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Distributed geo-services based on Wireless GIS - a case study for post-quake rescue information system

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Abstract

With the continuous evolution and extension of wireless communication technology, geographic information system has been developed from desktop to mobile, from wired to wireless environment. The research and development of wireless GIS have made capture, query, and transmission of geo-data more simple, open and standardized. The distributed geo-services based on web and/or wireless web supported by a large number of middleware vendors have particularly rich research contents and wide applications. Many open source GIS software programs have emerged in the recent decade and benefited countless users worldwide. The open source means geographic information can be exchanged and applied without any commercial purpose. It has become a development trend in Wireless GIS application.

A useful application of Wireless GIS is the handling of natural disasters such as earthquakes. Earthquakes frequently strike us, particularly in the current period of crustal activity. With the changing environment, other natural disasters related to climate, such as floods and hurricanes are also continuously threatening people’s lives and properties. Facing these disasters, the most urgent thing is to find and rescue trapped peoples. The related geographic information can be delivered and retrieved by both experts and social volunteers. This thesis is dedicated to the construction and implementation of a post-quake rescue information system based on open source data and software programs. The emphasis is laid on the assessment of losses in the disaster area, estimation of collapsing buildings and trapped population, and efficient transmission of all the rescue-relevant information.

To realize the wireless web GIS functionality in the proposed post-quake rescue information system, the author chooses Tianjin, China, as the test bed with its basic map information and open source thematic layers as starting point. Google image maps overlaid with Volunteered Geographic Information from other open source software programs, such as uDig, Geotools, OpenLayers, PostGIS are utilized as fundamentals to create rescue database and visualize various aspects of the database. The realized workflow of using open source data and software programs to develop distributed geo-services for rescue purposes is independent of official data sources, therefore, flexible enough to react on emergency situations. The distributed geo-services for post-quake rescue can be adjusted and transferred to other post-disaster rescue systems.

Key words: post-quake assessment, rescue information system, distributed geo-services, hyper map model, wireless communication, open source software

Zusammenfassung

Mit dem kontinuierlichen Aufbau und der Erweiterung der drahtlosen Kommunikationstechnologie, sind Geo-informationssysteme vom Desktop auf Mobile Geräte, von drahtgebundenen zu drahtlosen Umgebungen, weiterentwickelt worden. Die Forschung und Entwicklung von drahtlosem GIS hat die Erfassung, die Abfrage und die Übertragung von Geodaten einfacher, offener und standardisiert gestaltet. Die auf Internet und / oder drahtlosem Internet basierenden dezentralisierten Geo-Dienste bieten, unterstützt von einer großen Zahl von Middleware-Anbietern, besonders umfassende Forschungsinhalte und umfangreiche Anwendungen. Viele Open-Source GIS-Programme sind im letzten Jahrzehnt entstanden und unzählige Anwender profitieren weltweit davon. Open-Source bedeutet, dass geografische Informationen ausgetauscht und angewandt werden können, ohne eine kommerzielle Bestimmung. Dieses ist zu einem Entwicklungstrend im Bereich drahtloser GIS-Anwendungen geworden.

Eine nützliche Anwendung ist der Einsatz von drahtlosem GIS bei Naturkatastrophen wie z.B. Erdbeben. Erdbeben treten häufig auf, insbesondere in Gebieten die eine hohe Spannung in der Erdkruste aufweisen. Mit der sich wandelnden Umwelt, bedrohen auch Naturkatastrophen im Zusammenhang mit Klima, wie etwa Überschwemmungen und Wirbelstürme, fortwährend das Leben von Menschen und ihren Habseligkeiten. Angesichts dieser Katastrophen ist die dringendste Aufgabe Menschen in Not zu finden und zu retten. Die damit in Beziehung stehenden geografischen Informationen können sowohl von Experten als auch von Freiwilligen bereit gestellt und abgerufen werden. Diese Arbeit ist dem Aufbau und der Implementierung eines Rettungsinformationssystems für nach einem Beben basierend auf Open-Source-Daten und -Software gewidmet. Der Schwerpunkt liegt auf der Bewertung der Schäden im Katastrophengebiet, die Abschätzung einstürzender Gebäuden und der Bevölkerung in Not, sowie die effektive Übertragung aller Rettungsrelevanten Informationen.

Zur Realisierung der drahtlosen Web-GIS-Funktionalität innerhalb des vorgeschlagenen post-Beben Rettungsinformationssystems, verwendet der Autor die chinesische Stadt Tianjin als Testgebiet mit Geobasisinformationen und thematischen Open-Source Layer als Ausgangspunkt. Google Bildkarten, die durch Open-Source-Programme, wie uDig, Geotools, OpenLayers und PostGIS, mit „Volunteered Geographic Information" überlagert werden, bilden die Grundlage zur Erstellung einer Rettungsdatenbank und zur Visualisierung verschiedenster Aspekte der Datenbank. Der realisierte Workflow der Entwicklung dezentral verteilter Geo-Dienste mit Open-Source-Daten und -Software für Rettungszwecke ist unabhängig von öffentlichen Datenquellen und daher flexibel genug um auf Notfallsituationen zu reagieren. Die dezentral verteilten Geo-Dienste für post-Beben-Rettung können auch in andere post-Katastrophen-Rettungssysteme überführt und angepasst werden.

Schlüsselwörter: Post-Beben Bewertung, Rettungsinformationssysteme, dezentrale Geo-Dienste, interaktive Multimedia Kartenmodelle, drahtlose Kommunikation, Open Source Software

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Chapter 1

Introduction

1.1 Background

Our daily life is exposed to various sorts of danger1, hazard2 / risk3, emergency4 and disasters5. Danger is something vulnerable, a hazard is a situation that poses a level of threat to life, health, property, or environment, the interaction between hazard and vulnerability leads to a risk, an emergency is a situation that poses an immediate risk to health, life, property or environment, and disasters can cause great loss life and/or property and ruin of historical sites in some circumstances. We can see the difference among these terms in Table 1.1; certainly they are often interchangeable under certain conditions.

Table 1.1 Comparison of danger, hazard / risk, emergency and disaster

	Danger	Hazard/Risk	Emergency	Disaster
Level of destruction	Low	Poses a level of threat to life, health, property, or environment	An immediate risk to health, life, property or environment	Cause great loss of life and/or property
Manageability	Some can be avoided or predicted	Some can be prevented	Emergency services can help	Hardly predictable; Post-processing
Example	Warning signs at swimming pool	Food poisoning, stock market risk	Train derailment	Earthquake, flood, hurricane

A disaster is either a natural or man-made hazard which has resulted in an event of substantial extent causing significant physical damage or destruction, loss of life, or drastic change to the natural environment. It can be ostensively defined as any tragic event with great loss stemming from events such as earthquakes, floods, catastrophic accidents, fires, or explosions. As a sudden-onset disaster, earthquakes strike suddenly, without any warning. Earthquakes can occur at any time of the year and at any time of the day or night. On a yearly basis, 70 to 75 devastating earthquakes occur throughout the world[6]. A series of major earthquakes, magnitude 7.3 in Haiti, 8.8 in Chile and 6.7 in Taiwan, have triggered widespread debate among experts as to whether the earth is entering a seismically active period. Most of earth quakes occur suddenly at a certain location with short duration. The current level of science and technology cannot yet solve all the problems that human beings face. At a conference of experts held in London in 1996, a broad consensus was reached that earthquakes are inherently unpredictable. They are not predictable now and will not be predictable in the

[1] http://en.wikipedia.org/wiki/Hazard
[2] http://en.wikipedia.org/wiki/Danger
[3] http://en.wikipedia.org/wiki/Risk
[4] http://en.wikipedia.org/wiki/Emergency
[5] http://en.wikipedia.org/wiki/Disaster
[6] http://oem.cob.us/DisasterEarthquake.asp

future[7] in terms of the site and time. What is possible is to predict earthquake magnitudes and related parameters based on the local conditions of seismic zone. Since the occurring time, location and magnitude of earthquake can't be accurately predicted, the focus of current efforts is laid on how to mitigate future earthquake disaster, protect human life and property. An overview of the development of earthquake science is given by (Chen & Li 2003) in which several trends are summarized. They include advances from the plate theory to the study of plate boundary, from deep to shallow crustal structure of the transition, from observation to simulation of the transition, and from the earthquake hazard to earthquake risk research.

Viewing from the process of the earthquake, people's action or response can be classified as seismic monitoring and early earthquake warning, earthquake disaster monitoring and earthquake rescue, integrated assessment of seismic and disaster mitigation decision support and some other stages (Li et al. 1993). These stages are interrelated with each other and constitute a long-term research agenda. Table 1.2 illustrates the information that various stages need.

Table 1.2 Required information in different stages of earthquake research

Research phases	Seismic monitoring and simulation	Earthquake early warning	Earthquake disaster monitoring and earthquake rescue	Integrated assessment of seismic and disaster mitigation decision support
Required geographic information	Geological, topographic, model data	Statistical data such as population, weather etc.	Model data, population, positional information	Population, life and property, economic information

Research on earthquake disaster mitigation advances towards two main directions: One is concentrated in Japan, China and other large-scale earthquake-prone countries with key economic and densely populated areas where urban seismic risk assessment such as fault detection of seismic activity, ground deformation analysis and site response analysis is carried out; the other is the close cooperation between the government and seismologists with the focus on how to formulate the earthquake emergency response plan, build the response system and rescue system after the earthquake (Chen & Li 2003). Both directions need the support of a geographic information system (GIS) which combines the computer science and spatial data, contains a series of spatial operations and analytical tools for geo-sciences, environmental sciences and engineering design and also for business planning, management, and provides decision support to its users (Du et al. 1995).

With the development of Internet, especially the development of World Wide Web (WWW) technology, the distribution, searching and browsing of information has undergone a revolutionary change and brought great convenience to human beings. Various industries have managed to run their corresponding information systems on WWW (Badget and Sandler 1995; Strand 1996). At present, most commercial relational database management systems can be run in the Internet (Zhuang 1997; Oracle 1997). Web GIS or Internet GIS has become a mainstream for the further development of geo-information technology (Coleman & Mclaughlin 1997; Evans 1996; Peng 1998; Korte 1997). Furthermore, distributed GIS as GIS program working in the wireless network environment is made possible with the recent development of wireless communication technologies which include:(1) the rapid expansion of low-cost band-width in the Internet and (2) a new generation of web-enabled desktop computers and mobile devices (Peng & Tsou 2003).

[7] http://www.china.org.cn/2010-03/15/content_19613575.htm

Wireless communication has overcome the limitations of Office Web applications and allows access to information and the release of information at any time and any place. Therefore, the management, simulation and evaluation of sudden disasters based on wireless communication research is increasingly favored by those who are involved in rescue work.

1.2 The research purposes and hypothesis

Looking at the list of major earthquakes[8] [9] in Table 1.3 and imagining the suffering people and the scope of damage, everybody will get emotionally shocked and naturally wish to do something for them. However, the rescue work for those trapped in earthquake is never easy and timely enough to minimize the loss of life and property.

Table 1.3 Major earthquakes in the 21st century

Year	Date	Magnitude	Fatalities	Region
2011	01/11	9.0	28050	Honshu Janpan
2010	01/12	7.0	222570	Haiti
	02/27	8.8	507	Offshore Maule, Chile
	04/14	7.1	1706	Yushu China
2009	09/29	8.1	192	Samoa Islands region
	09/30	7.5	1117	Southern Sumatra, Indonesia
2008	05/12	8.0	87587	Eastern Sichuan, China
	01/14	7.2	12	Japanese
2007	08/15	8.0	514	Near the Coast of Central Peru
	09/12	8.5	25	Southern Sumatra, Indonesia
2006	05/26	6.3	5749	Java, Indonesia
	11/15	8.3	0	Kuril Islands
2005	03/28	8.6	1313	Northern Sumatra, Indonesia
	10/08	7.6	80361	Pakistan
2004	12/26	9.1	227898	Off West Coast of Northern Sumatra
2003	09/25	8.3	0	Hokkaido, Japan Region
	12/26	6.6	31000	Southeastern Iran
2002	03/25	6.1	1000	Hindu Kush Region, Afghanistan
	11/03	7.9	0	Central Alaska
2001	01/26	7.7	20023	India
	06/23	8.4	138	Near Coast of Peru
2000	06/04	7.9	103	Southern Sumatera, Indonesia
	11/16	8.0	2	New Ireland Region, P.N.G.

Recently a wireless LAN was set up in post-earthquake Haiti[10]. However, the wireless LAN is only used in a hospital. To help people who live in active earthquake area, more and more volunteers begin to take part in the rescue work by contributing their own information - Volunteered Geographic Information (VGI). VGI is the harnessing of tools to create, assemble, and disseminate geographic data provided voluntarily by individuals (Goodchild 2007). Some examples of VGI are Wikimapia, OpenStreetMap, and Google MyMaps. VGI can also be seen as an extension of critical and participatory approaches to geographic information systems

8 http://www.mapreport. com/subtopics/d/e.html.
9 http://cn.reuters.com/news/globalcoverage/2010worldearthquake
10 http://www.networkworld.com/news/2010/032310-haiti-wlan.html

(Elwood 2008) and as a specific concern within online or web credibility (Flangin & Metzger 2008). These sites provide general basic map information and allow users to create their own content by marking locations where various events occurred or certain features exist, but have already shown on the basic map.

After an earthquake, people usually pay more attention to rescue work in order to mitigate the disaster. Some efforts are dedicated to issues such as self-help or self-safety. The article "triangle of life" gives advice about earthquake safety[11]. Other researches deal with specific topics of how to reinforce concrete building to withstand earthquake (Krimgolg F. 1988), how to quickly repair the road after the collapse (Han 2010), how to manage the rescue efforts and analyze casualties of the earthquake, how to develop emergency medicine (Zhang et al. 2010), how to quickly visualize 3D buildings in danger[12] (Jahnke et al. 2009); how to make earthquake data immediately available, e.g. using a wireless seismic RT 1000 system[13] (Softpedal 2010), how to build up an earthquake monitor for iphone[14]. More general researches are focused on topics such as the interoperable use of remote spatial databases using standardized Geo Web Services; integrating grid computing and server-based GIS to facilitate disaster management (Ertac 2010). Similar to VGI, people can benefit from the integrated application of advanced open source software and share knowledge with others in terms of rescuing the suffering people in the disaster areas. The most decisive factor for any kind of rescue work is time.

Concerning about the recent earthquakes, information through telephone and network communication also contributed greatly to the rescue work in a short time. The typical rescue process begins with searching and locating the subject to be freed. For example, in Christchurch earthquake happened on Feb.22.2011, a girl who studied there was crushed under the debris. She used her mobile phone and informed her father who was in China at that time, thus very far away from her position. The Chinese father quickly called the consulate which in turn contacted the rescue team. By that time, however, the rescue team on site could no longer detect life signs any more in that building in which the girl was trapped. Apparently this girl lost the best time for rescue in Christchurch (Chen 2011). This case reminds us of the necessity to develop a more efficient way of information dissemination so as to allow a timely rescue work.

The thesis aims at building up a server system to collect process and disseminate basic and actual data and information about traffic, population, water, housing, land, geological structures and so on from different sources. The system is composed of several distributed services. First, the server extracts the relevant information from the raw data and sends it to the ambulance/rescue center; Second, if the besieged person has PDA or wireless phone or AGPS tracker, he or she can send his or her own position information directly to the server which then quickly transmits it to the rescue center; Third, through the server, the information is sent to governmental departments, news agencies or individual volunteers involved in rescue work, as long as they have access to the wired or wireless Internet. These services may lead to substantial time saving, hence an efficient rescue.

A number of advanced performances are expected from this server system:

Comprehensive information handling

Relief work needs all the geographic information be put into a comprehensive rescue information system. In general, technologies for open source software application and development are walking in the forefront of research. The server system is based on the

[11] www.snopes.com/inboxer/household/triangle.asp
[12] www.pf.bv.tum.de/prj/
[13] http://news.softpedia.com/news/Wireless-Seismic-RT-1000-Wireless-System-Makes-Earthquake-Data-Available-Faster-161364.shtml
[14] www.switchonthecode.com/tutorials/building-an-earthquake-monitor-for-iphone-using-mapkit

current technologies and methods and allows the most recent technology to be incrementally integrated for the purpose of assuring smooth data flows and sharing real-time geographic information and services;

Real-time positioning

As soon as the earthquake takes place, the server system is able to react in real time and helps to locate the positions of the besieged personnel and forward the information to rescue team on site;

Ambulance services

The server system is connected with other distributed servers that provide ambulance services and other life-saving medical treatments.

The test data are chosen from the city of Tianjin with the following reasons. Firstly, Tianjin is a big city in the immediate vicinity of Beijing with a large population density and fast commercial development; Secondly, Tianjin is located in a risky seismic belt. Figure 1.1 illustrates the seismic zones in China and Tianjin[15]. According to statistics, five earthquakes of Richter magnitude scale between 7 and 7.9 and more than 140 earthquakes of Richter magnitude scale ≥ 4.7 were recorded in this belt. The two most significant earthquakes that have hit this belt are Sanhe earthquake, 8.0 in 1679, and Tangshan earthquake 7.8 in 1976 (Tian & Zhang 1992).

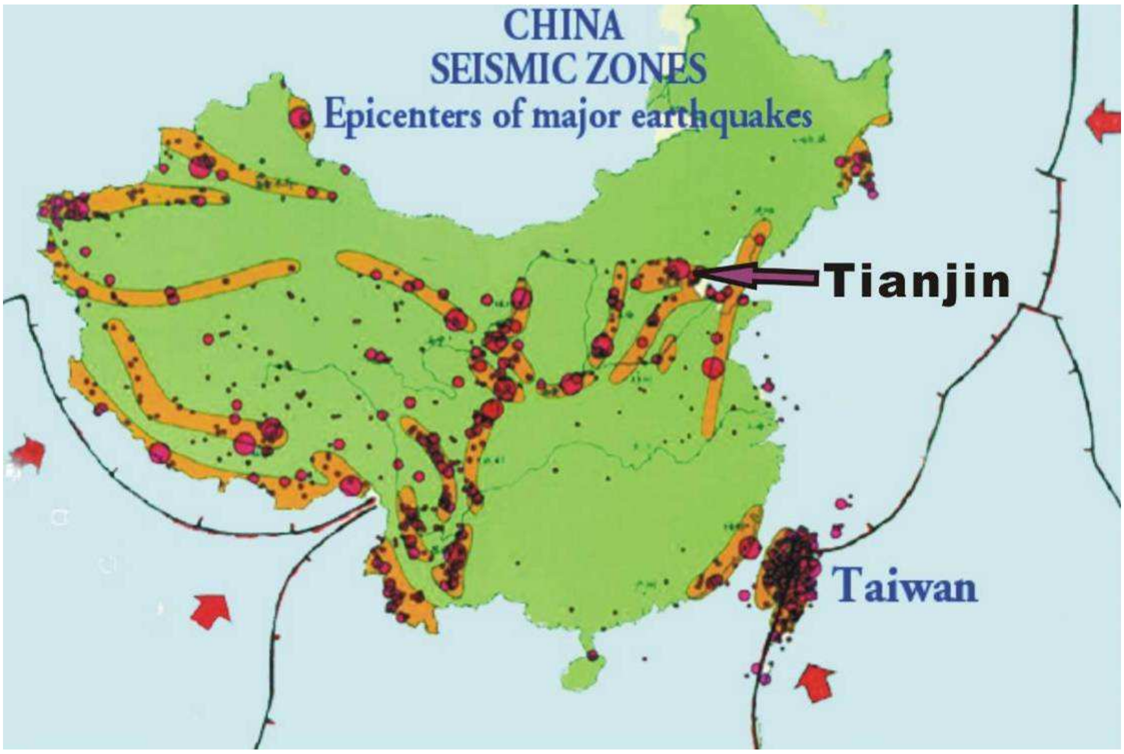

Figure 1.1 The seismic zones in China

The district map of Tianjin China and Tianjin census data and open-source software are chosen to simulate a post-earthquake person recue information platform. In addition, WebGIS server and OGC standards for WMS and WFS are used to publish maps and attribute data from different databases. Using OpenLayers and Google Maps, information can be overlaid

[15] www.drgeorgepc.com/tectZonesChinaEpic.jpg

on the image map. Network client terminals are able to use wireless browser to retrieve map information and then forward it to rescue team in disaster area and activate the necessary rescue work.

As to the implementation of the system, a comparison among a number of commonly used GIS software has been made, as shown in Table 1.4.

The open-source software, such as Geoserver, GeoTools, PostGIS, uDig etc. are suitable for the thesis work.

Table 1.4 Functional comparison of the commonly used GIS software

GIS software	Free	Open source	MS Windows	Linux	Web
Autodesk	viewer(s)	no	yes	yes	yes
ESRI	viewer(s)	no	yes	yes	yes
Geoserver	yes	yes	yes	yes	yes
Geotools	yes	yes	Java	Java	Java
GRASS	yes	yes	yes	yes	yes
gvSVG	yes	yes	yes	Java	no
Intergraph	viewer(s)	no	yes	no	yes
Mapinfo	viewer(s)	no	yes	no	yes
PostGIS	yes	yes	yes	yes	yes
Smallworld	no	yes	yes	yes	yes
Supermap	viewer(s)	no	yes com. Java.net	yes(Solaris &AIX&HP-UX)	yes(AJAX & Flex& Silver light)
uDig	yes	yes	yes	yes	no

1.3 Structure of the thesis

The structure of thesis is reflected in Figure 1.2.

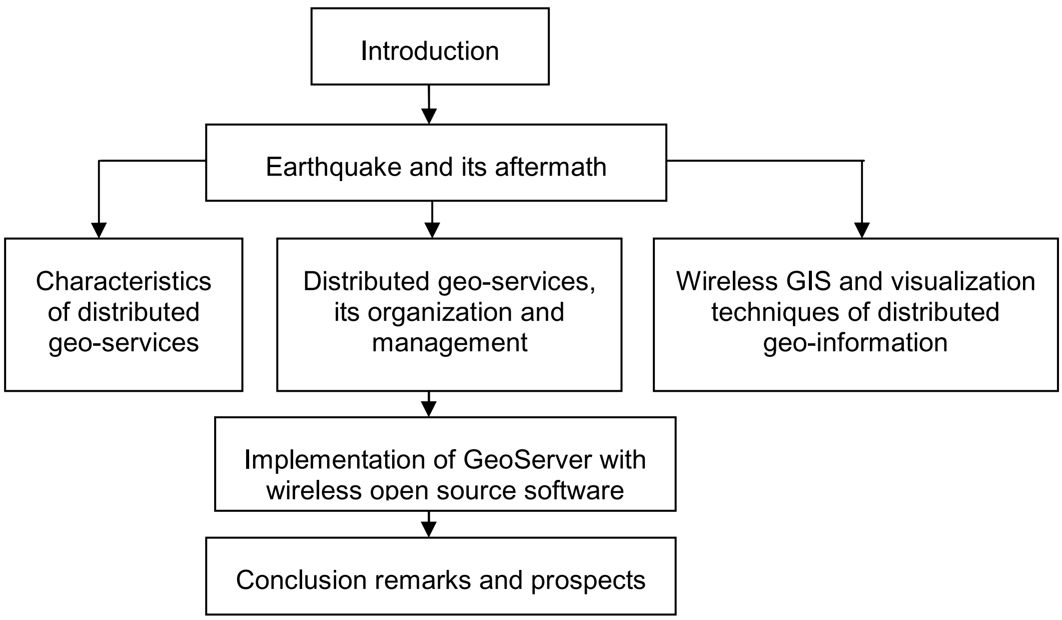

Figure 1.2 The thesis structure

The structure of thesis is arranged as follows: Following the introduction in Chapter 1, Chapter 2 addresses the nature of earthquake, its aftermath and required databases for post earthquake rescue work. Chapter 3 is dedicated to the concept, characteristics, and types of distributed geo-services. Chapter 4 describes the organization and management of distributed geo-services. Chapter 5 introduces the principles of wireless GIS and its development and applications. Geospatial data visualization represented by SVG is highlighted. Chapter 6 deals with the implementation of the GeoServer and the database of the rescue system; Chapter 7 summarizes the implementation results and gives an outlook along with the remaining problems to be solved.

Chapter 2

Database for rescue work of earthquake disaster

After an earthquake disaster, fixing the positions of besieged sufferers in the shortest time and conducting rescues at the most rapid pace are the most urgent things. Both tasks require a prompt evaluation of sufferers’ spatial distribution and constraints for rescue work based on the available geographical information about the disaster region, and dissemination of the information through the fastest channel such as wireless communication. The relevant decision-making staff and rescuers can use this information to make rescue schemes. This chapter is focused on the contents of database for rescues.

According to geoscientists, some places on the Earth are entering into a period when earthquakes may frequently occur because of the accumulation of the gravity. The forecast of earthquakes, thus prevention of the colossal damage of the calamity, has been a concern as well as a difficult issue since long time. However, the current technologies do not yet allow a precise prediction of earthquakes; lots of efforts made so far are concentrated on the mitigation of post earthquake disaster.

2.1 Factors that influence casualties of the earthquake

In light of the previous data and experiences, the direct losses caused by the earthquake are not only related to the magnitude of the earthquake, but also to the social and economic conditions of the local area. These influence factors are only partly understood (Yuan 1991).

Magnitude and hearth depth

The larger the seismicity, the greater release of the energy, hence the greater damage it causes. A strong destruction can be caused by a shallow focal depth and a high intensity of seismicity. Some special earthquakes have a shallow focal depth, but they may “unexpectedly” cause gigantic damage even if the magnitudes are not too big.

Population density and the level of economic development

The severity of the earthquake losses also depends on the number of people and the population density of the area. More casualties and heavier damages occur in densely populated areas (Li & Ling 2001). If earthquakes occur in human-sparse areas, like mountains, deserts or seabed, even if they are strong, they won't cause great casualties or losses. For example the earthquake of magnitude 7.9 that happened in northern Tibet on 8th November, 1997 caused little loss. If this earthquake hit a densely populated and economically developed areas, it may cause greater losses. The Tangshan earthquake of magnitude 7.8, for example, has cost 242,000 human lives, injured 78,000 people and almost completely demolished the whole city. Therefore, the disaster area and population density can be used as direct influence factors of earthquake losses in analysis (Yu et al.2009; Qian 1996; Chen et al. 2008; Wang 1993).

Quality of buildings

Collapse and severe damages of buildings can directly cause casualties and property losses. Quality of buildings and their shockproof coefficients can directly affect casualties.

Occurring time of disasters

Time has some relations with casualties. Relevant studies have shown that for the Richter magnitude scale between 6 and 9, the ratio of death rates of earthquake between daytime and night time are: 0.06, 0.13, 0.25, 0.43, 0.74, and 0.98 respectively (Zheng et al. 2002). This means that under general circumstances, earthquake that happens at night can cause greater damages and casualties. Such as the devastating Tangshan earthquake occurred at 3:42 in the morning when most people were in deep sleep (Qian 1996).

Among these factors, some can be predicted, such as magnitude and hearth depth; some can be improved, such as quality of buildings, some are not precisely known, such as the population density, the level of economic development and hypotheses about the occurring time of disasters. It is therefore worthwhile to set up a database and keep this basic information in advance and updated. Depending on the demand of rescue work, the database mainly stores the information on building, population and road. Mobility of the population, that is, dynamic people do not have to be considered because at the moment of the earthquake, outdoor mobile people are more likely to survive than those within the buildings. Many researches on the acquisition or derivation of population density, road and building information have been reported (Krisp 2008; Zhang et al. 2010; Chen et al. 2009; Liu & Meng 2009; Fan & Meng 2009; Jahnke et al. 2009; Krisp & Spatenková 2010; Krisp & Murphy 2008). These basic data components can be integrated in a database system which serves as a foundation for casualty evaluation model.

2.2 Earthquake and its evaluation methods

An earthquake is the result of a sudden release of energy in the Earth's crust that creates seismic waves. An underground location where the earthquake happens is called the source; the source projected to the Earth's surface vertical is called the epicenter[16]. Each earthquake can be described by a number of parameters.

2.2.1 Magnitude, intensity and isoseismic line

Earthquake magnitude[17] is referred to the size of earthquake and related to the released seismic energy. Magnitude as an observing parameter was firstly proposed by the U.S. seismologist Charles Francis Richter in 1935. The magnitude scale was originally applied only to areas near the earthquake and local earthquake. In 1945 Beno Gutenberg promoted the application of the magnitude of distant earthquakes and deep earthquakes, thus laid the foundation for magnitude system. There are many kinds of widely used magnitude scale, the most commonly used is the surface wave magnitude M_s, using broadband seismometers to record the coming teleseismic surface wave, and then calculate the magnitude according to surface wave amplitude and period. The surface wave magnitude is expressed as:

$$M_s = Lg\left(\frac{A}{T}\right)_{\max} + \delta\left(\Delta^0\right) + C_s$$

Where A is the displacement of two horizontal vectors to the synthesis of the amplitude of ground motion to microns; T stands for the corresponding period in seconds; $\delta\left(\Delta^0\right)$ is the starting function of surface wave magnitude, only related to the epicentral distance Δ^0 (earthquake measuring point and the middle of the large arc degrees); C_s is a station correction value (Bao et al. 2002).

The magnitude of the standard currently used in China is a common international classification according to table Richter scale[18], divided into 9 levels in actual measurement.

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16 http://en.wikipedia.org/wiki/Earthquake
17 http://www.hudong.com/wiki/%E9%9C%87%E7%BA%A7
18 http://en.wikipedia.org/wiki/Richter_magnitude_scale

The magnitude is associated with amplitude of seismic waves recorded in a seismograph. The larger the earthquake is, the larger the magnitude number. An increase of one unit in magnitude corresponds to an increase of approximately 32 times the earthquakes energy (Levy & Salvadori 1995; Levy et al. 1997; Bolt 1988; Hu 2006).

The Mercalli intensity scale[19] is another system for characterizing earthquakes. This scale is based on qualitative observations, such as building damage. National and regional earthquake grading standards are usually different from each other. There is a high incidence of earthquakes in Asia. China suffers from many earthquakes every year. Therefore, it is not surprising that in the thesis many references about earthquakes come from China.

Intensity refers to an earthquake intensity of vibration in the location (Guo 1996; Hu 2006). For an earthquake, the area of its spread can be assessed in each location covered by vibration. Locations with the same intensity can be chained to an intensity line or isoseismic line. Idealized isoseismic should take the form of concentric circles, but in fact, due to differences in the building, geology, topography etc. seismic lines are some irregularly closed curves. Adjacent isoseismic lines have an intensity level difference of 1 degree. In general, with the increasing distance from the epicenter, the intensity degree diminishes. The magnitude and the seismic intensity have a rough correspondence, as shown in Table2.1 (Li 1995; Yin 1995).

