning, emergency response. Its approaches are used to propagate, share, and access geographical information.

GIS Web Services

A variety of commercial and open-source software options are available for setting up GIS servers. Examples include GeoServer (link is external), Map Server (link is external), and Esri ArcGIS Enterprise (link is external). Their core common feature is the ability to create Web services for GIS and mapping. A Web service is a piece of code that runs on the server and can perform some action in response to a client request. For example, a Web service might receive some bounding coordinates and an image format from a client, draw a map image, and then send the image back to the client. Another type of Web service might receive some vector feature coordinates, calculate an intersection of those features, and send back to the client the coordinates of the intersecting feature set.

In order for a client and server to interact successfully, both must understand the format and protocol for issuing the request and receiving the response. Most WebGIS transactions are executed over hypertext transfer protocol (HTTP) or its encrypted counterpart HTTPS. Furthermore, the client and server must understand a common syntax for the parameters of the request and the format of the data to be returned. To facilitate this, the Open Geospatial Consortium (OGC) has defined open specifications for GIS Web services. These include the Web Map Service (WMS) and Web Map Tile Service (WMTS) for requesting maps, the Web Feature Service (WFS) for requesting vector feature geometries and attributes, the Web Coverage Service

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(WCS) for raster data requests, and the Web Processing Service (WPS) for spatial data processing operations. In the realm of proprietary software, the Esri GeoServices specification outlines very similar types of services for map delivery, vector feature transfer, "geoprocessing", 3D scene viewing, and other GIS-related operations.

GIS Client Applications

Clients of a WebGIS can include locally installed desktop apps, browser-based apps, and native mobile apps. Open source and proprietary application programming interfaces (APIs) abound for creating custom Web and mobile applications that consume GIS Web services. These include Open Layers (link is external), Leaflet (link is external), and the ArcGIS APIs (link is external). In order to provide an intuitive user experience, these client apps and APIs often hide the details of all the Web service requests occurring in the background. For example, a user of a client app may pan and zoom a map without needing to know all the required parameters for the back-end Web service to redraw the map with a new scale and bounding coordinates.

Many maps displayed in client apps originate from multiple Web services that are each treated as layers in the final displayed map. For example, a common workflow is to request a base map image from one Web service and a thematic map overlay from another Web service. The thematic layer can be requested either as an image or as vector data to be drawn by the client. The client app combines the layers and may allow the end user to toggle their visibility or order. Decoupling the base map from the thematic layers allows clients to reuse base maps in many applications, or employ base maps from well-known third parties, such as Google Maps. The term "mash-up" is often used to describe a map created from two or more Web services in this way.

The server can deliver vector data to client apps either as a standalone file or a streaming set of features. Popular file formats for this kind of data include GeoJSON, Esri GeoServices JSON, and KML. The OGC has also defined a specification for vector features called Geography Markup Language (GML), although the verbosity of this format has led to performance concerns (Yang et al. 2005). The approach of drawing graphics on the client promotes interactivity and generally improves speed, although it can also slow down apps when the files contain many features.

Some client apps may allow the editing of vector features transacted back and forth between a GIS database. WebGIS administrators must decide whether to expose the production copy of their database for editing or restrict editors to modifying an intermediate copy that is quality-checked by an analyst. Policies must also be established for conflict resolution when multiple editors are working on the same database at the same time, especially if these editors commonly upload bulk changes after offline edit sessions.

GIS users are increasingly deploying mobile devices such as smart phones and tablets as clients of GIS servers. Because these devices are easily portable, they can send location information to the server in real time as the device is carried from place to place; however, mobile clients are also useful in circumstances where connections to the server are intermittent or unavailable. To support these offline or partially connected scenarios, the server sometimes allows a data extract or download functionality so that some data may be placed locally on the device in preparation for fieldwork. The server might also allow a data upload or synchronization action wherein edits made in the field can be sent back to the server and reconciled with the server's copy of the data.

WebGIS Performance

Users of the Web expect a fast response from their apps, which can be challenging with the massive amounts of data and processing required by GIS. Administrators can improve speed by reducing the number of transactions between clients and servers, as well as the amount of information in each transaction. Only the minimum necessary map layers and attribute data should be included in server requests and responses. Simplification of map symbols, vector coordinate geometries, and decimal numbers (through rounding) can reduce the size, or payload, of Web transactions, with the awareness that such measures will trade away some precision.

Strategies for speeding Web map performance include the use of tree indexing, multithreading, and cluster computing (Yang et al. 2005). Another tactic is to pre-calculate the results of common requests. For example, if Web users will frequently need to view the area measurements of polygons, these areas can be pre-calculated using desktop software and written into an attribute field. The server can return this value faster than it could perform the area calculation.

Another common example of pre-calculation is the division of data into a multi-scale pyramid of tessellated regions, or "tiles" that the server caches and passes out to clients without having to extract or draw data in real time. The integration of pre-drawn rasterized map tiles with asynchronous JavaScript and XML (AJAX) fetching techniques creates a map navigation experience so fast that it can appear "seamless". Pioneered by Google Maps to great popular acclaim in the mid-2000s, this approach is now common in Web maps.

The tile motif has been expanded to vector data packets which are drawn by the client, allowing a more flexible restyling of cartography than is possible with rasterized tiles. WebGL (Web Graphics Library) technology is often used for drawing vector tiles or thematic features on the client side in a way that is faster than the traditional SVG (scalable vector graphics) approach.

Security and Data Integrity in WebGIS

WebGIS administrators must ensure that sensitive data is not revealed to a larger audience than intended. Security rules can be applied at various tiers and may restrict access to end user applications, GIS Web services, map layers, geographic features, or feature attributes (Bertino et al. 2008). When vector data is proprietary or copyright-protected, it may be desirable to show only a rasterized image of map data rather than allow the download of each vertex coordinate. Limits should be placed on the scope of Web service requests to avoid Web scraping, mass downloads, or enormous data processing jobs that overburden the server (whether intentionally or unintentionally).

WebGIS administrators must work closely with their organization's existing IT management staff to ensure that Web services are secure. For greater administrative control and end user convenience, WebGIS systems and apps should be integrated with the organization's existing login infrastructure when feasible. Standard Web safety practices can boost the security of a GIS, such as granting users only the minimum privileges necessary to do their jobs, restricting physical access to server machines, requiring strong passwords that are changed on a regular basis, and so forth. All passwords and any sensitive spatial or tabular data should be transferred in encrypted form via secure sockets layer (SSL) connections. Any user input allowed into the WebGIS should be screened by client and server code for malicious intentions, such as structured query language (SQL) injection attacks.

WebGIS and Society

Makers of maps and GIS data often rely on the Web as a simple way to deliver content to the public. This includes the sharing of downloadable vector and raster data files through searchable Web sites sometimes called Geoportal. Where governments are mandated to share data, doing so online can be more economical than using traditional hard media formats (Plewe 1997). The Web also augments the potential of public participation GIS (PPGIS); for example, inviting national park visitors to point and click on a Web map to identify areas of high intrinsic value and places lacking maintenance (Brown and Weber 2011).

The increasing interactivity of browser-based and mobile apps, along with the relative in expense of satellite navigation receivers, has allowed mass public creation of spatial data through the Web. This is notable because such activities were traditionally the prerogative of trained experts. The changing tides are evident in the many user-generated layers shared in Google Earth, the emergence of volunteered geographic information (VGI) projects such as OpenStreetMap (link is external), or the simple attachment of geographic coordinates to social media posts. Furthermore, ready-made Web application templates and embeddable frames have made it easier for non-experts to introduce maps and GIS into client applications. To what degree these forms of "neogeography" have actually democratized mapping and spatial data creation is a point of active discussion (Turner 2006; Goodchild 2007; Haklay 2013), although the Web has certainly enabled alternative cartographies and counter mappings to reach a wider audience than would otherwise be possible.

WebGIS Development Methodologies

There is a growing need for standardized approaches to the development of these systems. Few authors have published some methodologies that are presented in Table 5.1.

Open-Source WebGIS Solutions in Disaster Management

Open-source software is becoming very popular in GIS domain. The open-source software is developed in collaborative manner and is available with source code for its reuse, modification, and redistribution as per technology-neutral published license. Open-source software for geospatial data creation, management, processing, analysis, presentation, dissemination, and catalog creation are available under different category of open-source GIS. Open-source software for geospatial information manipulation and processing is categorized in many types: desktop viewer, Web client and server, middleware, database management, file converter, and so forth (Torre 2005).

Free and open-source software are now common in GIS and geography as well. All kinds of GIS software can be found depending on the needs, although their categorization is not easy (Steiniger and Hunter 2013). Steiniger and Weibel (2009) have identified seven major types as following: Desktop GIS, Spatial Database Management Systems, Web Map Servers, Server GIS, WebGIS clients, Mobile GIS and Libraries and Extensions.

In opinion of Siki (2009), the main benefits of using free and open-source software are not the low price but the direct interaction between the developers and users. They all belong to the same community resulting in shorter development periods. Using open-source and free software is also

Table 5.1 WebGIS development methodologies

Methodology	Overview	Strengths/Weaknesses
WebGIS development cycle (Alesheikh et al. 2002)	A hybrid approach adapted from the waterfall model and the classical Software Development Lifecycle (SDLC). Development is split into 8 successive phases in the following order; requirements analysis, conceptual design, hardware and software survey, database design and construction, acquisition of GIS hardware and software, WebGIS system integration, application development and WebGIS use and maintenance	Suitable for the novice developer as it offers a simplified step by step approach. However, the methodology is not practical for large projects and it does not put any emphasis on user involvement and testing which are critical components during the development of such systems
Rapid GIS development (Cavaco et al. 2010)	Based on rapid application development methodology. Supports the rapid development of database-centric GIS applications. It is more of an implementation framework than a methodology	The framework derives its strength from its underlying principles of interoperability, minimizing coding, generalization of graphic editing, auditing and authentication. However the framework is not clearly defined with clearly stated phases and deliverables. What it provides is a generalized approach to WebGIS development
WebGIS Navigational Development Techniques (NDT) methodology (Escalona et al. 2008)	This process integrates models from Navigational Development Techniques methodology with models from the organizational semiotic technique (Liu 2000). Consists of requirements engineering, conceptual design, navigational design, abstract interface design and implementation. Relies on formal model definitions to represent geographical concepts	Supports the rapid development of WebGIS applications. Furthermore during the requirements engineering, it introduces the use of the organizational semiotics to define requirements

financially beneficial since instead of spending money on commercial licenses, resources can be reallocated to actual development tasks.

A Web-based application named VINGIS can be mentioned in Hungarian literature that uses PostgreSQL, php and Map Server as open-source components (Katona and Molnár 2005). International examples cover the wide range of disaster and emergency management such as Ushahidi (non-profit software company that develops free and open-source software (LGPL) for information collection, visualization, and interactive mapping), that support resource organization and management.

Applications of WebGIS

WebGIS Advantage

By utilizing the Internet to access information over the Web without regard to how far apart the server and client might be from each other, WebGIS introduces distinct advantages over traditional desktop GIS, including the following.

A Large Number of Users

A traditional desktop GIS is used by only one user at a time, while a WebGIS can be used by dozens or hundreds of users simultaneously. Thus, WebGIS requires much higher performance and scalability than desktop GIS.

A Global Reach

As an ArcGIS user, you can present WebGIS applications to the world, and the world can access them from their computers or mobile devices. The global nature of WebGIS is inherited from HTTP, which is broadly supported. Almost all organizations open their firewalls at certain network ports to allow HTTP requests and responses to go through their local network, thus increasing accessibility.

Better Cross-Platform Capability

The majority of WebGIS clients are Web browsers: Internet Explorer, Mozilla Firefox, Apple Safari, Google Chrome, and so on. Because these Web browsers largely comply with HTML and JavaScript standards, WebGIS that relies on HTML clients will typically support different operating systems such as Microsoft Windows, Linux, and Apple Mac OS.

Low Cost as Averaged by the Number of Users

The vast majority of Internet content is free of charge to end users, and this is true of WebGIS. Generally, you do not need to buy software or pay to use WebGIS. Organizations that need to provide GIS capabilities to many users can also minimize their costs through WebGIS. Instead of buying and setting up desktop GIS for every user, an organization can set up just one WebGIS, and this single system can be shared by many users: from home, at work, or in the field.

Easy to Use

Desktop GIS is intended for professional users with months of training and experience in GIS. WebGIS is intended for a broad audience, including public users who may know nothing about GIS. They expect WebGIS to be as easy as using a regular Web site. WebGIS is commonly designed for simplicity, intuition, and convenience, making it typically much easier to use than desktop GIS.

Unified Updates

For desktop GIS to be updated to a new version, the update needs to be installed on every computer. For WebGIS, one update works for all clients. This ease of maintenance makes WebGIS a good fit for delivering real-time information.

Diverse Applications

Unlike desktop GIS, which is limited to a certain number of GIS professionals, WebGIS can be used by everyone in an enterprise as well as the public at large. This broad audience has diverse demands. Applications such as mapping celebrity homes, tagging personal photos, locating friends, and displaying Wi-Fi hot spots are a few of the many current examples of WebGIS.

WebGIS for Disaster and Emergency Management

Disasters are dynamic processes (Alexander 1993) and are spatially oriented (Waugh 1995). According to (Montoya-Morales 2002) most current tools that are used for disaster management focus on the temporal component of the four phases of disaster management, leaving an obvious gap in dealing with the spatial element. Emphasis on the spatial dimension makes GIS technologies ideal for simulating the complex spatial relationships during extreme situations, while still being able to integrate other modeling tools.

The importance of WebGIS stems from its accessibility to many users. There are many authorities involved in planning, decision-making, and communications during disaster management operations. Desktop GIS does not provide instant and effective multi-user platforms for the same project, which require distributed GIS capability. WebGIS provides ease of use in terms of the technical background required from user perspective. Many decision-makers with limited or no GIS background can access geospatial information simultaneously. Decision-makers are generally divided into two general groups: response teams working in the field and decision-makers working in emergency operation centers (EOC). The EOC group works in different subgroups; communications, planning, and prediction, various sources of information can be gathered and used for disaster response and WebGIS is mostly used by the planning group as well as by field personnel and relief workers who need to access information about the current situation.

GIS Support for Disaster Management

Disaster management activities as grouped under into four phases that are related in time and function to all types of emergencies and disasters.

Mitigation

Mitigation efforts attempt to prevent hazards from developing into disasters altogether or reduce the effects of disasters when they occur. The mitigation phase differs from the other phases because it focuses on long-term measures for reducing or eliminating risk. Successful mitigation is a direct result of comprehensive planning and analysis. Disaster management planning is the process of analyzing a community's hazards, risks, and values to determine its vulnerabilities to natural, technological, and terrorist-based disasters. A comprehensive risk and hazard analysis provides the foundation for the development of mitigation, preparedness, response, and recovery plans. Disaster management planning requires acquiring, integrating, and analyzing vast amounts of information and data in a variety of disparate formats to develop a comprehensive risk-based emergency management program.

GIS technology provides the capability to map and analyze hazards of all types and visualize their potential impacts. When hazards are fused with critical infrastructure, population densities, and other community values, vulnerabilities can be observed, modeled, and better understood. Based on the potential impact of any particular hazard to critical values, priorities for mitigation can be established. Contingency and response plans can also be developed based on important values at risk. The risk and hazard assessment provides the foundation for the overall emergency management program. GIS optimizes the planning analysis process.

Identify and map, natural and technological hazards:

Can be categorized into: Natural hazards that may include earthquake faults, storm surge exposure, flammable vegetation and areas prone to severe weather events that divided into landslides and floods, Technological hazards may include hazardous materials locations, transportation corridors where hazardous materials are routinely shipped, Nuclear power plants and petroleum processing and storage facilities, identify and map critical values at risk which can be divided into population densities, critical infrastructure including government facilities, hospitals, utilities, and public assemblies, Identify values at risk that reside within the impacted areas of natural and/or technological hazards. GIS is used to model potential events (plumes, explosions, floods, earthquakes, etc.) and display projected areas of extreme, moderate, and light damage that could be caused by the event. Casualties can also be projected. Priorities for mitigation and emergency contingency and response plan development are highlighted through the use of GIS and develop site-specific strategies for mitigation to reduce losses; mitigation includes activities that prevent an emergency, reduce the chance of an emergency, or reduce the damaging effects of unavoidable emergencies. Mitigation activities take place before and after emergencies. Other mitigation functions may include enforcing building and fire codes, designating specific routes for hazardous materials shipments, requiring tie-downs for mobile homes, and shipping regulations for hazardous materials. Evaluate and model alternative mitigation strategies. Determine the best strategy for protecting critical assets from catastrophic damage or loss and reduce casualties.

Mitigation encompasses the comprehensive steps taken to prevent emergencies, reduce loss, and provide a proactive approach to the overall emergency management program. The hazard and risk assessment within the planning process provides the framework for decisions that are made in the preparedness phase.

Preparedness

Preparedness Emergency managers develop plans of action for when disaster strikes. Priorities for action plan development are identified in the planning and analysis process. Common preparedness measures include some of the following:

- Critical facility emergency contingency plans.
- Communication plans with easily understandable terminology and chain of command.
- Development and practice of multiagency coordination and incident command.
- Proper maintenance and training of emergency services.
- Development and exercise of emergency population warning methods combined with emergency shelters and evacuation plans and the stockpiling, inventory, and maintenance of supplies and equipment.
- Developing the facilities, staff, equipment, and tools necessary to plan, monitor, and facilitate emergency management decision making and information sharing.

GIS technology is utilized for preparedness as follows:

- Site selection for adequate evacuation shelters with consideration of where and how extensively an emergency might occur.
- Selecting and modeling evacuation routes.
  - Considerations for time of day.
  - Considerations for road capacity versus population, direction of travel, etc.
- Identification and mapping of key tactical and strategic facilities.
  - Hospitals.
  - Public safety facilities.
  - Suppliers to support response (food, water, equipment, building supplies, etc.).
- Training and exercises to test preparedness.
  - Identify incident locations and impacts; map incident perimeters.
  - Model the incident (plumes, spread, etc.).
  - Collect damage assessment, identify casualties, and prioritize for allocation of public safety resources.
  - Develop and distribute incident action plans.
- Providing a key capability for the command and control information system that enables situational awareness and incident management support.

To achieve comprehensive preparedness, a great deal of information must be gathered and managed. When disasters strike, the right information must be available at the right place to support emergency decision requirements.

Response

Emergency management assists in the mobilization of emergency services and resources to support first responders for complex emergencies. This can include specialist rescue teams, logistical support, public safety, volunteers, non-governmental organizations (NGOs), and others. The Emergency Operations Center (EOC) is responsible to support incident management operation needs and maintain continuity of operations for the community. Acquiring, managing, and maintaining status of resources from various locations is an important function.

GIS supports the response mission as follows:

- Provide warnings and notifications to the public and others of pending, existing, or unfolding emergencies based on the location or areas to be impacted by the incident. Areas in harm's way can be identified on the map, and mass notification can be performed from a GIS.