Table 2.1 Relationship between the magnitude and the seismic intensity

Magnitude	2	3	4	5	6	7	8	>8
Seismic intensity	1~2	3	4~5	6~7	7~8	9~10	11	12

2.2.2 Damage assessment

Damage assessment is conducted after the earthquake and aims to estimate the losses caused by the earthquake in short period of time, including casualties, destructed buildings and the number of homeless peoples[20] [21] (Liu 1999, Feng 2008). Based on the damage assessment, emergency measures can be taken and followed by reconstruction planning. Figure 2.1 illustrates the contents of the damage assessment. Here we mainly get statistical data about the casualties and homeless persons and transmit them quickly to rescue centre through wireless GIS.

Typically, the economic losses are estimated under conditions of known earthquake intensity.

2.2.3 Intensity determination

Two cases can be differentiated from each other.

- In general, intensity is obtained by the earthquake prediction.

Taking housing as example, for different buildings in different regions, different standards are used to assess the losses. The more detailed classification may lead to more accurate assessments and more workload as well (Clarkson & Gary 1978; Kasm et al. 2009; Gao 1991). In China, two categorization methods are prevailing as shown in Figure 2.2. One is by building type, the other by function.

The construction in China can either follow the formal regulations of housing design or appear without formal regulations.

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[19] http://en.wikipedia.org/wiki/Mercalli_intensity_scale
[20] http://www-sfb461.ipf.uni-karlsruhe.de/
[21] http://www.tmb.kit.edu/Forschung_578.php

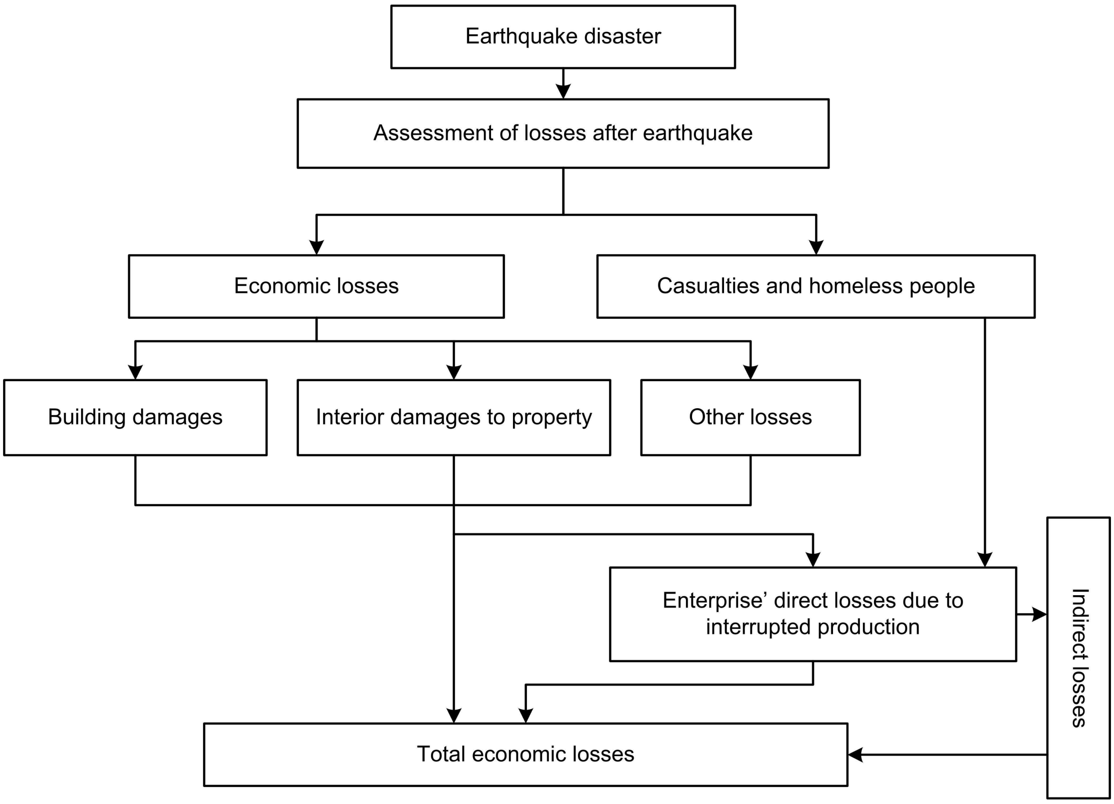


Figure 2.1 The analysis of economic losses after earthquake

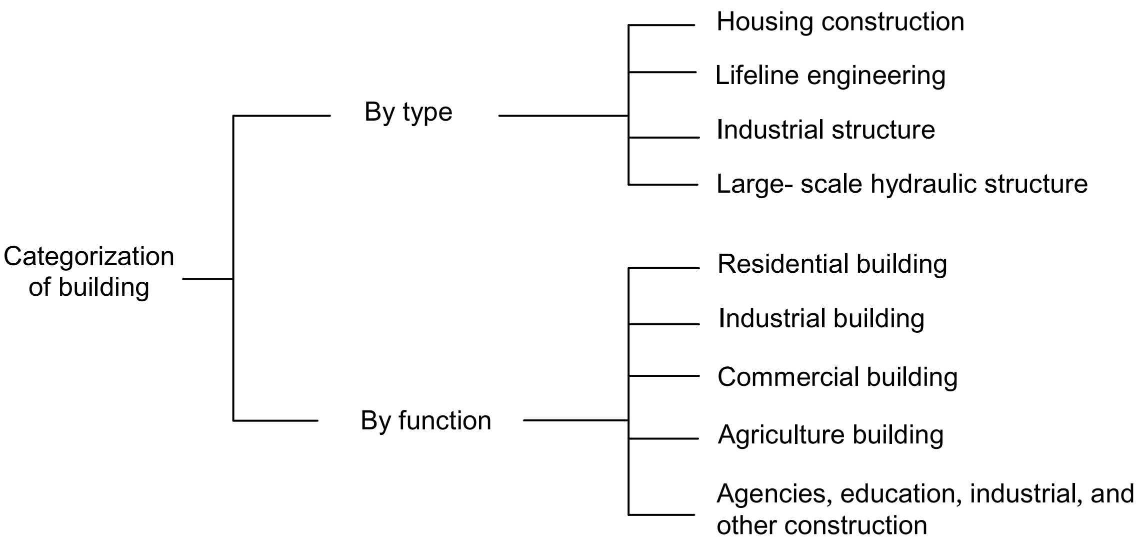


Figure 2.2 Building types in China

Constructions following the formal design regulations may include multi-storey and high-rise reinforced concrete buildings, multi-storey brick buildings, within the framework of multi-storey buildings, single plant of reinforced concrete columns, single storey of brick plant, single storey of bricks plant, single open plant, multi cavity brick, and single brick. Multi-storey and high-level reinforced concrete buildings reveal a good seismic capacity and are widely used as a major structure in high-rise office buildings, hotels etc. (Zhao, 1992; Guo & Chen 1991). Multi-storey brick buildings as the traditional Chinese housing structure have a long history and a poor resistance against earthquake damage. But if they are reasonably designed, they may meet the general requirements of seismic fortification. Therefore, these buildings are still widely used in earthquake zones (Zhou 1991). Within the framework of multi-storey buildings, brick is suitable for workshops of light industry, industrial instrumentation and country markets etc. Previous earthquakes showed that a small number of these structures are reasonable. Single plant of reinforced concrete columns reveal relatively good seismic resistance performance (Luo 1990), therefore, they are widely used in large and medium-sized enterprise as main plants. Single storey of brick plants, compared with reinforced concrete columns, have poor seismic capacity and are used by small and medium plants; Single open plants are a gathering place for people, such as theaters, cinemas, exhibition halls, gyms, the tall and spacious house, according to seismic specifications (China Seismic Design of Buildings Specification GBJ-89)), fortification can be properly improved to withstand earthquakes of magnitude up to 9 (Liu el. 1990; Specification); Multi cavity brick has poor seismic performance, is therefore generally restrained in areas where only earthquakes of magnitude <7 may occur; Single brick has a lower height, light roof. Under the same conditions it usually has a better seismic performance than the multi-storey brick buildings.

Housing without following the formal design regulations include load-bearing timber frame houses, brick houses column and soil embryo, soil embryo structure housing, rural housing, etc. are structures adopted in rural areas. These structures have poor seismic capacity.

Most of earthquake disaster predictions in China in accordance with the seismic design practice are carried out by classifying building types into multi-brick, single storey, single open plant, frame and so on. The establishments of such forecasting methods rely mainly on the experiences of damage based on a sufficient amount of the targeted seismic data, or a certain size and quality of the statistical sample. A reliable damage prediction model can then be set up by using appropriate mathematical tools such as probability studies, fuzzy mathematics, etc.

- Magnitude and the intensity are calculated after the earthquake, depending on the epicenter and the released energy

According to statistical seismic data since 1951 with known magnitude $M \geq 5.2$, epicentral intensities and estimated focal depths with regression analysis, (Guo, 2002; Guo, 1996; Jiang 1993) found the following relations between epicentral intensity and magnitude models.

$$LgE = 1.5M + 11.8$$

$$I_0 = 0.24 + 1.29M$$

Where

E — Released seismic energy

I_0 —Epicentral intensity

M —Magnitude

2.2.4 Assessment of economic losses

The first order of economic losses

By the damage intensity of I, the economic losses of housing construction and interior property can be calculated using the following equation (Yin 1995; Xiao1991):

$$L = A \cdot C \cdot \sum_K P_1(Loss|DR_K)P(DR_K|I_J) + \sum_r A_r \cdot C_r \cdot \sum_K P_2(Loss|DR_K)P(DR_K|I_J)$$

Where:

A —Total area of construction (m^2)

C —Average unit price of the building (yuan/m^2)

$P(DR_K|I_J)$ —Earthquake intensity is I_J, damage grade is DR_K, the average damage rate in Table 2.2 The average damage rate $P(Loss|DR_K)(\%)$.

$P_1(Loss|DR_K)$ —The average loss rate of the building damage grade is DR_K, in Table 2.3 Average loss of different earthquake grades $P(Loss|DR_K)(\%)$.

A_r — The building area of r classification (m^2)

C_r —Indoor building property of r classification (Yuan/ m^2)

$P_2(Loss|DR_K)$ —Loss rate of the indoor property during the earthquake damage grade is DR_k, in Table 2.3

Casualty estimation

The relationship between housing damage and casualties is shown in Table 2.4 (Tao, 1988; Li 1995).

The second order of economic losses

Earthquake damage may cause interruption of production facilities. This kind of second order losses can be calculated using the following equation (Yin 1995; Xiao1991):

$$L_2 = \sum_L \left(NP_I / 365 \right) \cdot n_I$$

Where:

NP_I — The average net output of enterprises (Yuan / year)

n_I — Enterprise production disruptions caused by the earthquake time (days)

Table 2.2 The average damage rate (Yin 1995; Xiao 1991)

Earthquake level	Average earthquake index	Damage index values	6-grade level	7-grade level	8-grade level	9-grade level	10-grade level
Largely intact	0～0.10	0.05	80	31	7	2	0
Minor damage	0.11～0.30	0.2	15	40	25	5	0.5
Medium damage	0.31～0.50	0.4	4.2	22	39	23	5
Serious damage	0.51～0.70	0.6	0.7	6	23	42	22.5
Partial collapse	0.71～0.90	0.8	0.1	0.9	4	20	32
completely destroyed	0.91～1.00	0.95	0	0.2	2	8	40

Casualty estimation

The relationship between housing damage and casualties is shown in Table 2.4 (Tao, 1988; Li 1995).

Table 2.3 Average loss of different earthquake grades (Yin 1995; Xiao1991)

Items	Largely intact	Minor damage	Medium damage	Serious damage	Partial collapse	completely destroyed
Construction	0.5	5	20	45	80	100
Indoor property	0	2	15	35	70	85

Table 2.4 Relationship between housing damage and causalities

Damage state	Slight wound ratio	Heavy wound ratio	Mortality ratio
Largely intact	3/100000	1/250000	1/1000000
Minor damage	3/10000	1/25000	1/100000
Medium damage	3/1000	1/2500	1/10000
Medium damage	3/100	1/250	1/1000
Destruction	3/10	1/25	1/100

Based on statistical data of earthquakes in China, following empirical equations (Tao 1988; Li 1995) were found:

When an earthquake occurs during the day,

$$d = 0 \cdot 000971^{0.5(I-7)} D_p$$

$$W = 0.008829 e^{0.5(I-7)} D_P$$

When an earthquake occurs during the night,

$$d = 0.0126(I - 4.76) e^{0.75(I-7)} D_P / (I + 0.25)$$

$$W = 0.068 e^{0.75(I-7)} D_P / (I + 0.25)$$

Where,

d — Mortality rate

W — Injury rate

I — Earthquake intensity

D_P — Construction damage rate (collapse rate + ½ serious damage rate)

Estimation of the number of homeless

When the housing is damaged by the earthquake, its residents will become homeless. The number of homeless serves as indicator for disaster management that addresses the related financial and material issues. It can be derived from the covered area of major housing damage and destruction. The number of homeless is calculated by (Yin 1995; Li 1995):

$$M = [DT_s(1) + DT_s(2) + DT_s(3)/2] m_0 / A_s - M_d$$

Where

M — The number of homeless

$DT_s(1)$ — Residential area of destructed housing

$DT_s(2)$ — Residential area of serious damaged housing

$DT_s(3)$ — Residential area of medium damaged housing

A_s — Housing area per household

m_0 — Population per household

M_d — Death toll of earthquake

In order to support the rescue work some basic data such as population in different times and different buildings should be statistically estimated.

2.3 The database for rescue work

The database for rescue work after earthquake contains basic data related to casualties and rescue evaluation necessitated by disasters. Positions in the database are typically related to the state before the earthquake takes place. After the earthquake, many houses and structures may collapse without moving the locations. Rescue workers are most concerned about the damaged property and population in endangered houses. The population is dynamically distributed and varies much between day and night and between from offices, schools and homes. Therefore, it needs to be stored in different databases for three different time periods so as to assure a high efficiency of the rescue information system.

Database models

The geo-database of ArcGIS represents one of the most popular database models worldwide. It couples geometry with semantic attributes and is suitable for rescue management. In comparison with previous data models, the actual generation of geo-database of ArcGIS proves more intelligent. Each element is no longer just a geometry field, but a record of the object with attributes and behaviors, therefore, the geo-database is essentially a relational database based on an object-oriented model (Yang 2008). As illustrated in Figure 2.3 the products contained in ArcGIS are desirable for the purpose of this thesis.

Figure 2.3 Products contained in ArcGIS[22]

[22] http://www.esri-germany.de/products/arcgis/index.html

At the physical level, the geo-database takes two data storage forms[23] .

(1) Enterprise Geo-database is the most robust of all the geo-database. Using large relational database (such as Oracle) plus ArcSDE (spatial data engine), the enterprise geo-database can conveniently store the mass data, and allow concurrent operations of different users, database updating and seamless spatial data management etc. Enterprise geo-database can be scaled to any size and support any numbers of users, running on computers of any size and configuration.

(2) Personal Geo-database. Personal geo-database mainly applies under individual conditions and is suitable for small databases. It adopts the Access as Microsoft Database (MDB). MDB is a Microsoft access software storage format. Due to the convenience of data manipulation it is commonly used in some small programs and designed for a single user working with smaller GIS datasets.

Both of data storage forms are implemented within relational database management system (DBMS).

Databases of basic rescue-based geographic information

In the vector database of earthquake-frequent districts, buildings are encoded as objects with national geodetic coordinates or World Geodetic System 84 (WGS84) which is adopted by the Global Positioning System.

The population and other attributes describing the disaster area are crucial for the targeted searching work and evaluation after earthquake. The buildings are categorized into residence, hospital, office building etc. After a daytime earthquake, the rescue work is focused on searching of people in all kinds of buildings, while after a nighttime earthquake; the rescue work is more focused on residential areas. The statistical population and actual population at a certain time point may be not the same. An example of population data records is given in Table 2.5 which is specified for a hospital and a school. A sample dataset of a district in Tianjin for rescue work is illustrated in Table 2.6.

Table 2.5 Sample data records for population

Land Nr.	Building Nr.	Attribute	Census population	Population Tday7-18	Population Tevening18-21	Population Tnight21-7
10002	6	school	456	456	0	0
10003	7	hospital	319	319	209	169
10004	8	resident	690	120	530	690

Earthquake can be described by three elements - earthquake moment, magnitude and epicenter. As introduced in previous sections, magnitude M represents the strength of the earthquake and is related to the amount of released energy. Earthquakes can be classified into the following categories according to the magnitude (Zhang 2008; Hu 2006):

- $M < 1$, ultra shock;
- $1 \leq M < 3$, weak earthquakes. They cannot be generally perceived;
- $3 \leq M < 4.5$, sensible earthquakes. They can be perceived, but generally do not cause damage;
- $4.5 \leq M < 6$, medium-strong earthquakes. They belong to destructive earthquakes depending on hearth depth, epicenter distance and etc.;
- $6 \leq M < 7$, strong earthquakes;

[23] http://www.esri.com/news/podcasts/transcripts/typesofgeo-databasesatarcgis92.pdf

- M ≥7 , violent earthquakes;
- M ≥8, tremendous earthquakes.

Table 2.6 A sample dataset of a district in Tianjin for rescue work

Id	Building Nr	Attribute	Floor count	Shock-grade	Land _Nr	Population	Street	StreetNr
3	901	Hotel	3	7	1	200	Nanmalu	29
3	902	Shopping plaza	3	7	2	150	Nanmalu	28
2	904	Residence	9	7	3	230	Rongyedajie	1
2	903	Residence	8	7	3	160	Rongyedajie	1
2	905	Residence	10	7	3	300	Rongyedajie	1
2	906	Residence	15	7	3	400	Rongyedajie	1
2	907	Residence	7	7	3	120	Rongyedajie	1
2	908	Residence	7	7	3	120	Rongyedajie	1
2	909	Residence	7	7	3	120	Rongyedajie	1
2	910	Residence	7	7	3	120	Rongyedajie	1
2	911	Residence	15	7	3	200	Rongyedajie	1
2	912	Residence	18	7	3	400	Rongyedajie	1
2	913	Residence	18	7	3	350	Rongyedajie	1
3	914	Hospital	4	7	4	50	Rongyedajie	2
2	915	Restaurant	5	6	5	300	Rongyedajie	3
2	916	School	3	7	6	80	Chengxiang donglu	1
3	917	Office building	16	8	7	239	Nanmalu	36
3	9181	Residence	21	7	8	540	Nanmalu36	36
3	918	Residence	23	7	8	540	Nanmalu36	36

Earthquakes with the same magnitude may cause different degrees of damages or different damages in different places. This requires people to use seismic intensity to measure the damages. As noted above, seismic intensity is related to magnitude, focal depth, epicenter distance, and soil conditions etc. Generally speaking，after an earthquake, the epicenter is most severely damaged and reveals the highest seismic intensity termed as the epicenter intensity. With the growing distance from the epicenter, the earthquake intensity decreases.

Seismic rating is based on state regulations according to the classification and design criteria for buildings. It is in line with intensity, structure type and height of houses. The shockproof coefficient of buildings can be divided into eight levels (Guo, 2002). The highest seismicity and the most powerful destruction occur in the epicenter. The higher the magnitude / epicenter intensity, the larger the influenced areas will be.

After an earthquake, people can only get the information about the position and magnitude of the earthquake. Using the available databases, it is possible to derive the earthquake area from the known epicenter position and then identify buildings which may collapse and further estimate the number of endangered people, depending on the time of the earthquake. Figure 2.4 demonstrates the location of the epicenter and its covered region using ArcGIS.

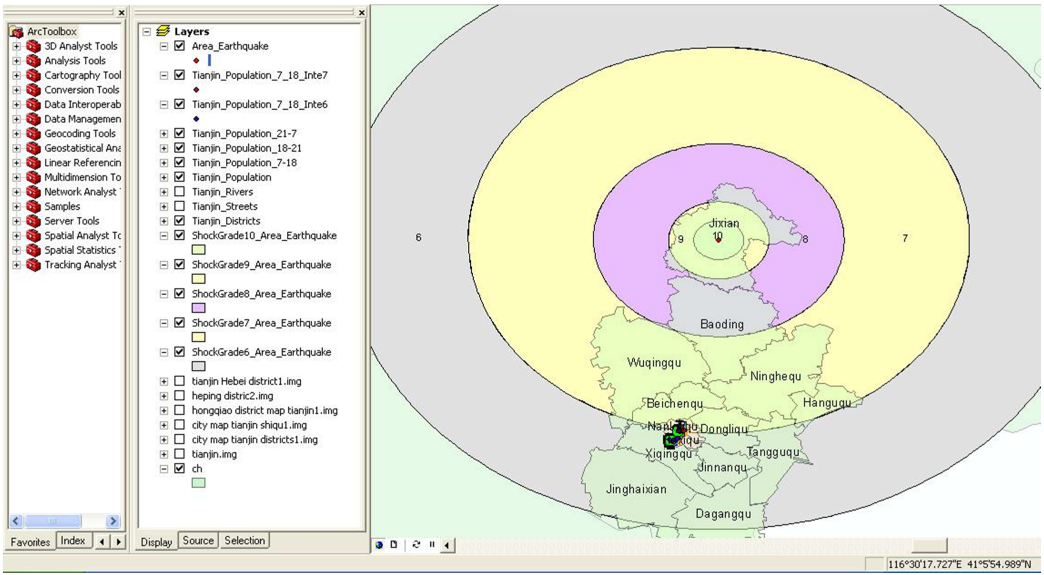


Figure 2.4 Demonstration of an earthquake region

The source data for GeoServer is stored as Shapefile or PostGIS database. As soon as an earthquake occurs, the seismic time and position of epicenter become known. Therefore, the number of casualties or besieged people and the number of buildings that may collapse can be estimated and quickly transmitted to the rescue organizations.

In accordance with the regular pattern of the people living in city, the earthquake periods can be divided into three stages:

- Earthquakes occur in daytime , represented by $T_{day7\text{-}18}$, from 7 am to 6 pm. In this period of time, the main buildings that involved in human activities are Office Buildings, Hospitals, Schools, Shopping Places, Stations, and Supermarkets. Using ArcGIS, it is possible to identify these buildings and store them in a file, for instance, Tianjin_Population_7-18.shp;

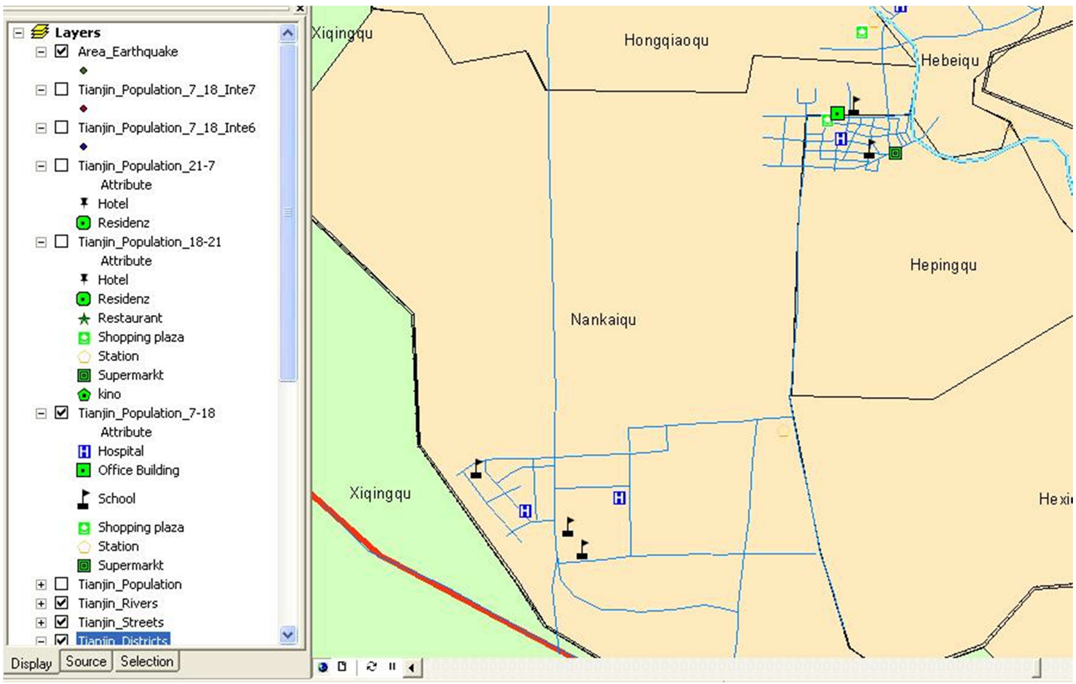


Figure 2.5 Endangered buildings in Tianjin by an earthquake from 7 am to 6 pm

- Earthquakes occur in the evening, represented by $T_{evening18\text{-}21}$, from 6 pm to 9 pm. In this period of time, the main buildings that involved in human activities are Restaurants, Hotels, Residential, Shopping Places, Stations and Supermarkets. The corresponding buildings can be stored in a file Tianjin_Population_18-21.shp;

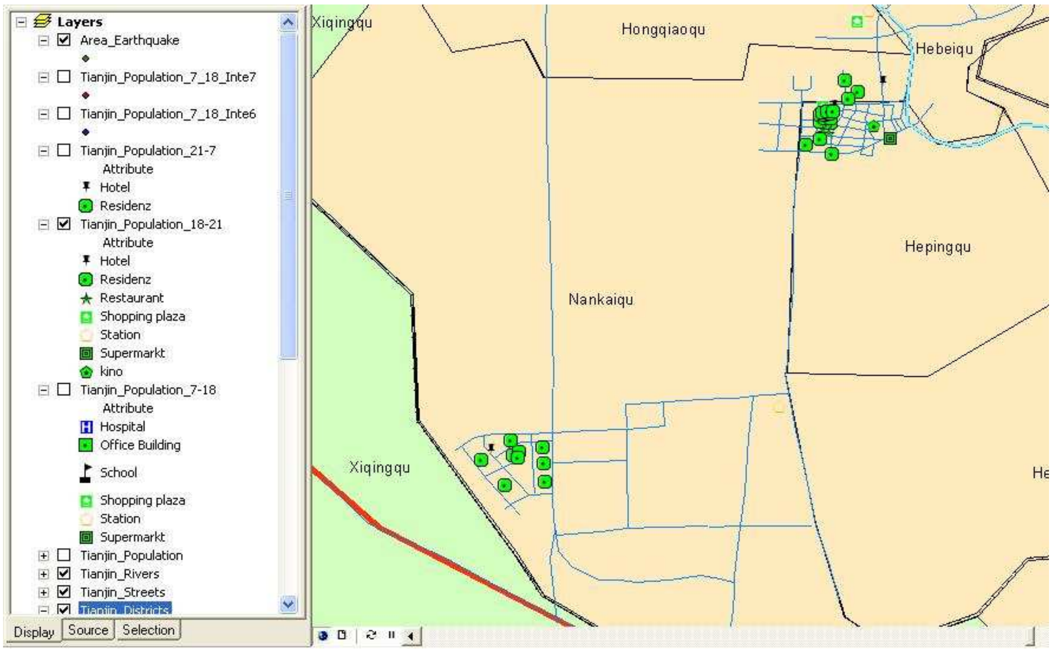


Figure 2.6 Endangered buildings in Tianjin by an earthquake from 6 pm to 9 pm

- Earthquakes occur at night , represented by $T_{night21\text{-}7}$, from 21 pm to 7 am next day. In this period of time, the main buildings that involved in human activities are Hotels and Residential houses. Therefore, the information can be stored in a file Tianjin_Population_21-7.shp.

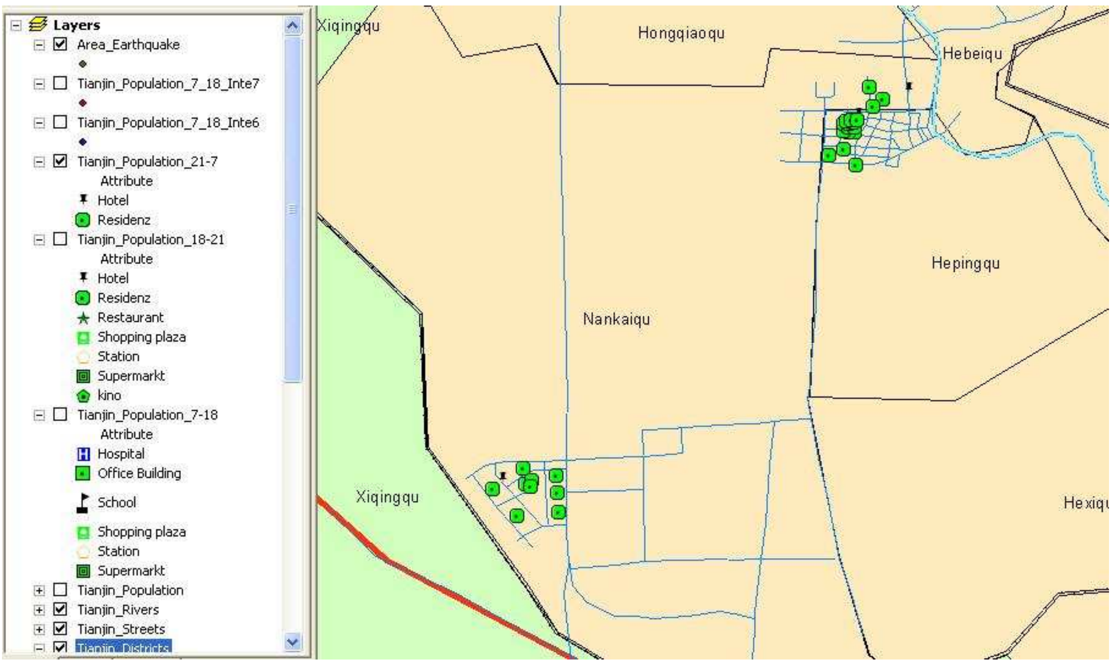


Figure 2.7 Endangered buildings in Tianjin by an earthquake from 21 pm to 7 am next day

As illustrated in Figure 2.5, Figure 2.6, Figure 2.7, the three Shapefiles can be retrieved to meet the needs of rescue teams engaged in different times.

Table 2.7 gives an overview of various layers of information which can be generated as Shapefiles and uploaded to a server.