- Determine appropriate shelter activations based on the incident location and optimum routing for affected populations to access appropriate shelters.
- Maintain shelter location continuity of operations: supply inventories, external power requirements, shelter population capacities, etc.
- Identify the locations and capabilities of existing and mutual aid public safety resources.
- Provide facilities for the assembly of department heads to collaborate, make decisions, and develop priorities. Provide the capability to create remote connections to the command center for officials and others who need to participate but are unable to come to the command center.
- Establish the capability to collect and share information among department heads for emergency decision making to support emergency operations and sustain government operations.
- Establish the capability to share information and status with regional, state, and federal agencies.
- Support incident management operations and personnel, provide required resources, and exchange internal and external information.
- Maintain incident status and progress; facilitate damage assessment collection and analysis.
- Assure the continuity of government operations for the jurisdiction considering the impacts of the emergency.
- Prepare maps, briefs, and status reports for the executive leadership (elected officials) of the jurisdiction.

Recovery

The aim of the recovery phase is to restore the affected area to its original state. It differs from the response phase in its focus; recovery efforts are concerned with issues and decisions that must be made after immediate needs are addressed. Short-term recovery is focused on restoring essential services and support. Long-term recovery efforts are concerned with actions that involve rebuilding destroyed property, reemployment, and the repair of essential infrastructure.

GIS is integral for recovery by providing a central information repository for assessment of damage and losses that provides:

- Identification of damage (triage-based on degree of damage or complete loss). GIS allows inspectors to code parcels with the degree of damage in order to visualize specific problems as well as area trends. (GIS on mobile devices expedites the difficult damage assessment problem and can include photographs and damage reports linked to the specific geographic sites).
- Overall damage costs and priorities for reconstruction efforts based on appropriate local criteria.
- Locations of business and supplies necessary to support reconstruction.
- Assess overall critical infrastructure damage and determine short-term actions for the following:
  - First aid and health.
  - Additional shelter needs.
  - Optimum locations for public assistance.
  - Alternate locations for government operations if government facilities are damaged.
  - Alternate transportation routes for continued operations.
  - Monitoring progress by specific location of reconstruction efforts for both long-term and short-term needs.
  - Publishing maps to share information with the public and other government organizations of progress toward recovery objectives (Fig. 5.1).

Natural Disaster Management Systems

NDMS include collection, analysis, and management of all the information related to natural disasters and fulfill planning and decision making needs. They are based on large and powerful relational geodatabases where all the spatial and descriptive data are stored (see, Savvaidis et al. 2006). The structure, interoperability, expandability, ease of disseminating information among interesting parties and the overall ability to assist in planning and decision making are key points for defining the usefulness and effectiveness of a NDMS.

The design of geodatabases for storing information related to natural disasters is a crucial part in the design phase of a NDMS (see, Zeiler 1999; Peters 2006). Difficulties arise from the fact that most of the information handled is related to time, while a one-to-many relationship is often needed in order to connect various types of data. Hence, bad or erroneous design may lead to a very complicated database structure. The time dependence requires that all the information is time-stamped, which means that each table in the geodatabase must include a field of type date/time, in order for the systems to allow the time-based management, filtering and querying of the stored information. Another consideration that has to be taken into account is that some of the data that will be inserted into the geodatabase follow specific standards, which have been defined by different authorities at different time periods.

Reliable spatial and descriptive data are also needed in a NDMS (see, e.g., van Oosteron et al. 2005). Data related to previous disasters is a valuable source of information, like

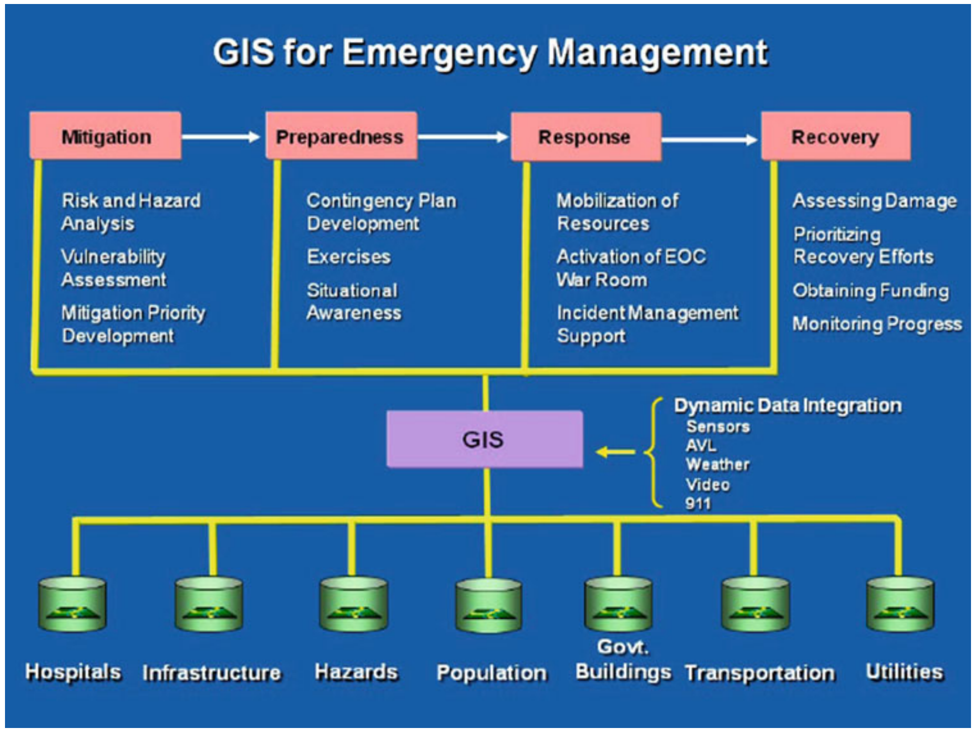

Fig. 5.1 GIS support of the emergency management workflow

for example information about the type of damage that buildings suffered, as given by in situ inspection of the buildings, or the forest area burnt due to a fire. This historical information is exploited when calibrating models and scenarios for possible future natural disasters, combining the work carried out by authorities competent to manage a disaster and the scientific research done by universities and institutes. In this way, the geodatabase of the NDMS may serve as a pool of information for many users belonging to different specializations and having various purposes.

The management of the geodatabase is done through Geographic Information Systems (GIS) and other supportive software packages and tools. When the GIS can be accessed through the Internet, then it is called a Web-based GIS. The latter provides many benefits to both the competent authorities for managing a disaster and the scientific community. Web-based GIS provide the ability to rapidly disseminate information. Thus, the competent authorities may receive in real-time crucial information from engineers, security forces, civilians, etc., while on the other hand scientists have remote access to the same information also in real time. Since Web-based GIS may be accessed through the Internet, a security policy must be also applied. The NDMS must be accessed only through a secure interface, while different categories of users must have different access rights to the system and the stored information.

WebGIS Approach for Flood Risk Assessment

Flood disasters impact the economy, natural resources, lives, property, and physical infrastructure. The magnitude of the impact depends on the emergency measures and the steps taken by the concerned authorities during the preparedness and the response phases. Providing accurate and quick information over the Internet could help reduce the loss. A standardized community-based risk assessment protocol was developed by Emergency Management Australia. This framework is based on six major elements as and discussed below.

Risk Context

The first phase is related to the establishment of risk context. Issues related to the problem at hand and the approaches of solving it are discussed in this phase.

Hazard Vulnerability

The second phase involves identifying risks in terms of hazard and vulnerability. The scope and nature of a hazard must be identified, as well as the setting of the community at risk.

Risk Analysis

The third phase in this process is risk analysis. In this phase, tools of problem analysis, for instance modeling software, are used to analyze risks associated with the problem identified in the risk context phase.

Risk Evaluation

The fourth phase is risk evaluation, which involves prioritizing the risk and comparing it against risk evaluation criteria. Risk thresholds are also established in this phase.

Communication

The last phase in this process deals with treating risks according to the result of the evaluation. Results obtained from the risk evaluation phase will be communicated to the concerned stakeholders to allow them to implement disaster management measures.

Web-Based GIS for Earthquake Disaster Management

Geographical Information Systems (GIS) provide the appropriate platform for the registration and management of data related to natural disasters as well as the proper mean for the presentation of the damage caused by natural disasters, which results from the scenarios analysis process. The advantage of the GIS lies in the ability to assimilate different layers of geographic data and correlate them with each other. Web-based GIS are Geographical Information Systems providing many capabilities for management and analysis of geographic data using technologies through the Internet. Those systems provide effective tools and methodologies for the management of the disasters and their impact.

Earthquakes are considered as one of the most destructive natural events, with evident impact on urban infrastructure and human fatalities (Savvaidis et al. 2005).

Earthquake, as the natural hazard, is the part of the world around human being. Its occurrence is inevitable. It destroys natural environment but the natural environment takes care of itself. So earthquake becomes a disaster when it crosses paths with the man-made environment, such as buildings, roads, lifelines, and crops.

Earthquake response phase includes activities take place during or just after an earthquake, which are designed to provide emergency assistance for victims. Just after the earthquake, repairing lifelines networks to stabilize the situation and reduce the probability of secondary damages (for example, gas network to prevent secondary damages or shutting off contaminated water supply sources…), search and rescue activities, transport and communication, evacuation are the priorities to operate. Quick rescue of people by search and rescue teams from collapsed buildings, after the impact of a destructive earthquake, can save considerable number of lives. Then, emergency sheltering should be managed and distribution of water, food, and public services should be provided also, medical heath centers should be identified in order to give medical care to the casualties.

Volcanic Hazard Identification

Risk is a measure of the expected probability of damage induced by adverse events. Risk, therefore, combines the multiple relevant hazards in a given area, of the exposed assets, their vulnerability and of the capacity of societies to cope with these hazards (e.g. Marzocchi and Woo 2009; Alberico et al. 2011). Boundary objects in volcanic risk management include, for example, scenarios and hazard and risk maps (e.g. Thierry et al. 2008; Felpeto et al. 2007), as well as tools such as Geographical Information Systems (GISs) to disseminate this material (Pareschi et al. 2000).

Web-based cartography has now reached maturity for disseminating the heterogeneous hazard and risk geographical information (e.g. Müller et al. 2006; Douglas et al. 2008). Consequently, numerous WebGIS tools have been developed for disseminating data and information relevant for volcanic hazard assessment. For example, the Glob volcano (http://www.globvolcano.org/) and EVOSS tools (Tait and Ferrucci 2013) provide Earth observation-based services aimed at monitoring volcanic natural phenomena. The tool developed with in the HOTVOLC project disseminates remote-sensing information on volcanic ash clouds in near real time (Labazuy et al. 2012). One important application of this tool is the management of volcanic ash crises and the associated threats for aircraft navigation. Finally, the Lav@hazard tool (Vicari et al. 2011) is focused on the production of services based on remote-sensing products and lava-flow scenarios. Such tools have considered the needs of the users and have proven useful to access the threats induced by volcanic processes and to take appropriate measures to prevent or manage a crisis.

All these tools share a common feature: their design was organized around key modeling tools or earth observation systems.

Forest Fire Hazard Zone Mapping

Forest and land fire can cause negative implications for forest ecosystems, biodiversity, and air quality and soil structure. However, the implications involved can be minimized through effective disaster management system. Effective disaster management mechanisms can be developed through appropriate early warning system as well as an efficient delivery system.

A forest fire can be a real ecological disaster, regardless of whether it is caused by natural forces or human activity. It is impossible to control nature, but it is possible to map forest fire risk zones and thereby minimizing the frequency of fire, avert damage, etc. Forest fire risk zones are locations where a fire is likely to start, and from where it can easily spread to other areas. Anticipation of factors influencing the occurrence of fire and understanding the dynamic behavior of fire are critical aspects of fire management. A precise evaluation of forest fire problems and decisions on solution methods can only be satisfactorily made when a fire risk zone map is available. Satellite data plays a vital role in identifying and mapping forest fires and in recording the frequency at which different vegetation types/zones are affected. A Geographic Information Systems (GIS) can be used effectively to combine different forest-fire-causing factors for demarcating the forest fire risk zone map.

The development of GIS (Geographic Information Systems) has provided a powerful tool for managing and solving emergency management problems. GIS is a professional computer system for collecting, storing, managing, retrieving, transforming, analyzing, and displaying of spatial data. It can be used for many kinds of purpose in both macro and microscales. GIS were designed to support geographical inquiry and, ultimately, spatial decision making. Especially in the natural disaster area, GIS has been applied in the simulation and early warning system, emergency management system, and disaster damage assessment, etc. Forest usually located in the rural area has covered large amount of territory. GIS as a spatially analysis tool has great advantage for forest fire risk management.

Summary

WebGIS allows the sharing of GIS data, maps, and spatial processing across private and public computer networks. Understanding WebGIS requires learning the roles of client and server machines and the standards and protocols around how they communicate to accomplish tasks. Cloud computing models have allowed Web-based GIS operations to be scaled out to handle large jobs, while also enabling the marketing of services on a per-transaction basis.

A variety of toolkits allow the development of GIS-related Web sites and mobile apps. Some WebGIS implementations bring together map layers and GIS services from multiple locations. In Web environments, performance and security are two concerns that require heightened attention. App users expect speed, achievable through caching, indexing, and other techniques. Security precautions are necessary to ensure sensitive data is only revealed to authorized viewers.

To effectively reduce the impact of every disaster, governments prepare a complete strategy, called disaster management. Availability of data such as: buildings, lifeline systems, roads, hospitals, etc., will help the managers to better decision-making. The majority of this data is spatial and can be mapped. So a Geographic Information Systems (GIS) can support disaster management as a powerful tool for collecting, storing, analysis, modeling and displaying large amount of data. Many organizations which involve in disaster management, require to access to the right data in the right time to make the right decisions. So designing a GIS to distribute geospatial information on a network such as Web, gives a chance to the managers of organizations to easy access to the information about disaster any time and any where they are.

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6 Artificial Intelligence and WebGIS for Disaster and Emergency Management

Introduction

GIS problems are often subject to what is known as curse of dimensionality, which means that the state space grows rapidly when the number of parameters increases. However, the use of intelligent algorithms reduces considerably the size of the state space and helps to quickly find the optimal configurations.

GIS can be thought of as theories and techniques designed to collect, store, manipulate, analyze, manage, and present geographically spatial data from the real world (Burrough 1986). It is usually considered to have four components: geo-database; geo spatial analysis; geo-modeling; and geo-visualization. GIS-based analysis can effectively derive useful information from large quantities of spatial data.

Artificial intelligence is a way of making a computer, a computer-controlled robot, or a software think intelligently, in the similar manner the intelligent humans think. An artificial neural network (ANN) is a type of artificial intelligence technique based on how the human brain functions (McCloy 2006).

Artificial intelligence provides sophisticated techniques for GIS projects while GIS is a powerful technology with the vast datasets and wide scope of applications for AI.

Geospatial information system (GIS) can provide a great environment for using machine learning algorithm for spatial data such as satellite images. Integrating this functionality with artificial intelligence algorithms for analyzing spatial data enables us to predict challenging disasters.

This chapter indicates relationships between artificial intelligence and geographic information systems critically.

Intersections of Artificial Intelligence and GIS

Intelligence is the ability to acquire and apply knowledge, reason deductively and exhibit creativity, and AI is defined as the ability to perform functions that are typically associated with the human intelligence. As the subject of AI has such a broad spectrum, there is no single definition for the role of AI in GIS. One particularly useful definition, nevertheless, is provided by Smith in reference (Openshaw and Openshaw 1997): "Artificial intelligence may be regarded as an attempt to understand the processes of perception and reasoning that underlie successful problem solving and to incorporate the results of this research in effective computer programs". However, this definition does not answer the purpose of current technological development in GI science.

Artificial neural network provides a mechanism for learning from data and mapping of data. They can solve complex problems and can "learn" from prior applications. ANNs can be trained to provide an alternative approach for problems that are difficult to solve such as decision-making problems in GIS. ANNs are biologically inspired and based on a loose analogy of the presumed workings of a brain. However, if the workings of the human brain are to be simulated using ANNs, clearly, drastic simplifications must be adopted. Similar to the neuron structure of the brain, ANNs also consist of neurons and connectors. Several architectures of ANNs have been developed, but generally, they all have the same components. In a feed-forward ANNs, neurons are aligned in rows, called layers. Each neuron in a layer is connected to all neurons of the preceding and succeeding layers.

Most neural networks are slightly more complex. For the geography, ANNs can advance our understanding of spatial phenomenon by making the modeling of complex systems more manageable and provide powerful, flexible tools that learn to recognize patterns and relationships via exploratory spatial data analysis (ESDA). Particular areas in GIS where ANNs have been applied include a classification of census data using a Kohonen self-organizing map (SOM) (Kohonen 1997) and prediction of precipitation or residential property values using feed-forward architectures.

Fuzzy logic theory generalizes crisp logic to allow truth values to take partial degrees. Since bivalent membership

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functions of crisp logic are replaced by fuzzy membership functions, the degree of truth values in fuzzy logic becomes a matter of degree, which is a number between 0 and 1. An important advantage of using fuzzy models in real-world representation by GIS is that, they are capable of incorporating knowledge from human experts naturally and conveniently, while traditional models fail to do so. Other important properties of fuzzy models are their ability to handle nonlinearity and interpretability feature of the models which are typical for geographical applications. Fuzzy sets allow for quick processing of information by the association of vaguely similar patterns while providing the means to deal scientifically with subjectivity—a territory that traditional science has essentially ignored (Yen and Langari 1999). Openshaw and Openshaw (1997) suggest that fuzzy logic techniques provide the ability to develop soft computing applications that permit computer models to be specified and built from linguistic statements, based on common sense or theory or rules of thumb.

AI and GIS Convergence

There is significant convergence of AI and GIS. AI provides sophisticated techniques for GIS projects while GIS is a powerful technology with the vast datasets and wide scope of applications for AI. For example, fuzzy logic has been successfully applied to imprecise spatial issues like data collection, representation, and analysis as well as classification of land, soil, and remotely sensed imagery.

Neural networks have been used by the GIS community now for several years as an alternative tool for classification and feature extraction (Lees and Ritman 1991). Openshaw and Openshaw (1997) demonstrated the usefulness of ANNs in modeling spatial interaction and classifying spatial data. Wang (1994) has shown that neural networks can be successfully integrated within a GIS for performing land suitability analysis.

Dantas et al. (2000) developed an application of ANNs in modeling of travel forecast for transportation planning in Boston metropolitan area. The model intends to quantify trips within the urban area through the representation of the land use–transportation system interaction. The data to express such a complex interaction were mainly obtained from satellite images and processed in GIS. Similarly, Pijanowski et al. (2002) applied neural networks and GIS in the Land Transformation Model (LTM) to forecast land use changes. ANNs were used to learn the patterns of development in the region and test the predictive capacity of the model, while GIS were used to develop the spatial, predictor drivers and perform spatial analysis on the results.

Yanar and Akyürek (2006) used Fuzzy Cell (a system designed and implemented to enhance conventional GIS software with fuzzy set theory) to construct fuzzy rules by capturing rules from human experts and to find spatial solution to decision problem. They trained the ANNs by obtaining fuzzy measures against input data to recognize patterns for reproduction of relevant sites for whole, large-volume data fast and in an effective manner.

Beres et al. (2008) applied neural network (multilayer perceptron) to handle the existing nonlinear relation between the target variable (frost days) and the predictors (location and elevation of the meteorological stations). The parameters of the model (number of neurons, activation function, optimal weights, and scaling) were tuned with the help of a validation dataset, minimizing the RMSE between predicted and measured values. After tuning parameters, maps were produced over a digital elevation model for different months. Modeling and analyzing the spatial distribution of the mean number of frost days per month was based on using neural networks and GIS tools considering risk factors.

Importance of AI in GIS

There is a pursuit to utilize techniques in artificial intelligence to promote the intelligent information processing in GIS. Techniques in knowledge-based systems in artificial intelligence have tremendous capability of modeling such real-world situations. AI-based models can allow users to justify both the weightings of the similarity algorithms and the predicted community types in real-world terms, i.e., similar situations in the case-base. Such models will enable the user to quantify the relative importance of the measured factors associated with the distribution of other spatial phenomena.

Most projects investigating AI methods in GIS applications have mainly following goals (Mann and Benwell 1996):

- To improve selection approaches in spatial patterns
- To assess the predictive accuracy and appropriateness of spatial modeling technique independently and as an integrated model for various datasets
- To use AI techniques to gain insight into important spatial functions and processes through rule extraction and factor sensitivity tests.
- Remote Sensing: ANN is increasingly being used for the purpose of determining spatial patterns. In the area of landscape ecology, landscape pattern is an important factor enabling classification (Bischof et al. 1992; Civco 1993; German and Gahegan 1996). Landscape patterns can be ascertained through analysis of pixels: their shape, color, connectivity, direction, edges, and patchiness. Using ANN, the weighting of pixels and their inter-relatedness provide clues about the relationships of objects on the landscape (Atkinson and Tatnall 1997).

Geospatial Artificial Intelligence

The field of geospatial artificial intelligence, or geoAI, has used many of the same techniques within general artificial intelligence (AI). However, there are both challenges and opportunities that AI has to face in applying geospatial knowledge that also addresses issues of time and spatial bias (Lin et al. 2017).

One challenge has been to develop automated map readers using deep learning techniques that can separate textual information, such as names of places, from map features, including contours. The development of optical character recognition (OCR) allows map readers to understand variation between types of information, such as textual and graphic based, so that they can be separated and interpreted together, such as naming of features (Li et al. 2018).

AI and Deep Learning for Geospatial

Machine learning (ML) refers to a set of data-driven algorithms and techniques that automate the prediction, classification, and clustering of data.

Deep learning refers to a subset of machine learning composed of algorithms that permit software to train itself to perform tasks, like speech and image recognition, by exposing multilayered neural networks to vast amounts of data.

Machine learning and deep learning can play a critical role in spatial problem solving in a wide range of application areas, from image classification to spatial pattern detection to multivariate prediction.

Spatial machine learning

- Incorporate geography in their computation
- Shape, density, contiguity, spatial distribution, or proximity.

Deep learning has become the most popular approach to developing artificial intelligence (AI). Machines perceive and understand the world. It empowers geospatial ecosystem by providing real-time near-human-level perception; integrates into analytical workflows and driving data exploration and visualization—automating the entire process of creating scalable insights from large amounts of data. Such machines will be able to "understand" geospatial information themselves and with deep learning, able to self-obtain geospatial information from their surroundings as per required to do their jobs, processing it in real time. This is truly an extraordinary time.

Data today comes to us in many different forms and resources. Geospatial is a key platform which uses geographic coordinates in bringing different data together. The most important part looking through AI and deep learning is to understand the context and not just the objects.

ArcGIS has machine learning tools such as classification, clustering, and prediction.

Clustering is the grouping of observations based on similarities of values or locations.

A classification is the process of deciding to which category an object should be assigned based on a training dataset.

Prediction is using the known to estimate the unknown.

Neural Artificial Intelligence in GIS

Artificial neural networks and techniques of deep learning to train deep networks are becoming dominant in specialized tasks like natural language processing, image processing, language translation and financial predictions, and many more interesting tasks. These technologies can also be applied to geospatial data of satellite images, data with latitude–longitude information, climate data, and geotagging data to manipulate and make predictions for various applications. New optimization techniques and powerful neuromorphic hardware can add extra layer to understand geospatial data in time series manner and uncover the tremendous benefits hidden inside GIS data.

Possible Applications

Disaster Management

The combination of GIS and expert systems (ES) greatly expands the utility of GIS. This allows the user to not only have a visual mapping capability with the ability to overlay the maps with information from many databases but also enables the computer to use expert abilities to make decisions based on the GIS information. The concept behind ES is the transfer of the technical expertise of a human to a computer program. This knowledge is then stored and users, not experts, can access and use the knowledge to assist in complex decisions when needed. When the expertise of hydrologists and meteorologists is available via the computer and combined with the topographic information and databases available in a GIS system, the result is a decision-support system that is available immediately for both planning and response to a disaster.

Predictions and Remote Monitoring

The neural system can handle complex weather and climate imagery data patterns that humans can not process at large scale in real time and come up with solutions for problems like climate change, air pollution, water pollution, and forest management using geospatial data. This neural framework can optimize on land data, agriculture data, regional-based crop data, and regional-based financial data to maximize economic benefits for society.

Internet of Things (IoT)

Every connected device that uses GIS application software can use a neural system as a platform to predict, adapt, learn, and make decisions for end users. Neural geospatial data system can be a core engine for self-driving vehicles and drones to adapt and manipulate an environment in a real-time manner using all kind of GIS data.

Geographic Consumer Behavior

Neural structures can learn and make predictions of consumer behavior using geographic data and come up with specialized regional solutions. Neural-based systems can create an ecosystem around various GIS applications and build a knowledge base to take effective and valuable decisions for tasks that require geographic information and expertise.

Integration with Geographic Information Systems

Environmental Systems Research Institute (ESRI) (1990) defines GIS as an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.

According to Thurston (2002), the integration of ANN modeling in GIS can be applied in many applications to improve decision-making process. Experimental studies have been carried out on the integration of ANN model and GIS system in property valuation (Brondino and da Silva 1999; Moon and Hagishima 2001; Hall and Morgan 2001).

Big Data, AI, the Value of GIS

Geospatial technology is adapting to a changing business climate where there is a heightened awareness of its value. Geospatial technology has evolved from web mapping (think Google Maps) and car navigation (think in-vehicle systems) to embedded geoprocessing for Hadoop and advanced visualizations for business intelligence solutions. Here are a few things to consider.

Big Data Is just Data

There are solutions now that can process the volume and speed of information more efficiently. Significantly, though, location continues to bring essential context and the capability to calculate more data, and hence, more answers to geospatial questions can be facilitated. Questions, that before seemed impossible to consider because of the myriad attributes required delivering an answer, are now possible to pose. Spatial calculations and spatial statistical models that benefit from crunching more data are facilitated by utilizing big data frameworks.

Security and Geospatial

Whether it is a natural disaster, terrorist activity or cyber-threat…every incident happens somewhere. Acquiring numerous sources of location-based data will provide the foundation in mitigating threats to personal, economic, and national security. With the aforementioned big data frameworks, connecting the electronic dots that may reveal the complex web of security threats becomes more feasible.

Geospatial Precision

Collecting geospatial data with high precision is driving many new applications. Our IT infrastructure (e.g., big data frameworks; computer clusters) has allowed new applications to be realized because it was believed to be too costly previously. For indoor location applications where mobile-trace data is available, as well as remotely sensed, Earth observation (EO) imagery, where higher spatial resolution is regularly captured, time to value is shorter. Machine learning is accelerating spatial data processing. Resource mapping and change detection that requires EO data is faster and therefore higher resolution data with more pixels to process is no longer an impediment.

Role of Artificial Intelligence Technologies in Crisis Response

Crisis events, like the 9/11 attack, Hurricane Katrina, and the tsunami devastation, have dramatic impact on human society, economy, and environment. The crisis response term is defined as the immediate protection of property and life during the crises events to reduce deaths and injuries. Crisis response requires urgent action and the coordinated application of resources, facilities, and efforts. It includes actions taken before the actual crisis event (e.g., hurricane warning is received), in response to the immediate impact of a crisis, and as sustained effort during the course of the crisis. Depending upon the magnitude and complexity of the crisis, response may be a large-scale and multi-organizational operation involving many layers of authorities, commercial entities, volunteer organizations, media organizations, and the public.

These entities work together as a virtual organization to save lives, preserve infrastructure and community resources, and reestablish normalcy within the community (Ashish et al. 2007). Artificial intelligence technology tries to improve the efficiency of the management process during the crisis response via: robotics sustaining urban search and rescue operations (Shah and Choset 2003), enhancing information sharing using ontologies, providing customized query to crisis actors (Bloodsworth and Greenwood 2005), and providing multi-agent systems for real-time support (Schurr et al. 2005) and simulated environments (Massaguer et al. 2006).

Robotics

Multi-robot solutions had been adopted in a wide range of crisis response operations. Specifically, robots are used in Urban Search and Rescue (USAR) operations. Urban Search and Rescue involves locating, rescuing, and medically stabilizing victims trapped in confined spaces. USAR workers have 48 h to find trapped survivors in a collapsed structure; otherwise, the likelihood of finding victims still alive is nearly zero. Robots can bypass the danger and expedite the search for victims immediately after a collapse. Their ability to navigate through tightly confined spaces which people cannot access makes them extremely useful for quickly getting to a location within the crisis site. Robots can be deployed to a large crisis to search multiple locations simultaneously to expedite the search process. They can map the area and identify the location of victims using Radio Frequency Identification (RFID) tags. During the search, they can deposit radio transmitters to be able to communicate with victims, use small probes to check victim's heart rate and body temperature and supply heat source and small amounts of food and medication to sustain the survivors (Shah and Choset 2003).

Challenges to Using Artificial Intelligences in GIS

There are though a number of challenges that remain despite some successful efforts. One challenge is varying temporal resolution. For instance, modeling and predicting chronic disease patterns that have long latency periods has not been successfully done. In this case, various factors, including long development periods and multiple physical, environmental factors could mean that existing spatial datasets may not be diverse enough, or even go back far enough in time, to allow forecasts to be easily made (VoPham et al. 2018).

Other areas of focus have been on enhancing low-resolution imagery to improve knowledge awareness for given areas or even historical data purposes. The use of convolution neural networks (CNNs) has been extended to low-resolution satellite imagery, and it has been shown to improve feature identification as low-resolution data could be enhanced with basic input in different spectral bands. This allows such approaches to possibly address the limitation of earlier satellite systems, such as the early Land sat systems, to be enhanced and better utilized for long-term land use change (Collins et al. 2017).

Summary

AI search techniques enable a fast and efficient way to optimize placement of spatial entities in a network. Furthermore, genetic algorithm offers to optimize alreadyoptimized solutions. While multithreading would be a good alternative to process simultaneously computations for different numbers of sensors, more sophisticated heuristics could, however, accelerate both SLOTS and GA.

Neural artificial intelligence (AI) is going to be an essential part of our life from education to major sectors like healthcare, energy, transportation, exploration, politics, and manufacturing. Today humans are heading toward new abundance created by computation and AI technologies on top of big data. In near future, neural artificial intelligence will drive innovation and solutions in major problems like climate change and health care to create a more knowledgeable, peaceful, and healthy society by making a prosperous and meaningful life for humanity.

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7 Cloud Computing and WebGIS for Disaster and Emergency Management

Introduction

Cloud computing is a way of supercomputing shares computer resources on Internet instead of using software or storage on local computers (Nurmi et al. 2009). It can provide scalable and on-demand services on computing, storage, software, and hardware with high reliability and safety to Internet users (Yang and Wu 2010). In addition, it is an extent of changing with the need, that is to say the manufacturer provides relevant hardware, software, and service according to the need that users put forward (Zhang et al. 2010).

Cloud computing is evolving as a key computing platform for sharing resources that include infrastructures, software, applications, and business processes. Virtualization is a core technology for enabling cloud resource sharing (Zhang and Zhou 2009).

Cloud computing can be perceived as having five key characteristics (on-demand self-service, ubiquitous network access, location-independent resource pooling, rapid elasticity, and pay-per-use), three delivery models (SaaS—software as a service, PaaS—platform as a service, IaaS—infrastructure as a service), and four deployment models (private, community, public, hybrid) (Foster et al. 2008).

At the same time, with the rapid development of Internet technology and Geographic Information Systems (GIS) technology in recent years, WebGIS which is GIS based on Web becomes reality. WebGIS is a kind of Geographic Information Systems, which is based on Internet platform, client applications using network protocols, running on the Internet (Yuan 2010). WebGIS differs from traditional GIS in that it masks the differences between diverse types of hardware, software, networks and databases, which results in interoperability among different applications and data sources (Han et al. 2010). Moreover, WebGIS improves the sharing and synthesis of multi-source data, especially makes the sharing of spatial data and geosciences models more widespread. The basic functions of WebGIS include a variety of applications through the use of spatial analysis, modeling, network technology, database and data integration technology, and further development environment to meet the broad needs of users. As a result, WebGIS proposes a higher demand for the hardware and software, especially the software such as system architecture, GIS platform, and development technology.

The emergence of cloud computing, no doubt, brings new opportunities for WebGIS. Thanks to cloud computing, the massive data that knowledge acquisition and decision support information needs can be scheduled and parallel processed entirely within the cloud instead of being transferred on the network (Yang and Wu 2010).

Principles of Cloud Computing and WebGIS

Cloud computing is the development of grid computing, distributed computing, and parallel computing. The basic principles of cloud computing are to make the computing be assigned in a great number of distributed computers rather than local computers. And cloud computing can enable each kind of application system according to need to gain the computation strength, the storage space, and all kinds of software service (Zhang et al. 2010).

WebGIS is a kind of Geographic Information Systems, which is based on Internet platform. It can realize storage, query, management, analysis, display, and output functions of spatial data in Internet environment. The basic idea of WebGIS is to make users query and manage geographic information in a certain network protocol and security mechanism (Choi et al. 2005).

WebGIS employs B/S model, which uses multiple hosts, multiple databases, and multiple clients connected to the Internet by distributed method. Because of its network position-setting, it has a good openness and compatibility, and it is easy to popularize. Compared with the traditional GIS, WebGIS has the following characteristics:

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– Cross-platform. Regardless of windows, Linux, or other operating system users, as long as the network connected, you can use the browser to get geographic information services which WebGIS provided.
– Dynamic interactivity. In the past, GIS system only focuses on geographic data processing itself, the interaction is weak. WebGIS changed the monotonous process, through interaction with users to adjust the display dynamically to complete diverse requirements.
– Extensibility. WebGIS can combine with Java, ActiveX, and other Web technologies to build flexible GIS applications.
– Distributed data storage. Most of data previously stored on the user's computer hard drive, easy to be deleted by mistake operating. However, the data is placed in network server and is managed by professional team. All of these ensure data security and make the use more efficient.

Cloud GIS

GIS is an integrated system of computer hardware, software, and spatial data (topographic, demographic, tabular, graphic image, digitally summarized), performs manipulative and analytical operations on this data to produce reports, graphics, and statistics, and controls geographic data processing workflows.

Cloud computing is "a type of parallel and distributed system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements." This definition reflects the fact that both computer and data exhaustive applications, such as GIS applications, can with good grace be moved to clouds (Buyya et al. 2008).

The cloud computing technology has revolutionized the way one works. Although GIS has been a late adopter of the cloud technology, the many advantages are compelling organizations to shift their geospatial functions to the cloud. Cloud-based tools are accessed for Web-based Geographic Information Systems. Data generated as maps are helping analyze and optimize operations in real-time. Applications in the cloud are helping manage isolated silos of GIS workflows, and thus, Cloud GIS could be defined as a next-generation on-demand GIS technology that uses a virtualized platform or infrastructure in a scalable elastic environment.

Cloud GIS has been a suggestive approach to upgrade the conventional GIS applications in order to provide broad-spectrum services to the users across the globe. The extensive use of GIS over the decades has been put to a question mark whether to shift it to more superior alternative, i.e., cloud computing paradigm. Geographic Information Systems (GIS) applications have been moving into the cloud with increased drive; global organizations like ESRI, Cloud GIS Ltd have already taken the quantum leap and taken a technological shift to cloud computing paradigm and are committed to provide on-demand services to their extensive shades of users. World's largest Cloud GIS infrastructure providers are Amazon (Amazon EC2 & S3), Microsoft (Microsoft Windows Azure, Windows Server Hyper-V), and IBM (IBM Cloud) which provide reliable and secure cloud IT infrastructure to the customers on demand.

Why Cloud GIS?

Cloud GIS provides authoritative tools which can help many businesses, especially, when optimization and cost reduction are critical. Some basic principles which characterize Cloud GIS to be accepted as the serious contender for next-generation GIS computing paradigm are:

- **Providing Application Infrastructure**
  Cloud GIS provides the dedicated framework for geoenabling business data and systems. For organizations previously invested in GIS, Cloud GIS resources can be exploited to increase the assistance, making the organizations business and geographic data easier to be analyzed, authored, and managed. Cloud GIS provides Web services and application hosting for the organizations to make the organizational geographic data to be easily accessed, published, and consumed.
- **Support Technology Infrastructure**
  Cloud GIS as a computing paradigm for geographical data provides subscribers' leverage of virtualized sophisticated hardware and software resources and full access to data creation, analysis, editing, and visualization. Simple collaborative utilities further enhance the spread of GIS across an office or across the globe.
- **Plummeting Support and Maintenance**
  Implementation of in-house Geographic Information Systems (GIS) within an organization requires people with specialized skills and elevated technical capabilities. Cloud GIS eliminates the need for in-house GIS potential for basic geoinformation access capabilities. For organizations that already have GIS capability, it will be complimentary for highly skilled in-house staff from having to take care of basic information requirements and letting them deal with more complex responsibilities and services. For customers, this means no bigger straight implementation investments and significant ongoing reductions in their in-house IT support and maintenance burden.

- **Reducing Implementation Cost**
  Cloud GIS has a tremendous capability of providing its consumers the advanced geotechnology infrastructure, the services, and the geospatial data. There is no huge initial investment in time and cost or partial maintenance. This is most significant because the cost of an enterprise Geographic Information Systems can be quite large. Cost becomes the basic reason why many organizations do not provide any GIS solutions to their customers. With Cloud GIS that threshold to entry is eliminated to a larger extent.
- **Leveraging Data Command**
  The essence of GIS is to provide imagery and topographic mapping, which act as a foundation against which other spatial data are encrusted. For GIS application providers, it costs a considerable amount of money to obtain and process from a spatial data vendor. The Cloud GIS has capabilities to provide the underlying data as component of the core services made available through standard Internet-enabled devices. The rapid elastic nature of Cloud GIS makes it sure that users can increase or decrease capacity at will. Cloud GIS provides the users capabilities to input, analyze, and manipulate spatial information. In addition to that Cloud GIS advanced services for storage and management of spatial information prove to be supportive for users.
- **Location-Independent Resource Pooling**
  Cloud GIS has the tremendous capability of providing location-independent resource pooling; processing and storage demands are balanced across a common infrastructure with no particular resource assigned to any individual user. The pay-per-use property of Cloud GIS provides the leverage that consumers are charged based on their usage of a combination of computing power, bandwidth use and/or storage.
- **Data Conversion and Presentation**
  A data conversion service implies the transformation and importing from one format into a new database. For any GIS, it is utmost importance and requires dedicated in-house technical resources which include infrastructure, software services, and skilled manpower. Cloud GIS provides its users the spatial data conversion services without any requirement of in-house resource capabilities and that too on demand. The advanced features like 3D presentation of spatial information in Cloud GIS remove the traditional “pancake perspective” that flattens all of the interesting details into force-fitted plane geometry.