Estimation of building collapses

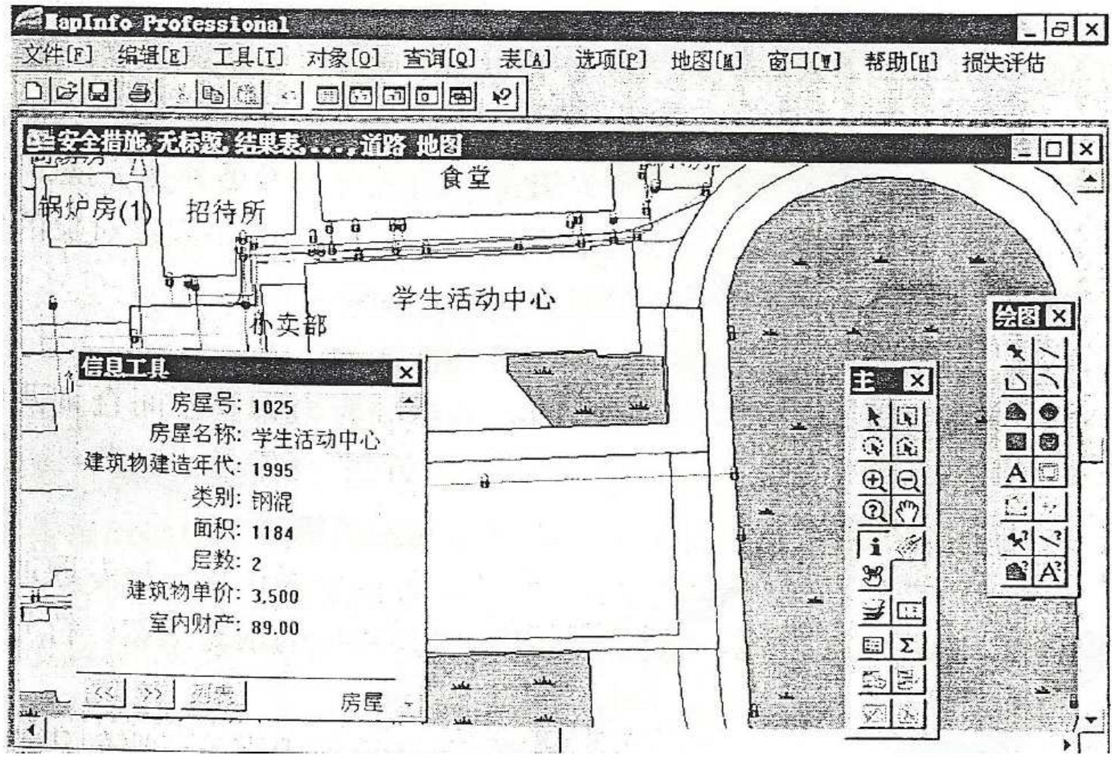
In addition to the basic data such as housing, traffic and demographic data, an estimation of houses that may collapse can also be conducted with a common desktop GIS, depending on housing structure and magnitude of the earthquake. An example about the assessment of earthquake damage losses is illustrated in Figure 2.8 (Liu, 1999). When the earthquake magnitude is input, its corresponding damage results will be assessed, which include the economic losses, property damage, and the number of homeless etc.

90% of the earthquake is caused by a plate motion. Different directions and ways of crustal plate movements produce different seismic types (Goldmann 2010). At the same time, various types of buildings on the surface will be differently damaged with different severities due to different focal depths of earthquakes. Some low-level earthquakes can also cause buildings' damages even collapse. The seismic housing damage is analyzed in this thesis on the basis of earthquake theory and empirical studies. The advantage is that it allows quick queries about the buildings that may collapse, and then trigger the necessary rescue work. Its drawback is that the retrieved information is not certain enough.

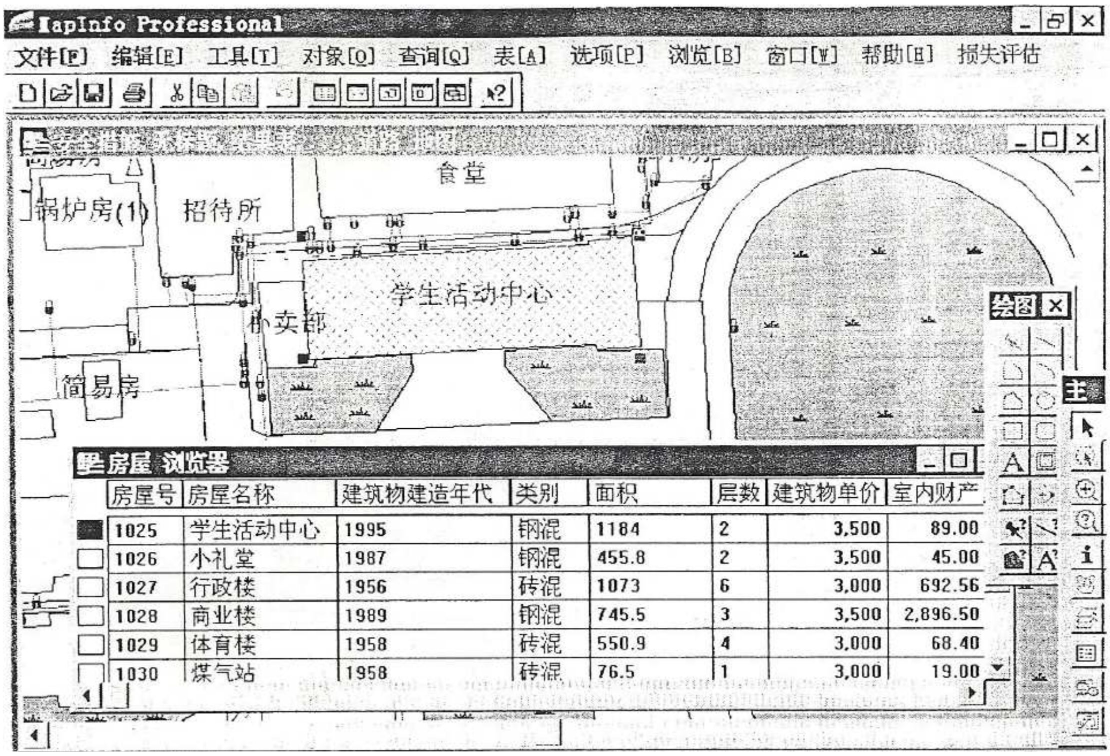
The estimated houses collapses can be simulated with 3D models and compared with the aerial photos or laser-scanning images of the concerned houses taken before the earthquake. In this way, the collapse grade after the earthquake can be visualized as shown in Figure 2.9 (Hommel 2010). Though it is limited by the weather conditions and the impact of the earthquake levels, this method can help people conduct a straightforward post-earthquake rescue and assessment.

Table 2.7 Shapefiles generated by ArcMap, which can be imported to the server

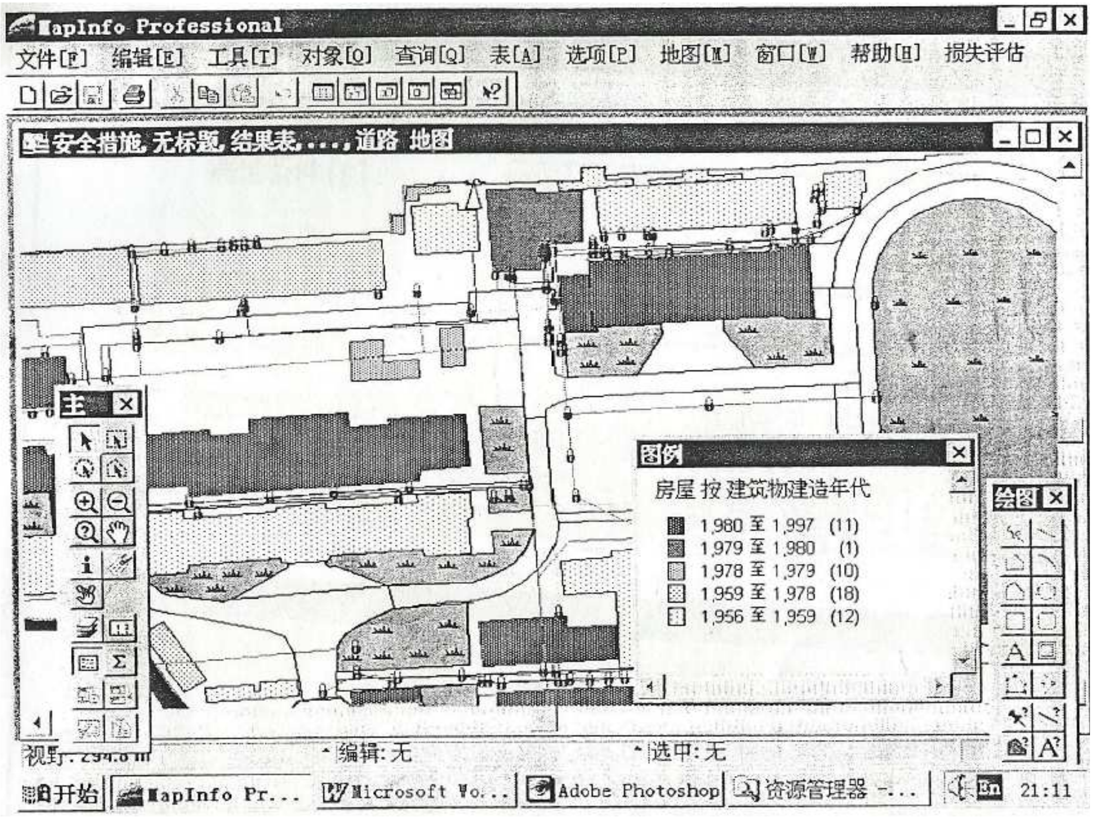
Data describe	ArcMap	
	shapfile	function
Administration region of China	Ch.shp	Basis layer
Administration region of Tianjin	Tianjin_Districts.shp	Basis layer
Tianjin Traffic	Tianjin_Street.shp	Basis layer
Tianjin water	Tianjin_Rivers.shp	Basis layer
Tianjin total population	Tianjin_Population.shp	Demographic information
Time 7-18 reference people in earthquake	Tianjin_Population_7-18.shp	Demographic information
Time 18-21 reference people in earthquake	Tianjin_Population_18-21.shp	Demographic information
Time 21-7 reference people in earthquake	Tianjin_Population_21-7.shp	Demographic information
trapped population in 7 intensity district	Tianjin_Population_7_18_Inte7.shp	Demographic information
trapped population in 6 intensity district	Tianjin_Population_7_18_Inte6.shp	Demographic information
Epicenter location	Area_Earthquake.shp	Epicenter geographic location
6. intensity district	ShockGrade6_Area_Earthquake.shp	6 Intensity region size
7. intensity district	ShockGrade7_Area_Earthquake.shp	7 Intensity region size
8.intensity district	ShockGrade8_Area_Earthquake.shp	8 Intensity region size
9. intensity district	ShockGrade9_Area_Earthquake.shp	9 Intensity region size
10. intensity district	ShockGrade10_Area_Earthquake.shp	10 Intensity region size


MapInfo Professional
文件[F] 编辑[E] 工具[T] 对象[O] 查询[Q] 表[A] 选项[P] 地图[M] 窗口[W] 帮助[H] 损失评估
安全措施,无标题,结果表,...,道路 地图
食堂
锅炉房(1)
招待所
学生活动中心
小卖部
绘图
主
信息工具
房屋号: 1025
房屋名称: 学生活动中心
建筑物建造年代: 1995
类别: 钢混
面积: 1184
层数: 2
建筑物单价: 3,500
室内财产: 89.00
房屋

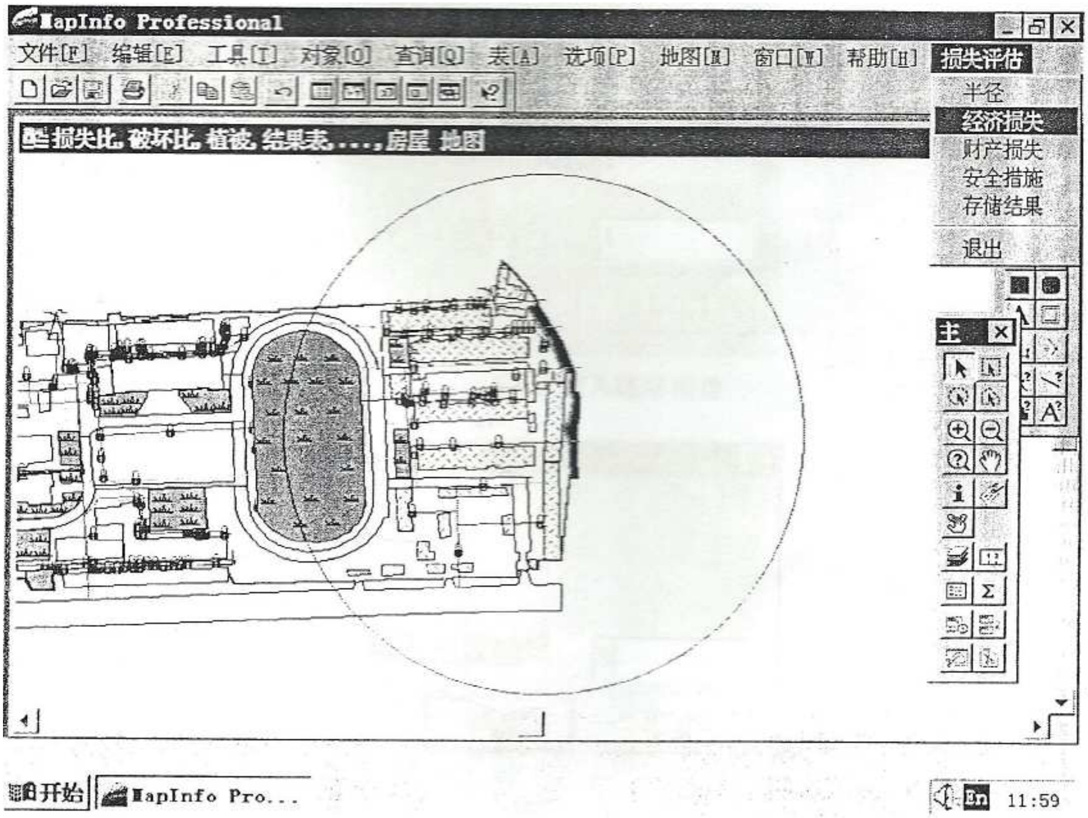
(a)


MapInfo Professional
文件[F] 编辑[E] 工具[T] 对象[O] 查询[Q] 表[A] 选项[P] 浏览[B] 窗口[W] 帮助[H] 损失评估
食堂
锅炉房(1)
招待所
学生活动中心
小卖部
简易房
绘图
主
房屋 浏览器
房屋号 房屋名称 建筑物建造年代 类别 面积 层数 建筑物单价 室内财产
1025 学生活动中心 1995 钢混 1184 2 3,500 89.00
1026 小礼堂 1987 钢混 455.8 2 3,500 45.00
1027 行政楼 1956 砖混 1073 6 3,000 692.56
1028 商业楼 1989 钢混 745.5 3 3,500 2,896.50
1029 体育楼 1958 砖混 550.9 4 3,000 68.40
1030 煤气站 1958 砖混 76.5 1 3,000 19.00

(b)



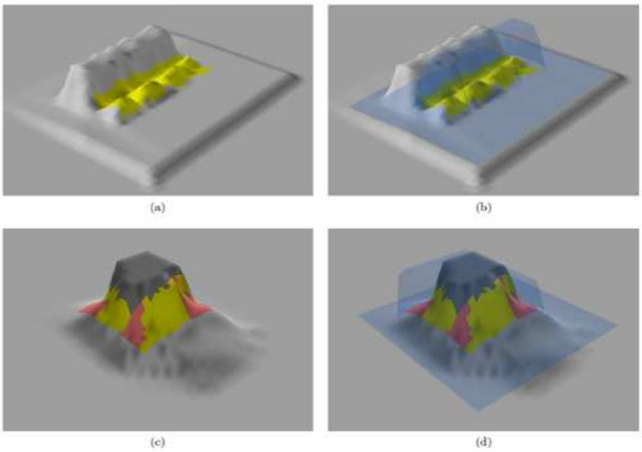
(c)



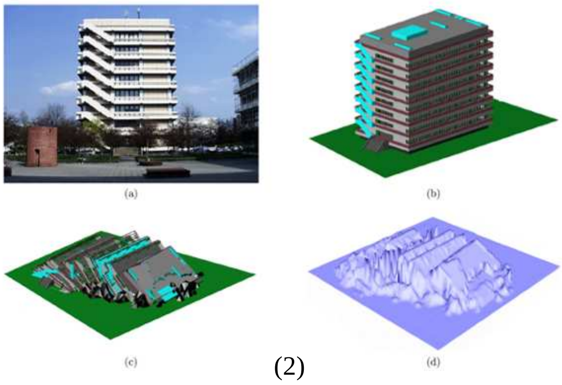
(d)

Figure 2.8 Basic housing information generated by the Desktop GIS Mapinfo.

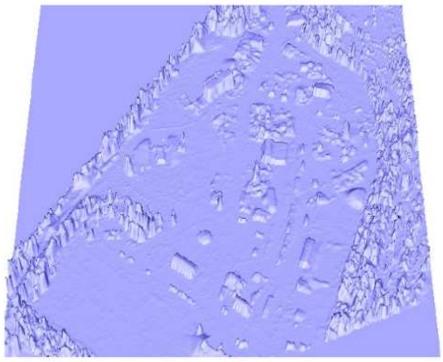
(a) Query through graphics; (b) Query through properties; (c) Classified houses according to the building age; (d) Damage assessment of earthquake area



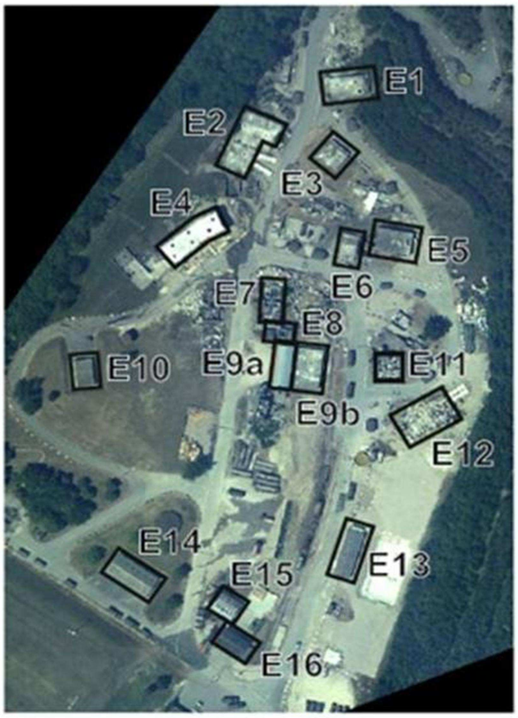
(1)



(2)



(3)



Building	Actually damage image
E1	5a. Horizontal stacking several floor + 9a. Skew position
E2	5a. Horizontal stacking several floors
E3	1.Slip surface
E4	5a. Horizontal stacking several floors
E5	0. Unchanged
E6	3. Graded stacking
E7	7c. Debris cone with vertically elements
E8	7c. Debris cone with vertically elements
E9a	0. Unchanged
E9b	5a. Horizontal stacking several floors
E10	0. Unchanged
E11	7ab. Debris cone + 7c. debris cone with vertically elements
E12	7ab. Debris cone
E13	0. Unchanged
E14	0. Unchanged
E15	0. Unchanged
E16	0. Unchanged

(4)

Figure 2.9 Simulation of the house collapses with 3D model in comparison with the aerial photos of these houses (based on Hommel 2010)

(1): (a, b) represent a 3-dimensional classification of the collapse of the building, (c, d) stand for inclined stacking the some saved parts (gray-brown indicates no change, yellow means collaped buildings, pink stands for graded stacking). Among them, (a, c) without building reference data, (b, d) with reference data overlayed with construction.(2): (a) is a campus building, (b) its CAD model, (c) Loss simulation of the building (grade stacking) (d) Synthesis of laser scanning data processing 3-D view. (3): simulated 3-D digital terrain model; (4): orthophoto map of analog sites and the actual loss of buildings.

Among others, (Hommel 2010) analyzed systematically different ways of housing collapse as shown in Figure 2.10, demonstrates the flow diagram of a typical GeoServer that can provide the information about buildings and people in disaster area needed by the rescue organizations.

Partition of earthquake zone

It is possible to divide the earthquake zone into five intensity grades (10, 9, 8, 7 and 6); their corresponding distances from the seismic center and areas are given in Table 2.8 (Guo 2002; Li 1995):

Table 2.8 The earthquake zone with five intensity grades

Area nr.	intensity grade	distance from seismic centre (km)	area (m^2)
1	10	10	10
2	9	10- 30	300
3	8	30- 50	2100
4	7	50-100	7500
5	6	100-150	12500

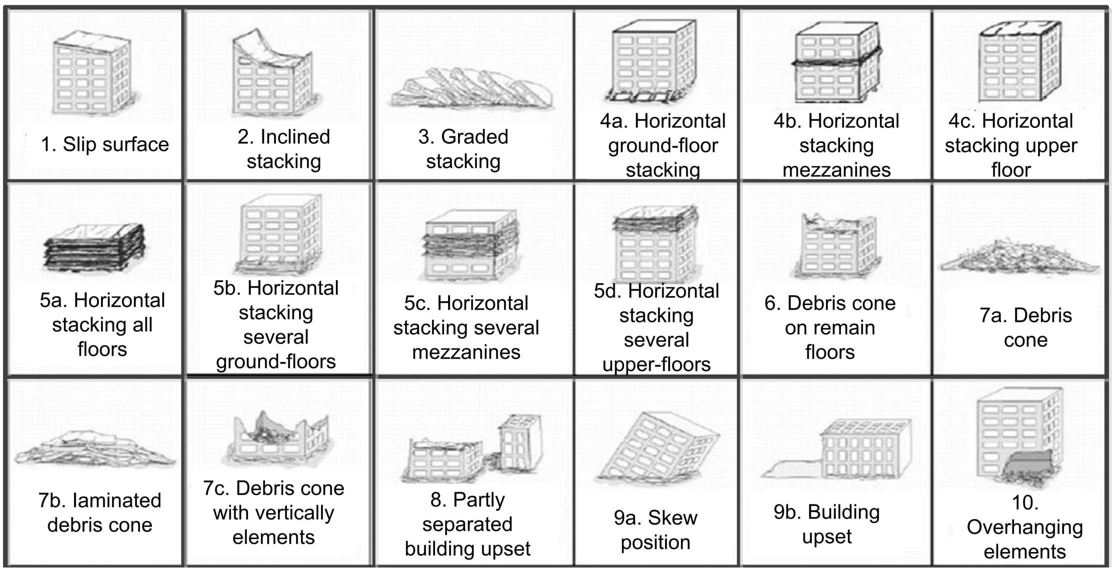


Figure 2.10 Different ways of housing collapse (Based on Hommel, 2010)

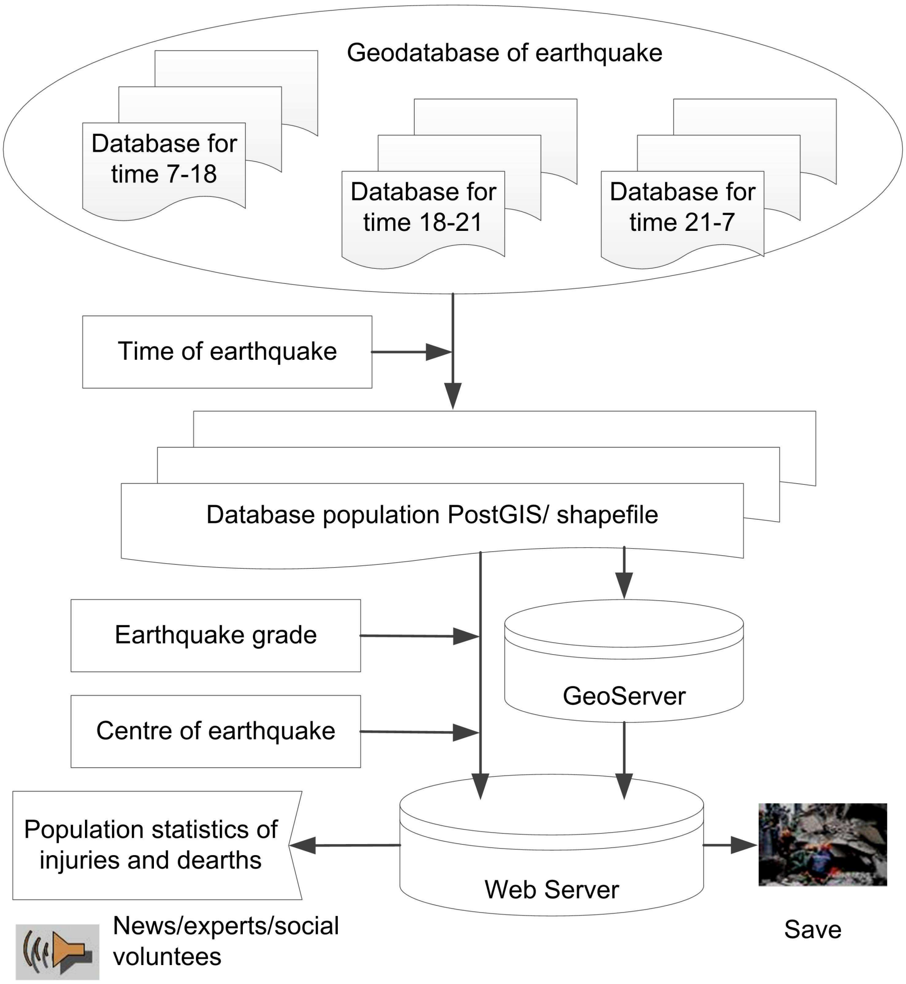


Figure 2.11 The flow diagram of a GeoServer that provides information of endangered buildings and people for rescue work

Statistics of casualties in the disaster area

The most intense earthquake area usually but not always has the most severe casualties. For example, if shockproof coefficients of buildings in the most intense areas are large enough, the corresponding number of the casualties might be small. Therefore, the evaluation of casualties should take both the intensity and shockproof of buildings into consideration. Building shockproof level is related to the seismic zone, geological structure and the housing structure.

After an earthquake, we can retrieve the right database corresponding to the occurring time of the earthquake and use ArcMap to highlight buildings in different seismic areas and store them in the relevant Shapefiles. Taking database for daytime as example, the buildings which cannot withstand the earthquake in ShockGrade6_Area and ShockGrade7_Area can be picked up using the Structured Query Language (SQL) which is a specialized language for updating, deleting, and requesting information from databases.

The population in each of these collapsed buildings can then be retrieved in the database and summed up for the overall area as the number of causalities. Figure 2.12 illustrates the casualties within the ShockGrade6_Area and ShockGrade7_Area. The detailed numbers are listed in Figure 2.13, Figure 2.14. Shock grade is related with intensity. Seismic level is related with earthquake magnitude. Little differences between them see table 2.1.

The total number of population in all areas is the total number of earthquake casualties. Since it is difficult to calculate the seismic levels, this statistical estimation may not be very accurate.

As soon as the population of the initial injury in the earthquake region has been calculated, the message can be sent to the server in a service center through telephone, mobile phone, PDA and other wire or wireless devices, which then transmits the information to the rescue team or news organizations or volunteers. This may substantially increase the efficiency of rescue organization and actions.

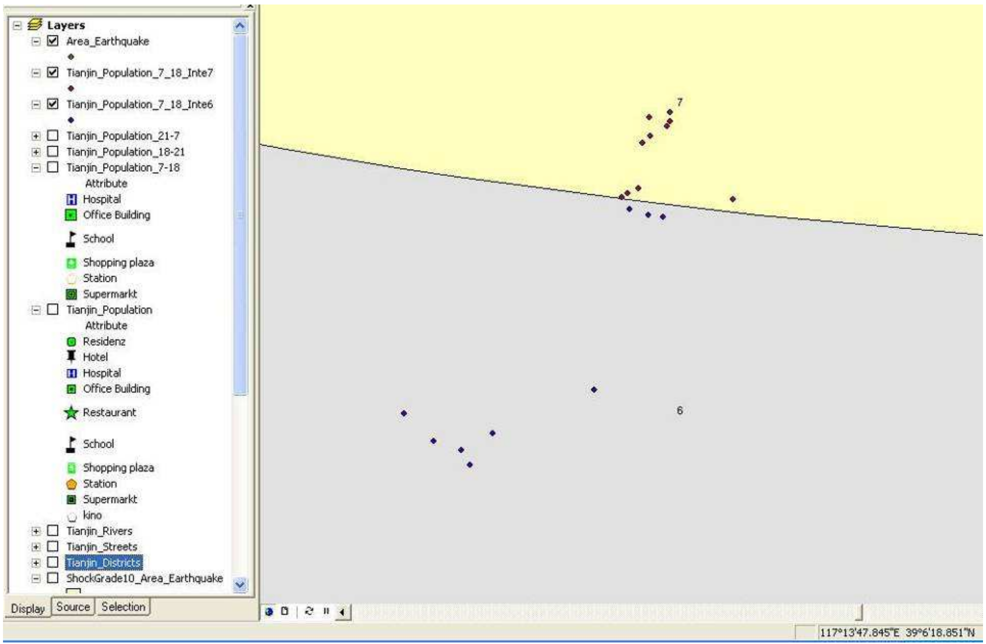


Figure 2.12 The population in shock-grade areas of 6 (grey) and 7 (yellow).

Each dot represents the site where there are people in danger.

	BuildingNr	Population
	106	569
	109	390
	118	300
Population sum		
	1259	

Figure 2.13 Population in endangered buildings in the area of shock grade 6

	BuildingNr	Population
	211	2000
	902	150
	916	80
	220	3500
	219	390
	216	290
	213	1290
	221	1290
	2170	3790
Population sum		
	12780	

Figure 2.14 Population in endangered buildings in the area of shock grade 7

Chapter 3

Distributed geo-services

With the extensive application of geo-services, more and more people in different fields get involved. Generally speaking, a computer network is a collection of computers and devices connected by communication channels that facilitate communications among users and allow users to share resources with other users[24] (Sutton 2008) There are a number of popular buzzwords for such a computer network such as Internet, bulletin board services, online services, and other services that enable people to obtain information from telecommunication networks (Moschovitis 1998; Shelly and Gary 2003). The basis of an information highway[25] is the Internet; information is the vehicle of highway with geo-information being its main part.

Geo-services aim to realize the share of geo-information. This chapter addresses the concept of geo-services, its working principle and contents, and introduces the prevailing geo-services.

3.1 Geo-information, geo-data and distributed geo-information

Geo-information, or geographical information, is the term applied to any information which can be linked to a specific point on the Earth’s surface. This can be related to altitude, the position of a road or bridge, the type or state of vegetation at a given point or statistical information such as an average temperature in a particular region[26]. Geo-information is extracted from geo-data which in turn are captured through terrain assessments (physical measurements, surveys, etc.) as well as the analysis of space-based or aerial imagery. Geo-data may be stored in a database, which have various storing formats and can be manipulated and enriched using various tools. Geo-information is the useful output produced by analyzing data with a kind of computer program called a "geographic information system", or GIS[27]. The environment in which a GIS operates is called a "spatial information system", and is designed and created to respond to the strategic spatial information needs of people or organizations.