Cloud GIS Architecture

Some providers look at cloud computing as way to provide computer or storage capacity as a service, provisioned from a parallel, on-demand processing platform that leverages economies of scale. Others may equate cloud computing with software as a service, a delivery model for making applications available over the Internet. IT analysts view cloud computing from the perspective of variable pricing without long-term commitments and massive elastic scaling of services. IT leaders look at cloud as an infrastructure architecture alternative that can reduce costs. End users, the media, and financial analysts have still other perspectives on what cloud computing represents (IBM 2010).

For GIS applications, the Cloud GIS can prove to be an approach to provide computer or storage capacity as a service, provisioned from a parallel, on-demand processing platform that leverages economies of scale to varied shade of users and organizations requiring GIS application services. Having said much about the Cloud GIS capabilities, it becomes very imperative to understand the underlying architecture of Cloud GIS system.

Figure 7.1 shows proposed Cloud GIS architecture which can be followed to develop a consolidated, elastic pool of computing and storage system to gather, manipulate, analyze, and display spatial data. We have followed a multi-tiered architecture approach which separates different logical components of Cloud GIS system to exploit the capabilities of each component at its best. The given system will be capable of providing flexible solution, heterogeneous platform, scalable (horizontally and vertically) infrastructure, secure and personalized environment, extensive business intelligence system, and elastic platform to the GIS users.

The proposed Cloud GIS architecture can be broadly divided into two major components which are:

- Cloud GIS Web Interface.
- GIS Server.

Cloud GIS Web Interface

The idea behind Cloud GIS Web interface is to provide flexible, robust, and cost-effective Web-based interface to the users by taking advantages of Web 2.0 and associated technologies. The Cloud GIS Web interface will be one of the core components of Cloud GIS which will be actually a zero downtime Web application with real-time content

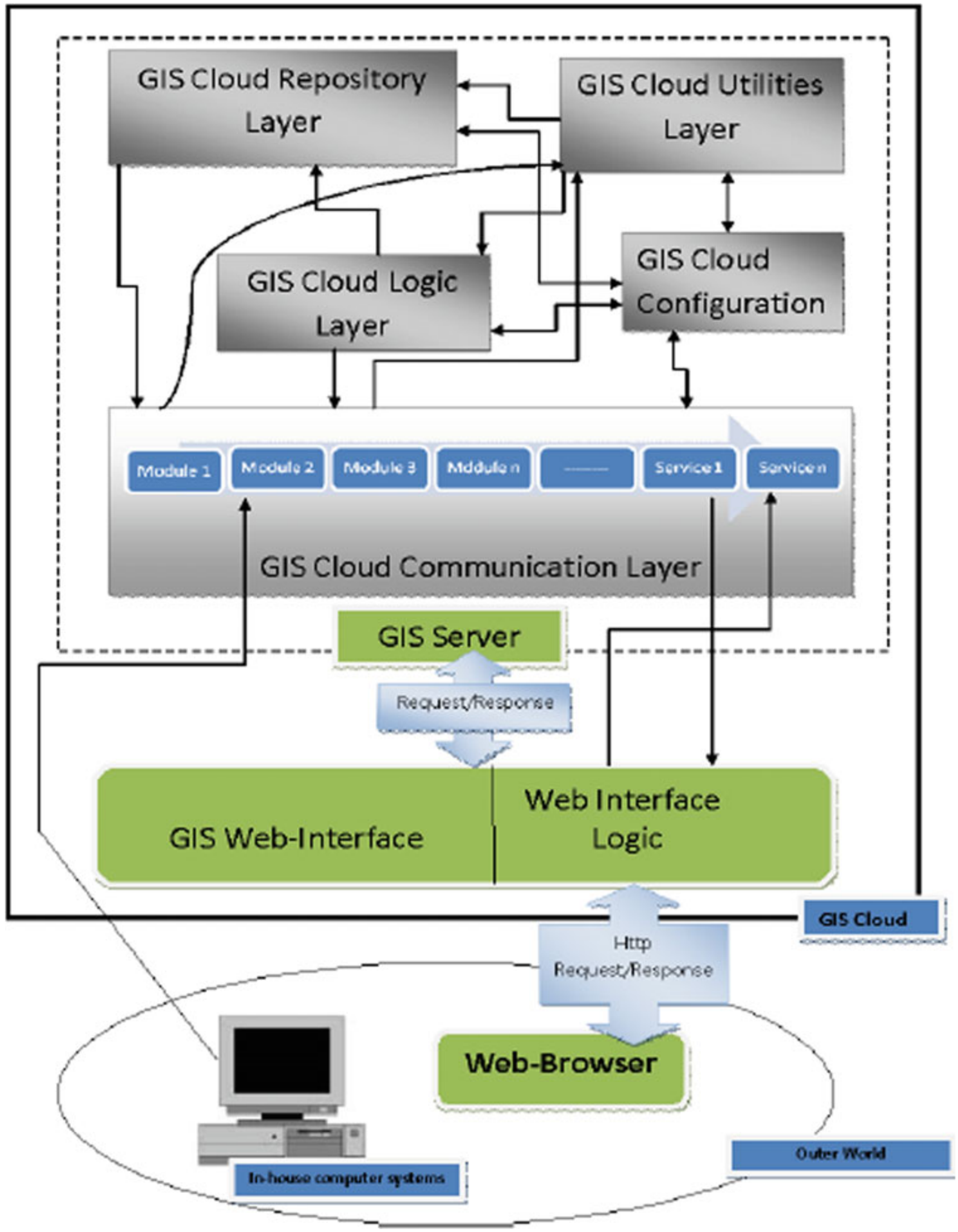

Fig. 7.1 Proposed Cloud GIS architecture (Bhat et al. 2011)

updates. The main aim will be to provide users a better experience by downloading it in less than 10 s. This allows user personal and complete interactivity. It makes content available using varied technologies like broadband, mobile, RSS and enhance employee productivity by creating a CMS which executes the workflow (from accessing raw content and delivering the processed copy) for publishing content in 3–5 min in routine situations and have exceptions to the process to take care of emergency scenarios. This process allow the GIS team to analyze user behavior and all online properties like online map production to chart out a more robust future growth roadmap and allow users to view, edit, and integrate maps in the system.

Integration of all elements, which allows interlinking of geospatial information in terms of text/audio/video/maps, etc., with each other across the spectrum.

GIS Server

The idea behind GIS server is to have scalable computing resources for Cloud GIS that manages shared resources such as databases, configuration, server logic, server-side utilities, communication interfaces, and high-powered processing infrastructure. The proposed Cloud GIS server will be composed of five tiers or layers which are:

- Cloud GIS Communication Layer.
- Cloud GIS Repository Layer.
- Cloud GIS Utilities Layer.
- Cloud GIS Logic Layer.
- Cloud GIS Configuration Layer.

Cloud GIS Communication Layer

Cloud GIS Communication Layer will be a communication interface of the GIS server composed of logical components [Module1, Module2 … Module(*n*) and Service1, Service2 … Service(*n*)]. This layer will be responsible for managing and controlling all the communication processes within the Cloud GIS system (inter-layer communication) and communication between Cloud GIS system and the outside world. Figure 7.1 shows that the in-house computer systems located at the GIS service provider organizations will communicate with the Cloud GIS system via Cloud GIS Communication Layer. There will be dedicated logical modules ranging from [Module1–Module(*n*)] which will serve for all the requirements for GIS service provider organizations mainly for paradigm shift (adoption of cloud technology). The dedicated logical modules will be responsible for providing enhanced capabilities to the GIS service provider organizations like creating and importing spatial, non-spatial, and temporal (the evolution of both spatial and non-spatial data over time) data into the Cloud GIS system. The authentication and authorization mechanisms will also be handled at the same level to enforce data security and privacy constraints.

There will also be present a standardized XML service-oriented messaging system (Esri 2005) for manageable approach to distributed computing, broad interoperability, and direct support for service orientation in the form of Web services [Sevice1–Service(*n*)] at the Cloud GIS Communication Layer. The Cloud GIS Web interface will consume these services based on the user requirements so that enterprises can integrate spatial, non-spatial, and temporal data and business processes with the Cloud GIS system using Cloud GIS Web interface.

Cloud GIS Logic Layer

This layer will act as the "heart" of Cloud GIS system and will contain all the logic forming the basis of the system. This layer will contain logic for complex processing tasks, presentation logic, business logic, and data access logic of Cloud GIS system.

Cloud GIS Repository Layer

This layer will be an application programming interface (API)-based data repository layer which unifies the communication between a Cloud GIS system and the spatial DBMS used for the system such as DB2, PostGIS, Oracle Spatial, SQL Server 2008 for maintaining spatial databases in the system. This will govern all the processes, mechanisms, and procedures used to store and access of spatial, non-spatial data in the Cloud GIS system. This layer will also hold spatial metadata which should be stored as part of the spatial databases and treated as decision aid to assist data users (Oliveira et al. 2010).

Cloud GIS Utilities Layer

This layer will be a collection of software utilities to support the optimization and seamless functioning of the Cloud GIS system as a whole. The utilities will include system profilers, schedulers, system logging, data conversion, data compression, and other focused GIS utilities for address lookup, mapping, routing, reverse geocoding, and navigation.

Cloud GIS Configuration Layer

This will be a system configuration management and storage component of the Cloud GIS system. Any change in the Cloud GIS system will result to a change in the configuration of the system as a whole, and the Cloud GIS Configuration Layer will maintain the system configuration in terms of its consistency and performance. There will be thread-based logical modules which will be monitoring the system performance, consistency, and change of state.

How Does Cloud GIS Work?

The cloud computing environment offers three base service models—software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS).

In the geospatial environment, the cloud SaaS supports three other service models:

- GIS as a service (GaaS).
- Applications as a service (AaaS).
- Imagery as a service (IaaS), where ready-to-use GIS datasets are available as data as a service (DaaS).

Benefits of GIS in the Cloud

- GIS in the cloud can put out information in the public domain, for continuous updates and open access.
- GIS in the cloud support shared resource pooling (networks, servers, service, storage).
- Large volumes of data handling, application management, and geospatial analysis are possible.
- On-demand service of online maps, geospatial data, imagery, computing, or analysis.

- Supports viewing, creating, monitoring, managing, analyzing, and sharing maps and data with other users.
- Facilitates inputs, validation, and collaboration by a global mobile workforce in real time.
- Managed services prevent data and work loss from frequent outages, minimizing financial risks, while increasing efficiency.
- Choice of various deployment, service, and business models to best suit organization goals.
- Supports offerings of client-rich GIS software solutions as a software plus service model—geocoding, mapping, routing.

Advantages for Cloud GIS

- Data Access
  Access can be via any Internet connection, anytime, anywhere. I see this as both an advantage and a disadvantage, if you have a good Internet connection, then it is great, but if you do not, then it will quickly become a source of frustration for your users.
- Distribution
  If you have a range of remote users, then Cloud GIS makes the distribution of your data, analysis, and systems very simple. No need to send data using DVD or downloading large datasets to update a local server.
- Data Capture
  Having a Cloud GIS allows data capture in real or near real time to be displayed directly onto your system. There are also many successful applications of where data has been captured by the general public and verified by users. One such success story is OpenStreetMap.
- E-commerce
  The ability to sell your data or online services to a wider audience can open up the income streams for your organization through Cloud GIS.
- IT Management
  The need to have dedicated GIS administrators will be reduced as you can outsource that to the Cloud GIS hosting organization.

Disadvantages for Cloud GIS

- Security
  Security is an important aspect of any system, and you will need to make yourself sure that the Cloud GIS hosts have good security in place, so your data is not accessed by users who should not be accessing it.
- Data Volume
  GIS data has always been big, taking up gigabytes on your own server. If you move to a Cloud GIS solution, then there is both the time to migrate the data to the host server and also for end users to access and download. Smart might be more relavant than clever sampling software out there for Web-based GIS, so the end user may not notice and issues if just viewing, but downloads maybe a different issue.
- External Hosting
  - This can be a major concern as the Cloud GIS hosting organization may not have your best interests at heart. They are a business after all and in it to make a profit, but they will also be striving to provide you with a valuable service, so they do not want things to go wrong.
  - What sort of backup and redundancy systems are in place with your Cloud GIS host. Make sure that they are not backing up your data during your business hours, or if they are that it does not impact on the delivery of your service. The universal distribution of cloud GIS servers make them accessible at any time from any where around the globe.
  - The cloud GIS host is offering dedicated servers for sharing data and they are capable of handling heavy system loads.
- Lack of Control
  Another downside of Cloud GIS is the lack of control you may have over the way your data is used, displayed, manipulated, and analyzed. To add a new function or layer may not be as simple as just loading a new dataset onto the server.
- Data Format
  What formats is the Cloud GIS application serving the data out in. Do you need to reformat your data?

Application of Cloud Computing Techniques in WebGIS System

WebGIS applications need a great quantity interaction with servers. The interaction includes simple functions such as roaming, query, search and complex functions such as geocoding, path calculation, spatial analysis. When published map services for enterprises, load balancing of multiple space application servers is very frequent, so we need good WebGIS system architecture to deal with massive data effectively and to meet the increasingly diverse needs of users. WebGIS and cloud computing are both based on Internet. Therefore, the solutions of cloud computing have an important reference for WebGIS system design.

Spatial Data Storage Services

It is estimated that more than 80% of data human beings collected are spatial related. There are many different types of spatial data: geometric data, attribute data, and relational data that express the mutual relationship of map elements. Because the data changes respectively with time, and in the process of data analysis, it integrates the history data and present data to make the collected information more intelligent service for users and enterprise, so the amount of data is very large. As a result, the management and maintenance of spatial data storage may cost a lot of hardware, human and financial resources. The emergence of cloud storage brings a new data storage model for spatial data in WebGIS (Yang and Wu 2010).

Cloud storage is a model of online storage where data is stored on multiple virtual servers, generally hosted by third parties, rather than being hosted on dedicated servers. It is applied through the cluster, grid, or distributed file system to assemble different kinds of storage devices to work together by application software. To users, cloud storage is not a storage device, but is a kind of data access service. Cloud storage services may be accessed through a Web service application programming interface (API) or through a Web-based user interface. To ensure high availability, high reliability, and economy, the cloud platform provides services for data storage, management, backup, maintenance by means of cluster and distributed file systems technology.

The kinds of cloud storage include Google File System (GFS) which is not open source and Hadoop Distributed File (HDFS) which is open source. Take GFS, for example. GFS is optimized for Google's core data storage and usage needs, which can generate enormous amounts of data that needs to be retained. The nodes of GFS are divided into two types: one master node and a large number of chunk servers. Master stores all the metadata of file system, including namespace, access control, and file block information. Chunk servers store the data files, with each individual file broken up into fixed size chunks of about 64 MBs, similar to clusters or sectors in regular file systems. Each chunk is assigned a unique 64-bit label, and logical mappings of files to constituent chunks are maintained. And each chunk is replicated several times throughout the network, with the minimum being three, but even more for files that have high end-in demand or need more redundancy.

Spatial Analysis Services

In WebGIS system, after spatial data is collected and converted into a usable format, enough hardware and software resources need to be allocated for analyzing the data. In most cases, the amount of collected data reaches to gigabytes or even terabytes, so handling this data becomes a challenge for most users and organizations, let alone analyzing this data, especially spatial analysis (Li et al. 2002). Spatial analysis is the core function of GIS, and it is also the basic difference between GIS and other computer system. From the perspective of interactive query between graphics and attributes of spatial entity objects, spatial analysis is to obtain derived information and new knowledge from spatial relationship of GIS targets. The analysis object is spatial relationship of GIS targets, and the contents include topological spatial query, buffer analysis, overlay analysis, and genomic analysis.

With the rapid development of geographic information industry, the relationship of GIS and human's various social activities are increasingly linked. SaaS is the future direction of GIS field. Recently, ESRI Company's ArcGIS10 is a true GIS platform based on cloud architecture. It can be deployed directly in the cloud computing platform and realize spatial data management, analysis, and processing function based on Amazon cloud computing platform. At the same time, SuperMap SGS is realized too, it is based on open-source architecture of cloud computing, and it serves for digital city in mapping-related GIS applications. Cloud computing stores data distributed in each node. When computing, each node reads and processes its own storing data, which can speed up the processing rate greatly. Once applying high computing capacity in network analysis, statistical analysis, terrain analysis, three-dimensional analysis, and other spatial analysis, the data processing capacity will be significantly enhanced based on cloud computing platform.

GIS Web Services

GIS Web services can be described as Internet-based applications which obtained geographic data through Internet used the data and related functions to complete basic geoprocessing tasks. GIS Web services make a reality the vision of creating a platform-independent distribution channel for GIS data. Applications can share data from different data sources and formats and have them combined in a single application, without it being apparent that data has come from different sources or locations. Developers can apply the GIS Web services to perform geographical information processing and return the results to the customized applications without maintaining the basic GIS system or the geographical data.

Issuers in WebGIS Application Based on Cloud Computing

While cloud computing offers great prospects for development of GIS, at the same time, it exists some issues in actual operation.

- First of all, once the spatial data is stored in the cloud, cloud providers will be responsible for the security of data transmission. Generally speaking, geographic information is usually confidential, because data is deposited in cloud providers' computers instead of in the local, so data leaks may occur. Once leaking data, the data owner will face a huge risk and crisis of confidence.
- Secondly, privacy issue is also one big problem. Different from the traditional computing model, cloud computing utilizes the virtual computing technology, users' personal data may be scattered in various virtual data center, even across the national borders, at this time, and data privacy protection will face the controversy of different legal systems.
- There are not standard for regulations of cloud computing; therefore, establishing regulations about technology, service customization, price and other aspects will be of great concern. And people also look forward to applying these norms and policies in the private cloud of GIS industry.
- Finally, long-term viability is also to be taken into account. You should be sure that the spatial data you put into the cloud will never become invalid even your cloud computing provider go broke or get acquired and swallowed up by a large company.

ArcGIS and the Cloud

ESRI considers cloud computing and technology important in the development and vision of the ArcGIS platform. Several options are available for companies that want to improve productivity and efficiency while reducing expenses and freeing up valuable IT resources to concentrate on newer business initiatives.

GIS services are available in the cloud so that ArcGIS users and developers can access ready-to-use maps including imagery, topography maps, and street base maps as well as task services.

GIS software as a service provides focused, cloud-based clients and applications that easily solve complex business problems using GIS tools and data but do not require GIS expertise to use.

Satellite Imagery and GIS

GIS technology stores, controls, analyzes, and gives outputs in the various forms of data for the purpose of discovering the basics of geography; GIS is extensively dealing with the location information which has an importance in so many applications such as agriculture, natural hazard management, military, environment, health, urban planning that research papers and articles are available on. On the other hand, GISs need to improve as the satellite and sensor technology developments; otherwise, it cannot obtain important advantages and maximum benefits from remotely sensed satellite images. Since the first picture obtained from a satellite, the resolutions of satellite images have been increased. High-resolution satellite images are one of the most powerful supporters for the GIS.

GIS uses the power of visualization by presenting the previously or instantly collected information in a different form. Therefore, it facilitates to give answers to the difficult questions pertaining to a particular subject by looking at the data in a way that is quickly recognized. GIS technology, analyzing massive spatial and attributed data of the Earth surface, helps simply illustrate patterns, make decisions, and solve problems much faster than using any other way. This technology is used by a huge number of industries and organizations for the purpose of crime mapping, monitoring ships, managing pipelines, making health impact assessments.

Military using areas of GIS can be listed such as mission planning, terrain analysis, intelligence. Geographic analysis is critical in military operations, tactical or logistical planning, and infrastructure management. Most national security decisions involve geography. Whether assessing potential terrorist targets, planning where to strike on the battlefield, or deciding where to locate a new building with minimal environmental impact, geography always comes into the equation. GIS software plays an increasingly important role in making these types of decisions. GIS software gives tools to reveal meaningful patterns in the geospatial data and provides the intelligence support needed for mission success. GIS lets capture, manage, analyze, and display geographically referenced information, giving a clear picture of data and the many complex relationships behind it.

Summary

Cloud computing is a new method of shared infrastructure, it can provide supercomputing services. At the same time, WebGIS is the integration product of GIS and Internet technologies, and it is inexorable trend with the development of GIS. The emergence of cloud computing brings new opportunities for WebGIS. This chapter first introduced the principles of cloud computing and WebGIS and then introduced cloud computing techniques in WebGIS applications, which included data storage, spatial analysis, and GIS Web services. Finally, several issues about cloud security, privacy, regulations standard, and long-term viability are proposed in WebGIS applications based on cloud computing.

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8 Immersive Environments for Disaster and Emergency Management

Introduction

Immersive environments are simulations that fill the user's visual field, giving the sensation of physical presence. Virtual Reality delivers immersion from the individual's point of view, while immersive rooms bring many viewers into the same simulation. Virtual Reality and other immersive Information and Communication Technologies (ICT) have a high potential for transforming the real world and the way in which we interact with it.

Immersive environments are digitally mediated learning environments designed to engage users in an artificially created, make-believe "world." Immersive environments may take on a broad range of forms, with affordances for varying degrees of sensory immersion and awareness of the user's physical self or the presence of others.

Immersive virtual Reality (immersive VR) is the presentation of an artificial environment that replaces users' real-world surroundings convincingly enough that they are able to suspend disbelief and fully engage with the created environment.

Immersion is basically a unique experience that is connected with the world of Virtual Reality. Over here the user whole exploring the three-dimensional world of Virtual Reality will simply immerse into this make-believe world as the real world. It is basically a feeling of involvement of the user in the virtual world intelligently designed by experts.

Elements of virtual environments that increase the immersiveness of the experience:

- Continuity of surroundings: The user must be able to look around in all directions and have continuity of the environment.
- Conformance to human vision: Visual content must conform to elements that allow humans to understand their environments, so that, for example, objects in the distance are sized appropriately to our understanding of their size and distance from us. Motion parallax ensures that our view of objects changes appropriately as our perspective changes.
- Freedom of movement: It is important that the user can move about normally within the confines of the environment. That capacity can be achieved in room-scale VR and dedicated VR rooms but requires complicated hardware for stationary VR and is impossible for seated VR.
- Physical interaction: A user should be able to interact with objects in the virtual environment similarly to the way they do with real-life ones.
- Physical feedback: The user should receive haptic feedback to replicate the feel of real-world interaction. So, for example, when a user turns a doorknob, they not only replicate the movement but experience the feeling of having that object in their hand.
- Narrative engagement: The user should have the ability to decide the flow of the narrative. The environment should include cues that lead the user to create interesting developments.
- 3D audio: For immersiveness, VR environments should be able to replicate natural positioning of sounds relative to people and objects in the environment and the position of the user's head.

An immersive environment is an illusionary experience that surrounds you such that you feel part of it. This has three basic types: Virtual Reality, mixed reality, and art.

Virtual Reality is digital experiences designed to feel real such as a game or movie that completely surrounds you and pulls you in.

Mixed reality is augmenting physical environments with digital elements such as a video game that occurs in the real world.

Virtual Reality and immersive environments, as part of the emerging technological evolution involving our senses and cultural, symbolic, and representative factors, may present interdisciplinary approaches. These approaches contribute to creating new languages, which involve disciplines such as interaction design, human-computer interaction, user

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experience, and interface, and even affective computing, which have new approaches in recent years with the evolution of ICT. Virtual Reality (VR) immersive technologies "support the creation of synthetic, highly interactive three-dimensional (3D) spatial environments that represent real or non-real situations" (Mikropoulos and Natsis 2011, p. 769).

Geographic Information Systems (GIS) are used for mapping and analysis of data pertaining to geographic locations. The location data may consist of vectors, rasters, or points. Vector data is typically used to represent boundaries of discrete political entities, zoning, or land use categories.

Raster data is often used to represent geographic properties that vary continuously over a 2D area, such as terrain elevation. Each raster represents a small rectangular finite element of information projected onto a regular 2D grid. It is simple to construct a triangulated mesh from such data. Unlike raster data, point clouds can represent concave, undercut surfaces, but it is harder to construct a triangulated mesh from such data.

Large volumes of digital spatial data have been created using geographic information system (GIS), computer-aided design (CAD), and image processing systems. The need to visualize and explore these data is becoming widely recognized (Rhyne 1997; Kraak and MacEachren 1999). At the same time, there is also a strong incentive to distribute the result efficiently.

Virtual Reality (VR) is a new way of visualizing and manipulating GIS data. Two-dimensional (2D) geographic information systems (GIS) data can be used together with three-dimensional (3D) computer-aided design (CAD) data to generate a virtual world in which the user can navigate, query, and manipulate the GIS and 3D CAD data. Over the past three years, we have developed the key to Virtual Insight or K2vI system which is a VR interface on several standard GIS databases that support visualization, manipulation, and editing of the GIS and CAD data in a virtual environment. The system uses a multi-view mode approach where each view mode has a preferred VR display.

The advent of Virtual Reality (VR) technology and the Internet has provided opportunities to satisfy these needs, as they are two important means for data representation, interaction and dissemination (Batty et al. 1998). The Internet, in particular, the World Wide Web (WWW), has experienced an astonishing growth in recent years, and the Web is now been widely used as a distributed computing environment. The GIS community has embraced this, and there is an increasing field of Internet GIS (or WebGIS) (Plewe 1997). However, current Internet GIS is still limited to map display and simple graphic manipulations such as zooming and panning. It lacks 3D visualization and interaction capabilities. VR, allowing for more realism in the portrayal of geographical phenomena (Smith 1997a, b), can play a significant role in making up this. On the other hand, geographical VR applications also need the support of spatial analytical functions, which could be provided by a GIS. As a result, there is a clear requirement for the integration of GIS, VR, and the Internet to complement and enhance each other to facilitate the exploration of spatial databases.

Integration of GIS, VR, and the Internet are made possible through the use of Virtual Reality Modeling Language (VRML), an ISO standard for describing interactive 3D objects and worlds to be experienced on the WWW. It is the existence of this standard and the widespread availability of VRML plug-ins, which makes Web-based 3D visualization feasible (Brodlie and Wood 2000). Through VRML, in conjunction with Java and HTML, GIS, VR, and the Internet can be combined in different ways to support Web-based modeling, visualization, and analysis. This is reflected in various VR applications in urban environments and the 3D cityscape (Martin and Higgs 1997; Fairbairn and Parsley 1997; Doyle et al. 1998). Arising from these applications, a number of GIS-VR prototypes have also been implemented. The integration of GIS, VR, and the Internet has been attempted in one way or the other, but there is still lack of a systematic investigation, which analyzes different integration strategies. In particular, an appropriate approach for the efficient and effective integration needs to be addressed.

Augmented reality is another visualization technique and is defined as a combination of the real scene viewed and a virtual scene generated by the computer in which the virtual objects are superimposed on the real scene (Backman 2000).

Augmented reality is connecting a world of data for people who may not be familiar with GIS where augmented reality, three-dimensional (3D), Virtual Reality (VR) are very important in GIS industry.

Concept of VRGIS, WebGIS, and Networked VR

Virtual Reality is the simulation of a real or imagined environment that can be experienced visually in the three dimensions of width, height, and depth and that may additionally provide an interactive experience visually in full real-time motion with sound and possibly with tactile and other forms of feedback.

VRGIS is used to represent the combination of VR and GIS technologies, that is, a conventional GIS with VR as the main interface and interaction method (Faust 1995; Raper et al. 1999). Because VR provides a rather realistic representation of the world, it can be a nice complementary tool for existing GIS. VRGIS has been widely used in urban and environmental planning, scientific visualization, archaeological modeling, education, and military simulation.

Internet GIS is the combination of the Internet and GIS, that is, a conventional GIS using the Internet as a basic information infrastructure for spatial data dissemination. Because of the nature of the Internet, Internet GIS is regarded as an interactive, distributed, dynamic, cross-platform, and client/server computing system, and it has the capability to access various forms of GIS data and functions in an interpretable environment (Plewe 1997; Peng 1999).

Before the Internet was made available, VR models were standalone like CAD models. Nowadays with the development of the Internet technology, these VR models can be networked, and participants can be involved in VR by logging in a network computer. A typical example is Active Worlds which has received increasing attention in the field of education, filmmaking, and urban planning (Active Worlds 1999). Users can interact with VRML worlds on the Internet by using the Java language. Some examples in the context of geographical applications can be found in Brown (1999) and Moore et al. (1999). More details about networked VR and associated techniques are given by Singhal and Zyda (1999).

GIS, VR, and the Internet

GIS can be defined as a spatial data processing system with three important components: spatial database, analytical functionality, and visualization capability. However, existing GIS is mainly 2D based, though there is a high demand for 3D visualization and analysis. VR is a computer graphic technology that can be used to emulate the real world in three dimensions, with which users can participate in the virtual environment by walking or flying. In terms of interaction with virtual environments internally or externally (MacEachren et al. 1999), we can have distinction between immersive or non-immersive VR. We employed desktop VR, a kind of non-immersive VR. The Internet is a network with millions of computers interconnected through various forms of telecommunications, providing infrastructure for information dissemination.

A full integration of VRGIS, Internet GIS, and networked VR provides many advantages for setting up a platform for distributed spatial decision-making. In such integration, GIS provides rather rich spatial data, VR helps to visualize the large volume of data in a rather realistic format, and the Internet facilitates information dissemination. Taking an example urban planning and design, a GIS or CAD package can be used to finish a 2D sketch plan, and VR is used to create a 3D urban scene from the 2D map or plan, and the Internet is used to facilitate public assessment by putting the VR model online. The above processes can continue recursively until a final design is agreed upon. The process may involve some analyses and geocomputation that are important to decision making.

As desktop VR and the Internet have gained some popularity, a number of projects have been carried out to incorporate VR and the Internet into the GIS environment. Under the banner of new technologies for urban designers, the Virtual Environments for Urban Environments (VENUE) project was set up which aimed to develop a suite of computer tools for urban planners and designers using GIS, VR, and the Internet technologies (Jiang et al. 1997; Batty et al. 1999). Within that project, various tools have been developed for modeling urban environments (Doyle et al. 1998). Another ambitious project is the VFC (Dykes et al. 1999b), which aims to develop virtual environments to facilitate student fieldwork. Many other projects have also been carried out. For example, Verbree et al. (1999) built a VRML interface for modeling, manipulation, and editing of spatial worlds, which demonstrated an approach for real 3D GIS operations. Kahkonen et al. (1999) demonstrated work on the development of NetGIS in line with Common Object Request Broker Architecture and other relevant standards for spatial object browsing and interrogation. In this tool, an established VRML file can be linked with a spatial object and viewed with a VRML browser upon request.

The effort in applying VR as a useful function of GIS is not limited to academics; the commercial company and private sector have also made a rapid response to the development. The most distinguished development in this connection is VRML. This has gained more acceptance as a technology for displaying 3D graphics as it is a simple and accessible way to create interactive worlds. The release of VRML has also been a major factor in the uptake of VR in the geographical field (Moore et al. 1999). This is due to the fact that since its inception, VRML has been employed for more realistic and interactive representation of geographical data such as terrain models and city blocks (Dykes et al. 1999a). Some socioeconomic information has also been explored in a rather realistic way through VRML models (Martin and Higgs 1997). Furthermore, GeoVRML, an extension of VRML, has been proposed and implemented to provide geoscientists with a suite of enabling functions for the representation of large volume and high precision georeferenced data. Recent advances in GeoVRML include a number of new nodes that enable the transparent and accurate representation of geographical data and support scalability to large spatial databases.

Some commercial VR tools have also been made available. Pavan (Smith 1997a, b), VirtualGIS (Schill 1999), and ArcView 3D analyst (ESRI Inc. 1997) are three typical examples with respect to the creation of 3D VRML models from GIS data. Pavan is a VRML compiler and project management system for the MapInfo GIS. It can create and generate navigable 3D (VR) models generated from data held in MapInfo. The resulting models can be represented by VRML and viewed interactively in most recent versions of Web browsers. VirtualGIS is an add-on application for 3D visualization and analysis to ERDAS Inc.'s IMAGINE Essentials and has similar functions to Pavan. ArcView 3D analyst also has similar functions and will be introduced later in §4.1. Obviously, in these three packages, the process of VRML model generation is not conducted on the Internet and is loosely connected with the process of VRML model browsing. In other words, these packages are still desktop tools. Rather than the loose coupling of GIS, VR, and the Internet, we will concentrate on the exploration of a tight coupling to provide an integrated environment for more comprehensive spatial data visualization, analysis, and interaction: full and seamless integration.

3D and VR Applications of GIS

Traditional geographic information systems (GIS) use geographically referenced data to produce highly accurate digital maps. These two-dimensional maps include well-recognized symbols that represent features such as mountains, forests, buildings, and transportation networks. Although this flat view provides an excellent means of orienting the user to the general nature and location of the geographic features for a given area, it does not provide the full experiential value that comes from immersion within a 3D environment. Therefore, the 3D is needed for GIS to represent a more realistic appearance of the environment.

Implementation of 3D in GIS

To implement and use the 3D in GIS, we must consider the following things: choose a data structure that allows detailed 3D modeling, develop the needed data, and build the 3D geoinformation database and data manipulation and delivery.

Successful Applications and Cases in 3D GIS

There are applications in 3D GIS such as urban planning, K2VI system, and VRML City Project.

Fundamental Geospatial Concepts Using Interactive Navigational Framework

In geospatial instruction, deep insights may be obtained from the visual representations, and the users can navigate within these virtual worlds, move, rotate, or scale the objects, and transform them in multiple ways. This kind of VR setup greatly helps the demonstration of geospatial concepts involving spatial coordination such as transformation and projection. The framework can be used to explain basic and sometimes tedious concepts such as projective and Euclidean geometry to students. Projective geometry is concerned with how something seems or appears, while Euclidean geometry is all about what things are actually. Understanding the relationship between Euclidean and projective geometry is a very inevitable aspect of geospatial education.

One transformational notion is to consider that an object itself is transformed, either by translation, rotation, or scaling. In such a case, if a geospatial object is translated, this can be thought of as the transformation being directly performed on the shape itself. It is also possible to approach transformation from another standpoint wherein the coordinate system itself is transformed and the object or objects in it are also subject to the transformation (to which the coordinate system was subjected to).

Conventional Two- and Three-Dimensional GIS Heritage

High monetary return from demolition and reconstruction of new buildings often blaze the trail for urban renewal. Nevertheless, event as such is also blamed for heritage sites isolation and removal of important cities' memories. In view of this, it is important to develop a digital GIS-based documentation system with all the spatial and non-spatial information for heritage buildings. This database includes information for each of the heritage building: geographic location, construction date, number of floors, construction material, current building usage, and current building status. It provides the basis for monitoring the heritage buildings' status and useful information to prioritize heritage buildings' maintenance and rehabilitation. Geodatabase as such can also act as a ground for protecting the threatened heritage from unintended urban growth and sprawl10or gild the lily in some of the heritages which can move up with times (Madden and Seifi 2011). As a matter of fact, the geodatabase can also open the dialogues between different stakeholders who may speak different languages due to different standpoints as the feast of reason and make common cause.

Categorized by heritage's building height and modern urban fabric nearby, the three-dimensional *X*-*Y*-*Z* GIS heritage database records the distribution of modern multi-story buildings in the study area which can be presented in 3D GIS-based map, 10. The *X*-axis refers to the horizontal axis which is parallel to the wall, *Y* is the vertical axis, and *Z* indicates the horizontal axis perpendicular to the wall. Based on

Photo Modeler Scanner software, photogrammetry helps us generate a digital model of the wall based on a three-dimensional georeferenced point cloud. The center of coordinates on one of the wall panels can be determined for orientation purposes and cloud scaling. These coordinates lay the ground for GIS georeferencing. ArcGIS with Spatial Analyst module can be used to raster layers, generate with the scaled and georeferenced point cloud that yields a digital surface model (Lopez-Gonzalez et al. 2016).

3D Mapping

Geographic information has been authored and presented in the form of two-dimensional maps on the best available flat surface of the era—scrawled in the dirt, on animal skins and cave walls, hand drawn on parchment, then onto mechanically printed paper, and finally onto computer screens in all their current shapes and sizes. Regardless of the delivery system, the result has been a consistently flat representation of the world. These 2D maps were (and still are) quite useful for many purposes, such as finding your way in an unfamiliar city or determining legal boundaries, but they are restricted by their top-down view of the world.

Three-dimensional depictions of geographic data have been around for centuries. Artistic bird's eye views found popularity as a way to map cities and small-extent landscapes that regular people could intuitively understand. But because these were static and could not be used directly for measurement or analysis, they were often considered mere confections, or novelties, by serious cartographers, not a means of delivering authoritative content.

3D mapping and cartography have applications across a broad swath of industries and in government and academia.

Advantages of 3D Map:

- Vertical information.
- Intuitive symbology.
- Showing real world.
- Human style navigation.

Important 3D terminology

- Maps and scenes.
- Local and global.
- Surfaces.
- Real size and screen size.

Joint Use of GIS and AR

Developing a GIS using AR for its display induce some technological, methodological, industrial, and commercial challenges. Indeed, associating these two types of technologies requires both the common and specific stakes of these applications to be taken into account. From a technological point of view, it is necessary to perfect new adapted hardware and software architectures. It is also necessary to develop new interactions and visualizations of geographical digital data. It is also useful to study the implications of the use of AR techniques on a GIS (and vice versa). Exploring the synergy between digital geographical data and AR becomes inevitable and the development of new GIS methods specific to this type of application should be created. Many different fields such as tourism, environment, civil engineering, and road, and sea navigation are interested in this type of application.

Augmented Map

The aim of an application of this type is to enable one or several people to explore geographical data coming indifferently from the physical world or the digital world. For example, the prototype proposed by Liarokapis et al. (2005) is a system for presenting geographical information. Data is described by 3D digital models. Presented as a specific GIS framework for presenting geographical data inside or outside, the experiments proposed only show the indoor application by proposing handling data via markers.