The concept of distributed geo-information (DGI) refers to the geospatial information distributed in the Internet in a variety of forms, including maps, images, data sets, analysis operations and reports[28] (Plewe 1997). DGI typically serves for data sharing, geospatial information disseminations, online data processing and the development of location-based services. The applications of DGI have evolved from map drawing and display to web map exploring; from the integration of web GIS functions to geo-collaborative GIS through which users could share the common GIS database and communicate with one another in real time (Zhou 2007).

DGI possesses the following characteristics:

[24] http://en.wikipedia.org/wiki/Computer_network
[25] http://www.webopedia.com/TERM/I/ infor mation_highway.html
[26] http://www.astrium.eads.net/en/news/2009/ what-is-geo-information
[27] http://en.wikipedia.org/wiki/Geographic_information_system
[28] http://iaeg2006.geolsoc.org.uk/cd/PAPERS/IAEG_396.PDF

- Distributed - the spatial data are stored in different departments, different places and published in different web sites;
- Multi-scaled - the spatial data have different scales or resolutions;
- Heterogeneous - the spatial data are diversely managed in different databases and formats;
- Massive - unlike text data which can be queried and explored by clients using a single record, spatial data can be queried and explored either partially or wholly. That is, one single operation may have the access to a part or the whole database.

Distributed GIS is defined as a network-centric GIS tool that uses the Internet or a wireless network as a primary means of providing access to distributed data and other information, disseminating spatial information and conducting GIS analysis. Distributed GIS is necessary from different perspectives as listed in Table 3.1. It enables many new mapping applications such as public notification and locating services, routing and navigation applications, electronic atlases, interactive yellow pages, geo-demographic and environmental condition maps, virtual tourism, E-commerce etc.

The development of Distributed GIS is focused on three aspects - server, client and Internet communication. The server stores data and application programs; the client makes use of data and application programs; the Internet communication controls the stream of information between the server and the client (Zhou 2007).

Table 3.1 Necessity of distributed GIS from different perspectives

Management perspective	Globalization of geographic information access and distribution
	Decentralization of geographic information management and updating
User Perspective	Need for coping with the increasing size and variety of geospatial data set
	Need for customizable GIS modules
	Demand for location-based information from the general public
Implementation perspective	Facilitate the development of open GIS for both data-oriented and process-oriented applications

3.2 Distributed geo-services

Different comprehensions of geo-services are possible, depending on the applications. A geo-service can support one or more users with useful information about space and time, such as weather forecast over a region within three days, real-time traffic information about a certain section of a highway, guidance about location of a hotel and room reservation. According to (Meng 2002), each geo-service is composed of geo-objects and operation tools that can handle these geo-objects. According to ISO 19119, the geo-services are defined as a collection of geo-operations that are accessible through an interface. They involve data (input, output or tightly-coupled data) with a geographic reference[29]. In this thesis, a geo-service is regarded as the process of geo-data handling according to certain standards and formats and the transmission of the results through servers and wired/wireless data communication methods to users.

Depending on the different tasks, geo-services deploy one or some specific service platforms and provide different functions to the end users. A basic service platform usually performs currency service and special service (David 2008). Currency service platforms, such as SUN

[29] http://isotc211.org/

iPlanet application server[30], BEA Web logic application server[31], IBM Web sphere application server[32] etc., are middle application servers usually used in the IT domain; Special service platforms, such as ESRI ARCIMS[33] and MapInfo J-Server[34], are targeted to GIS users.

A subset of geo-services is geo-data services that are tightly coupled to geo-data (Fallahi 2008). Many users need geo-data services to produce maps, answer queries about the content of the map and give further information what maps can be produced and which maps can be queried and so on. Currently, different approaches have been used to link GIS with different disaster models. According to (Goodchild 2000) these approaches can be classified into full integration (embedding), loose coupling and close or tight coupling.

Distributed geo-services represent a special case of geo-services characterized by physically distributed information, interface and interoperability. While data and operations are physical distributed among different servers, the interface brings them together and the interoperability allows the sharing of data and operation. Each distributed geo-service involves a service provider and a service consumer and supplies several independent or associated geographic information services such as Human interaction services, model / information management services, workflow / task services, processing services, communication services and system management services[35]:

Human interaction services are services for management of user interfaces, graphics, multimedia, and for presentation of compound documents;

Model / information management services are services for management of the development, manipulation, and storage of metadata, conceptual schemes, and datasets. They include geographic register services, geospatial metadata services, WMS (Web Map Service), WFS (Web Feature Service), WCS (Web Coverage service), toponym data services, and DEM (Digital Elevation Model) data services;

Workflow / task services are services that support specific tasks or work-related activities conducted by humans. For example, they support the use of resources and development of products involving a sequence of activities or steps that may be conducted by different persons;

Processing services are services that perform large-scale computations involving substantial amounts of data;

Communication services are services for encoding and transfer of data across communication networks;

System management services are services for the management of system components, applications, and networks. They also include management of user accounts and user access privileges.

Web Map Service (WMS[36]): The OpenGIS[37]® Web Map Service Interface Standard provides a simple HTTP interface for requesting geo-registered map images from one or more distributed geospatial databases. A WMS request defines the geographic layer(s) and area of interest to be processed. The response to the request is one or more geo-registered map images (returned as JPEG, PNG, etc) that can be displayed in a browser application. The interface also supports the ability to specify whether the returned images should be

[30] http://en.wikipedia.org/wiki/IPlanet
[31] http://download.oracle.com/docs/cd/E13222_01/wls/docs100/index.html
[32] http://www-01.ibm.com/software/webservers/appserv/was/
[33] http://www.esri.com/software/arcgis/arcims/index.html
[34] http://reference.mapinfo.com/common/docs/routing_j_server/routing_j_server_cndata.pdf
[35] http://www.opemgis.org/techno/abstract.htm
[36] http://www.opengeospatial.org/standards/wms
[37] http://www.opengis.com/

transparent so that layers from multiple servers can be combined or not (WMS). In the context of WMS a "Map" is a raster graphic "picture" of the data rather than the actual data itself (Kolodziej 2003).

Web Feature Service (WFS[38]): The OpenGIS Web Feature Service Interface Standard defines an interface for specifying requests for retrieving geographic features across the Web using platform-independent calls. The WFS operations include:

- Get or Query features based on spatial and non-spatial constraints;
- Create a new feature instance;
- Get a description of the properties of features;
- Delete a feature instance;
- Update a feature instance;
- Lock a feature instance.

The specified feature encoding for input and output is the Geography Markup Language (GML)[39] although other encodings may also be used.

Web Coverage service (WCS): The OpenGIS® Web Coverage Service Interface Standard defines an interface and operations that enable interoperable access to geospatial "coverages"[40]. The term "grid coverages" typically refers to content such as satellite images, digital aerial photos, digital elevation data, and other phenomena represented by values at each measurement point[41].

Since 2000 the Runder Tisch GIS e.V. ("Round Table Geographic Information Systems"), a vendor-neutral non-profit organization situated at the Technische Universität München, has been gaining and exchanging experiences of applying, developing and coupling OGC Web Services from different vendors (Schilcher and Donaubauer 2005).

3.2.1 The necessity of distributed geo-services

The widespread application of computers and use of geographic information system (GIS) have led to the increasing analysis of geographic data across multiple disciplines. With the advances in information technology, society's reliance on such data is growing. Geographic datasets are increasingly being shared, exchanged, and used for purposes not intended by their producers. The following aspects reflect the necessity of distributed geo-services:

Governmental investment

Many framework databases are maintained by governmental agencies with corresponding funding programs. The ownership and copyright of information belong to the government, and the data need to be efficiently accessible for the general public.

Demand on added values

The production and maintenance of spatial information is expensive. Its cost efficiency is dependent on how many users it reaches most efficiently.

Demand on free data

Lots of information in Internet is produced by governments, universities and other non-profit institutions, and intended for the sharing free of charge among Internet users.

Demand on related information services

[38] http://de.wikipedia.org/wiki/Web_Feature_Service
[39] http://www.opengeospatial.org/standards/gml
[40] http://www.opengeospatial.org/ogc/glossary/c
[41] http://www.opengeospatial.org/standards/wcs

Free data need to be distributed with a navigation tool so that users may easily find their wanted products. Using maps, for example, query tool and query results can be visualized, thus allow a straightforward searching and finding.

Demand on enterprise information

An enterprise web usually provides information communication services for its staff. Spatial information makes the major part of the internal information in an enterprise and can be better disseminated with distributed geo-services.

3.2.2 The server contents of geo-services

Geo-information sharing is possible at different levels of services for different distributed users. Raw data, maps, queries and analytical operations belong to the main geo-services contents.

Raw data

Without any treatment, the original GIS data can be directly downloaded to the clients who need raw data and will process and analyze them using their own GIS. What matters here is how the original data formats can be better understood by users in the distribution process.

Maps

Maps are the most commonly used form of geo-information sharing. There are two basic map images. One is the pre-generated map image that contains symbol information and allows a direct use. Another map image allows users to have some controlling authority such as selection of how to show feature types, symbols and other operations to change the map image. Map images can be static or dramatic. Users can do zooming and panning operations.

Simple queries

Simple queries include spatial location and thematic inquiries. Input for queries can be clickable maps and geographic coordinates. They can also be keywords and names. Simple queries are made possible with help of the geo-information database technology. The query results can be reported to the user in form of maps or text.

Analytical operations

They deal with complex spatial queries and analysis. Multi-topic queries, the calculation of optimal distance, buffer analysis are some typical analytical operations. Some users are allowed a certain authority to modify the original data. Most users, however, can only conduct analysis and create a new data collection without changing the original database.

3.2.3 Users of distributed geo-services

At present, the domain of GI is experiencing a rapid growth of computational power and improvement of information quality, making large spatial data archive available over the Internet. Recently available web applications, like Google Maps, have introduced GIS services to ordinary Internet users, offering them high-resolution aerial imagery with responsive performance (Tu & Abdelguerfi 2006). Moreover, there is an increasing demand on the information sharing among different stakeholders, leading to numerous international and national initiatives to set up global, international, national and local infrastructures for the collection and dissemination of geographic dada. Some examples of the national SDI (spatial data infrastructure) in different countries are NSDI (National Spatial Data Infrastructure) in USA, NGDF (National Geospatial Data Framework) in UK, APSDI (Netscape Server Application Programming Interface) in Asia Pacific, INSPIRE (infrastructure for Spatial Information in the European Community) in Europe etc (Bernard 2005; Lorenzino et al. 2008).

Moreover, a growing number of public institutions and private companies have adopted GIS to handle their internal geo-information. A number of commercial and open source software packages with powerful functionalities are available to support such local activities. The management of information is becoming the main challenge in the immediate future for every agency. In addition, the large amount of the produced GIS data along with the availability of high-speed networks and sophisticated computer science technologies is creating heterogeneous user groups which typically include:

- ***Public institution*** that requires geographic information to support institutional duties, e.g. emergency, health care, urban planning, tourism, etc;
- ***International, national or local institution*** that coordinates and integrates geographic information provided by different GIS agencies;
- ***Research institution*** that analyzes the availability and the quality of geographic information covering a specific study area;
- ***Private company*** that uses geographic information in order to create business services, products and geo-market;
- ***Non-expert user*** who needs to quickly and easily locate any kind of geographic feature, address, location name, institution, business activity, etc.

To support all these kinds of users, GIS agencies have started to adopt a SDI model (Bernard et al. 2005; Groot et al. 2000; Nebert 2004; Lorenzino et al. 2009). Users of distributed geo-services can be divided into business user, domain user, GIS user, and market user. Different users are provided with different software of distributed geo-services.

Business user: Distributed geo-services are important information for enterprises and their personnel. Business users have no or little experience with complex GIS, and do not attempt to do so either. They are only interested in some relevant enterprise information and need distributed geo-information application programs. Therefore, user interface and GIS operations should be designed in a friendly and easily comprehensible way to help business users get GIS function and data with little effort. This philosophy is also useful for users who do not use GIS but only browse information.

Domain experts: The domain experts are very familiar with thematic matters to GIS, but do not know much about how to use GIS. For the domain experts, distributed geo-information application programs do not have to provide assistant text to help them understand the domain nor to provide user-friendly interface. Instead, they need to make the whole spectrum of available GIS functions incl. thematic mapping functions available and create the results through interaction. Some special functions of distributed geo-information are very useful to allow domain experts to conduct analysis and browse the finding result in most detail.

GIS user: GIS users own GIS software, they can thus use GIS and Internet. Distributed geo-services can help the users disseminate GIS data, without finishing the map production. However, integrated data integration and text matching etc. can help them raise the efficiency of using distributed geo-information.

Marketing user: Marketing users are particularly interested in sharing distributed geo-information due to its global nature. They know little about the enterprises which provide distributed geo-services. They do not have their own GIS either. Therefore, they can’t handle complex information. Instead, they need the simplest and easy-to-get information such as predesigned map image and annotations.

3.2.4 Access rights of distributed geo-services

Since different user types pose different demands on distributed geo-services. Service designers must balance the different requirements and answer questions such as whether users should be shown the whole or only a part of available information, whether users should be permitted to edit the data or they can only access to read-only data, where users should be allowed to share data from GIS software or only browse the map image, what level of distributed geo-services should be made available to the target user, which services are free of charge and which services are bound to internal use. As soon as the requirements are clearly formulated, distributed geo-services can be installed at different levels of access rights and functional complexity for system administrators, super users, common users and guest users.

3.3 Geo-service architecture

The aforementioned ISO 19119 is based on the Reference Model of Open Distributed Processing RMODP (ISO/IEC 10746). The components, connections, and topologies in the geo-service architecture are defined through a number of viewpoints (Percivall 2002):

The computational viewpoint for service chaining

The computational viewpoint is concerned with interaction patterns between the components (services) of the system, described through their interfaces. The key to meet the needs of geographic uses is the combination of services to achieve specific results to a task. ISO 19119 enables this through service chaining. A service chain is defined as a sequence of services where, for each adjacent pair of services, occurrence of the first action is necessary for the second action. ISO 19119 enables users to combine data and services in ways that are not pre-defined by the data or service providers. The level of data/service interoperability will be achieved in stages. At first service catalogues will hold entries with tight data and service binding. Eventually the infrastructure will be available for a user to determine which data can be accessed by a loosely coupled service.

Information viewpoint for semantic interoperability

The information viewpoint is concerned with the semantics of the information processing. Each particular service will need to define its syntactical interface through operations and its semantics through description of the meaning of the operations and their legal sequencing. There exist multiple possible taxonomies for services.

Engineering viewpoint for distribution

The engineering viewpoint focuses on mechanisms for distribution of services across network. The approach of ISO 19119 is to distribute services using multi-tier architecture model to support a flexible deployment. The logical architecture is the arrangement of services and associated interfaces that are present in the system. The physical architecture is the arrangement of components and associated interfaces that implement the services. The components are hosted on hardware computing resources or nodes. The logical architecture can be mapped to multiple physical architectures. All tiers could be mapped into one monolithic application or could be mapped using different physical client-server architectures. As shown in Figure 3.1, thick user interface client architecture typically contains a large part of the functionality in the user service. A thin user interface client (typically a web browser) mostly contains user dialogue and presentation code. A Web browser client interacts with Web server, using the Internet HTTP protocol with content presented in HTML and/or XML.

Technology Viewpoint for cross-platform interoperability

The technology viewpoint of ISO RM-ODP is concerned with the underlying infrastructure in a distributed system. To achieve the technological interoperability, an infrastructure that allows the components of a distributed system to interoperate is needed. This infrastructure, which may be provided by a Distributed Computing Platforms (DCP), allows objects to interoperate across computer networks, hardware platforms, operating systems and programming languages. The communication between the objects in a DCP is handled by a “communication service”. In the two systems depicted in Figure 3.2, Communication A allows the components of System A (Client A, Geo-data Server A and GIS Service Component A) to interoperate, while Communication service B allows the components of System B to interoperate. To allow System A to interoperate with System B, the components of System A must be able to request services from the components of System B and vice versa.

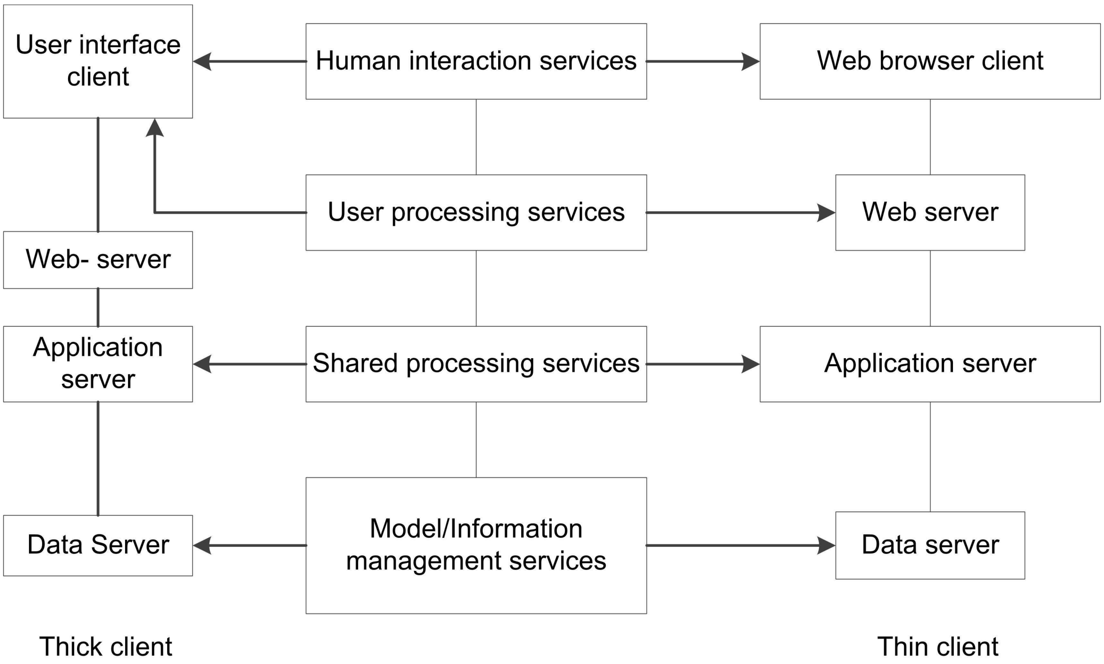
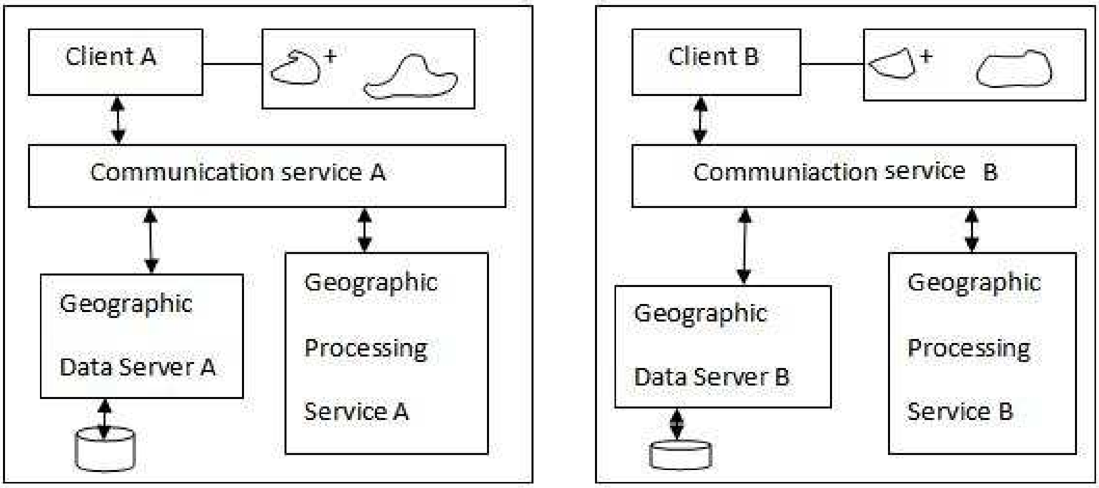


Figure 3.1 Four logical tiers to thick and thin clients (based on ISO 19119)



Geographic Services on Platform A Geographic Services on Platform B

Figure 3.2 Interoperability Reference Model from technology viewpoint model of view (based on ISO19119)

3.4 Distributed geo-services based on the Internet

The most popular and vital way of distributed geo-services based on the Internet is a multi-tiered structure.

3.4.1 Concepts and characteristics

Distributed geo-services based on Internet are distributed geo-information application server systems which use Internet environments and provide spatial data and GIS functions required by various kinds of GIS applications. Normally they possess a number of characteristics:

HTTP/HTTPS agreement This involves a hypertext transmission agreement on the data transmission layer; document flow, object data flow and HTML or XML document flow on the data exchange layer. The web framework must have a WWW server, necessary firewall mechanism to protect the network safety, and digital signature technology to protect the information safety.

Integration of server/client calculation systems: Similar to other client/server application programs, a GIS task can be decomposed to allow the client and the server to finish the subtasks separately and then connected through communication protocol. While the client requests data, analysis tool, application module etc. and displays the result, the server accomplishes the processing work, sends the result to client via web, or sends data and GIS analysis tool to client.

Server and client interaction: A traditional desk GIS depends on a graphic user interface (GUI) to operate GIS functions, but distributed geo-services depend on web explorer and plug-in software module to provide interactions between user and Internet GIS program.

Distributed system: Distributed geo-services inherit the advantage of Internet that can capture and operate data stored on different servers. In other words, data and analysis tool are individual components or modules which can be accessed by users anywhere.

Dynamic system: Database and application programs are maintained in server. Once they are updated, every client can access to the new version.

Trans-platform: The usage of distributed geo-services is independent of client and its associated hardware platform. As long as the user has the Internet access, he can get and use the services and resources from anywhere.

Hypermedia information system: With the functionality of a web explorer, distributed geo-services provide hyperlinks to different hierarchical levels of spatial information and hypermedia information. For example, user can browse a provincial map from a country map, a city map from a provincial map via hyperlinks, or access to other multimedia information incl. videos, voices, texts and graphics.

Interoperability: In order to capture and share long-distance GIS data, functions and application programs, distributed geo-services possess the necessary interoperability.

3.4.2 Service-oriented architecture and web services technologies

An application-centric Web is not a new concept (Newcomer 2000). But most of these systems, such as Java servlets[42] modules, ASP Active Server Pages[43], JSP Java Server Pages[44], and Cold Fusion Web application[45] and so on, were used as a part of tightly coupled platform and as a result they can't offer services to other business solutions. Web services technologies can overcome this limitation and provide communication between the platform and the application. Web services are about delivering distributed application via programmable URLs[46] (Amirian & Mansourian 2006). More precisely, web services are loosely coupled self-describing services that are accessed programmatically across a distributed network, and they exchange data using a protocol that is neutral to vendor, platform, and language (Marks & Werrell 2003). In fact, web services are implementation of a conceptual architecture, which is called Service Oriented Architecture SOA (Newcomer & Lomow 2005). According to (Marks & Werrell 2003), SOA is the emerging generation of software implementation in the paradigm of distributed technologies. Figure 3.3 illustrates the seven distinct layers of the services stack according to (Marks & Werrell 2003).

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[42] http://en.wikipedia.org/wiki/Java_Servlet
[43] http://de.wikipedia.org/wiki/Active_Server_Pages
[44] http://de.wikipedia.org/wiki/JavaServer_Pages
[45] http://www.adobe.com/products/coldfusion/
[46] http://www.boutell.com/newfaq/definitions/url.html

XML: eXtensible Markup Language
WSDL: Web Services Description Language
BPEL4WS: Business Process Execution Language for Web services
WSFL: Web Services Flow Language
TCP: Transmission Control Protocol
HTTP: Hypertext Transfer Protoco
SOAP: Simple Object Access Protocol
UDDI: Universal Description, Discovery and Integration
WFML: Web Form Markup Language
WSXL: Web Service Experience Language
TP: Transmission Path Layer
SMTP: Simple Mail Transfer Protocol
FTP: File Transfer Protoco

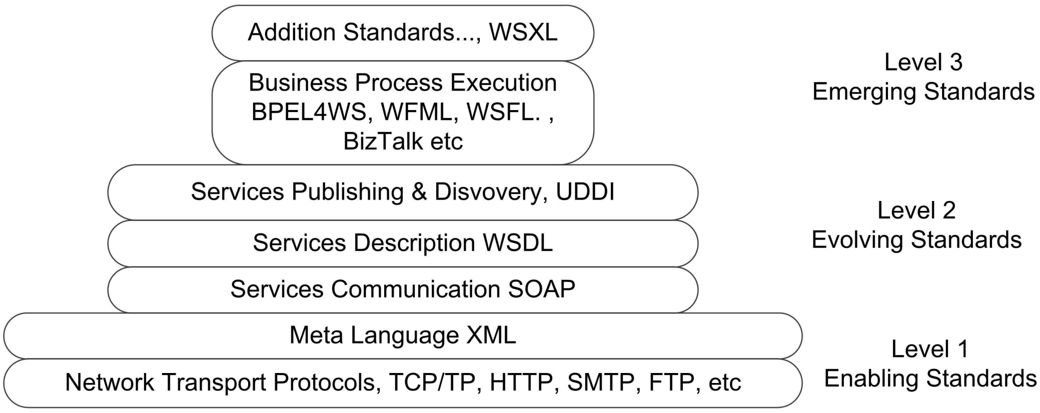

Figure 3.3 Web service stack (based on Marks & Werrell 2003)

As illustrated in Figure 3.4, these layers establish an explicit mapping between elements of SOA[47] as a conceptual and technology-independent architecture and web services as specific collection of standards, protocols and technologies. SOA consists of three primary roles: service provider, service requester and service broker that are distributed computational nodes on the network. Service provider publishes its own service with service broker. Service requester uses the service broker to find desirable services and then binds to a service provider to invoke the service.

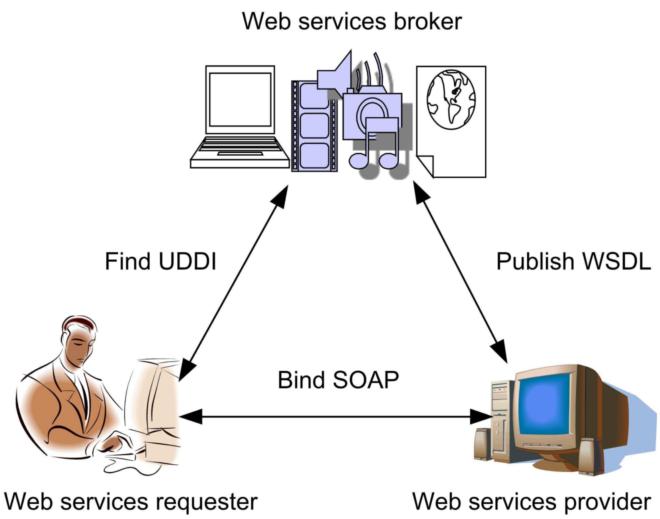

Figure 3.4 Mapping between SOA and web services technologies (based on Marks & Werrell 2003)

[47] http://en.wikipedia.org/wiki/Service-oriented_architecture

Consequently this loosely coupled architecture[48] provides a new and promising solution for implementation of complex collaborative applications such as a distributed GIS services. The integration of GIS and web services simply means that GIS can be more extensively implemented, and people will be able to take mapping, data, and reprocessing services from many servers and integrate them into a common environment[49].

GIS web services can be categorized as processing service and geo-data service. The GIS processing services provide different GIS functions and operators. The GIS geo-data services provide access to GIS data. According to (Peng & Tsou 2003), a common format of geospatial data such as GML (Geography Markup Language) could be provided to increase data interoperability.

On account of separation between executable environment and description of service or separation between semantic and functionality of services, web services can be created using any software platform, operating system, programming language and object model. So it is not a difficult task for a developer to bridge heterogeneous computing platforms, such as J2EE, CORBA and .NET.

Table 3.2 Comparison of .NET, CORBA and J2EE

CONCEPTION / Feature	.Net	CORBA	J2EE
Type of technology	Product	Standard	Standard
Interpreter	CLR **(**Common Language Runtime)	No designation	JRE (Java Runtime Environment)
Middleware vendors	30+	OMG (Object Management Group); neutral	Microsoft
Protocol	ORPC (Object Remote Procedure Call)	IIOP (Internet Inter-Orb Protocol)	JRMI (JavaRemoteMethod Invocation*)* utilizing JRMP (JavaRemoteMethod Protocol)
Interface	Multiple	Local, Remote, Service, metadata	Local, Remote
Dynamic Web pages	ASP(Active Server Pages).NET	No designate	JSP (Java Server Pages)
Middle-tier components	.NET management components	CCM (CORBA Component Model) CORBA (Common Object Request Broker Architecture)	EJB (Enterprise Java Bean)
Database access	ADO (ActiveX Data Objects).NET	ORB (Object Request Broker)	JDBC (Java Data Base Connectivity) SQL (Structured Query Language)/J
SOAP, WSDL, UDDI	Yes	Yes	Yes
Implicit middleware (load-balancing, etc)	Yes	Yes	Yes
Language support	Language neutral	Language neutral	Java only
Portability	Windows	No relationship with platform and middleware	No regarding with platform and middleware
Share context	Once storing	Distributed storing	Distributed storing

48 http://en.wikipedia.org/wiki/Loose_coupling

49 http://www.esri.com/library/whitepapers/pdfs/spatial-data-standards.pdf

3.4.3 Implementation strategy

The solutions of the popular distributed geo-services include Microsoft's .NET Platform, Object Management Group (OMG)' CORBA standards, and Sun Microsoft systems Java2 Platform, Enterprise Edition (J2EE[50]) (Farily 2000; Darryl 2003; CSCI3007 2007; Vawter & Roman 2001) as illustrated in Table 3.2.

Generally speaking, the efficiency of Microsoft's net platform is higher, but it suffers the weakness of poor trans-platform performance. CORBA (Common Object Request Broker Architecture) is completely interoperable and open-ended, but highly complex and experiences a slow upgrading. J2EE has a quick standard development and allows smooth transformation, but relies on Java.

To summarize, distributed geo-services should possess the advantage of interoperability and support the semantic expression and transformation. They should be generally applicable and portable, and enable scalability and compatibility of heterogeneous massive data. With regard to all these properties, J2EE has the potential to gain the most widespread application in the future. In the thesis the open software running under the J2EE environment such as GeoServer is required.

[50] http://www.myplick.com/view/eVSoH-0xmq-/CORBA-vs-J2EE-vs-Microsoft-Technologies

Chapter 4

Organization of distributed geo-services

A distributed geo-service regardless of its users and applications is characterized by distributed storage of its data, centralized processing mechanism and the data dissemination in different formats. This chapter gives an in-depth analysis of the geo-data, middleware services and organization and management of geo-data.

4.1 Geo-information in distributed geo-services

Geo-information handled in distributed geo-services reveal a number of special characteristics:

Geo-information is spatially distributed. First, it is horizontally distributed (Al-Ahmadi 2008; Zhao & Wang 2008) and can be mapped onto a two-dimensional map sheet at different scales. Through hyperlinks, different places can be connected, retrieve and queried; Second, it is vertically distributed at different layers (Zhou et al. 2010; Yasuda et al. 2006). For example, urban geo-information includes real estate of urban area and multi-story underground pipelines. Different layers of geographic information may need different departments to collect and maintain data, thus the database server will be distributed among different departments with different network addresses.