Summary

Virtual Reality (VR) is an environment where the human perception of a simulated environment is as close to the perception of the real world as possible. There are significant developments, but it is a new technology and will need to evolve much more before it can claim to satisfy the human perception fully. In any case, the nature of today's VR practice creates a natural desire to make this environment more giving than the natural, by adding more information, because it is possible. To use the VR as an interface to a rich database (as in GIS) is one obvious outcome of this thinking.

This chapter explores the way in which GIS, Virtual Reality (VR), and the Internet are closely integrated through the link of Virtual Reality Modeling Language (VRML) for spatial data visualization, analysis, and exploration. Integration takes advantage of each component and enables the dynamic 3D content to be built, visualized, interacted with, and deployed all on the Web.

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9 Public Participation WebGIS for Disaster and Emergency Management

Introduction

All disasters have shared the characteristic of being monumentally costly. The growing prevalence of natural disasters is driving people to pay more and more attention to emergency management. Progress in catastrophe analysis capabilities based on Geographic Information Systems (GIS) may allow the needs of public participation to be considered. Synchronous data sharing between citizens and emergency workers could effectively promote the process of decision-making. With the development of the Internet and technology, Internet-based PPGIS becomes an affordable and accessible GIS tool for public engagement.

Emergency and Emergency Management

Emergency is a course of events that endangers or adversely affects people, property, or the environment. Emergency situation is a deviation from planned or expected behavior of ideal state.

Emergency management procedure consists of several phases from planning to mitigation and preparedness (as pre-emergency phases) and response and recovery (as during and post-emergency phases). In all phases, emergency management requires precise and reliable information about the current situation of emergency, existing sources, and facilities.

Spatial data can considerably facilitate disaster management because most of the required information for disaster management has spatial nature. In this regard, Geospatial Information System (GIS) as a tool to collect, store, model, analyze, and display large amount of spatially information layers supports all aspects of emergency management. Spatial Data Infrastructure (SDI) and WebGIS are appropriate frameworks to facilitate such collaboration in managing spatial data for disaster management.

Disaster Management

Disaster can be defined as a source of danger, and its consequences can adversely affect humans in terms of life, property, and environment when the level of danger, and the consequences, exceeds the ability of the affected society to cope using its own resources (Alexander 1997).

Comprising the source of danger in common, disasters could vary in terms of types and their impacts on human societies (Eshghi and Larson 2008; Kimberly 2003; Perry and Mushkatel 1984; Shaluf 2007; Turner 1976).

Disasters can be categorized into three main categories including:

- natural (such as earthquake, extreme heat or cold, fire, flood, hurricane, landslide, thunderstorm, tornado, tsunami, and volcanic eruption).
- man-made (such as biological, chemical, nuclear and radiation threats).
- hybrid (for instance, extensive clearing of jungles cause soil erosion, and subsequently heavy rain causes landslides; the location of residential areas, factories, etc., at the foot of an active volcano or in an avalanche area, and floodplain disasters).

Role of Communication Media in Disaster Management

The significance and the unique role of the media in natural disaster situations are unarguable. The media constantly act as a transmitter of valuable information throughout the disaster management life cycle (Perez-Lugo 2004). It is further argued that this didactic function of the media varies only in content across various phases of disaster management. Seydlith et al. (1990) suggest that during mitigation phase,

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the communication media provides factual information about the approaching disaster and remedies to immediately prepare for its impact. After disaster, the media focus their attention on the supposedly most affected areas, providing estimates of the damages and losses and helping communities in their recovery efforts. During the long-term mitigation phase, the media act as disaster information provider through coverage of non-local disasters (via movies, documentaries, news, and special programs) which eventually helps the community to raise disaster awareness and prepare for future events (Rodriguez 1997). It is evident from the above discussion that even the contents of the transmission changes during various phases of disaster management, the media are still perceived to serve a didactic function because it is assumed that people keep watching, reading, and listening to obtain information on disaster mitigation, response, and recovery (Quarantelli 1996).

The Importance of Public Engagement

Public participation is a vital part of planning. It is not only dealing with deliberate hearings, but also seeking and facilitating public involvement in planning topics and the decision-making process (Goodspeed 2008). Effective participation is a two-way process that includes sending information out to public and getting their ideas, concerns, and thoughts back (Godschal et al. 1994). According to Brody et al. article (2003), "citizen participation is widely viewed as a key component in the planning process, and for the most part, planners accept the notion that participation is important to producing enduring plans."

Tools for Collaboration and Participation

Traditional techniques to facilitate public participation in environmental management are similar as those to facilitate public participation in urban planning processes such as media, public meetings or hearing, workshops, polls and surveys, focus groups, electronic networks, and interviews (Godschal et al. 1994). Table 9.1 shows the pros and cons of traditional public participation techniques.

The term Internet-based PPGIS is more like a comprehensive concept than an unambiguous definition. It is the combination of Web-based GIS, PPGIS, volunteered geographic information (VGI), and integrated with social media to address a specific issue (Fig. 9.1).

Functions of PPGIS

For the term Web-based GIS, it is like a technological definition to describe the potential of this rising tool. First, through the Internet-based GIS, everyone can publish and access spatial data. What is more, Internet-based GIS can be used to create interactive maps to facilitate the communication between different groups—for example, specialists like planners can communicate with the general public, especially those who have lower socioeconomic status. Third, Web-based GIS can:

Provide basic GIS functions (for instance, pan, zoom, and query attribute data) with browsers (Drummond and French 2008).

For the term PPGIS, the name is more issue driven. The objective of the tool is very clear—facilitate public participation. According to Weiner et al. (2002), PPGIS is a system that mainly addresses the local level and can be used in much socioeconomic contexts. Another important function of PPGIS is to gather both qualitative and quantitative information. Both Internet-based GIS and PPGIS are cost and time saving, easy to use, efficient, accurate, and productive. They provide enhanced communication and collaboration, more efficient allocation of resources, and improved access to timely data and information (Sieber 2006; Drummond and French 2008; Thomas and Sappington 2009).

Integration of Internet-Based GIS with PPGIS

The integration of Internet-based GIS with PPGIS to enhance public participation in planning processes is one aspect of future trends of the GIS development (Weiner et al. 2002; Drummond and French 2008). VGI represents a new data collection method—user-generated data (Goodchild 2007). Social media, such as Facebook, MySpace, Twitter, and YouTube allow individuals to become part of the larger political process through their personal digital products. Because online social networking and Virtual Reality tools allow information to be spread more quickly, it is possible to grow groups to thousands instead of holding a planning meeting for a few dozen people (Owyang 2008). Marring PPGIS with the Internet platform and using citizens as sensors (Goodchild 2007), along with the help of social media, people can be encouraged to participate effectively in the environmental management policy-making process.

Table 9.1 Pros and cons of public participation techniques

Technique	Description	Advantages	Disadvantages
Media	Press release, TV, radio, newspaper	Informing information	No communication
Public meetings/hearings	People present official statements and assertions of fact	Anyone could join and contribute	Citizens rarely engage in, and opinions cannot be extensive
Workshop	Public convened with a specific urban planning plan, expressing opinions through exercises or games	More interactive and two-way communication	Limited participators
Polls and survey	Identify concerns and interests of public via mail, email, Web site, etc	Can collect different opinions from large and diverse population	Costly, low respond
Focus group	Generate understanding of public opinions from a small group of people	Help planners send information and get feedback immediately	Limitation on numbers of gathered citizens
Electronic networks	Use Internet to informing and get people involved	Low cost, reach more people	Not everyone has the device to access to Internet
Interview	Private conversation in person or via telephone	Can get citizen's deep thoughts	Time and money consuming

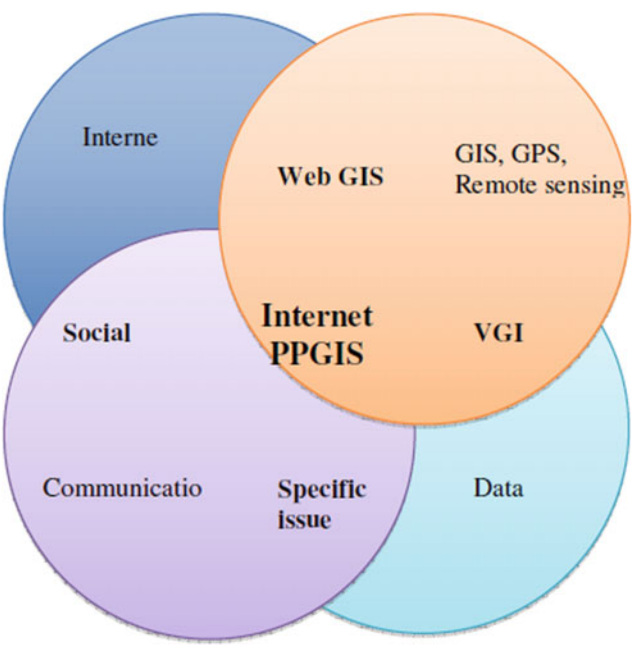

Fig. 9.1 Framework of Internet PPGIS

Role of Mobile GIS in Emergency Management

Mobile GIS is an appropriate technology for infield data collection, sharing, and usage. Mobile GIS is a movable GIS that makes spatial data acquisition, storage, sharing, and analysis in every time and everywhere possible for users.

In mobile GIS, not only data are movable but also hardware and software are. This characteristic makes mobile GIS an efficient technology in managing spatial data, particularly in emergency management.

Mobile GIS Has Two Fundamental Applications in Emergency Management

- Mobile GIS facilitates infield data collection and real-time updating of EOC database. Collected data can be about location of victims, burning buildings, closed routes, etc.
- Using mobile GIS, emergency workers can access to EOC database which represents current status of

emergency situation. Mobile GIS provides the capability of analyzing these data to make the best infield decisions for emergency operations.
- Finding the best path to get into specific destinations and priorities emergency operations based on current situation are two examples of this analysis.

Many parameters should be considered while designing a mobile GIS for a specific application especially for emergency management. One of them relates to the architecture of the system. Generally there are five different architectures for mobile GIS:

- Stand-Alone Client

This is the simplest mobile GIS architecture. In this architecture geodata, mobile GIS software and the customized application reside entirely on the client that is a mobile device.

- Client–Server

Here the geodata is moved to a separate computer and served to the client by GIS server software through a wireless network. However, dependency of this system to the continuous connection between client and server reduces its flexibility. In other words, if the connection fails, the mobile GIS will no longer work.

- Distributed Client–Server

Geodata is stored in the server, but some parts of information are also stored into mobile device. In this architecture, the mobile GIS (client) is usable even if being disconnected from the server. When the mobile device is connected to the server again, the data is synchronized with the server.

- Services

This architecture views the GIS server as a Web service and allows for other Web services to be part of the application as well. As long as these Web services use the same communications protocol, the mobile device(s) can communicate with all of them. Furthermore, the Web services can also communicate between themselves.

- Peer-to-Peer

In this scenario, a peer-to-peer architecture will allow for communication between mobile devices. Each mobile device will store a part of information so that the requirement to a server will be removed.

Wireless network is the most important infrastructure that is required for implementation of mobile GIS in emergency management to provide online communication between emergency workers and EOC. In the context of emergency management, mobile environment should be considered from two aspects: the size of the network and the used protocol. The size of wireless networks can be personal (WPAN), local (WLAN), and wide (WWAN). Each of these has its specifications that should be considered under the emergency situation but generally the size of network has a direct relation to the extent of incident. Therefore, different network architectures should be considered with respect to extent and levels of emergencies. In addition, the efficiency of networks strongly depends on the used protocol. So, it should be considered which protocol has more compatibility with the emergency management specifications.

Importance of Mobile GIS for Disaster Management

Mobile is today one of the most critical components of any disaster management operation. Speed, accuracy, and efficiency are cornerstones of successful disaster management, and today's mobile devices, in combination with GIS-based mobile apps, have become essential.

GIS is fundamentally mapping and locational analysis software. A GIS serves as a central storage point for all disaster-related (authoritative) data. It acts as the common operating platform, providing focused mobile maps and tools designed for disaster management. ArcGIS from ESRI is one of the more popular GIS platforms. With a common operating platform, organizations can start to engage users in a meaningful and mission-specific way. That means providing new tools and data to office-based and field-based staffs and sharing critical, potentially lifesaving data with the general public.

Mobile Apps for Disaster Management

There are three key areas in which disaster management field crews work:

- Command and control (incident management).
- Response (search and rescue, situational awareness).
- Recovery (damage assessment, debris removal).

Mobile apps for disaster management provide a set of focused maps, tools, and data. Critical functionality required by mobile users engaged in disaster management includes:

- Interactive maps which include both switchable base maps and relevant layers.
- Finding an address on the map or geocoding (convert a physical address to point on map).
- Navigating.
- Data collection.
- draw, measure, reporting tools.

Offline and Mobile Disaster Management

Key element of any mobile app used for disaster management is offline capabilities. Any mobile GIS app which does not work offline is of little use in a disaster situation. Given the often widespread destruction associated with disasters, mobile apps need to be able to function with or without wireless connectivity.

Use of Social Media in Disaster Management

This section of chapter attempts to underline the potential of social media applications such as Facebook, Twitter, Flicker, and YouTube in disaster management process.

"Social media" refers to Internet-based applications that enable people to communicate and share resources and information. The emergence of this new communication channels represents an opportunity to broaden warnings to diverse segments of the population in times of emergency. These technologies have the potential to prevent communication breakdown through reliance on just one platform and thereby reinforcing the diffusion of warning messages but also present policymakers with new challenges.

Social media refers to the applications that are either completely based on user-generated content or in which user-generated content and the actions of users play a substantial role in increasing the value of the application or service (Kaplan and Haenlein 2010) various sorts of social media applications ranging from instant messaging to social networking sites offer an instrument for the audience to interact, connect, and communicate with each other and their mutual friends (Pine 2007). These applications are intended to generate, initiate, and circulate new and emerging sources of online information about audience's experiences of using products, brands, services and/or issues by allowing them to "post," "tag," "digg," or "blog," and so forth on the Internet (Senior and Copley 2008). Recent trends in the use of social media underline the fact that there is not only an increasing number of people opting for the use of social media applications, but there is also a significant increase in the number of these applications (Dennis and Valacich 1999).

The use of social media for emergencies and disasters on an organizational level may be conceived of as two broad categories. First, social media can be used somewhat passively to disseminate information and receive user feedback via incoming messages, wall posts, and polls. A second approach involves the systematic use of social media as an emergency management tool. Systematic usage might include: (1) using the medium to conduct emergency communications and issue warnings; (2) using social media to receive victim requests for assistance; (3) monitoring user activities and postings to establish situational awareness; and (4) using uploaded images to create damage estimates, among others.

The type of sender and receiver such as emergency management agency or a community member has their own social needs and requirements in disaster management process. Dimensions of possible interaction between communities and disaster management agencies are:

- Interaction between agency to agency.

Dealing with a disastrous event is generally beyond the capacity of a single agency or an organization (Waugh and Streib 2006). Although, most of these agencies deal with the specific set of disaster operations and specializes in their professional domains. They need to collaborate and coordinate with other agencies for information and resource sharing.

Yanay et al. (2011) suggest that well-planned and effective coordination and collaboration could improve the performance of an individual agency and enhance the outcomes of emergency management plans—especially the plans related to the rescue and response. Disaster management agencies need to work in collaboration with each other. In context of timely and effective information sharing, constant, reliable, and flexible communication channels are highly required throughout disaster management life cycle (Shaluf et al. 2003; Toft and Reynolds 1994). Such communications channels should be established and maintained both at inter- and intra-organizational levels.

- Interaction between Agency to community

Although the natural disasters are rarely impossible to prevent, their consequences could be minimized by better planning and efficient execution of such plans. One of the key responsibilities of most of the disaster management agencies is to monitor various situations which could lead toward a potential disaster such as amount of rainfall, level of water in rivers and dams, any uncontrolled bushfire and/or an upcoming storm. In case of any abnormal pattern observed, appropriate, correct, and timely warnings need to be issued to the communities. This paper suggests that the interaction between disaster management agencies and communities involves the following three types of tasks.

- Interaction between Community to community

During mitigation, community members can help each other in preparing for disasters by sharing their information, expertise, resources, and support. Similarly, during disaster or just after disaster, community members are generally the first respondents to the victims (Lichterman 2000).

Social Media in Disaster Risk Management Can Be Used as

- As surveillance, monitoring, situation awareness and early warning system tool through the technical approaches of crowdsourcing and data mining or by relying on volunteers trained to support media monitoring for humanitarian response.
- Social media can be used as a tool by providing information and instructions, with real-time alerts and warnings. Social media represents one more channel for emergency services to send an alert and warning. This is the case for natural disasters like storms or tornadoes. Provision of information and instructions with social media like blogs can be used to provide advice by posting information such as emergency phone numbers, location of hospitals requiring blood donations, evacuation routes.
- Social media can be used to mobilize volunteers both during and after a crisis. Social media can also be used to indicate willingness to help in the event of an emergency. In addition, it can improve the disaster response by mobilizing online volunteers far away from the epicenter of the crisis to relay information provided by emergency services.
- The social media can be used to identify both survivors and victims. Social media can help to know if family and friends are safe and combined with use of mobile phones can help to report an accident precisely and to send requests for assistance.
- Using social media for risk and crisis communication can help to counter inaccurate press coverage or to counterbalance rumors and manage reputational effects.
- Social media can be used to collect funding and support by encouraging donations when major catastrophes occur or by facilitating the supply of support. During an emergency, people who want to help by providing blankets or a safe place to stay for victims of a disaster often do not know who to turn to.
- Social media can be used after a crisis to facilitate the lessons learnt processes and as useful materials for risk and crisis researchers. The content of social media during a crisis can be a rich material for social scientists to analyze in order to have a better knowledge of risks and crises.
- Social media risk and crisis communication are useful tools to build trust. The use of social media could improve transparency and trust in public authorities. Government authorities and more broadly experts are not easily trusted anymore in crisis situations after cases of misinformation.
- Social media can be used to enhance recovery management in two ways: through the sending of information on reconstruction and recovery and through the provision of stress management.
- In post-crisis phases, social media can be used to send information about recovery, reconstruction, etc. Social media can be used to communicate recovery of infrastructure (bridges, routes, water supply) and to identify areas that are in most need of recovery.
- In post-crisis phases, the social media can help identify where stress management is most needed in the recovery phase and to offer tools for managing stress through interactive platforms.

Social Media in Disaster and Crisis

The following are some of the ways in which social media can be used in disaster risk reduction and crisis response:

- A listening function

Social media are able to give a voice to people who do not normally have one. They also enable a remarkably democratic form of participation in public debate and facilitate the exchange of information and points of view. During an emergency, through their tendency to coalesce opinions (or stimulate monetary donations), social media are capable of revealing some aspects of the mental and emotional state of a nation. This may seem a rather exaggerated claim, but it should be noted that Quarantelli (1997) argued that the advent of modern information and communications technology involves changes that are as profound as those that occurred after the invention of printing. Listening function involves constantly or periodically sampling the varied output of social media. This enables currents of popular opinion and public preference to be gauged.

- Monitoring a situation

Whereas the listening function involves the passive collection of information, monitoring is conducted in order to improve reactions to events and better to manage the general public by learning what people are thinking and doing.