Geo-information originates from multiple sources and is communicated in different formats. Due to worldwide diverse development, geo-information is stored in different database management systems and in different data formats. For example, terrain data, aerial image data and pipeline information in an underground pipeline system can be respectively stored using Oracle 8i spatial data Option (SDO), SQL Server BLOB and Sybase. Different GIS vendors have created different data formats for the exchange. For example, Arc/Info uses the E00 data format, MapInfo defines MIF/MID format, while Autodesk adopts DXF data format.

Geo-information is operated on different platforms. The deployment of distributed geo-services takes place on different platforms including the operating system and the hardware. SUN Solaris, Linux and Windows are some popular operating systems[51].

Geo-information is accessed by different clients. There are three types of PC client: specific geo-information browsers, universal browsers with geo-information plug-ins and universal browser. Specific geo-information browsers, such as ESRI’s ArcExplorer, can remotely access geo-information and combine it with locally stored spatial data; Using a webmap server such as MapXtreme of MapInfo, geo-information can be retrieved from a remote web server through HTTP protocol, displayed and manipulated by means of plug-ins; Universal browsers such as Netscape, Internet Explorer, Mosaic and other emerging WWW browsers usually display raster images.

[51] http://www.nsa.gov/ia/guidance/security_configuration_guides/operating_systems.shtml

4.2 Internet as geo-information processing environment

Interoperability is a property referring to the ability of diverse system and organization to work together (inter-operate)[52] (Miller 2000). NCGIA, national center of geographic information analysis was among the first organizations committed to interoperability issues[53]. UCGIS, a university consortium for geographic science proposed short-term and long-term plans for GIS interoperability[54].

The Open GIS Consortium, an alliance of government agencies, research organizations, software developers, and systems integrators, has been engaged since many years in the effort to define open GIS and to develop a set of requirements, standards, and specifications which support the open GIS. The overall goal is to encourage software developers and integrators to adhere to these requirements and create tools, databases, and communications systems that can maximize the utility of systems and resources and take advantage of technological advances. As noted in the Open GIS Guide, the objective of the technological development is to enable application developers to use any geo-data and any geoprocessing function or process available on "the net" within a single environment and a single work flow(Gardels 1996). Interoperability of geo-information addresses both data and data processing. There are six levels of interoperability between two or more spatially independent GISs: network protocol, hardware or operation system, spatial data files, DBMS, data model, application semantics (Bishr 1998).

Internet provides new opportunities for the GIS development, and its integration with GIS into Internet GIS has become a mainstream (Strand 1996, Varhol 1997). Internet GIS can operate in heterogeneous computing environments for a variety of data sources which can be accessed and processed in the Internet (Bishr 1996).

4.2.1 Multi-tiered architecture of distributed geo-services

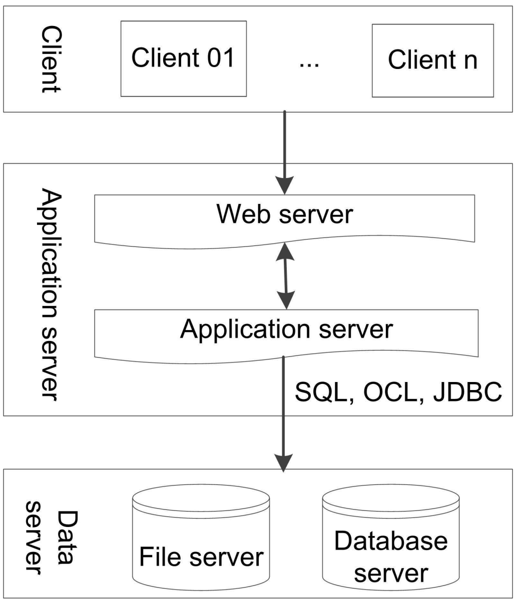

Figure 4.1 The basic architecture of distributed geo-services

52 http://en.wikipedia.org/wiki/Interoperability
53 http://www.ncgia.ucsb.edu/conf/interop97/
54 http://www.ucgis.org/

A service is basically a software module that is accessed only through its interface, usually in request/reply manner (Natis 2003). A service must be self-contained and perform a specific task, in such way that the client is not expected to know anything about the Internet functionality of the service[55]. Once a web service is deployed, other applications (and other web services) can be discovered and triggered. Distributed geo-services are logically structured in a multi-tiered architecture as illustrated in Figure 4.1, which consists of clients, application server and data server. Components in each tier mutually communicate via Internet. Different tiers are linked through a set of standard agreements.

4.2.2 Geo-information flow in distributed geo-services

Geo-information in a distributed geo-service usually flows from data providers, through service providers to service consumers. Data providers possess the spatial and space-related raw data, for example, traffic data, meteorological data, which can be maintained in various database systems and data formats; service providers organize, process and transfer the obtained raw data into information and knowledge for the target users; service consumers retrieve the information and knowledge for their applications.

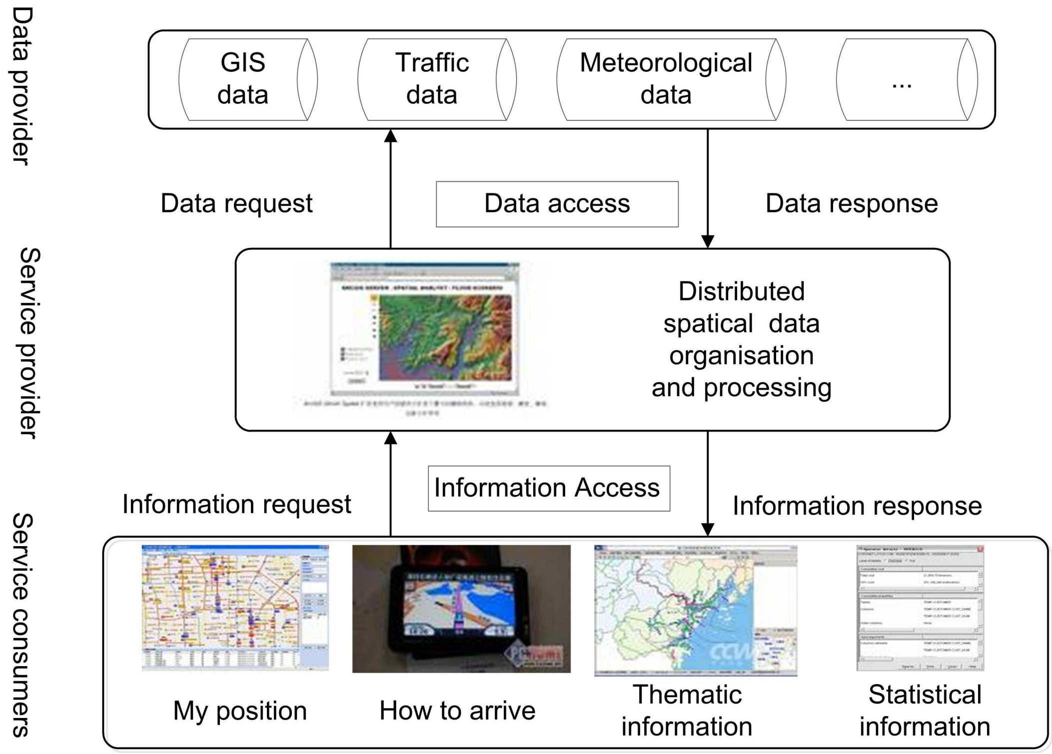

Figure 4.2 Information flow in distributed geo-services

As illustrated in Figure 4.2, geo-information flow in distributed geo-services can be decomposed into the following steps:

- Service consumers request a particular service from geo-service providers;
- Distributed geo-service providers analyze the request, identify the required data, then transmit the data queries to data providers;
- Data providers process the request, then send the data to the distributed geo-service providers;

[55] http://www.capeclear.com/technology/architecture/

- Distributed geo-service providers process the data based on user's request and deliver the information or knowledge as results to consumers;
- Consumers apply the information or knowledge to fulfill their tasks.

4.3 Access of distributed geo-information

In order to open the market for new user groups, especially for non-GIS-experts, innovative approaches for the access of existing spatial data sources are required (Schilcher 2004). The distribution of geo-information takes two forms: (1) source data are maintained on different servers; (2) methods of processing geo-information are developed by different service providers. Therefore, the interoperability refers to the handling of both heterogeneous source data and heterogeneous processing environments[56] (Wilson 1998). For distributed geographic information of the visit in distributed geographic information services, Three methods are possible to approach the distributed geo-information: access of distributed source data, access of distributed GIS components and self-service (Yang et al. 2004).

4.3.1 Distributed geographic source data

Source data are typically maintained in the following forms:

- Plain texts which are accessible in all kinds of GIS environments
- Objects with geographic locations and geometric shapes
- Objects with geometric and semantic attributes
- Relations among objects

The access flow of distributed source data is illustrated in Figure 4.3. A variety of source data maintained in systems such as ArcInfo, MapInfo, and MGE GIS can be directed accessed by data-service providers through the Internet communication protocols such as HTTP (Hypertext Transfer Protocol), FTP (File Transport Protocol), as well as web servers (Lemon, 1997; Hall et al. 1996).

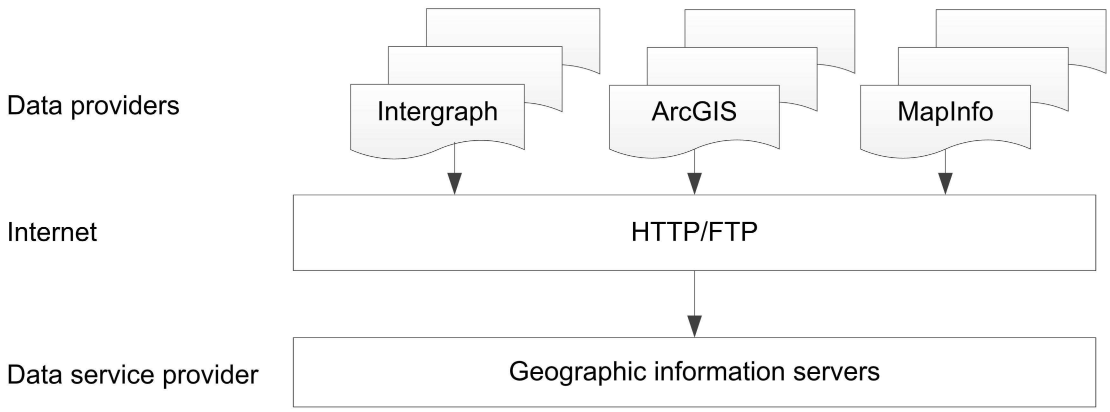

Figure 4.3 Access of distributed source data

Methods to recognize and manage the source data are necessary and can be embedded in the vendor system. If the server for distributed GIS is not running on the corresponding parts or if some data formats are incompatible, the geographic data can't be used even if they are available in Internet. Currently, data formats from ArcInfo, MapInfo, and MGE for different operating systems are widely accepted. Still, many other formats developed by other less

[56] http://www.ucgis.org/

well-known vendors are circulating in the Internet and not yet commonly recognizable. In order to satisfy the requirements of distributed geo-services for multi-source data, the direct access can be complemented by approaches.

4.3.2 Distributed middleware

As illustrated in Figure 4.4 distributed middleware (Chen et al. 2008) lies between distributed geographic source data and distributed geo-service providers and plays a two-fold role: first, it identifies a variety of geographic datasets; second, it analyzes and processes the data. In essence, methods of data interpretation embedded in distributed source data can be regarded as the first role of distributed middleware. Distributed middleware separates data acquisition processing from value-added services; middleware servers are only responsible for reading the original spatial data formats, coding geographic spatial information and sending it to distributed geo-server. In this sense, the middleware server is also a distributed geo-service provider, but it provides the interpretations of geographic data to clients. It is more flexible than distributed data sources.

Distributed middleware for distributed geo-data processing and management has many advantages. The geo-data server can directly use the processing result from the middleware without having to interpret the format itself; many geo-data processing components do not need to be accommodated on the geo-data server, thus can lead to reduced maintenance cost; the processed and analyzed geo-information can run in a distributed way, allowing the sharing of analytical functions and distributed computing. The disadvantage is that each geographic data format needs to be treated by the corresponding components.

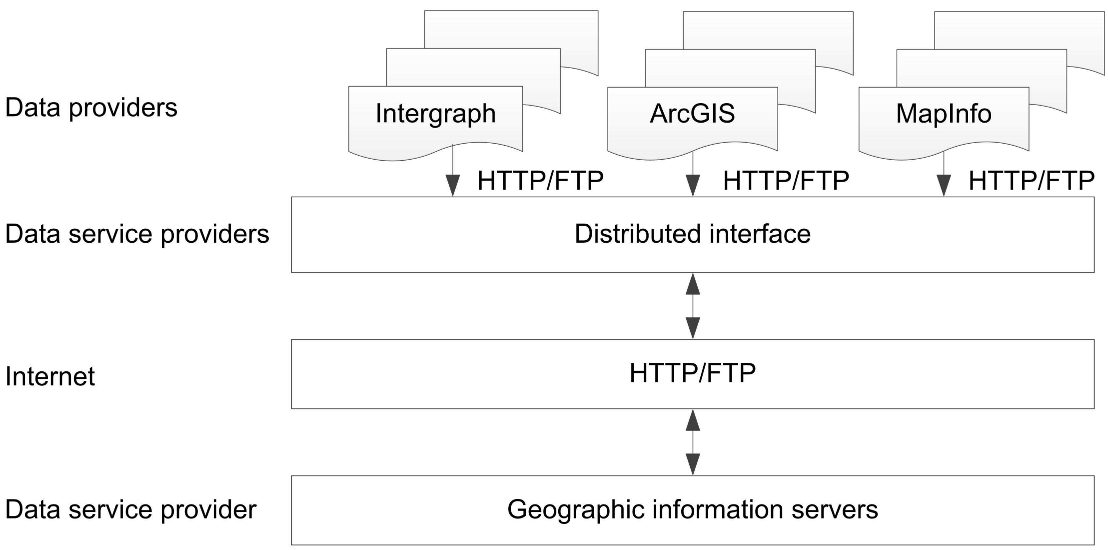

Figure 4.4 Distributed middleware

4.3.3 Independent services (self-service) of geo-information

Both the direct data access and middleware approach require a relatively open data format. Therefore, they may become powerless if the data to be disseminated are confident. Moreover, with the increasing amount of source data, a variety of new data formats may inevitable emerge. This poses a tremendous increase of investment for the direct data access and middleware approach. With these concerns, the self-service approach was introduced by (Chen et al. 2008).

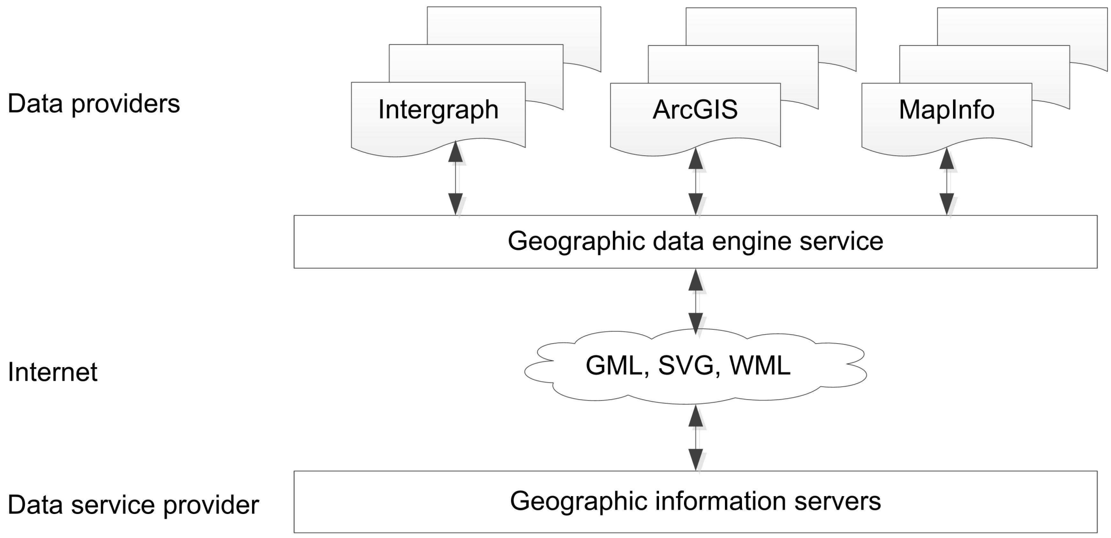

Figure 4.5 Self-service approach of geo-information

Although it is difficult to determine a standard data format for geo-data, a standard for geographic data exchange can be legally defined. GML3.0 (Geography Markup Language) was defined as geospatial data exchange standards by ISO[57]. As shown in Figure 4.5, each GIS vendor can create their own geographic data engine to allow the public data transformation free of charge, but it needs an exchange mechanism for the data content. Distributed geo-services based on XML for general geographic requests are sent to geographic data engine with self-maintenance by the manufactures, engine service processes the request, packs request results into a standard format of geographic data, and then goes back to the distributed geo-services.

As an example, a web prototype VISQUE (VISualise and Query Using Earth) has been developed as a middleware by at Edinburgh University (Henry 2009). In the case study of this thesis, the GeoServer is built on the basis of Geotools[58]. Geotools is a Java-based middle ware platform. The rationale behind this choice is that a self-service approach of geo-information is more convenient and useful to users who prefer wireless functions during the post-earthquake rescue work. An example in GML format for people rescue looks as follows.


```
−<wfs:FeatureCollection xsi:schemaLocation="http://localhost:8080/ http://localhost:8080/geoserver/wfs?service=WFS&version=1.0.0&request=DescribeFeatureType&typeName=Tianjin%3Atianjin_population http://www.opengis.net/wfs http://localhost:8080/geoserver/schemas/wfs/1.0.0/WFS-basic.xsd">
    −<gml:boundedBy>
        <gml:null>unknown</gml:null>
        </gml:boundedBy>
    −<gml:featureMember>
        −<Tianjin:tianjin_population fid="tianjin_population.1">
            <Tianjin:id>3</Tianjin:id>
            <Tianjin:buildingnr>901</Tianjin:buildingnr>
            <Tianjin:attribute>Hotel</Tianjin:attribute>
            <Tianjin:floorcount>3</Tianjin:floorcount>
            <Tianjin:shockgrade>7</Tianjin:shockgrade>
            <Tianjin:land_nr>1</Tianjin:land_nr>
            <Tianjin:landname>Shubo Hotel</Tianjin:landname>
            <Tianjin:population>200</Tianjin:population>
            <Tianjin:street>NanMaLu</Tianjin:street>
            <Tianjin:streetnr>29</Tianjin:streetnr>
            <Tianjin:district>Hepingqu</Tianjin:district>
            <Tianjin:city>Tianjin</Tianjin:city>
            <Tianjin:state>China</Tianjin:state>
        −<Tianjin:the_geom>
```


57 http://www.citygmlwiki.org/index.php/Basic_Information Feb.26.2010
58 http://www.geotools.org/

```
            −<gml:Point srsName="http://www.opengis.net/gml/srs/epsg.xml#4326">
                <gml:coordinates decimal="." cs="," ts=" ">117.18796672,39.15152794</gml:coordinates>
            </gml:Point>
        </Tianjin:the_geom>
    </Tianjin:tianjin_population>
  </gml:featureMember>
−<gml:featureMember>
……
```

4.4 Distributed geo-data organization based on hypermaps

4.4.1 Hypermap - concept and development

Maps have always provided their users with access to georeferenced data[59]. Hypermedia allows the integrated use of non-georeferenced data in many applications. Application fields such as earth sciences, urban planning, environmental management and tourist industry, require the combination of maps with the non-georeferenced data. A map with hyperlinks is termed as a hypermap that can structure the individual hypermedia components. (Laurini et al. 1990; Kraak & Vandriel 1997; Voisard 1999) described the hypermap as a multimedia hyperdocument with geographical access or georeferenced hypermedia. Using a hypermap, for example to retrieve spatial information based on associative and logical combinations, is expected to be an efficient and easy method to understand the environment (Laurini & Thompson 1992).

The design of a hypermap is based on hypertext and hyperdocument principles. When content elements such as sound, images, and video, are involved in the hypertext environment it is appropriate to call it hypermedia, but only if the user has an interactive control to navigate the system (Nielsen 1995). The World Wide Web is a prime example of a hypermedia network.

Hypermap varies from a static map which could be navigated by the user (Rhind et al. 1988) to a dynamic map with HyperGeo model (Caporal 1995). Other researchers reported on the hypermap in relation to specific hypermedia. Among them were (Cassettari 1993; Parson 1995), (Milleret-Raffort 1995; Jiang et al. 1995; Jen et al. 1996; Dbouk et al. 1996), and (Fonseca et al. 1996). (Lindholm et al. 1994) discussed hypermedia as interface to geographic data. (Buttenfield et al. 1994) described a proactive system which was also built in an authoring environment. The Alexandria digital library project (Buttenfield 1995) also included some elementary hypermap functionality. Using the IconAuthor authoring environment[60], the hypermap concept and an accompanying prototype are developed.

More mature hypermaps function as an interface to a database that contains hypermedia data which are related to coordinates (Huffman 1993). This means that each document in the database has a coordinate (a geotag) linked to it. The geotag of a photograph can refer to the location the photo was taken, the geotag of a voice is related to a location where it was heard, and the geotag of a text can refer to the place where it was written or stored. However, a geotag is not the only link to the documents. They also have ordinary hypertext links which allow the user, after a document has been accessed via the hypermap, to continue to browse the database along those links. The relationships among hypermap, multimedia, hypertext, hyperdocument, and hypermedia are illustrated in Figure 4.6 (Stefanakis 2006).

[59] http://www.savbb.sk/~nedela/CMbook.pdf
[60] http://is.uni-sb.de/diskussion/autsyst/iconauth

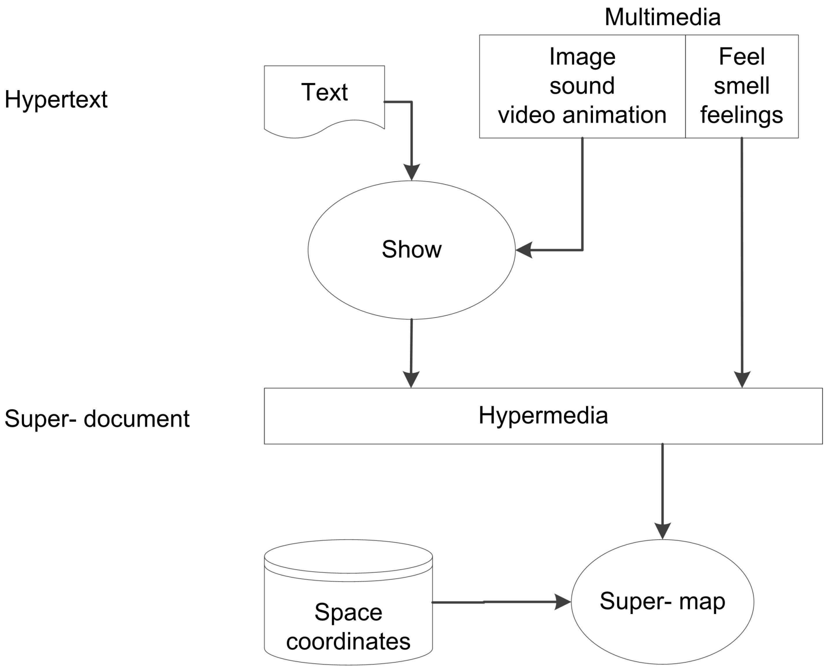

Figure 4.6 The relationships among hypermap, multimedia, hypertext, hypermedia, hyper-document

With help of a hypermap a tourist, for example, can easily locate all sight spots within a zone of 2 km around a hotel and visit any of them depending on his personal interest. Further links connected to each sight spot may reveal other. Hypermaps are also useful for commercial purposes in addition to navigation and recreational purposes.

Figure 4.7 A Google map image and its geotags

Geotagged Google maps as successful example of VGI play an important role in the rescue work in this thesis. Figure 4.7 illustrated a Google map image and a number of geotags. These geotags can reflect thematic information necessary for rescue work.

4.4.2 Distributed hypermap model

Aforementioned the concept of hypermap defined by Kraak and Vandriel (1997) is merely a geo-referenced hypermedia. For a use in Internet GIS, a Distributed Hypermap Model (DHM) that can organize and manage GIS data on servers and clients is proposed by (Yuan et al. 2000).

Following the object-oriented principle, a hypermap H based on the DHM is regarded as a set of spatial object O^S (Grady 1996).

$$H = \{O_1^S, \ldots\ O_2^S, \ldots\ O_i^S, \ldots\}$$

The DHM model means that hypermap is employed on distributed clients and servers, implemented by distributed components. It runs in a platform-independent environment in order to express distributed geographic information in the Internet (Yuan et al. 1999). Each spatial object O^S consists of four elements - object identity ID, hypermedia H^M, hypergraph H^G and hyperlink H^L . We express it as:

$$O^S = \{ID^S, H^M, H^G, H^L\}$$

For example, Geosurf as a product of WebGIS platform in Wuhan University[61] is a prototype system of Internet GIS using DHM. The relationship among hypermap, hypermedia, hypergraph and hyperlink is shown in Figure 4.8. The differences of hypermap between Kraak and Yuan (Based on Kraak & Vandriel 1997; Yuan et al. 2000) are summarized in Table 4.1.

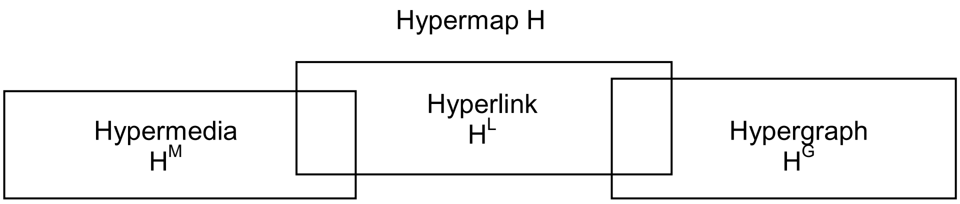

Figure 4.8 The concept of hypermap (Based on Yuan et al. 2000)

4.4.3 Hypermap and distributed geo-services

A hypermap is organized according to a pyramid structure and an R-tree structure (Guttman 1984). R-trees are used as efficient spatial access methods. A two dimensional space is split into a number of hierarchically nested minimum bounding rectangles ("rectangle" is what the "R" in R-tree stands for). Each node of an R-tree has a variable number of entries (up to some pre-defined maximum). Each entry within a non-leaf node stores two pieces of data: a way of identifying a child node, and the bounding box of all entries within this child node[62].

The relation between Pyramid and R-tree is illustrated in Figure 4.9. Suppose the document spatial area can be delimited by a rectangle; if the document spatial area is not a rectangle, it can be approximated using a number of rectangles so that a subdivision bounding boxes in R-tree is possible and the accuracy can be easily controlled (Guttman 1984).

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[61] http://www.gispark.com/html/jichu/2006/1020/355.html
[62] http://en.wikipedia.org/wiki/R-tree

Table 4.1 The difference of hypermap between (Kraak and Vandriel) and (Yuan et al.)

Hypermap	Kraak & Vandriel (1997)	Yuan et al. (2000)
Types of information expression	The definition considers hypermap as the combination of hypertext and hypergraph	This model is based on object-oriented concept, considering both hypermedia and hypergraph as attribute and spatial attribute describing internal states of a spatial object. A hyperlink is considered as a set of operations and non-sequential links, which refers to relations between two object states, between two objects, between two hypermap states, or between two hypermaps.
Purpose	Hypermedia with geographical coordinates	Spatial object description, browsing, multiscale information management, definition of both metadata and contents
Functions	Navigation and browse	All functions of GIS in distributed surroundings such as distributed components and distributed computation.

The layers in the R-tree are arranged in a pyramid structure:

- The bottom layer corresponds to a small-scale map,
- Each upper layer is a sub-graph of the lower layer,
- The upper layer contains layers of their sub-graphs,
- Neighboring layers are linked with each other,
- Map can cover an R-tree seamlessly.

Distributed geo-information services need to handle many different source data. These source data can be maintained in a standard format such as that defined by GML, or in an interchange format such as MapInfo MIF/MID, or an arbitrary format defined by a non-spatial data provider. These different source data are independent of each other. A hypermap has a spatially referenced graphic structure (Guttman 1984) and allows spatial query (Papadias 2001) and navigation (Timothy 1995). Its graphic contents and operations are interlinked (Yuan et al. 2000).

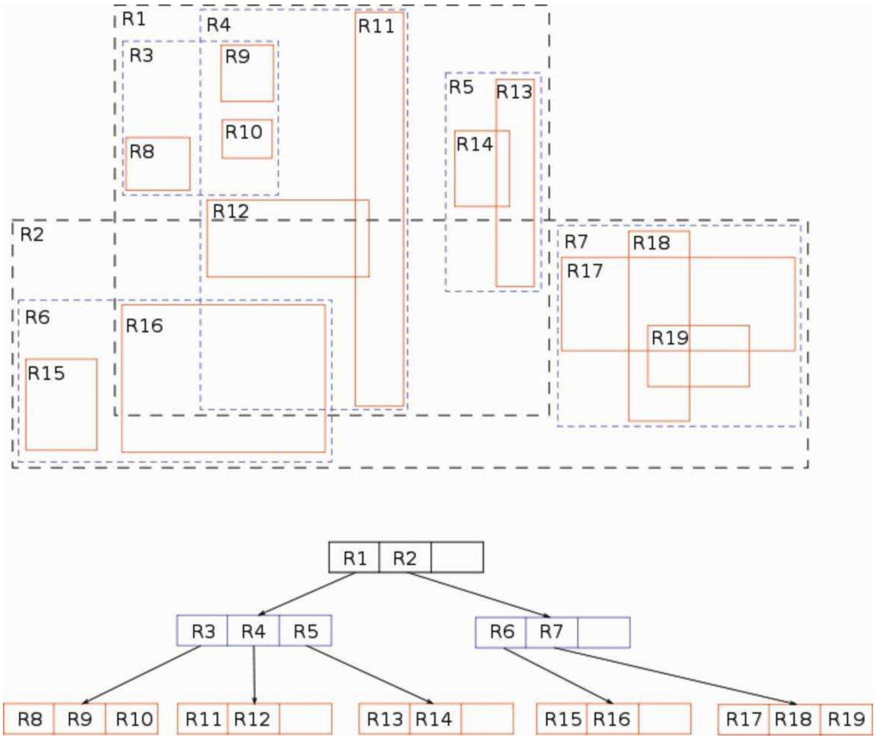

Figure 4.9 R-tree and Pyramid for a 2D rectangle (Guttman 1984)

Distributed geo-services therefore can be seen as hypermaps with different types of operations. As demonstrated in Figure 4.10 distributed geo-services spread on different servers can be regarded as nodes. Each node can operate multiple hypermaps, such as joint, cross, difference, projection, selection, involution and link, thus create a new hypermap.

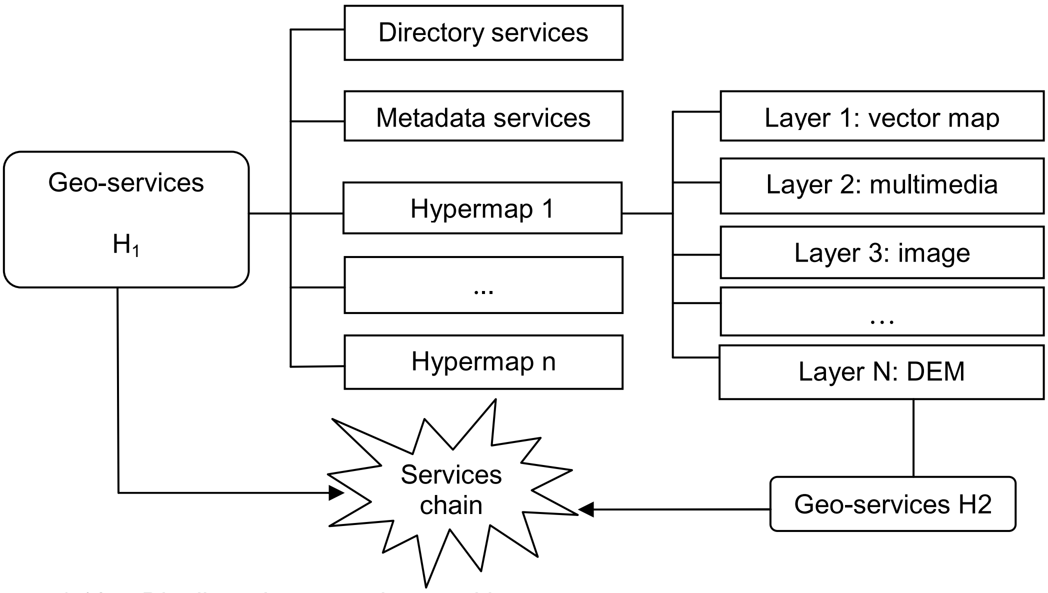

Figure 4.10 Distributed geo-services and hypermaps

4.5 Source and target data for earthquake rescue work

Figure 4.11 provides an overview of source data relevant for post-disaster assessment and rescue work. Statistic demographic information is included in the personal host server. Theoretically, all relevant datasets at the finest possible level of detail should be made available. For this study, sample data are simulated and organized in one or more servers. They include meteorological data, various statistical data, image data which can complement each other for the rescue work. Figure 4.12 demonstrates the test area and the target database which is essentially composed of estimated population trapped in endangered buildings at different times.

If the overall system is able to maintain the actual distributed source data before the earthquake and immediately estimate the damaged property and associated population in danger, it can substantially improve the efficiency of loss assessment and rescue work after the earthquake and provide meaningful support for reconstruction work.

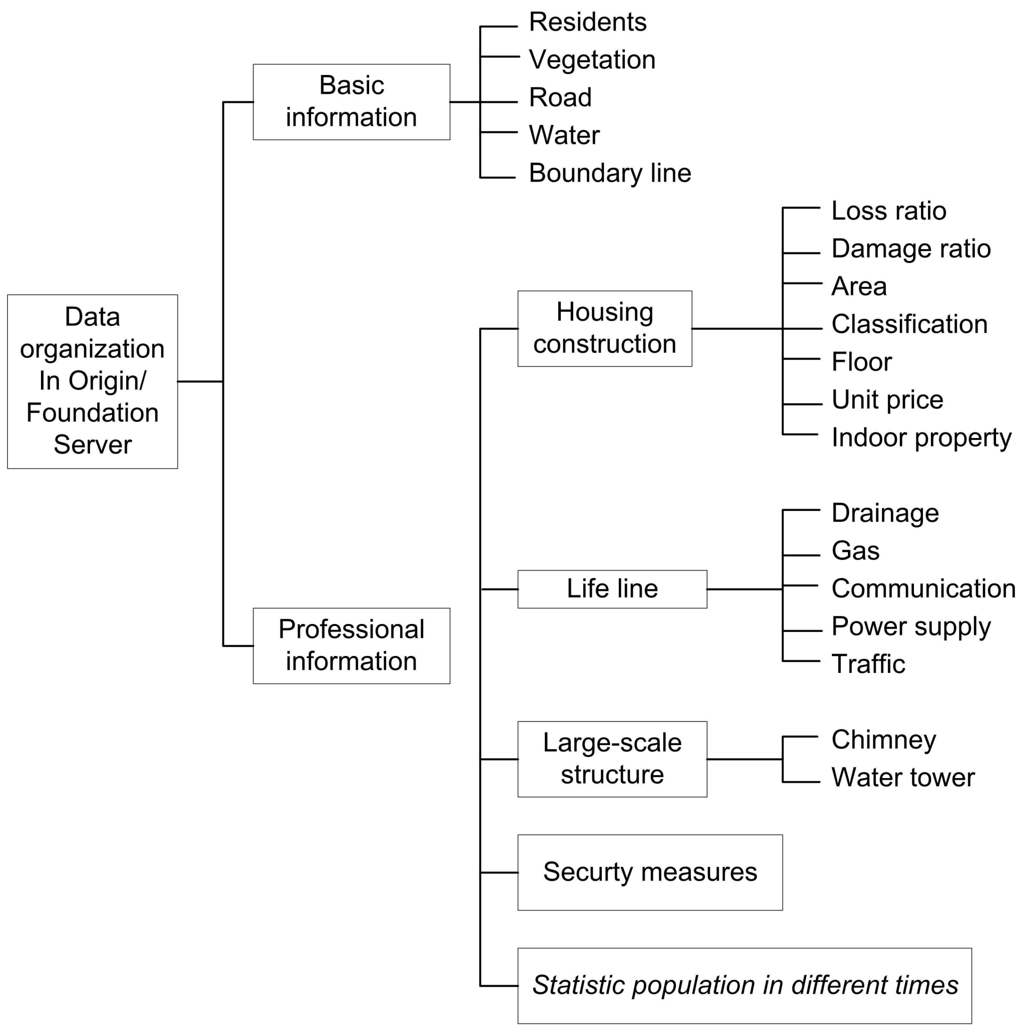

Figure 4.11 Organizational structures of source data relevant for rescue work

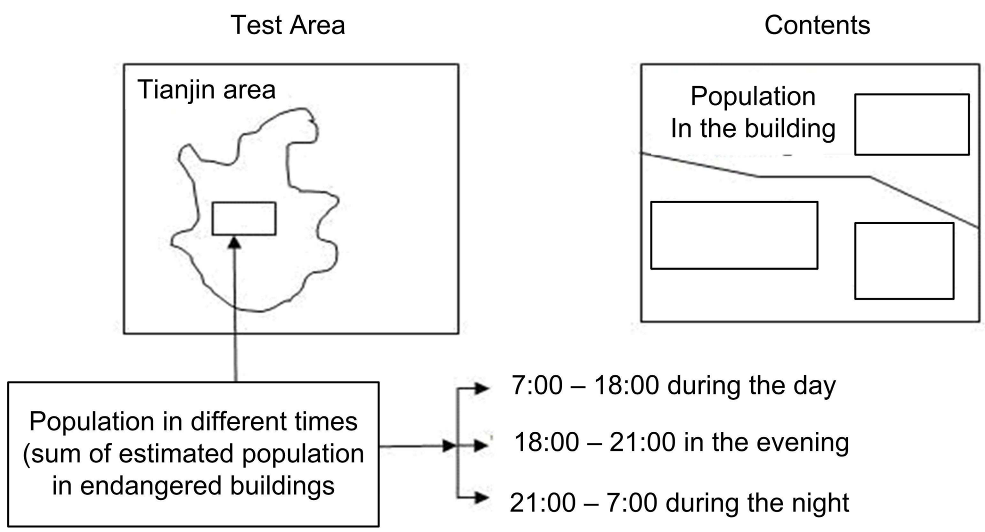

Figure 4.12 Organizational structures of the target data for rescue work

Chapter 5

Wireless GIS and visualization of distributed geo-information

Geo-services without the wireless and visualization techniques are powerless. Geographic visualization service is the premise of effective implementation of geographic services (Meng 2002). We are currently witnessing a renaissance in Geographical Information System (GIS) technology. With the emergence of new spatial database, web and wireless technology, GIS is merging with the mainstream wireless technologies (Terry et al. 2002).

5.1 Wireless GIS

With the development of Internet, the Web is changing from a static to dynamic information and computing platform. The pervasive applications of geo-information have forced the GIS to evolve from a platform-dependent, tight and closed environment to a distributed, loosely coupled and open environment. The emergence of web & wireless services technology and mobile computing device has finally led to a platform for distributed data integration and interoperability and thus changed the way of using GIS. Traditional GIS operations can now be wirelessly conducted (Goodchild 2008; Nitin 2005; Patterson 2007).

The growing wireless capabilities have created new horizons for service providers. As a sub-field of GIS, the Wireless GIS uses Internet/intranet and World Wide Web as a means of disseminating and processing geo-information (Priti et al. 2006). It allows the retrieval of location information and associated services in both static and mobile environment. In the latter case, wireless information access is particularly useful for those who work outdoors in the field and need to identify and solve problems on site and those who are on the way to a destination and need to get informed of the actual traffic situation. Though the location information is fundamental for humans to understand and operate with the world (Winnie et al. 2002), it is significant to know when, how, how quickly one move and the direction or route that one takes. Real-time tracking is an efficient and valuable element for delivery of emergency services and many other applications. Wireless GIS is considered to be a key contributor in providing services and contents, as well as a part of mobile computing industry and must meet some standards to provide above facilities. The role of Wireless GIS is to capture location information on moving objects and events and to transfer this information to recipients who may also be on the move.

URISA[63] is a nonprofit association of professionals using GIS and other information technologies to solve challenges in state / provincial and local government agencies and departments. URISA is considered to be the premier organization for the use and integration of spatial information technology to improve the quality of life in urban and regional environments. It also provides volunteer GIS along with wireless GIS[64] to support for underdeveloped countries and to support disaster recovery efforts.

OpenGIS specifies interoperable solutions that "geo-enable" the Web, wireless and

[63] http://www.urisa.org/
[64] http://www.urisa.org/node/546

location-based services, and mainstream IT. The specifications empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications[65].

5.2 Characteristics of Wireless GIS

Wireless GIS is the integration of the following technologies:

- Internet
- GPS technology & services
- Mobile devices
- Wireless communication technology & services
- Spatial data processing

Internet

The Internet is a global network of interconnected computers, enabling users to share information along multiple channels. It is a "network of networks" that consists of millions of private and public, academic, business, and government networks of local to global scope that are linked by copper wires, fiber-optic cables, wireless connections, and other technologies[66]. Internet GIS is similar to the client-server architecture of the web, users can access, manipulate and retrieve GIS data without necessity of GIS software.

Internet has expanded the range of services to the users. The development of client-server technology helps to carry large spatial data on a thin network. A thin client is a computer or a computer program which depends heavily on some other computers (its server) to fulfill its traditional computational roles (Thin Client definition[67]). Thick clients are full-featured computers that are connected to a network. Unlike thin clients, which lack hard drives and other features, thick clients are functional regardless of whether they are connected to a network or not. When a thick client is disconnected from the network, it is often referred to as a workstation[68].

GPS technology & services

GPS is the important component in mobile communication as it determines the location on the earth surface and keeps the track of mobile objects equipped with a functional GPS receiver. It is a kind of handset-based positional technology. Another handset based positional technology is Assisted Global Positioning System (A-GPS) which can provide positioning services with support of additional information (Su et al. 2006a; Wunderlich et al. 2006). A-GPS or Wireless A-GPS can perform positioning tasks that the traditional receiver can’t. On the one hand it utilizes wireless communication network such as GSM network to provide the needed assisted information data to A-GPS-receiver, such as almanac, ephemeris, time stamp, Doppler shift and so on. On the other hand, a highly sensitive A-GPS-receiver is able to capture feeble satellite signal. In particular, its indoor position function can extend the GPS applications to areas such as emergency transaction processing, touring information query, and children tracking. This is a desirable advantage for earthquake rescue work.

With the rapid development of electronics and semiconductor technology, GPS receiver has reached a magnitude of millimeters. A large number of GPS receiver chips have been embedded in smart phones which allow the receipt of both mobile phone signals and satellite signals. Most of the mobile wireless communication service providers such as Deutsche

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65 http://www.cadcorp.com/about_us_ogc/cadcorp_and_the_ogc.htmsupport
66 http://en.wikipedia.org/wiki/Internet
67 http://abitabout.com/Thin+client
68 http://www.techterms.com/definition/thickclient

Telekom and O2 provide A-GPS server. However, users of A-GPS have to pay for some additional communication costs to achieve the indoor navigation and positioning services. Table 5.1 demonstrates some differences between GPS and A-GPS based on (Eisfeller et al. 2005; Wieser & Hartinger 2006; Michler & Strey 1998).

Table 5.1 Differences of GPS and A-GPS

Items	A-GPS	GPS
Receiving environment	Indoor, Outdoor	Outdoor
Signal power	-160dBm (Decibels with respect to one milliwatt)	-130dBm
A-GPS Server	Required	Not necessary
Assisting information	Required (Almanac, Ephemeris, Time stamp, Doppler shift and so on)	Not necessary
Wireless	Required	Not necessary
TTFF: time to first fix	Indoor：1 second Outdoor: 0.001 second	40 second

Mobile devices

A mobile device is a pocket-sized computing device, typically having a display screen with touch input and/or a miniature keyboard. In the case of the personal digital assistant (PDA) the input and output are often combined into a touch-screen interface. Enterprise digital assistants can further extend the available functionality for the business user by offering integrated data capture devices. Mobile devices have been designed for many applications and include: Mobile computers, personal navigation device and so on[69]. Mobile devices have inherent advantages concerning personal assistance in mobile environments: they can present up-to-date geospatial information in an individual, dynamic, and flexible way to mobile users, i.e. unbound to space (Reichenbacher 2004).

Mobile communication devices have evolved to take advantage of expanding network bandwidth and meet the demands of user community. Mobile phones allow the communication for people on the move. The significant improvement in the storage capacity, processing speed and functionality of mobile devices over the past few years, coupled with a corresponding drop in price, has resulted in a greater distribution of these devices. Processes that previously required cumbersome computers can now be performed on mobile devices. The introduction of compatible operating systems and wireless communication protocols for mobile devices have also improved the interoperability between mobile applications and applications running on the desktop and the web. The GIS based on handheld devices - mobile GIS - has become the new branch of GIS (Liu et al. 2002). Theories, methods and implementations of the map-based mobile services can be found in (Meng and Reichenbacher 2004). An example about Wireless Mobile GIS Solutions is elicited in[70].

Wireless communication technology & services

Wireless communication infrastructure, technology and services are being rapidly improved to provide remote access to the Web and the back office via cell phones and PDAs. They are characterized by the following elements (Li 2008):

- 3G – It is ITU (International Telecommunication Union) specification for third generation of mobile communications technology. It has a bandwidth of up to 384 Kbps when a device is stationary or moving at pedestrian speed, 128 Kbps in a car, and 2 Mbps for embedded applications, and works wirelessly. This standard with its wide bandwidth allows the transmission of large data volumes. It has been operation

[69] http://en.wikipedia.org/wiki/Mobile_device
[70] http://www.intergeo.de/archiv/2004/Intend.pdf

in Europe and elsewhere for sometime, where the population density supports the additional cost of the infrastructure. Now 4G is emerging (Sofoklis et al. 2008);

- GPRS (General Packet Radio Service) - It is a standard for wireless commutations and runs at speeds of up to 115 kilobits per second;
- CDMA (Code-division Multiple Access) – It is a digital cellular technology that uses spread-spectrum techniques. CDMA does not assign a specific frequency to each user; every channel uses the fully available spectrum;
- WLAN (Wireless Local Area network) - It is a type of local-area network that uses high-frequency radio waves rather than wires to communicate between nodes.

Spatial data processing

All major database vendors have enabled their database products to allow storage, management and query of spatial information and released software products for web-based visualization and analysis of spatial information. These same vendors have also released software products for use on mobile devices. For example, ESRI has released desktop GIS, server GIS, online GIS, mobile GIS and their constant updates.

Geo-information is manipulated, analyzed and visualized using spatial processing technologies (Fred & Jäncke 2007). Usually, space-related data are geo-coded, compressed and sent through a thin network. Many standards like WML and Mobile Location Protocol (MLP) are used to integrate various processing components. Much work is still going on to improve the standards so that spatial data can be easily transmitted through wireless network without any errors and congestion problems.

5.3 Architecture and applications of Wireless GIS

5.3.1 Architecture

The architecture of a Wireless GIS obeys a client-server model approach, as shown in Figure 5.1. Its server consists of three elements:

- RDBMS(Relational Database Management System)
- A web-based spatial interface
- A routing engine

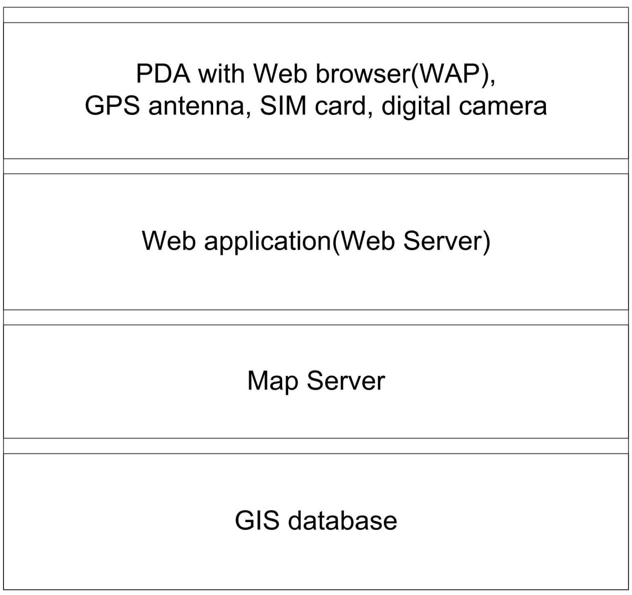


Figure 5.1 The 4-tier architecture of a Wireless GIS

Spatial database is used to store all types of massive GIS data, while the conventional RDBMS is responsible for the management function. As a gateway between the spatial and semantic data, RDBMS brings data to the users through Internet. As demonstrated in Figure 5.2, it is also responsible for merging, deletion and insertion of spatial data and efficient in spatial indexing and searching. A web-based spatial interface is responsible for gathering data from RDBMS and providing it to wireless clients. It enables integration of data from various users and provides tools so that data could be transferred and accessed easily in user's environment. Between the GIS database and the wireless server, a spatial database engine, which could be ODBC or SDE, is necessary in order to provide services to users.

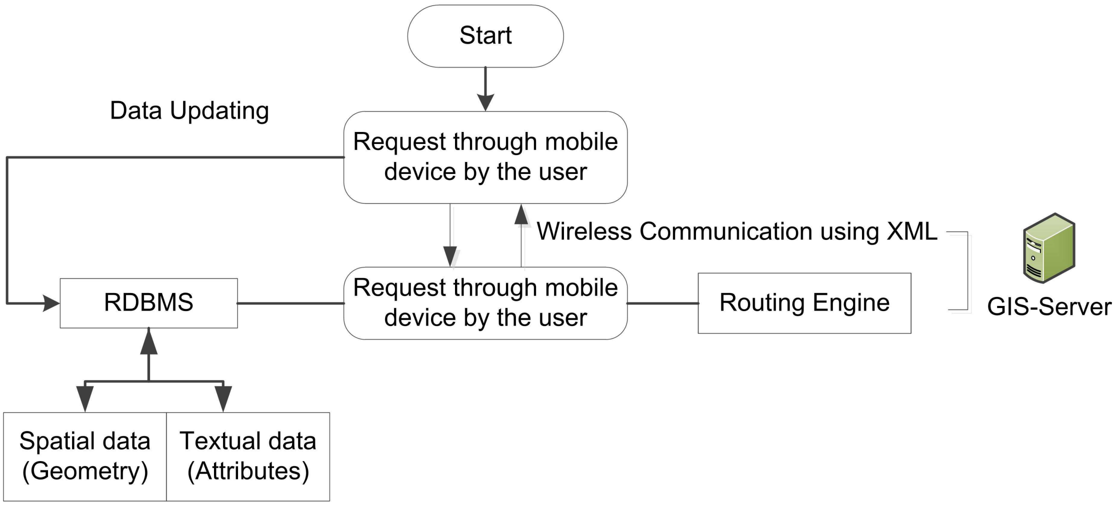


Figure 5.2 Wireless GIS operation (Priti et al. 2006)

5.3.2 Applications

Traditional data collection is time consuming and error prone. Geographic data in the field is recorded in form of paper maps, sketches and notes. These analogue materials were then manually or semi-automatically digitized in the office. By the time when the database was accomplished, the data may be already out-dated. With the support of Wireless GIS, data collection can take place directly in the field in form of digital maps stored in compact mobile devices, spread through wireless network and allow the development of location-based services. Different users require different services. An example of such services is emergency response basically to locate the mobile within a certain radius of area. Some providers use spatial information to offer searching facilities by providing addresses to mobile that are not graphically enabled, for example, the list of restaurants, banks, shops and some others within the user present location.

Many network providers use Wireless GIS to tune their network range according to the user's location to provide them better coverage and reliable services. Tracking function is well exploited and has large potential for rescue work, apart from the fact that it also causes some ethic concerns in terms of protection of private sphere in non-emergent situations. Today, users from various disciplines, ranging from fire fighters, police officers, engineering crews, surveyors, utility workers, soldiers, census workers to field biologists are increasingly making use of Wireless GIS for their tasks. Some of typical applications of Wireless GIS are illustrated in Figure 5.3.

Related terms to wireless GIS

With the advances and convergence of GPS, Internet, and wireless communication technologies, wireless GIS is being extensively studied and explored from different perspectives and has thus led to related terms - mobile GIS, telecartography (Gartner 2003), mobile cartography etc. The mobile GIS is mainly deployed for field data acquisition and validation (Pundt 2002) and in emergency vehicle routing services (Derekenaris et al. 2001). Its target users are field workers and consumers of location-based services. It is therefore sometimes termed as filed-based GIS (Pundt & Brinkkotter 2000) and Location-based services (LBS) (Peng & Tsou 2003). (Tsou 2004) defined the mobile GIS as an integrated software/hardware framework for the access of geospatial data and services through mobile devices via wired or wireless networks. The field-based GIS focuses on GIS data collection, validation and updating in the field, such as adding new point data or changing the attribute tables of an existing GIS database. Location-based services focus on business-oriented location management functions, such as navigation, street routing, finding a specific location, or tracking a vehicle (Jagoe 2002). Telecartography or mobile cartography mainly addresses theories, methods, and technologies of dynamic and adaptive cartographic visualization of geographic information and its interactive use on mobile devices where visualization is adapted to either one or all components of the actual usage context location, time, user, activities, information, and system (Reichenbacher 2004).

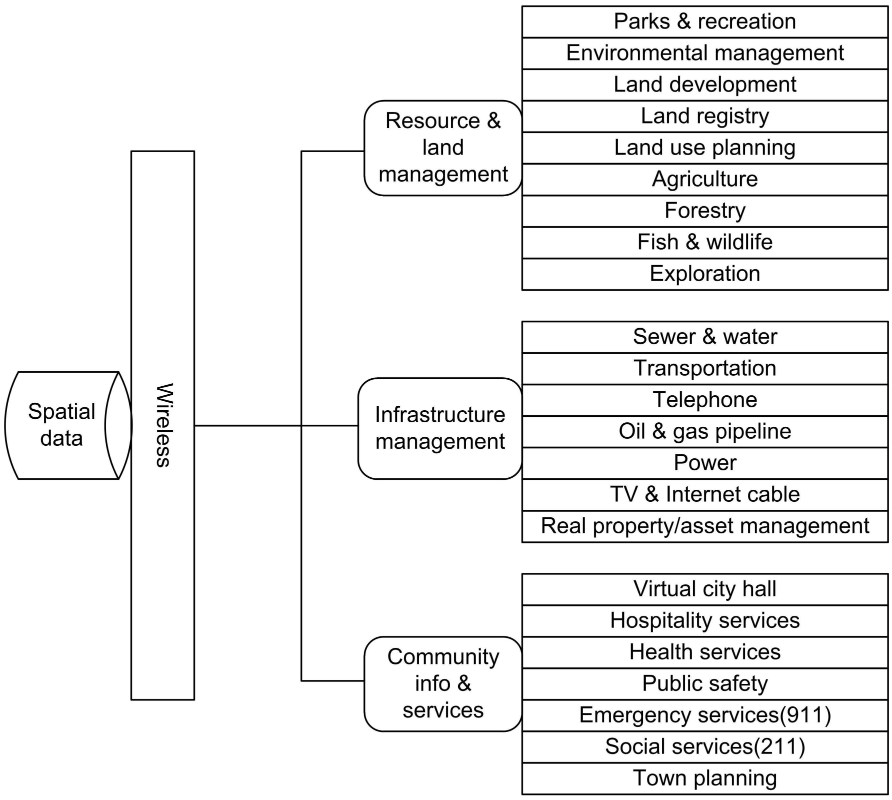
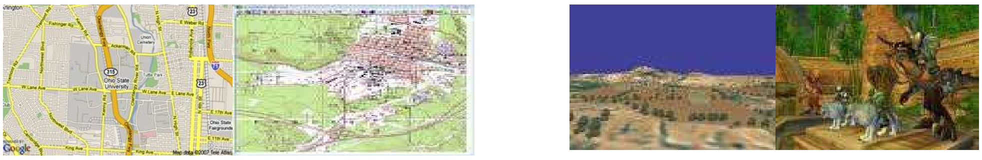


Figure 5.3 Applications of Wireless GIS

5.4 Visualization techniques of distributed spatial information

With the development of Internet, the distribution, searching and browsing of information have undergone a revolutionary change. Over the past ten years considerable advances in hardware and software development have been observed in the field of digital cartography. Visualization techniques of spatial information are significant in both desktop GIS and Wireless GIS. They have evolved from simple to complex, from one-fit-all style to all-fit-one style, from static to dynamic, from 2D to 3D expressions, from mono- to multimedia deployment which allows the realization of virtual reality. Figure 5.4 shows some examples along the evolution of visualization techniques.

According to OGC about the specification of Internet map interface, the Internet-based geo-information visualization contains four basic processing steps: query, generation, expansion and display. Query, also known as filtering, deals with the extraction of a subset from the original datasets that satisfies the conditions in the client query; Generation, also known as generation of display series, has the task to convert the query result into a display element; Expansion, also known as forming, integrate various display elements to constitute a final map; Finally the map is sent to display service for final rendering. For Example, Google Earth supports plain text content, as well as full HTML and JavaScript within description balloons (Henry 2009). This feature has been exploited to enable the querying of the underlying spatial database from Google Earth service. When WebServer such as Geoserver produces KML documents containing data layers and attribute data it also creates an additional document which generates a balloon containing the query window. The query window comprises a JavaScript-enhanced form that allows the user to create queries. Depending on the query type, GeoServer will generate output as a table in HTML or as a layer in KML. The resulting KML layer or HTML through WMS service of GeoServer can be displayed in Google Earth.



(a) (b)

Figure 5.4 Stages of geo-information Visualization

(a): Simple, static, 2D, mono map visualization; (b): Complex, dynamic, 3D, multimedia visualization

5.4.1 Contents and features of distributed geo-information visualization service

According to experiences obtained from the Internet-based geo-information applications, visualization services at clients' side can be categorized into: raster or image map, vector map, 3D map and virtual geographic environment (VGE), as listed in Table 5.2.

Raster or image map is the most commonly used visualization form of the Internet GIS. An image map can be generated using two distinctive methods: one is pre-generation of the map image by superimposing map symbols on the image background; the other allows the user to have some authority to control the outlook of the map, such as choosing display types, changing map symbol etc. An image map can be view-only image or a dynamic one that allows the user to change the viewing scale and port with zooming and scrolling operations etc. The pre-generation is often finished at server side using common function interface, such as NSAPI (Netscape server application programming interface) or ISAPI (Internet server application programming interface), or directly adopting server-side webpage technology, such as ASP (active server pages), JSP (Java server pages), CGI (common gateway interface), PHP (Hypertext processing), SSI (server side includes), Servlet (server applet, or Java applet) etc. The resulted image map is often stored in a standard format such as JPEG (joint photographic experts group), GIF (Graphic interchange format), PNG (portable network graphic format). At client side, the image map can be displayed using a common browser. This is an approach of thin client.

Vector map is a common visualization mode in traditional GIS. Since the common browsers do not support vector map, browser functions need to be extended with help of tools such as Plug-in, Activex, Java, DXF, ActiveCGM, and SVG etc. In comparison to raster map, the vector map has a more attractive and accurate outlook. Besides, a vector map can be conveniently zoomed, scrolled and displayed in layers. However, transmission of large vector data may lead to a longer first download time. A multi-scale vector database is a necessary remedy. Moreover, the browser server resource for vector maps proves uneven. Often the map symbols cannot be as completely rendered as in traditional GIS. If the vector datasets are stored in a document on the server side, they need to be converted into a file stream or object flow that the client browser can read, usually by using a spatial data engine middleware. And then the expanding and display will be carried out on the client side; If the vector datasets are stored in a database on the server side, a subset will be picked up by means of a spatial data query middleware and transferred through a spatial engine at client side. Client expansion and display can be done through data flow transmission, following the thick server/middle client mode.