- Integration of social media into emergency planning and crisis management

The full integration of social networks into disaster management would require many of them to change their working practices, as, in the words of Palen and Liu (2007), "command-and-control models do not easily adapt to the expanding data-generating and data-seeking activities by the public." Nonetheless, there is immense potential to make data dissemination a two-way process, in which information is both received from the public and fed to it (Crowe 2012; Jennex 2012; Sykes and Travis 2012).

- Crowdsourcing and collaborative development

In most disasters, the first responders are the public. Moreover, social capital is involved in the form of the mobilization of skills, leadership, networks, support systems, and so on (Dufty 2012). This involves the concept that social networks and interaction between people increase productivity and lend added value to outcomes. The social networks benefit from the particular skills of their members. One aspect of the formation of social capital through social media is crowdsourcing.

- Creating social cohesion and promoting therapeutic initiatives

Social media can be used to make people feel part of particular initiatives. They can foster a sense of identification with local or online communities.

- The furtherance of causes

Social media such as Twitter can be used to launch an appeal for donations.

- Research

The understanding of social reactions to stress, risk, and disaster can be enhanced by the use of social media.

Public Safety and Crisis Information

Social media have been used to disseminate a wide range of public safety information before, during, and after various incidents. Prior to an incident (or in the absence of an incident), many emergency management organizations provide citizens with preparedness and readiness information through social media. Social media are also used for community outreach and customer service purposes by soliciting feedback on public safety-related topics.

Situational Awareness and Citizen Communications

Social media could be used to alert emergency managers and officials to certain situations by monitoring the flow of information from different sources during an incident. Monitoring information flows could help establish "situational awareness." Situational awareness is the ability to identify, process, and comprehend critical elements of an incident or situation. Obtaining real-time information as an incident unfolds can help officials determine where people are located, assess victim needs, and alert citizens and first responders to changing conditions and new threats.

Another potential benefit of social media is that it may increase the public's ability to communicate with the government. While current emergency communication systems have largely been centralized via one-way communication from the agency or organizations to individuals and communities.

Social media could potentially alter emergency communication because information can flow in multiple directions. One benefit of two-way communication is helping officials compile lists of the dead and injured, and contact information of victims' friends and family members.

Social Media and Recovery Efforts

The use of social media for recovery purposes has generally been limited to providing preparedness and readiness information to individuals and communities. Social media could, however, play a role in recovery; use social media to accelerate the damage estimate process by transmitting images of damaged structures such as dams, levees, bridges, and buildings taken from cell phones.

Functions and aims of social media for communication in disaster management:

- *Dialogue and backward channel*

The interviewees focus on the dialogic function of social media. In contrast to unidirectional Web sites, they have a backward channel via which enquiries about warnings can be resolved or feedback can be obtained within volunteer groups. Aid organizations use the dialogue tool to establish relationships with donors or stakeholders, respond to questions or criticism, and answer requests by those affected.

- *Collecting donations and organizing resources*

Aid organizations and independent volunteer groups can use social media to collect donations. Aid organizations try to extend their reach with social media, inviting a broad public to donate. For volunteer groups, the focus is the network of friends and acquaintances; this also determines which channel they decide to use.

- *Informing*

The information function of social media initially relates to early warning and preparation before a disaster.

- *Creating transparency*

Social media make aid activities transparent and comprehensible; for example, by publishing donations, expenditure, and volunteers' activities. Aid organizations also recognize that their supporters demand more and more openness.

- *Organization and coordination of volunteers*

Social media can be used to channel volunteers and organize and coordinate them. Because these are often relatively closed groups, it can at least be assumed that there is a certain degree of collective collaboration. Social media can strengthen the group identity.

Crowdsourcing for Disaster Management

Recent advances in information technologies and communications, coupled with the advent of the social media applications have fuelled a new landscape of emergency and disaster response systems by enabling affected citizens to generate georeferenced-real-time information on critical events. The identification and analysis of such events are not straightforward, and the application of crowdsourcing methods or automatic tools is needed for that purpose. Whereas crowdsourcing makes emphasis on the resources of people to produce, aggregate, or filter original data, automatic tools make use of information retrieval techniques to analyze publicly available information.

Local Information and Global Response

The velocity, variety, and volume of social media information as a particular type of big data can be leveraged in all phases of an emergency management life cycle. Increasingly, emergency organizations are embracing social media and mobile apps to issue alerts and provide updates for incidents (i.e., the official Facebook, and Twitter accounts from fire services, rescue, and civil protection organizations).

Crowdsourcing

The term crowdsourcing was defined by Howe (2006) "the act of taking a job traditionally performed by a designated agent and outsourcing it to an undefined, generally large group of people in the form of an open call."

Crowdsourcing is a sourcing model in which organizations use predominantly advanced Internet technologies to harness the efforts of a virtual crowd to perform specific organizational tasks (Saxton et al. 2013).

Crowdsourcing technology brings together a distributed workforce of individuals in order to collect resources, process information, or create new content. The implementation of a crowdsourcing system can vary widely, from complex online Web sites that coordinate a million simultaneous workers to low-tech, ad hoc approaches that use a shared spreadsheet (Quinn and Bederson 2011).

The three key elements intersecting in Web-based crowdsourcing are (Saxton et al. 2013):

- The crowd.
- The outsourcing model.
- Advanced Internet technologies.

Different levels of effort by the crowds involved:

- Crowd as sensors

People generate raw data just because some processes are automatically performed by sensor-enabled mobile devices (e.g., processes run in the backend by GIS receivers, accelerometers, gyroscopes, magnetometers) which can be later on used for a purpose (i.e., mobile phone coordinates for positional triangulation, traffic flow estimates). This type of data collection has been defined elsewhere as "opportunistic crowdsourcing" (Chatzimilioudis et al. 2012).

Opportunistic crowdsourcing requires very low data processing capabilities (if any) on the side of participants and is the most passive role in the contributing information chain.

- Crowd as social computers

People generate unstructured data mostly by using social media platforms for their own communication purposes (e.g., sharing contents or socializing in Facebook, Twitter, Instagram). Social media users do not process information in any specific form, but these data can later be reused to extract semantically structured information. As in the previous role, there is no explicit participatory effort in any crowdsourced initiative or project).

- Crowd as reporters

People offer first-hand, real-time information on events as they are unfolding (e.g., they tweet about a hurricane making landfall and the reporting damages in a specific location). This user-generated content already contains valuable metadata added by users themselves (e.g., hashtags) than can be used as semi-structured, preprocessed data.

- Crowd as microtaskers

People generate structured, high-quality, interpreted data by performing some specific tasks over raw data (e.g., labeling images, adding coordinates, tagging reports with categories). This role requires an active participation of users in the crowdsourcing effort, and it may exploit special skills or require different levels of previous training.

The Role of the Crowd in the Disaster Management Cycle

Disaster management cycle defined as "the complete set of phases related to disasters and their management" (UN-SPIDER 2014). While disaster relief agencies and organizations may conceptualize the disaster management phases differently, most models generally include the following (Fig. 9.2):

- Mitigation.
- Preparedness.
- Response.
- Recovery.

Fig. 9.2 Disaster management cycle

Mitigation refers to "the lessening or limitation of the adverse impacts of hazards and related disasters"; preparedness includes "the knowledge and capacities developed by governments, professional response and recovery organizations, communities, and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions"; response involves "the provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety, and meet the basic subsistence needs of the people affected"; recovery extends to "the restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors" (UNISDR 2009).

The role of the "crowd as a sensor" is especially relevant in the preparedness and training phases when sensors can provide critical information of events or sub-events for different geographical locations and at large scale. People may contribute data either inadvertently or by explicit consent. While GPS location services require users' explicit permission of access on both Android and iOS systems, other location sensors such as accelerometers and gyroscopes do not (Liu 2013).

The role of the crowd as a "social computer" and as a "reporter" may be critical in the other three steps of the life cycle (response, recovery, and mitigation) where people and organizations (citizens, volunteer groups, and emergency authorities) can engage in multi-way information sharing and provide near-real-time updates on the events as they occur (Chon et al. 2012). Given the ever-growing amount of information that people share during a disaster, leveraging social media information posted on Twitter or Facebook becomes most relevant to facilitate situational awareness during an emergency (Cameron et al. 2012). Yet, there are a number of critical issues when using social media information: trustworthiness of the sources, veracity and accuracy of information, and privacy.

Some of these issues are easier to handle as the crowd actively take the role of a "reporter." In that case, as users tend to be already identified, verifying the reported information and therefore both the trustworthiness of the source and the verification process are less problematic. The people who report and use the reported information can even be part of the crowdsourced verification process.

The role of the crowd as a "microtasker" is especially relevant when it comes to produce and analyze structured data, both in the preparedness and training phases or later in the response and recovery ones.

Summary

Emergency management requires precise and reliable information about the current situation of emergency, existing sources and facilities, while more than 80% of this information has spatial component or location. Considering the urgent and time-sensitive nature of emergency situations, it is necessary to collect and use spatial information of the current state of the emergency within the minimum waste of time. With the development of technology and the popularity of customer terminal equipment such as personal computer, smartphone, and tablet, Internet-based communication is an inevitable development trend of data exchange.

Mobile technologies and social media have transformed the landscape of emergency management and disaster response by enabling disaster-affected citizens to produce real-time, local information on critical events.

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10 WebGIS Decision Support System for Disaster Management

Introduction

DSS means interactive computer-based systems, which help decision-makers utilize data and models to solve unstructured problems.

DSSs couple the intellectual resources of individuals with the capabilities of the computer to improve the quality of decisions. It is a computer-based system for management decision-makers who deal with semi-structured problems.

Characteristics of DSS

Following are the salient characteristics of DSS: DSSs incorporate both data and models; they are designed to assist managers in their decision processes in semi-structured or unstructured tasks, they support managerial judgment; rather than replacing it and DSS improve the effectiveness of the decisions; not the efficiency with which decisions are being made.

Benefits of DSS

Following are the main benefits of DSS: A DSS enables the solution of complex problems that ordinarily cannot be solved by other computerized approaches; a DSS enables a thorough quantitative analysis in a very short time. Even frequent changes in a scenario can be evaluated objectively in a timely manner; DSS imparts ability to try several different strategies under different configurations, quickly and objectively, data collection and model construction experimentations are executed with active users' participation; thus greatly facilitating communication among managers and routine application of DSS results in reducing or eliminating the cost of wrong decisions. Thus, decisions are of a high quality and have a greater chance of successful implementation.

Components of Decision Support Systems (DSSs)

Decision support systems consist of:

- DSS Database

It consists of various mathematical and analytical models that are used to analyze the complex data, thereby producing the required information. A model predicts the output in the basis of different inputs or different conditions or finds out the combination of conditions and input that is required to produce the desired output.

- DSS Software System

It consists of various mathematical and analytical models that are used to analyze the complex data, thereby producing the required information. A model predicts the output in the basis of different inputs or different conditions or finds out the combination of conditions and input that is required to produce the desired output.

Advances in information technology, including hardware, software, and networks, provide potential solutions to the problems of data accessibility. Current advances in computational speed, storage, World Wide Web (WWW) and software provide great opportunities to develop Decision Support Systems (DSS) with the advantage of information dissemination for decision-makers and program integration (Shim et al. 2002).

The Internet is another factor to be considered when developing DSS nowadays. Advances in communication networks have overcome many difficulties in the use of timely and spatially distributed resources in the decision-making processes. Therefore, one of the greatest benefits of using information technologies in decision-making is the potential to overcome limited resources in terms of time, data, and communication (Pandey et al. 2001).

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Spatial decision can be defined as a choice that is made between two or more alternatives. Individuals have to make many decisions every day. The potential choices in a decision are formed after defining certain minimum objectives, and alternatively, more demanding objectives.

Spatial Decision Support Systems (SDSSs)

A spatial decision support system (SDSS) is an interactive, computer-based system designed to assist in decision-making while solving a semi-structured spatial problem. It is designed to assist the spatial planner with guidance in making land use decisions.

The decision-making process can be seen as a process in which decision-makers try to find the best action (solution) to move from an initial situation to a desired goal situation.

The complicated nature of spatial decisions and the requirement for the accumulation, management, and analysis of a variety of datasets make it necessary to utilize computer-based tools. There are several tools, technologies, or systems such as Geographic Information Systems (GIS), decision support systems (DSSs), expert systems (ESs), remote sensing (RS), and spatial decision support systems (SDSSs) available to support spatial decisions. GIS software often plays a fundamental and central role in SDSS.

The combination of DSS and GIS makes it easier for the decision-makers to weigh options and therefore leads to more impartial and open-minded decisions. Spatial decision support systems (SDSSs) allow different options of land use to be traded off against each other.

Spatial decision support systems (SDSSs) are designed to provide the vital information required by decision-makers where location issues are involved in decisions. SDSS may be used for a selection of optimum locations for response teams, the design of evacuation routes or for allocating evacuees to shelters (National Research Council 2007).

A great number of decision support systems and their derivations (such as SDSSs) have been developed and more are now being developed for emergency management operations. These include a broad range of emergency applications such as fire and storm simulations and evacuation planning.

GIS can be a powerful tool for analysis purposes because each phase in emergency management life cycle is geographically and spatially related to each other. According to Thomas et al. (2003), geotechnologies are at the center of the emergency management life cycle, and GIS supports the decision-making process by providing people with a tool for assessing and analyzing the geographic nature. After the September 11 disaster in New York City, geotechnologies were implemented for this reason. To make the right decisions, emergency managers need the accurate and quick information about emergencies. They need to have decision support systems for dealing with emergencies in a timely and accurate manner.

Decision-Making

Decision-making is the process that leads to a choice between a set of alternatives. Geographical decision-making means analyzing and interpreting geographical information that is related to the alternatives in question. Decision-making is often used in land suitability analysis, or site selection, as well as location-allocation modeling (Aronoff 1993).

Decision-Making Process

Decision-making is a sequential process (Malczewski, 1999):

- Defining the decision problem (objective).
- Determining the set of evaluation criteria to be used.
- Weighting the criteria Generating alternatives.
- Applying decision rules.
- Recommending the best solution to the problem.

Decision-Making and GIS

Organizations depend on continual decisions. Executives guide the enterprise in deciding on long-term strategies, while middle managers decide on tactical initiatives to achieve middle range project goals. Knowledge workers make decisions to analyze business problems, conduct research, develop products, and generate creative decisions to put the enterprise in the forefront" (JB Pick 2007).

The decision-making process can be structured into three major phases, namely: the intelligence phase, the design phase, and the choice phase. GIS has been found to be very useful in the intelligence phase, which involves data acquisition, storage, retrieval, manipulation, analysis capabilities and effective presentation of information for decision-makers (PB Keenan 2004).

GIS is capable of generating a set of alternative decisions based on the spatial relationship principles of connectivity, contiguity, proximity and the overlay methods, however, models for generating decision alternatives operate in the background, detached from the decision-maker's insight and qualifications and therefore without the added value of the decision-maker's intelligence.

Web-Based GIS and Spatial Decision Support System

Geographic Information Systems (GIS) have been widely used for spatial data manipulation for hydrologic model operations and as a supporting tool to develop spatial decision support systems (SDSS). Information technologies, including GIS and the Internet, have provided opportunities to overcome many of the limitations of computer-based models in terms of data preparation and visualization and provide the possibility to create integrated SDSS. The Web-based SDSS can be helpful for management decision-makers.

Web-Based SDSS Components for Model-Based Approach

A Web-based DSS is a computerized system that delivers decision support information or decision support tools to a manager or business analyst using a "thin client" Web browser like Internet Explorer or Netscape Navigator. The computer server that hosts the DSS application is linked to the user's computer by a network with the Transmissions Control Protocol/Internet Protocol (TCP/IP) protocol. In many companies, a Web-based DSS is synonymous with an enterprise-wide DSS that supports large groups of managers in a networked client–server environment with a specialized data warehouse as part of the DSS architecture.

The Web-based DSS definition can be extended such that a Web-based SDSS includes a Web-based GIS as a problem solver using a geographic data query/display/analysis process.

A Web-based SDSS can combine several different components; essentially a Web-based SDSS is comprised of Hypertext Markup Language (HTML) user interfaces, Internet interface programs, computational models and geographic databases. A conceptual Web-based SDSS framework using CGI has user interface HTML pages, interface CGI applications, a computational model, a WebGIS application and a GIS database and files. This approach results in a server side and client side, which is beneficial for data integrity, system management, communication speed and "lightweight" download HTML pages when using high-performance server platforms (Plewe 1997).

Web-based SDSS user interfaces include menus, graphical maps, control buttons and form input. These interface utilities conduct selections, input data and map display/queries, usually using HTML tags, Java applets, JavaScript and other Internet protocols. The events occurring on the client side are submitted to the server through the HTTP protocol and jobs requested by the client are implemented through CGI or other Internet interface applications. The interface CGI works for communication including receiving data submitted, file management on the server side, running applications including computational models and writing results into files or standard out to the client browser. A WebGIS CGI performs GIS database manipulation including GIS data reading, querying, image preparation for requests from the client and HTML page standard out preparation.

Web-based SDSS development languages and protocols are abundant. Although most computer languages can write CGI applications, specific languages for Web application development are often preferred because of their efficiency and functionality. HTML, C, Practical Extraction and Report Language (PERL), Java and Hypertext Preprocessor (PHP) are commonly used for Web application development.

Decision Support Systems (DSSs) and Spatial Decision Support Systems (SDSSs)

The main objective of SDSS is to support decision-making by employing quantitative approaches with the use of geographic information that is stored within the GIS.

A decision support system is a computer-based system which supports decision-maker in organizing information and models to solve problems (Sauter 1997; Turban 1990). According to Sauter (1997) DSS technology can be used to help decision-makers as follows:

- Respond to situations quickly.
- Generate better alternatives.
- Look at more facets of a decision.
- Solve complex problems.
- Consider more options for solving a problem.
- Brainstorm solutions.
- Utilize multiple analyses in solving a problem.
- Implement a variety of decision styles and strategies.
- Use more appropriate data.
- Better utilize model.
- Have new insights into problems and eliminate "tunnel vision" associated with premature evaluation of options.

SDSS is explicitly designed to provide the user with a decision-making environment that enables the analysis of geographical information to be carried out in a robust, yet flexible manner and a typical SDSS has four components:

- analytical tools enabling the user to investigate data.
- decision models enabling the user to carry out scenario based investigations.
- a geographic/spatial database providing data for analyses and decision support.

- A user interface providing easy access to the decision models, database and analytical tools for the user while also providing an attractive and comprehensive display of the output.

The role of SDSS in emergency management

A decision-maker might use the basic functionality of a GIS to find the optimal route from the fire station to the incident area. For this analysis, the analyst might require the locations of fire stations, road networks, the barrier information, etc. This information could be the main inputs for emergency response decision and GIS could behave as a SDSS in this analysis. Some analysts also want to analyze the existing location of fire stations and want to find the optimal location of them. Some would like to determine the service areas on existing fire stations to help evaluate accessibility. In addition to this, some analysts use service areas to identify how many people, how much property, or anything else that is within the neighborhood. If these types of analyses and decisions were frequently made it would be useful to code a macro for making spatial operations easy. Such a system would use a database, spatial models, and suitable interface and might be considered a DSS in terms of traditional definitions (Keenan 2003).