Table 5.2 Categories of visualization services

Contents category	Raw data	Query	Genera-tion	Expan-sion	Service	Realization technology	Rendering elements
Raster, Image map	Document	Server side	Server side	Server side	Thin service thin client	Html, CGI, PHP, ASP, servlet	Text, pic-ture, sound, multimedia
	Database	Server side	Server side	Server side	Thick service thin client		
Vector map	Document	Server side	Server side	Server side	Thick service medium client	Java, SVG, Activex, Plug/ins, ActiveCGM	Symbol, color, fill model
	Database	Server side	Server side	Server side	Thick service medium client		
3D map	Document	Server side	Server side	Server side	Thick service thin client	Java3D, OpenGL, Choromeffects	Texture, light, ma-terial
	Database	Server side	Server side	Server side	Thick service thin client		
Virtual environment geographic	Document	Server side	Server side	Server side	Thick service thin client	VRML	Shape, texture, animation, perspective
	Database	Server side	Server side	Server side	Thick service thin client		

3D maps can be directly displayed, queried, and analyzed in universal web browsers are rare. Although many technologies exist, ranging from Java3D, Viewpoint, Cult3d, pulse3D, shout3D, blaxxun, shockwave3d to Atmosphere B3D, only a few such as OpenGL of SGI Company, Java3D of SUN, Chomeffects of Microsoft are used to create 3D maps. OpenGL (Open Graphics Library) is a standard specification defining a cross-language, cross-platform API for writing applications that produce 2D and 3D computer graphics. The interface consists of over 250 different function calls which can be used to draw complex 3D scenes from simple primitives[71] [72]. Java 3D is a scene graph-based 3D application programming interface (API) for the Java platform. It runs on top of either OpenGL or Direct3D. Since version 1.2, Java 3D was developed under the Java Community Process[73]. Microsoft announced Chromeffects to play 3D graphics and video through a web browser or in separate player software for ads with flashing text and other animation, or to generate user interface enhancements for web-based applications. Chromeffects are expected to deliver complex

71 http://en.wikipedia.org/wiki/ OpenGL
72 http://www.opengl.org/registry/doc/glspec40.core. 20100311
73 http://en.wikipedia.org/wiki/Java3D

multimedia over low-bandwidth connections. Using HTML, XML, C++, VBScript, and Jscript, developers can turn a web browser into a rippling, 3D space with audio and video playback. Later versions of Chromeffects were planned to have the ability to be used for representing databases in 3D[74].

A virtual geographic environment VGE is related to technologies such as 3D GIS, remote sensing, geo-visualization, geo-computation, virtual reality, network and communication, agents, geo-cognition and so on. A VGE is a multi-user and intelligent environment that simulates the reality. Geo-spatial analysis, geo-visualization are main components in a VGE that can support collaborative work, planning and decision making, as well as serve for training, geographic education, and entertainment[75] (Meng 2008).

Generally speaking, vector maps in the web environment should meet a number of basic requirements: limited broadband, transparent spatial visualization services, independence of application program, and scalability and server-side rapid response. Four visualization approaches, incl. server-side approach, client-side approach, intermediate data-conversion approach, and client-server collaborative work are possible. Among them, client-server collaborative work approach can meet the massive data visualization on diverse display devices, the effective data transfer and a smart scaling technology, however, are more difficult to achieve, particularly in the design of communication interface (Liu et al. 2001).

5.4.2 Visualization in distributed web environment

Progressive transmission of vector map

As an efficient strategy, the progressive transmission of vector map data becomes an active issue (Bertolotto & Egenhofer 1999; Buttenfield 1997; Buttenfield 2002; Sester and Brenner 2004; Oosterom 2005; Oosterom 2006). With the development of WebGIS, transmitting large volumes of geospatial data via the Internet has become commonplace. Nevertheless, the low efficiency of geospatial data transmission remains a problem. Although the current Internet bandwidth has been expanded many times compared to years ago, it is still unable to meet the increasing requirements of quickly distributing large data sets on the web (Al et al. 2008).

Progressive transmission of raster images over the World Wide Web has been successfully realized through the incremental and progressive methods. For example, compression mechanisms (e.g., JPEG, wavelets) are employed to generate complete versions of an image at lower resolution that can be used in progressive raster transmission (Bertolotto & Egenhofer 2001); alternatively, a raster image can be split into a number of smaller chunks and placed in a temporary directory on the server. These chunks are then returned to the client and displayed in the Internet browser one chunk after another (Chow 2008; Goodchild 2008; Wilson 2008; He and Wang 2009).

The progressive transmission of vector map is also possible (belussi et al. 2007), though the working principle is different In a traditional GIS, the point, line, surface symbols are placed in a coordinate system, visualized using various graphic variables. These symbols are linked with the real world objects. They can be arranged at different visual layers but the rendering takes place at the same time. In a distributed web environment, however, the limited bandwidth does not allow the download of all the data to the client at the same time; therefore, a vector map has to be split into a file flow or object flow which is then progressively transmitted. The creation of a file flow or an object flow is termed as data caching. It should assure that the transmitted file flow or object flow can reproduce the consistency and completeness of the original dataset (Ying 2007). This thesis uses Ajax (Asynchronous JavaScript and XML) technology to create a vector data network. Through submitting asynchronous Ajax XMLHttpRequest, the transmission load can be reasonably reduced,

[74] http://en.wikipedia.org/wiki/Chromeffect
[75] http://en.wikipedia.org/wiki/Virtual_geographic_environments

leading to a result similar to the desktop application. Ajax technology has been successfully applied in the tile-based transmission of raster graphics. The difference of Ajax technology from the traditional transmission mode lies in the fact that the Ajax engine can handle some of the client's request so as to reduce the pressure on the server side.

Vector map design for networked applications

Vector map with symbols reveals a much better expressiveness than raster images. Abstract map symbols are an indispensable element in any mapping software. However, the design of map symbols for a web-based application has to consider the resolution of the graphic display device and the transmission speed of the network. The web-based design can be regarded as the extension of the general map design and realized by any platform-independent Java AWT (Abstract Window Toolkit) which is tailored for the broadband network. The AWT contains windowing, graphics, and user-interface widget. It is now part of the Java Foundation Classes (JFC) - the standard API that provides a graphical user interface (GUI) for a Java program. Another method for the narrowband network is called the remote extension of maps. The local extension functions of the map symbols are implemented on the server where the specific formats of raster map are then generated and transmitted to the client. The display and extension graphics are completed on different client devices. The image services of software Geosurf - GeoSurfImageRenderer and GeosurfServlet have this capability (David et al.2006).

Construction of 3D virtual scene

The development of computer and multimedia technologies has led to the flourishing of virtual reality technology (Bulter 2006). The virtual reality modeling language (VRML) (Nadeau 2004) is deployed to construct virtual worlds incorporating 3D shapes, light sources, animations, sound effects and other atmospheric effects. Each virtual world is described by one or more VRML files and transmitted across the Web with the “model/world” Multipurpose Internet Mail extension (MIME) type (Nadeau 1999). VRML has the potential of creating visually pleasing graphics, however, it’s no easy work to add the finest details while keeping a reasonable file size and providing powerful navigation functions. Moreover, VRML is not available under all various operating systems.

Unlike VRML, Java 3D proves a more powerful and cross-plattform language. Java 3D is developed on the basis of OpenGL (Open Graphics Library) and DirectX. Java3D is an object-oriented computer language. It possesses a lot of functions for graphic display, and can be directly linked with pointing devices such as a mouse, thus allow an interactive manipulation of a 3D WebPages as shown in Figure 5.5[76]. Being developed as an extension to the Java language, Java 3D offers a high-level Application Programming Interface (API) for 3D scene description and graphical control. In this sense, it is tightly coupled with a fully capable programming language. Furthermore, because it is a Java API, Java3D allows a fully object-oriented approach to define and control the virtual agent and its environment. It is capable of providing better integration of 3D content, interface and events within the system. Java 3D’s sophisticated event model allows for interesting object interactions, such as object-to object connections, as well as a unified interface between timer and scene change events. Java3D is also designed to take advantage of multi-threaded programming techniques, allowing for better performance from the implementation (Arya & Harron 2004).

5.5 Scalable Vector Graphics

Data visualization sometimes involves in the expression of the data format. Scalable Vector Graphics (SVG) plays an important role for this purpose. SVG is a family of specifications of

[76] http://www.johnmunsch.com/images/Java3DFlyThrough.jpg

an XML-based file format for describing 2D static or dynamic vector graphics[77].

The SVG specification has been under development by the World Wide Web Consortium (W3C) since 1999. SVG images and their behaviors are defined in XML text files. This means that they can be searched, indexed, scripted, required and compressed. Since they are XML files, SVG images can be created and edited with any text editor, but specialized SVG-based drawing programs are also available. All major web browsers support and can render SVG markup directly (Peter 2008, Dean 2010).

Figure 5.5 Java 3D virtual scene

SVG allows three types of graphic objects:

- Vector graphics
- Raster graphics
- Text

The SVG 1.1 specification defines 14 important functional areas or feature sets: Paths, Basic Shapes, Text, Painting, Color, Gradients and Patterns, Clipping, Masking and compositing, Filter Effects, Interactivity, Scripting, Animation, Fonts, and Metadata (Huang 2008). Two mobile profiles were introduced with SVG 1.1: *SVG Tiny* (SVGT) and *SVG Basic* (SVGB). These are subsets of the full SVG standard, mainly intended for user agents with limited capabilities. In particular, SVG Tiny was defined for highly restricted mobile devices such as cell phones, and SVG Basic was defined for higher-level mobile devices, such as PDAs. Images can be rasterised using a library such as ImageMagick, which provides a quick but incomplete implementation of SVG, or Batik, which implements nearly all of SVG 1.1 and much of SVG Tiny 1.2 but requires the Java Runtime Environment (Andersson et al. 2008).

An example

SVG is an open format, free, and easy to learn. An example is shown in Table 5.3[78], Figure 5.6 and Figure 5.7 with SVG, the worldwide partner universities of TUM are visualized.

[77] http://en.wikipedia.org/wiki/Scalable_Vector_Graphics

[78] http://portal.mytum.de/international/kooperationen/partneruniversitaeten/index_html/document___view?

Table 5.3 156 Partner universities of TUM

Nr.	Partner Universities of TUM	Date	Representative
1.	University of Illinois, Urbana, Illinois/USA	30.07.1974	IO
2.	Technische Hochschule Huazhong, Wuhan/China	10.09.1980	Prof. E. Steinbach
3.	Tokyo Institute of Technology , Japan	15.01.1982	IO / Prof. T. Bock
…	...	…	…
154.	Chulalongkorn-University , Thailand	30.11.2009	IO
155.	Peking University, VR China	11.12.2009	Prof. L. Meng
156.	Harbin Engineering University, VR China	27.05.2010	IO

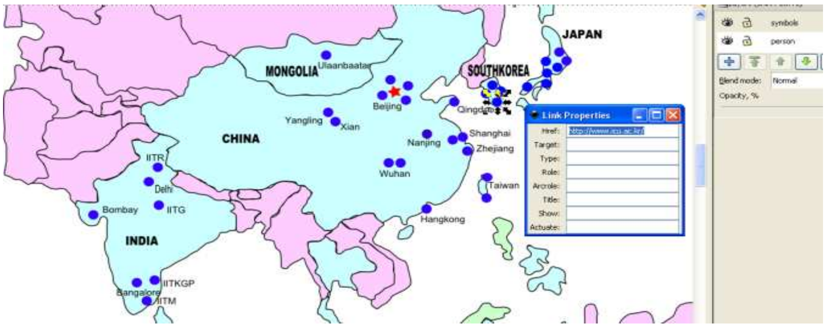


Figure 5.6 Each blue dot is hyperlinked to the corresponding partner university

Using inkscape, firefox or Arcmap, partner universities of TUM worldwide or in different contitents can be accessed and displayed in a cascading manner as shown in Figure 5.8.

Each blue dot on the map is in turn linked with the corresponding university. Its frame information will be displayed with a single mouse click while its website information can be accessed with a double click. No doubt, the widespread enabling software will make SVG a useful visualization tool for time-critical applications.

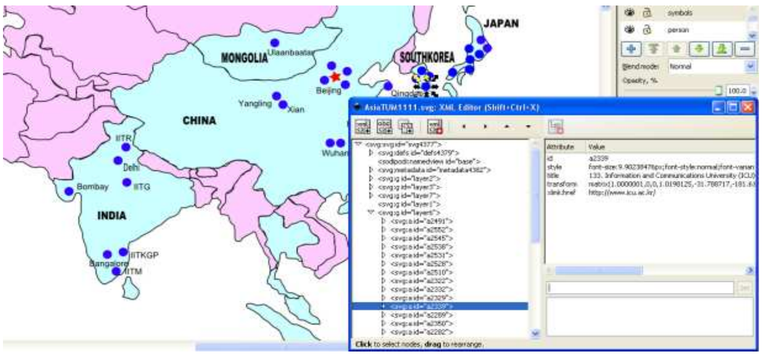
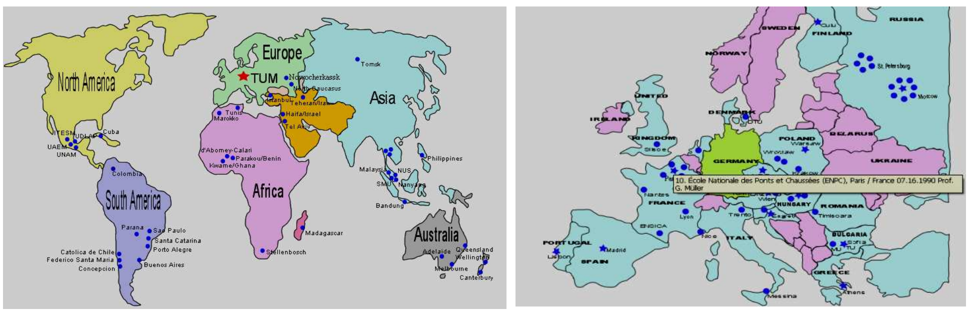


Figure 5.7 Input of attribute data using XML Editor.



(a) (b)

Figure 5.8 SVG maps showing the TUM partners in the world and Europe

(a): SVG TUM partners in the world (b): SVG showing the TUM partners in Europe

Chapter 6

Implementation of post-quake rescue information system - a case study

6.1 Overview

Whenever an earthquake disaster strikes, human lives are threatened. How to rescue the besieged in the mass disaster has been a prevalent concern. Related researches and experiments are being carried out all over the world. In this case study, a database from Tianjin region in China is constructed. It mainly contains information about administrative division and statistic population. With the assistance of Web & wireless GIS server and the standard WMS and WFS of OGC, it releases maps and attributes from distinct databases. Meanwhile, it uses OpenLayers to upload the images of Google Map and can thus superimpose further information on image maps. Network clients can receive all map information by means of the wireless web browser. The GPS technique makes it possible for clients to check up their location on the network map so that they can rescue themselves when they are trapped. Moreover, their positions can be instantly transmitted to the web & wireless GIS server, which informs other clients such as the rescue centers of the position and assists them in finding out the direct route to carry out the rescue works. Figure 6.1 shows the functions of such a rescue system.

System implementation

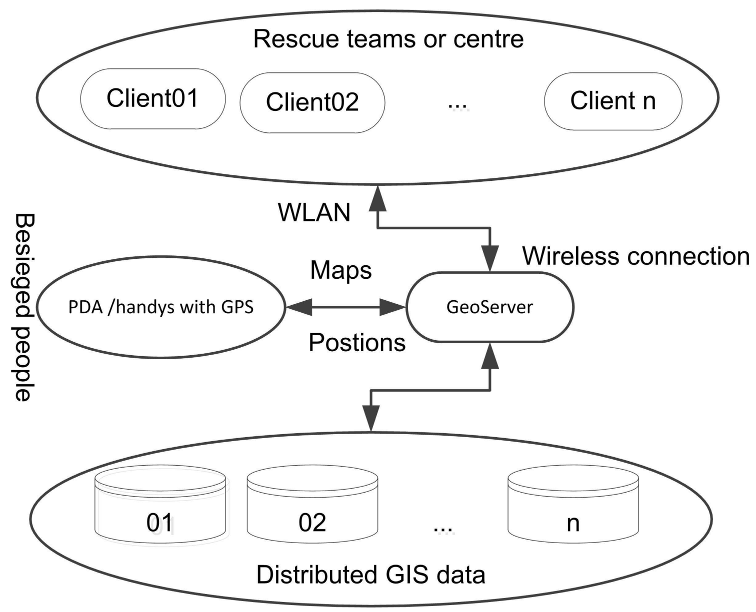


Figure 6.1 Functions of the rescue information system

The workflow of the rescue system is characterized by a number of steps: Construction of the database with a desktop system; Creation of local host website through which the distributed information will be released; Description of the information in the local host by GeoServer;

Spread the distributed information by GeoServer and peanut dynamic domain to press, civil emergency centre and volunteers who have access to the Internet or wireless devices. The process of demonstrated is in Figure 6.2.

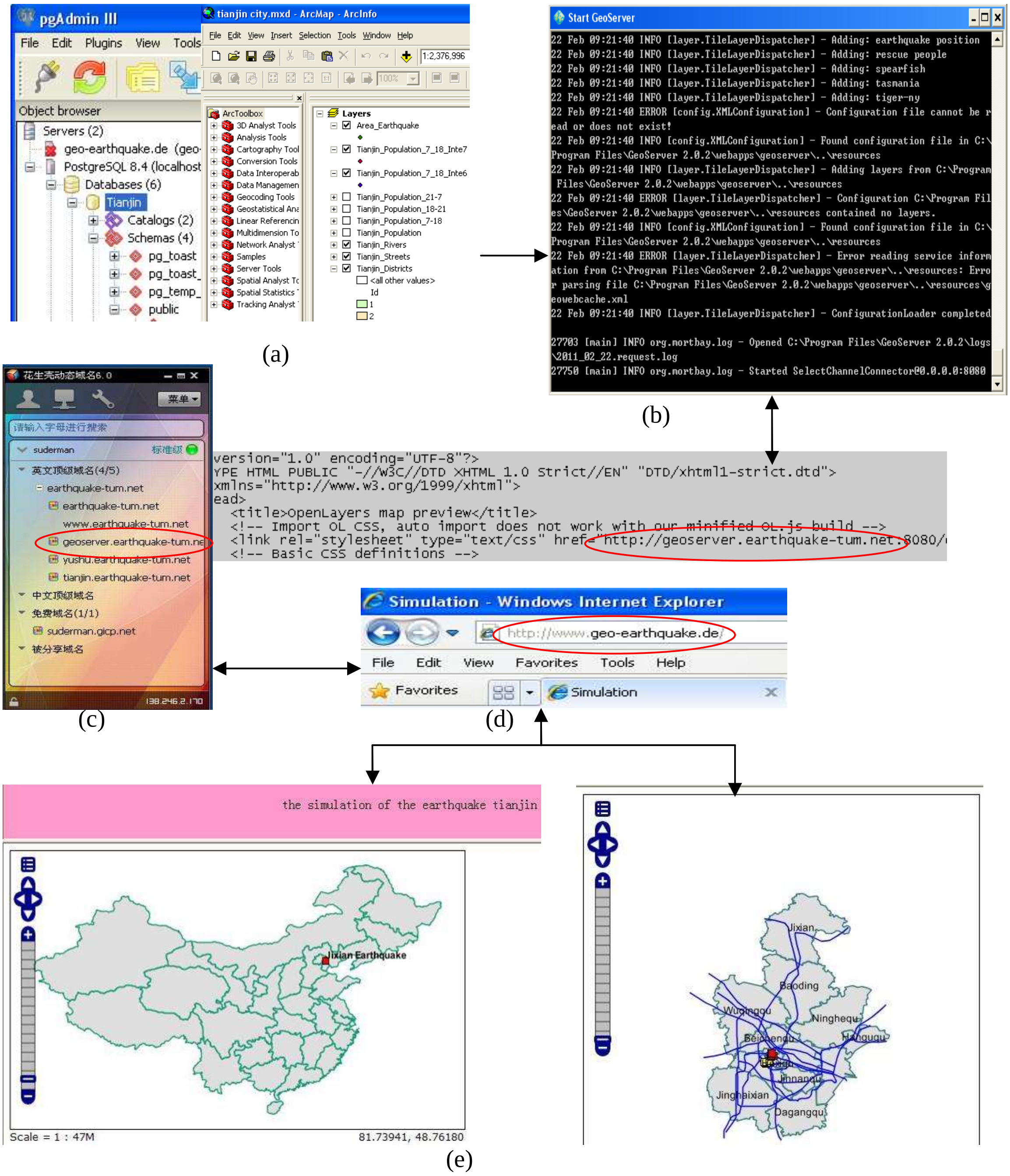


Figure 6.2 The process of information release

(a) Database creation (b) Run GeoServer (c) Run the peanut shell server, which is a special Web server, where the local host can links with the hosting of peanut shells "http://geoserver.earthquake-tum.de" (d) Web server (e) Web clients, implementation of the browser of GeoServer data

The user can visit the established GeoServer, for example www.geo-earthquake.de which is a domain name and the virtual host, can use a peanut shell to create a simple server built inside on the computer with the domain name www.earthquake-tum.net. Through a peanut shell, several sub-domain names can be linked and established. In the beginning, the user can see a few peanut shell addresses which are sub-domain names. Simulations are connected to www.geo-earthquake.de and www.earthquake-tum.net, and then are directed to access the established GeoServer which holds the data.

This functional chain is dependent on the related open source software and technologies.

6.2 Open source Web GIS software

6.2.1 Application technologies of open source Web GIS software

GPL: The licenses for most software are designed to restrict the freedom to share and change it[79], General Public License (GPL) is intended to guarantee the freedom to share and change free software and make sure the software is free for all the users. This General License applies to most of the Free Software Foundation's software and to any other program whose authors are committed to use it. GPL is an open source software license or copyleft license. The majority of GNU programs and more than half of the free software use it. The GPL grants the recipients of a software program the rights of the free software definition and uses copyleft to ensure the freedoms are preserved. The most important feature of GPL is that released software (such as: the most influential Linux) can modify, translate the derivative works, or even as long as any part of the codes GPL release, then all procedures are to be bounded by the GPL license, that is Continuously to comply with the provisions of GPL license, this is also called GPL's "viral effect"[80].

GeoTools, GeoServer use GPL license agreement. Several technologies adopted in the case study are introduced as follows:

Ajax (shorthand for Asynchronous JavaScript and XML) is a group of interrelated web development techniques used on the client-side to create interactive web applications. With Ajax, web applications can retrieve data from the server asynchronously in the background without interfering with display and behavior of exiting page. The use of Ajax techniques has led to an increase in interactive or dynamic interfaces on web pages. Data is usually retrieved using the XMLHttpRequest object. Despite the name, the use of XML is not actually required, nor do the requests need to be asynchronous[81]. Google Map is a typical example that uses Ajax to achieve Web content without refreshing update, request and display online maps (Jesse, 2008). Openlayers in this thesis also makes use of Ajax.

JSON: (JavaScript Object Notation) is a lightweight text-based open standard designed for human-readable data interchange. It is derived from the JavaScript programming language for representing simple data structures and associative arrays, called objects[82]. In other words, it will be sent to the browser's data encoding format from XML to JSON objects, JSON objects can be easily turned into a JavaScript object.

MVC design pattern: Model-view-controller is a design pattern used in software engineering[83]. Model is the main body of the application; view is responsible for generating the user interface part; controller is based on user input, controls and updates the data model of the user interface. MVC design pattern is composed of a model for the application development, an interface and separated display and data. OpenLayers for the case study use

[79] http://www.opensource.org/licenses/gpl-2.0.php
[80] http://en.wikipedia.org/wiki/GNU_General_Public_License
[81] http://en.wikipedia.org/wiki/Ajax_(programming)
[82] http://en.wikipedia.org/wiki/JSON
[83] http://en.wikipedia.org/wiki/MVC

an event-driven design pattern; it is a software architecture pattern promoting the production, detection, consumption of, and reaction to events.

6.2.2 Historical background and current situation of open source web GIS

Platform confrontation

GIS developers are still confronted with two platforms: J2EE and .NET. With the publication of Java 5.0, J2EE has been renamed to JavaEE (Perrone et al. 2003). .NET and the Integrated Development Environment tool Visual Studio 2005 were released by Microsoft[84]. Compared with the Java and .net platforms 2011, .NET has no evident advantages or disadvantages. Their differences can be only discerned in the requirement of the application and the user's habit. Consequently, it is comprehensible to provide interfaces for both Java and .NET to satisfy distinct demands.

Table 6.1 gives an overview of the main open source WebGIS platforms which are developed using the Java tool.

Table 6.1 Several major open source platforms of WebGIS

platform	Present version	Create data	Authorize protocol	Support form and interface									
				ESRI Shape	MapInfo MID/MIF	Oracle	MySQL	PostGIS	Other format*2	OGC*8 WMS*9 Server	OGC WFS*10 Server	OGC WCS*11 Server	MS .Net
Deegree[85]	2.0	2005	LGPL	√	√	√	√	√	GML2.1.1	√ *4	√ *5	√ *6	
Openmap[86]	4.6.2	2005	OpenMap License	√	√ *1	√ *3	√		VPF RPF DTED	√			√ *7
GeoServer[87]	1.3	2005	GPL 2.0	√		√	√	√	GML2.1.1 ArcSDE	√	√		
GeoTools[88]	2.1RC1	2005	LGPL	√		√	√	√	ArcGrid ArcSDE GeoMedia	√			
JShape[*12][89]	4.0	2004	JShape License[*13]	√									

*1 an entity only supports point
*2 raster format, JPEG, GIF, PNG, (Geo) TIFF, PNM, BMP
* 3 support needed for a separate class
* 4 compatible with OGC WMS 1.1.1
* 5 compliant OGC WFS 1.0.0
* 6 compatible with OGC WCS 1.0.0
* 7 limited support
* 8 OGC

[84] http://en.wikipedia.org/wiki/Microsoft_Visual_Studio
[85] http://deegree.sourceforge.net
[86] http://openmap.bbn.com
[87] http://geoserver.sourceforge.net
[88] http://www.geotools.org
[89] http://www.jshape.com

* 9 Web Map Service (WMS) based on Web services, raster and vector graphics
* 10 Web Feature Service (WFS) using GML format for Web-based transmission of vector graphics data services
* 11 Web Coverage Service (WCS) using Web-based format for transmission of raster graphics raster data services
* 12 supports J2SE/J2EE/J2ME and MIDP / KJAVA mobile development
* 13 not a completely free open source platform

Free global image data

Massive image data in storage and distribution technology formed a climax of GIS (Yuan and Atallah 2011). Now a variety of software environments are available for the easy preview and display of high-resolution remote sensing images. Images published in Google Earth have demonstrated the effect. Much work of professionals for remote sensing and GIS has been taken over by this globally prevailing platform, which has invoked the worldwide awareness of the performance of 3D GIS.

Real-time mobile maps and open source GIS

If the mobile device providers intend to deliver and map the locations of its customers, people may face the phone shouting "Hey, where are you" and the days of "positioning by roar" could be over. Currently available value-added mobile services include SMS, MMS / Cai E, WAP, Java / BREW, and IVR 5. With the rise of 3G networks and further improvement of mobile technologies along with the increasing open source GIS, the real-time map of mobile phone location services has become a reality.

Unlike commercial GIS software, the data for open source GIS software do not have the compatibility concern. Developers can focus on the function of the development. As a result of intensive research in the academic community, open-source GIS software has very advanced general functions. A number of different features of the open-source GIS software can be found under www.freegis.org site. There are a large number of established open source GIS software products such as GRASS, data conversion library OGR, GDAL (Geospatial Data Abstraction Library), library of map projection algorithms Proj4 and Geotrans. It is relatively simple to use desktop products such as Quantum GIS, Java platform, Map Tools and Map Server which provide a variety of tools for spatial analysis and calculations and support dynamic languages such as Python popular pet in the open source world. Open source GIS software is also easy to use. Many existing open-source GIS tools provide a Python interface to facilitate system integration.

6.3 Composition of the open source web GIS

6.3.1 System structure

Common GIS applications include a GIS kernel, spatial data import/conversion, spatial data engine, application servers, desktop applications web applications and mobile device applications. Each actual application may require trade-offs among these components.

Geotools

Geotools is a Java-based middleware platform. With an open source GIS API the fundamental GIS functions can be accessed. The GeoServer in this case study is built on the basis of GeoTools[90].

Spatial Data Import

It is responsible for the conversion of geographic data from external files, databases, and

[90] http://www.giswiki.org/wiki/GeoTools_(Java)

WMS / WFS servers. In the case study, Shape file format from ESRI is adopted.

Google Map does not use a standard WMS / WFS protocol. In order to get free access to high-resolution satellite maps of Google Map, users can call the Google Map API which provides customized WMS / WFS layers.

Spatial Data Engine

While commercial GIS is typically built upon Oracle, DB2, ArcSDE, open-source web GIS tend to adopt PostgreSQL and MySQL. Our case study uses PostgreSQL.

Application server

GeoServer is a J2EE-based open GIS application server, implements OGC (Open Geospatial Consortium) developed by WMS and WFS (WFS-T) specifications. As the central part of a GIS application system, GeoServer has the responsibility for business processing tasks and support the formats of Google Earth KML/KMZ. It is worthwhile to mention that GeoServer can serve both desktop computers and mobile devices.

Desktop applications (client/server)

Open source desktop applications are represented by the user friendly Desktop Internet GIS uDig which is a use of Eclipse RCP (*Eclipse* Rich Client Platform) and the GeoTools and can perform its function at a fast speed.

Web applications (browser/server)

OpenLayers is a use of AJAX technology, the development of WebGIS client, its internal structure is based on MVC (Model-View-Controller). It has good readability and scalability, and is compatible with Firefox 1.0 +, Internet Explorer 6.0 +, Mozilla 1.3 +, Navigator 6 + and other browsers.

Mobile Clients

Spot is of mobile device-based mapping and navigation software. Its maps can be accessed through the OGC WMS[91]. It provides a Bluetooth GPS interface. The software belongs to sharing software, but the access to GPS interfaces is not free of charge.

6.3.2 GeoServer

Effect and purpose

GeoServer is the core of webGIS. It uses OGC standards to collect the source data and get linked with clients, thus enables users to obtain the required maps, attribute data and webGIS services. GeoServer is used in the case study to create earthquake maps and provide networked information services for trapped people and rescue teams in disaster regions.

System requirements and installation

Our GeoServer in the case study can run under Windows and Linus. Java is used as its operating environment. Therefore, a Java JDK runtime environment is installed first by downloading the JDK from [92] and setting a JDK path in the environment variable. From [93] an installation package GeoServer.exe can be downloaded. Upon the completion of the installation, the GeoServer can be started, following the Start menu Geoserver - Start GeoServer. Once the server is started, a browser can be opened by entering "http://localhost:8080/geoserver" and the Geoserver welcome interface appears as shown in Figure 6.3.

Data conversion and upload

[91] http://www.skylab-mobilesystems.com/downloads/spot/manual_bb.pdf
[92] http://java.sun.com
[93] http://geoserver.org/

- Data conversion

Since our GeoServer supports ESRI Shape file format SHP, it requires the conversion of all GIS data formats to SHP before the data are transmitted and distributed to clients.

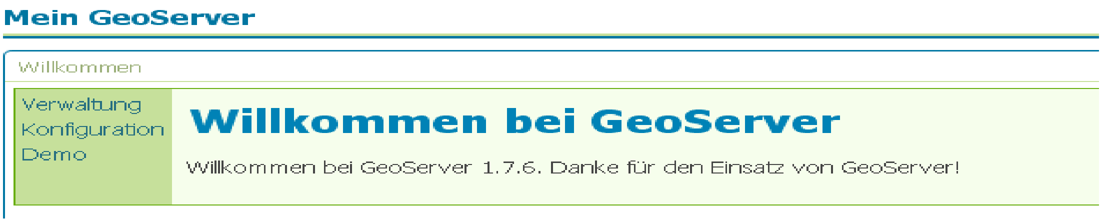


Figure 6.3 The staring interface of the GeoServer

- Release of SHP data

At first, a DataStore and a FeatureType are respectively created as shown in Figure 6.4 and Figure 6.5 by following the available instructions step by step.