Integration of Expert Knowledge and GIS Models: Knowledge Acquisition and Representation

Knowledge acquisition (KA) is the first step to make an expert system. KA is the process of transferring conceptual knowledge from the knowledge source to knowledge engineer (or expert system builder).

Model Organization

Varied models have been developed and integrated with GIS to solve difficult problems. Valuable models have been put in practice. In the process of models construction through database, grammar and implication should be defined first. Grammar and implication bridge the communication channels for model constructor and user.

Integration of GIS Models and Domain Knowledge

Model is a simplified reality and is designed for computer problem solving. Knowledge utilization is the most prominent character of spatial decision system. Expert knowledge is important in problem solving, but model is also indispensable and most spatial problems solving depends on spatial models (also referred as GIS models), in tasks that can be mathematically expressed. In the intelligent system, although knowledge base and model base are dependently organized, they must cooperate. The fusion of spatial analysis and expert knowledge is an effective way to realize their cooperation in a sophisticated problem solving. Model can be used by expert knowledge to solve some structured and well-formed problems, in this way expert knowledge and models are connected together.

A model unique identical number is input through model use interface and the corresponding model then can be driven to run. The function relation between spatial analysis model and expert knowledge experiences three periods. The original spatial decision support system depends totally on models and expert knowledge is embedded in model during the first period.

Spatial Decision Support Systems (SDSS)

Any decision-making problem falls within the range from completely structured to unstructured (RH Sprague 2005). Structured decisions occur when the decision-maker can structure the problem and these decisions can be programmed and solved by computers, unstructured decisions occur when the decision-maker is unable to structure the problem and have to solve the problem without the assistance of a computer. Most real-world problems are found between these two extreme cases, these decisions are called semi-structured. The structured part of the problem is handled by computers while the unstructured part is dealt with by the decision-maker.

Semi-structured decision problems are spatially related, a concept known as spatial decision support systems (SDSS) evolved as a field of research, development and practice parallel to decision support systems (DSS) during the late 1980s. By definition, DSS should provide integration and regeneration of information (PB Keenan 2004). This supports the exploratory nature of the decision-making process and allows the development of alternatives by using information system technology to increase the effectiveness of decision-makers.

Characteristics of DSS Can Be Outlined as Follows

- Explicit design to solve ill-structured problems.
- Problem solving in an interactive and recursive manner.
- Ability to explore different alternatives.
- Ability to combine analytical models with data in a flexible manner.

- Capacity to support different styles and levels of decision-making.
- Powerful easy to use user interface.

Decision-makers have indicated that inaccessible spatial data and especially difficulties in synthesizing and viewing various recommendations or solution scenarios are primary obstacles to spatial problem solving using normal DSS (Malczewski 1997). When the spatial element is included with DSS, the spatial information processing and management are possible, hence SDSS.

SDSS could be defined as an interactive, computer-based system designed to support a user or group of users in increasing effectiveness of decision-making while solving a semi-structured spatial decision problem. Its development has been associated with the need to expand Geographic Information Systems (GIS) capabilities for handling complex, ill-defined, spatial decision problems.

An SDSS supports a user by providing tools to explore the problem in an interactive and recursive fashion in all phases of the decision-making process. For the system to improve the effectiveness of decision-making, the decision-maker's input, judgment and the computer-based programmed must be incorporated into the decision-making process.

SDSS Provides a Framework for Integrating the Following

- Database management systems.
- Graphical display capabilities.
- Tabular reporting capabilities.
- Analytical modeling capabilities.
- Decision-maker's expert knowledge.

GIS normally provides database management systems, graphical display and tabular reporting capabilities, and supports structured decisions well. These elements of GIS are complemented by the analytical modeling capabilities of SDSS as well as the incorporation of the decision-maker's expert knowledge to support ill-structured spatial decision problems (PJ Densham 2004).

SDSS Architecture

SDSS requires four major operations to support decision-making; data input, data management, analysis and presentation. In addition, three key modules are needed:

- A dialogue generation and management system (DGMS).
- A database management system (DBMS).
- Analytical procedures in a model-based management system (MBMS).

The DBMS of a SDSS must support cartographic display, spatial query, and analytical modeling by integrating three types of data, locational (e.g., coordinates and chains), topological (attribute-bearing objects, e.g., points, lines, polygons), and thematic (attributes of the topological objects). The database must permit the user to construct complex spatial relations between all three types of data.

The DBMS could either be a relational, hierarchical, network or object-oriented data model depending on the data and application. It must have capabilities for managing internal and external databases for data acquisition, storage, retrieval, manipulation, directory, queries, and integration.

The MBMS must include tools for generating value structure, preference modeling, and multi-attribute or multi-objective decision rules. This implies that the decision-maker could recommend alternative solutions for formal analysis. The system must have capabilities to model uncertainty in the form of data uncertainty, decision rule uncertainty, sensitivity analysis and error propagation analysis. The types of models include analytical models, which should have capabilities to handle goal seeking, optimization, simulation and what if scenarios and statistics, and forecasting models, which facilitate exploratory, and confirmatory spatial data analysis, time series, and geostatistics.

GIS can store and retrieve data from the database based on the query done by user. The data retrieval and storage of geographic data into database and analysis of this data is done with help of functions which are defined by the users. Along with the user-defined function, GIS has other function to manipulate and analyze geographic data that are scalar operation, overlay operations, connectivity operations, visualization of data.

GIS-Aided (S) DSS Applications

- BASIS (Innovative GIS/Berry and Associates//Spatial Information systems).

Emergency management planning tools also play an important role in emergency response. These tools allow evaluation of alternative ways to respond to an emergency. They may be used for estimation of emergency event impact and include capability of emergency impact modeling tools. For instance, an online tool which is developed by Innovative GIS/Berry and Associates//Spatial Information systems (BASIS) can be used for forest fire response planning (Jain and McLean 2003; Innovative GIS 2003). Some questions have been answered using this tool:

- What is the best route to the farthest location?
- What is the estimated elapsed time at each step along the best route?
- What portion of the map area is within an 18-minute response time?
- HURREVAC (Hurricane Evacuation)
  Another example of GIS-aided (S) DSS is HURREVAC which stands for "Hurricane Evacuation" and is a restricted-use computer program funded by FEMA and USACE for emergency managers tracking hurricane route and assisting the evacuation decision-making for managers. The real-time data analysis tools allow the managers to make exact decisions based on FEMA Hurricane Evacuation Studies and distributed real-time forecast data.
- GIERS (GIS-BASED INTELLIGENT EMERGENCY RESPONSE SYSTEMS)
  Terrorist attacks in World Trade Center show the importance of quick emergency response in urban areas and multi-story buildings, which is resulted in structural damage. With this goal, (Kwan and Lee 2005) examine the opportunities of using 3D GIS for the development and implementation of GIS-based Intelligent Emergency Response Systems (GIERS) helping quick emergency response to terrorist attacks on multi-level structures.
- CEMPS (CONFIGURABLE EMERGENCY MANAGEMENT AND PLANNING)
  Another example of GIS-based spatial decision support system is Configurable Emergency Management and Planning Simulator (CEMPS) which is designed for contingency planning in emergency evacuation.
- KXSDSSES (KING'S CROSS SPATIAL DECISION SUPPORT SYSTEM FOR EMERGENCY SERVICES)
  Similar with CEMPS, KXSDSSES provide the designation of contingency planning before an emergency evacuation rather than real-time emergency management use.

Summary

Decision-making is the process that leads to a choice between a set of alternatives. Geographic Information Systems (GIS) have become an effective tool for decision support. Spatial decision support system (SDSS) is a relatively new field developed based on Geographic Information Systems (GIS) and Decision Support System (DSS). Geographical decision-making means analyzing and interpreting geographical information that is related to the alternatives in question.

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Web-based GIS software

- Open WebGIS
  Open WebGIS is an open-source Geographic Information Systems. It is a Web-based system, and it functions both in online and offline modes. In Open WebGIS, users can create, export, and add layers in many common geospatial formats (GML, KML, GeoJSON, GPX, Shapefile, TIFF, ArcGrid, CSV, OSM); make vector layers with points, lines, polygons; add WMS layers; use WPS; style their own data; share as embedded maps; share as Web pages; customize Interface; use analysis functions; create 2D, 2.5D, and 3D maps, charts, and so on.

- AspMap
  AspMap is a Web-mapping component for embedding spatial data access, display and analysis capabilities in Web applications and services. AspMap supports ASP and ASP.NET.
- Google Earth
  Google Earth combines satellite imagery, geographic data, and Google's search capabilities to create a virtual globe application that you can download to your desktop to access online spatial data.
- Google Maps
  Using Google Maps on individual Web sites, called map hacking, is a fast and easy way to add geographic information to personal Web sites.
- iMapper
  Free user-friendly ArcView extension. The purpose of this extension is to allow ArcView users to display their maps and data to people over the Web in a quick and easy fashion without having to have a Map Server.
- Map Server
  Map Server is an open-source development environment for building spatially enabled Internet applications. The software builds upon other popular open source or freeware systems like Shapelib, FreeType, Proj.4, libTIFF, Perl, and others.
- Map-TV
  Map-TV is a Map Server that has a built-in Web server. This Map Server uses ESRI Shapefile format for data display
- ArcIMS
  ArcIMS is specifically built to serve GIS on the Internet and is designed to make it easy to create map services, develop Web pages for communicating with the map services, and administer sites. It allows distribution of geographic information via the Internet and allows real-time integration of data.
- TatukGIS Developer Kernel ASP.NET Edition
  ASP.NET Web Forms SDK for custom WebGIS development using C#, VB.NET, Oxygene, and other .NET-compatible languages. Support for HTML5 technology enabling smooth, multi-touch compatibility with leading Web browsers and platforms (iOS iPhone and iPad, Mac OS, Android phone and tablets, Windows mobile devices).
- WebGIS Version 3.0
  WebGIS Version 3.0, developed by NAC Geographic Products Inc., contains the Java applet, which publishes Geographic Information Systems and intelligent maps created by the GIS editing software NACMAP on Web pages.
- Active Maps
  Active Maps is a powerful, flexible, and popular online GIS for Web authors, GIS specialists, and all users. The main features include Vector GIS for display, query, and analysis of spatial data. Functions include zoom in, zoom area, zoom out, unzoom, pan, identify, table, query, label, hyperlink, tracking dynamic objects and database connections, etc.
- Internet Mapper
  Internet Mapper is a system designed to publish interactive maps connected to databases on the Internet. It mainly permits two main types of functions: to display

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using maps the results of database queries and to obtain information regarding elements within the maps. Internet Mapper supports several different types of output formats like BMP, GIF, PNG for browsers with no add-ons, Flash for standard browsers with a plug-in from multimedia, VML for Internet Explorer 5.x, and SVG for future 6.x browsers.

- AltaMap Server
  AltaMap Server has been designed to add mapping capabilities to a Web site. Dynamically generated maps can be easily included with AltaMap Server components. A custom Web-based GIS application can be easily developed with the Map Server components using any scripting language.
- Map Viewer Web
  The software, residing on a server, is accessible using the Internet, and it provides a view-only mode for Web-enabled Java™ technology. It contains an Intelligent Locate feature which helps to locate and display maps based on user-defined queries. The Attribute Review allows viewing of database information associated with a feature. It allows "view manipulations" like pan, zoom. It supports popular database systems apart from Oracle 8i Spatial.
- GeoMedia Web Map
  GeoMedia Web Map allows communication geographically through smart maps on the Web. This Windows-based technology enables to combine and distribute GIS information from multiple sources over the Internet.
- ModelServer Discovery
  ModelServer Discovery is a product for Web-based dissemination of geoengineering data brought by Bentley. Images are displayed in standard Internet formats including SVF, CGM, and JPEG. Attribute information can be obtained from a relational database which can also be queried using SQL.
- Maptitude for the Web
  Maptitude for the Web includes all of the regular capabilities of Maptitude, plus special capabilities that make it easy to design, test, and publish interactive map applications on Web sites. Maptitude for the Web produces HTML output and does not require installation of additional application server software or browser plug-in.
- EtakMap® Web server
  EtakMap Web server software helps to locate business locations via Web sites. It provides address-to-address driving directions from anywhere to the desired locations. On the map, it not only locates the desired spot but also displays the addresses on the map. The map includes pan and zoom features so that viewers can explore the surrounding area.
- Lava
  The Lava GIS browser is a 100% Java GIS browser, completely hardware-independent, fast, customizable, and the ideal solution for corporate intranets or the Internet. It supports map integration from different servers, access to large, seamless databases, raster and vector data and advanced caching to reduce network traffic.
- Autodesk MapGuide Server
  Autodesk MapGuide Viewer enables access and interaction with intelligent maps through Web browsers and other custom applications by which viewers can pan and zoom, make queries, create dynamic buffering zones, measure distances, etc.
- Cadcorp SIS
  The SIS ASC allows users to develop server-based fully functional GIS applications which can be accessed through HTML browser. When combined with ActiveX Data Objects (ADO), powerful Internet applications can be written which combine SIS mapping technology with database retrieval. It can read and display any of the standard data formats read by all other Cadcorp SIS products.

Emergency Operations Center

EOC is the official structure that brings together decision-makers from many ministries and government agencies, as well as representatives of the private sector in some cases. It is set up to facilitate the coordination of response efforts in all regions affected by the disaster.

Requirements of an Emergency Operations Center

- Establishing a specific location, and stocking it with response equipment and technology.
- EOC location should be a safe distance from the effects and potential risks of an incident.
- EOC should be able to sustain operations 24/7 during all emergencies without interruption.
- EOC staff must be thoroughly trained, drilled in the proper processes and procedures, and understand specified roles and responsibilities for coordinating full-scale emergency response effort.
- Procedures and processes should guard against unauthorized disclosure of sensitive information.
- EOC should enable effective communications to/from the incident, responders, and local authorities. The EOC should provide sufficient communication access.
- EOC should be the central point for shared operations and exchanges of information. The EOC should be able to accommodate any surge in response and accommodate those individuals necessary for interoperability.

EOC should contain:

- Communications equipment (phones, radios, Internet connection).
- Copies of emergency response plans and EOC procedures.
- Plot plans and/or building blueprints.
- Appropriate number of chairs and table space.
- Status boards.
- A list of EOC personnel and descriptions of their duties.
- Contact information for employees and responders.
- Building security and utility systems information.
- Technical and hazard information.
- Backup power, communications, and lighting.
- Fire extinguisher(s).
- Emergency and first aid supplies.
- Miscellaneous tools deemed necessary to respond quickly and appropriately to an emergency.

Functions of an Emergency Operations Center

EOC serves as the coordination hub for an incident response, provides a central intelligence arena for decision-makers and response team personnel to gather critical information, coordinate response activities, and manage personnel as the emergency situation dictates. A safe location equipped with effective technology allows for communication with staff and response teams.

EOC should be organized to carry out five major functions:

- Command
  - Responsible for overall response management.
- Operations
  - Responsible for coordinating all operations to support the incident action plans.
- Planning
  - Responsible for collecting, evaluating, and disseminating information and for coordinating development of incident action plans.
- Logistics
  - Responsible for procuring facilities, services, personnel, equipment, and materials.

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- Finance/Administration
  - Responsible for tracking incident costs, forecasts, and payment of responders, contractors, and claims.

When a reportable incident has a probability for a significant negative impact, the EOC may be activated. Initially, the EOC may

- Act as the communications link between corporate headquarters and the affected facility.
- Ensure that specifically trained response individuals are available or are being mobilized in the event their expertise is necessary.
- Update executive management as the incident transpires and changes.
- Monitor TV, radio, and wire services to determine accuracy of public information.
- Ensure that employees and the impacted community are adequately informed of the incident and response actions.
- Ensure that necessary equipment is available on site. This may require ordering and arranging delivery of equipment and materials from contractors.

Disaster Management and Emergency Room

Emergency and Disaster Management

An emergency is an event that can be responded to using the resources available at hand, implying that there is no need to request external assistance.

A disaster is characterized by impacts that overwhelm the capacities of local responders and place demands on resources which are not available locally. Hence, an event is declared as a "disaster" when there is a need for external assistance to cope with its impacts.

When an emergency or a disaster affects a city or a region, efforts are conducted initially to care for the wounded, to restore lifelines and basic services, and subsequently to restore livelihoods and to reconstruct communities. Such efforts can be structured in three phases:

- **Response phase**

Where activities such as search and rescue, rapid damage and needs assessments, and the provision of first aid are conducted, followed by the opening and management of temporary shelters for those left homeless as well as the provision of humanitarian assistance to those affected.

- **Rehabilitation phase**

Where basic services and lifelines are restored, even on a temporary basis, including the road network and other essential facilities including bridges, airports, ports, and helicopter-landing sites.

- **Recovery phase**

Where reconstruction efforts are carried out on the basis of a more precise assessment of damage and destruction of infrastructure. In addition, efforts are conducted to reconstruct infrastructure when needed and to restore the livelihoods of those affected.

Emergency Planning

Emergency planning can be defined as the process of preparing systematically for future contingencies, including major incidents and disasters. The plan is usually a document, shared between participants and stakeholders that specify tasks and responsibilities adopted in the multi-agency response to the emergency. It is a blueprint for managing events and, as such, should be responsive to management needs. It should specify the lineaments of action, collaboration, command, and communication during a civil contingency such as a disaster or major event; in other words, it is the framework for emergency response. The maintenance of public safety, limitation of damage, protection of the vulnerable and efficient use of life-saving resources are some of the goals of the plan. Although the end product is a document, emergency planning is more a process than an outcome, especially as the plan itself will need to be updated over time as circumstances change.

Emergency and Disaster Planning as a Process

Emergency planning should be a process, rather than a product or outcome. At its most essential, it must match urgent needs to available resources, and do so in a timely way that avoids procrastination and delay. Good emergency plans are realistic as well as pragmatic.

Emergency planning is an approximate process that, in many instances, is little more than codified common sense. It also involves a collective effort and is thus a participatory process. In order to avoid sins of omission or commission, it requires experience and training.

The essence of emergency and disaster management is its capacity to tackle pressing needs with maximum efficiency and celerity but with scarce resources and in the absence of much necessary information. Before the event, the plan must

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make assumptions about what is needed during the event. Those assumptions need to be considered within the compass of what is feasible with the available human and technical resources. One reason why the plan must constantly be updated is that one assumes there will be a program of continuous improvement in the resources and one trusts that it will take place in light of the evolving body of knowledge of hazards and the needs that they provoke.

Emergency Planning and Emergency Management

The primary resource is information, and hence, everything possible should be done to ensure that flows of vital data and communications are unrestricted and properly focused on essential needs. Emergency management, as supported by prior and on-going planning, should ensure that organizations can work together effectively under unfamiliar circumstances, possibly including organizations that have no formal relations under normal, non-emergency circumstances. The plan should ensure that every participant in the response to an emergency has a role, and that all anticipated tasks are covered such that the risk of hiatuses or disputes about responsibilities is minimized.

One way to demonstrate the connection between emergency planning and emergency management is through the provisions to manage information. Emergency communication needs to be sustained, flexible, and clear. Decisions and communications need to be recorded. The emergency planner can help this process by ensuring that the technological means of communication are present and are robust in the face of potential failure, the protocols for sending messages are established, and the priorities for communication are known to participants.