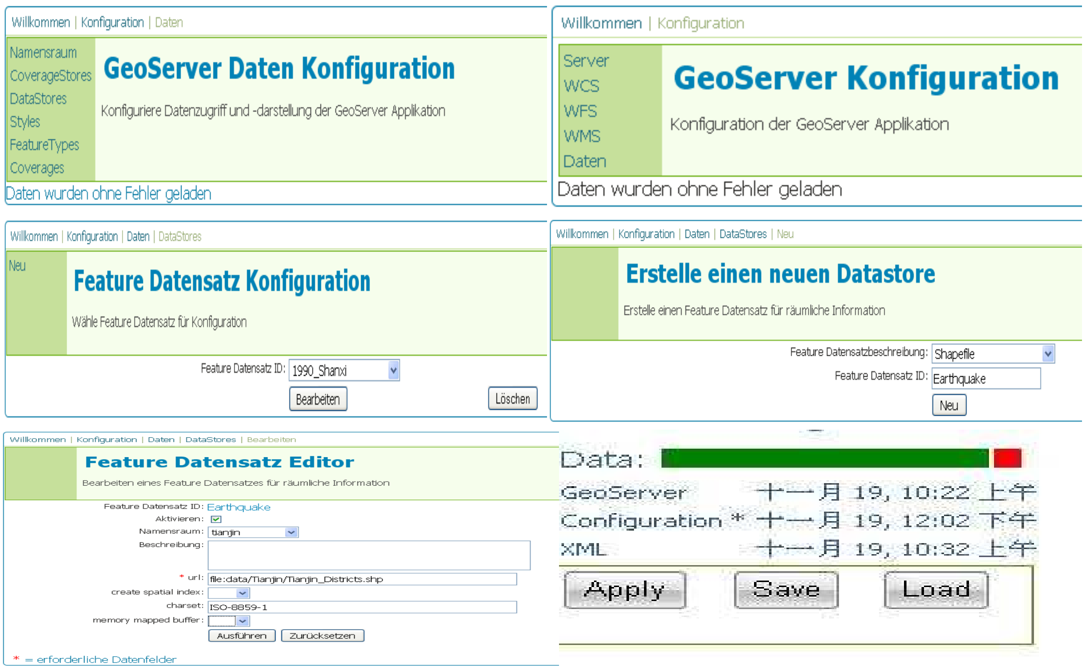


Figure 6.4 Creation of data storage

Data browsing

- The following website is created for the FeatureType in our case study:

http://localhost:8080/geoserver/wfs?request=getfeature&service=wfs&version=1.0.0&typename=Tianjin_Districts

An excerpt looks as follows:

-<wfs:FeatureCollection xsi:schemaLocation="http://localhost:8080/
http://localhost:8080/geoserver/wfs?service=WFS&version=1.0.0&request=DescribeFeatureType&typeName=tianjin:
Tianjin_Districts http://www.opengis.net/wfs http://localhost:8080/geoserver/schemas/wfs/1.0.0/WFS-basic.xsd">
−<gml:boundedBy>
<gml:null>unknown</gml:null>
</gml:boundedBy>
−<gml:featureMember>
−<tianjin:Tianjin_Districts fid="Tianjin_Districts.1">

−<tianjin:the_geom>
−<gml:MultiPolygon srsName="http://www.opengis.net/gml/srs/epsg.xml#4326">
−<gml:polygonMember>
−<gml:Polygon>
−<gml:outerBoundaryIs>
−<gml:LinearRing>
−<gml:coordinates decimal="." cs="," ts=" ">
117.23301227, 39.87011423 117.23042847, 39.88034166 117.22978162, 39.89521921 117.22040228, 39.90201114 117.20875898, 39.89586607 117.20293732, 39.89263181

……………………….
117.2989431, 39.83791545 117.30047638, 39.84481519 117.28284371, 39.84864838 117.27287743, 39.85094829 117.26061123, 39.85554812 117.26444441, 39.86168122 117.2498783, 39.86628104 117.23301227, 39.87011423
</gml:coordinates>
</gml:LinearRing>
</gml:outerBoundaryIs>
</gml:Polygon>
</gml:polygonMember>
</gml:MultiPolygon>
</tianjin:the_geom>
<tianjin:Id>1</tianjin:Id>
<tianjin:Name>Jixian</tianjin:Name>
<tianjin:Area>159300000</tianjin:Area>
<tianjin:Population>810000</tianjin:Population>
<tianjin:City>Tianjin</tianjin:City>
<tianjin:State>China</tianjin:State>
</tianjin:Tianjin_Districts>
</gml:featureMember>
−<gml:featureMember>
−<tianjin:Tianjin_Districts fid="Tianjin_Districts.2">
−<tianjin:the_geom>
…………………..

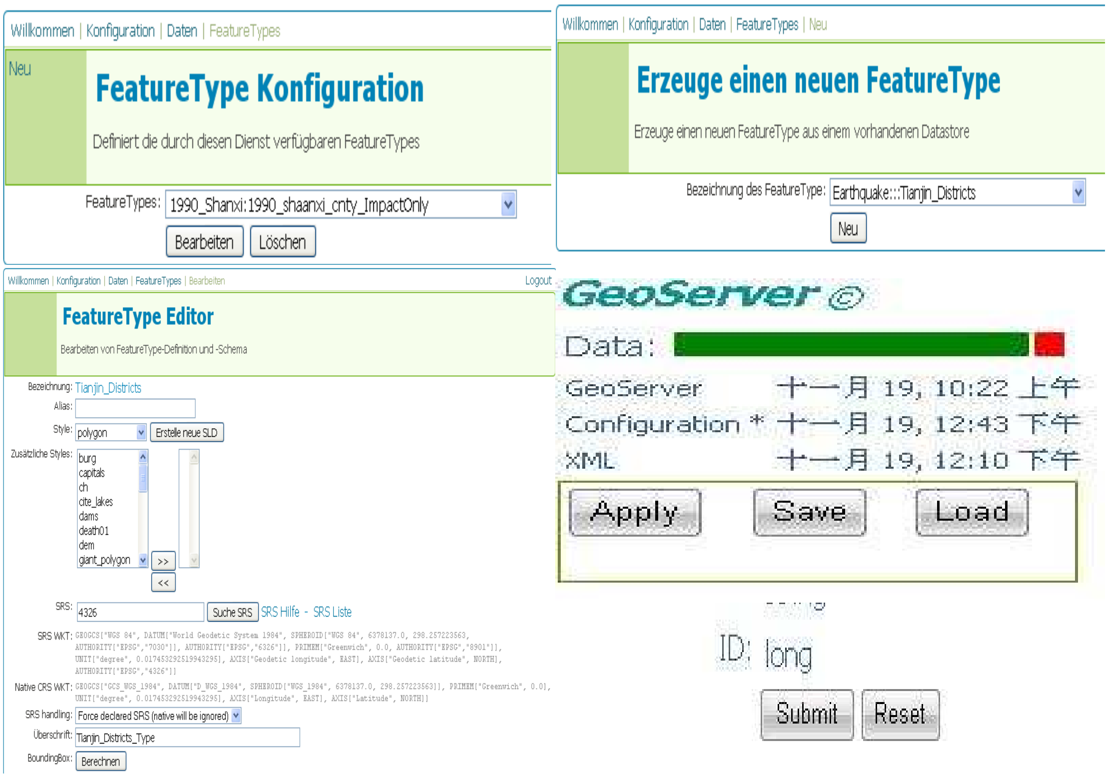


Figure 6.5 Creation of FeatureType

The WMS is available under:

http://localhost:8080/geoserver/wms/kml_reflect?layers=Tianjin_Districts

This link can be opened via Google Earth. Its layers can be overlapped with GoogleEarth image map as shown in Figure 6.6.

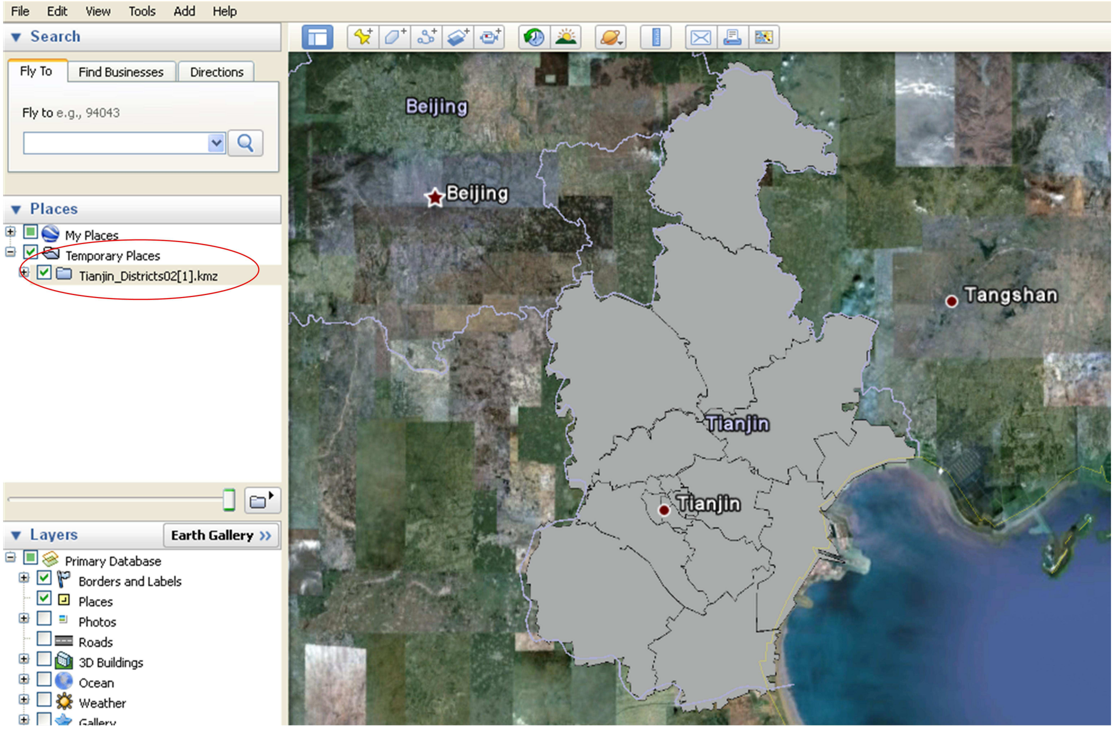


Figure 6.6 Layers of the test bed Tianjin overlaid on Google Earth image map

6.3.3 PostgreSQL and PostGIS

The rescue database in the case study is constructed using the object-relational database management system PostgreSQL[94]. PostgreSQL is released as open source software under an MIT-style license. Like many other open source programs, PostgreSQL is not controlled by any single company, but it has a global community of developers and users.

PostgreSQL is evolved from the Ingres project at University of California, Berkeley (Worsley et al. 2002). Many ideas of Ingres were propagated to PostgreSQL which has added the newest features such as the ability to define types and to describe relationships. PostgreSQL can retrieve information in related tables using rules. It has been maintained by a group of database developers and volunteers around the world. The PostgreSQL project continues to make major releases (approximately annually) and minor "bugfix" releases, all available under the same license, based on contributions from proprietary vendors, support companies, and open source programmers at large.

PostGIS is an extension of PostgreSQL with the purpose to support spatial data store and application, similar to the Spatial Extension of ArcSDE and Oracle. Being issued by the GPL license, PostGIS has fully realized “Simple Features specification for SQL” of OGC standard and got OGC authentication in 2006.

As mentioned in the previous section, Shape file format of ESRI Company is popularly supported and adopted for our case study. Although GeoServer can quickly create online map services by using Shape file, some disadvantages of Shape file should be kept in mind:

- Shape file supports only one layer, thus has limited significance in practice;

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[94] http://en.wikipedia.org/wiki/PostgreSQL

- Direct storage of data in Shape file is not safe because Shapefile data can be easily contaminated by viruses and wrongly deleted;
- Shape file used for source data is inefficient;
- Some words cannot be analyzed in Shape file.

PostGIS database

To overcome the disadvantages of Shape files and make geographical information more convenient to query, a PostGIS database is generated using postgreSQL. A screen shot is shown in Figure 6.7.

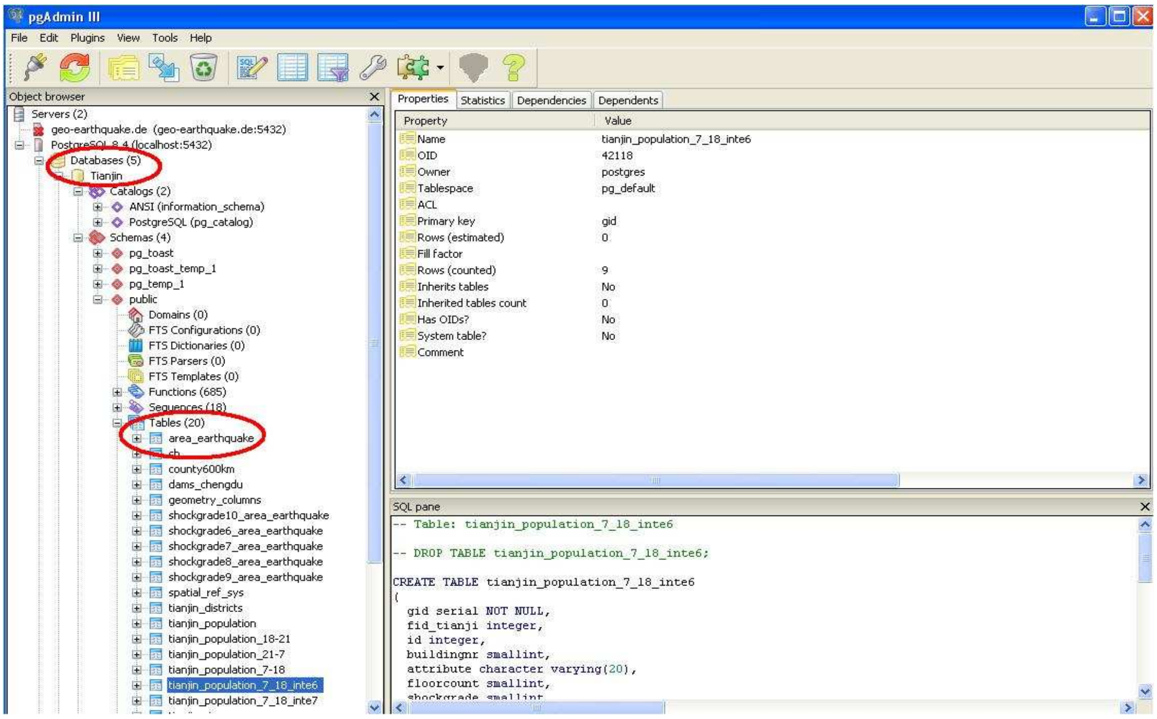

Figure 6.7 PostGIS database generated using PostgreSQL

6.3.4 OpenLayers

OpenLayers is an open source JavaScript library for map display in web browsers. It provides an API for the web-based geographic applications similar to Google Maps and Bing Maps. The library includes components from the Rico JavaScript library and the Prototype JavaScript Framework. OpenLayers is used by *OpenStreetMap* project for its "Slippy Map" map interface[95].

The access method of OpenLayers to geo-spatial data follows the industry standards such as WMS and WFS of OpenGIS. OpenLayers uses object-oriented organization and some components of Prototype.js (Prototype of java script) and Rico (Reco java script). The maps supported by OpenLayers include WMS, Google Maps, KaMap MSVirtualEarth etc. New versions of OpenLayers provide vector drawing functions, allows therefore dynamic display of primitives such as points, lines and polygons. In addition, users can define a utility class of OpenLayers to perform some reusable functions. OpenLayers can be downloaded from the website www.openlayers.org and unpacked.

The released data listed in Figure 6.8 is provided by GeoServer. GeoServer can also release raster data in tiff format without redundancy.

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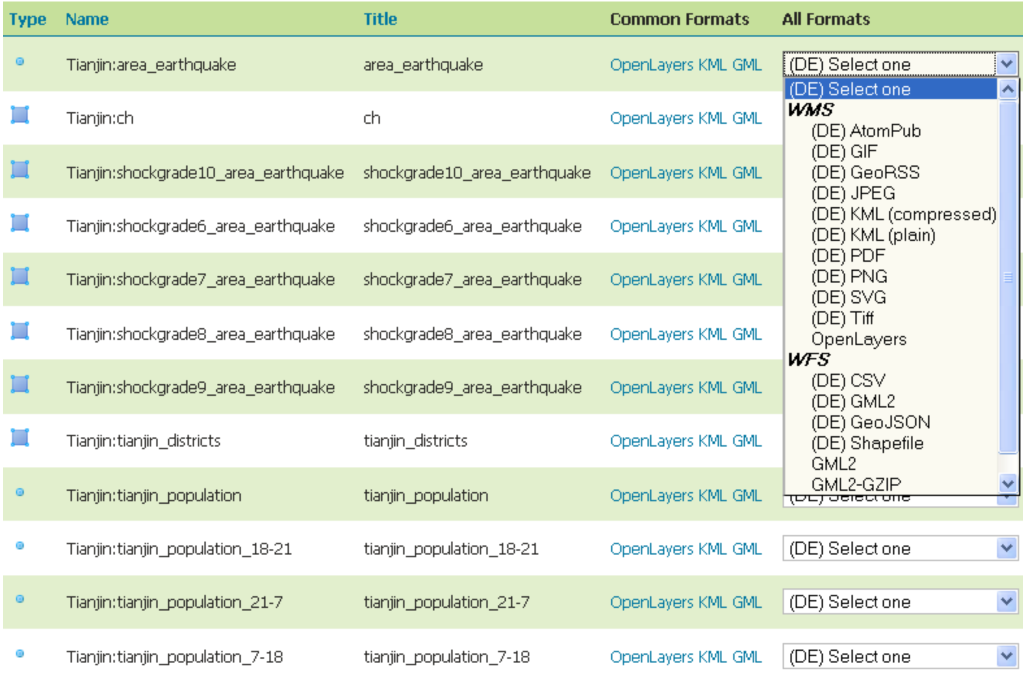
[95] http://en.wikipedia.org/wiki/OpenLayers



Type	Name	Title	Common Formats	All Formats
	Tianjin:area_earthquake	area_earthquake	OpenLayers KML GML	(DE) Select one
	Tianjin:ch	ch	OpenLayers KML GML	
	Tianjin:shockgrade10_area_earthquake	shockgrade10_area_earthquake	OpenLayers KML GML	
	Tianjin:shockgrade6_area_earthquake	shockgrade6_area_earthquake	OpenLayers KML GML	
	Tianjin:shockgrade7_area_earthquake	shockgrade7_area_earthquake	OpenLayers KML GML	
	Tianjin:shockgrade8_area_earthquake	shockgrade8_area_earthquake	OpenLayers KML GML	
	Tianjin:shockgrade9_area_earthquake	shockgrade9_area_earthquake	OpenLayers KML GML	
	Tianjin:tianjin_districts	tianjin_districts	OpenLayers KML GML	
	Tianjin:tianjin_population	tianjin_population	OpenLayers KML GML	
	Tianjin:tianjin_population_18-21	tianjin_population_18-21	OpenLayers KML GML	(DE) Select one
	Tianjin:tianjin_population_21-7	tianjin_population_21-7	OpenLayers KML GML	(DE) Select one
	Tianjin:tianjin_population_7-18	tianjin_population_7-18	OpenLayers KML GML	(DE) Select one

Figure 6.8 Layers and the preview map

6.3.5 Google Maps API

Google Maps has a wide array of APIs that allow their users to embed the robust functionality of Google Maps in their own websites and applications and overlay their own thematic layers on the top of Google image maps.

Before using Google Maps API, one has to apply for a key to Google. The method is rather straightforward as long as the website in which the Google Maps should be embedded is known. In our case study, it is "www.geo-earthquake.de:8080/geoserver".

Google Maps API does not have problems concerned with browser compatibility and support a number of popular browsers such as Firefox/Mozilla, Internet Explorer 5.5+, Safari 1.2+ and Opera.

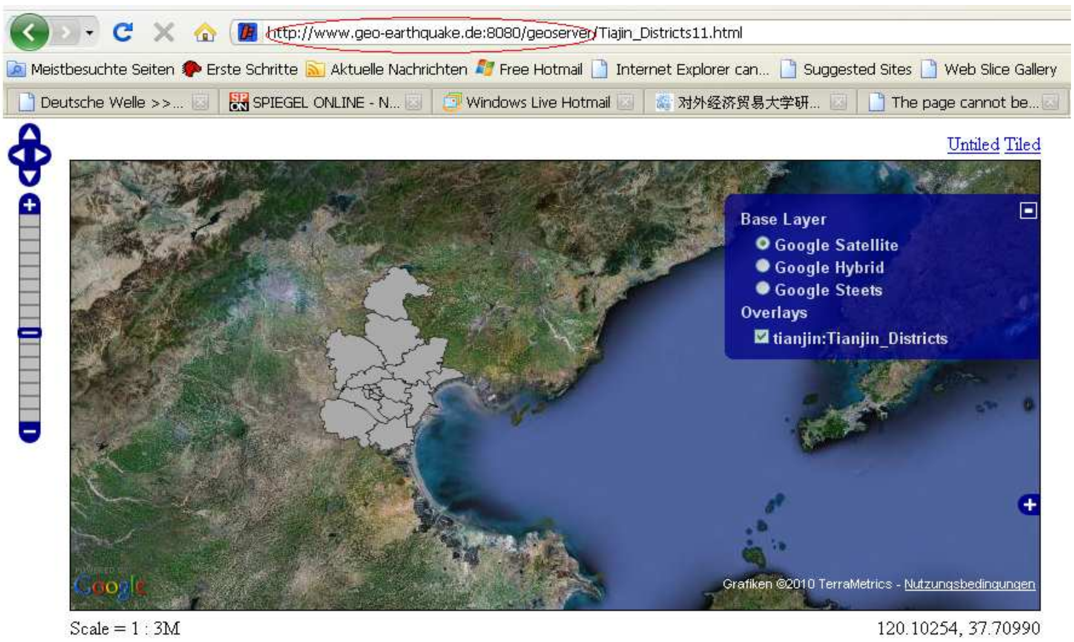


Figure 6.9 Google image map and the overlay of thematic information

Once the Google Map is downloaded to the client's terminal with Openlayers, further thematic layers can be superimposed on the image. As shown in Figure 6.9, the administrative boundaries of Tianjin Districts are overlaid over the optional layers of Google Map (satellite image, streets or both). Its corresponding script is expressed as follows:

> *Googlesatellite = new OpenLayers. Var. Google (" Google Layer type ", {Satellite G_SATELLITE_MAP: maxZoomLevel, ' ': 18}),*
> *Googlesatellite [j addLayers (map),*
> *Googlebybrid = new OpenLayers. Var. Google (" Google Layer type: Hybrid ", G_HYBRID_MAP} (),*
> *Googlebybrid [j addLayers (map),*
> *GMapsStreets = new OpenLayers. Var. Google (" Google Layer type {Steets ", G_NORMAL_MAP: maxZoomLevel, ' ': 18}),*
> *GMapsStreets [j addLayers (map),*

6.3.6 Browsers of networked terminal and desktop GIS

Internet Explorer or Firefox

Internet Explorer is a graphic web browser, developed by Microsoft. It runs on Microsoft Windows, Apple Macintosh and UNIX. Mozilla Firefox is an experimental project developed by Mozilla, and was created by Dave Hyatt and Blake Ross.

Google Earth

Google Earth is a virtual globe, map and geographic information program. It was originally called EarthViewer 3D and created by Keyhole, Inc., a company acquired by Google in 2004. It maps the Earth by the superimposition of satellite imagery, aerial photos and GIS 3D globe[96]. The Internet is affecting GIS in three major areas: GIS data access, spatial information dissemination and GIS modeling/processing (Peng and Tsou, 2003). Google Earth has been praised in conducting research in 3D space for a range of scientific projects (Butler 2006; Pearce 2007; Nourbakhsh & Sargent 2006) and the use of Google Maps API and GML (Geographic Mark-up Language) have revealed a great potential for developing Internet GIS solutions (Chow, 2008). Google Earth is a tool based on global coverage and adopts the WGS84 (World Geodetic System 1984 Co-ordinate Reference System). Hence, for geospatial datasets that are in a projected map coordinate system, it is essential to pre-process the data by transforming the map projection into latitude and longitude before loading geometries into the database (Henry 2009). Google Earth and other geobrowsers afford tremendous ease of access and use which no traditional GIS has ever managed to achieve (Goodchild, 2008).

Loading and browsing the layers from GeoServer

Google Earth provides economic flexible overview. Users can view the location information and analyze the geographical spatial relationships. Google Earth must create customized interfaces that can output its data formats KML or KMZ in compression or uncompressed way. In our case study, GeoServer adopts standard WMS format and is used to output KML/KMZ data. Recently a KML reflector public procedure has been developed. Users can now output KML/KMZ without having to adjust the WMS (Wilson 2008; Shepherd 2008; Chow 2008).

6.3.7 uDig

uDig is a GIS software program produced by a community led by Canadian-based consulting company Refractions Research. It is based on the Eclipse platform and features full layered

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[96] http://en.wikipedia.org/wiki/Google_Earth

Open Source GIS. It is written in Java and released under GNU General Public License. uDig has a walkthrough in Flash with quick learning instructions. uDig can use GRASS for complex vector operations and also embeds JGRASS and specialized hydrology tools from the Horton Machine. It supports shapefiles, PostGIS, WMS, and many other data sources[97].

As open-source desktop GIS software based on EclipseRCP and GeoTools, uDig supports public standard released by OpenGIS, especially WMS and WFS. Besides, it can edit and check map files in shapefile format. It is not only an application but also can be used as a core platform for the development of new desktop/Internet GIS. In the case study, uDig is adopted for the convenient color design and editing of file format SLD (Style Layer Descriptor) supported by GeoServer. By means of SLD, elements of a rendered layer, such as the layer Tianjin_Districts, can be refreshed as shown in Figure 6.10. uDig also can edit the released data, create maps and modify data functions.

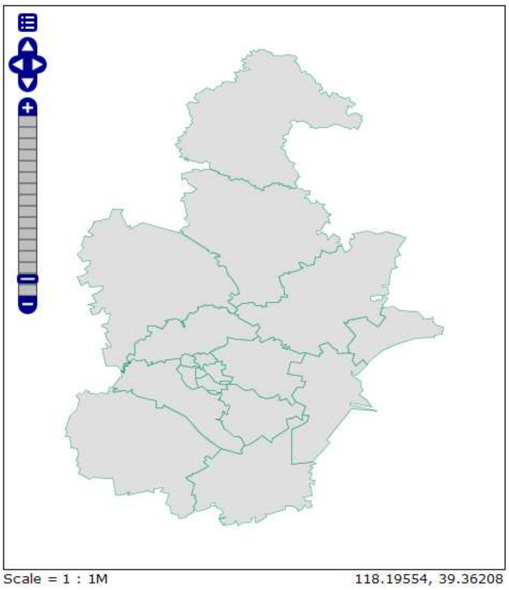

Figure 6.10 the layer of Tianjin district refreshed by means of SLD

6.4 Post-quake evaluation and rescue information system

6.4.1 System requirements

- A desktop GIS: Since GeoServer supports shapefile format developed by ESRI. The currently popular ArcGIS of ESRI is adopted for the case study. In principle, other desktop GIS can also be used as long as their files can be converted to the shapefile format;
- GeoServer: The widespread windows and Unix operation system can be easily connected with the Internet. Both are therefore suitable to support the GeoServer which, however, should assure the real-time data acquisition and post-quake evaluation so as to guide the rescue work;
- Virtual host and Website: The information must be released through virtual host which can be accessed by clients. At the same time, special-purpose website is necessary as the interface to release the information and assure the connection;
- Client: For stationary users, computer or notebook must be equipped with Internet

97 http://en.wikipedia.org/wiki/UDig

Explorer or Firefox to connect the cabled and / or wireless networks. For mobile users, wireless connection is necessary;

- GPS receiver: It is necessary to receive and send coordinators of users to and from the server.

6.4.2 The coordinate system

Since the post-quake evaluation and rescue work needs a close connection with Google map and Google Earth image map which are WGS84 (World Geodetic System 84), our GeoServer adopts the same coordinate system and allows the transformation to other coordinate systems. Being conformal to maps of OpenLayers, EPSG:4326 is adopted as the default projection for our case study. Maps based on other projections can be transformed to the default projection by adjusting the parameters during the installation. The following script explains the transformation routine:

SimpleMap = OpenLayers.Class (OpenLayers.Map,{nitialize: function (div, options){
OpenLayers.Map.prototype.initialize.apply (this,[div,options]) installate the map, then use this.projection=new OpenLayers.Projection("EPSG:900913"))
Show the coordinates of present map, such as EPSG: 900913 is Mercator coordinates, at the same time use
this.displayProjection=new OpenLayers.Projection("EPSG:4326")

Its corresponding codes in Java are

```
SimpleMap = OpenLayers.Class(OpenLayers.Map,{
   /*Install the map according to the map parameters of map engine */
   initialize: function (div, options){
  OpenLayers.Map.prototype.initialize.apply(this,[div,options]);
      //the present map adopt    coordinates(Mercator coordinates)
      this.projection=new OpenLayers.Projection("EPSG:900913");
         //adopt coordinates of data
      this.displayProjection=new OpenLayers.Projection("EPSG:4326");
      this.units="m";
      //this.numZoomLevels=16;
      //this.maxResolution=78271.51695;
      //this.numZoomLevels=15;
      //this.maxResolution=39135.758475;
      this.numZoomLevels=14;
         //Resolution=20037508*2/256*2^(zoom+1),zoom value 0~15
      this.maxResolution= 19567.8792375;
      //matching longitudes and latitudes（-180，-90，180*2，90）
      this.maxExtent=new OpenLayers.Bounds(-20037508, -20037508,20037508*2,20037508);
      this.restrictedExtent=new OpenLayers.Bounds(6679169.333,0,20037508*2,13358338.667);
      this.restrictedExtent=new OpenLayers.Bounds(-20037508, -20037508,20037508*2,13358338.667);
      this.addLayer(new SimpleTileCache("baseMap",TILE_PIV_URL,{isBaseLayer:true}));
      this.div.oncontextmenu = function () { return false;};
      if(CENTER_LONLAT){
         this.zoomToLonLat(new OpenLayers.LonLat(CENTER_LONLAT[0],CENTER_LONLAT[1]),DEFAULT_ZOOM);
      }
   },
   /**
    * the coordinates of location to coordinate points, input points is the same with the showing coordinates
    *  lonlat the same with showing coordinates points { OpenLayers.LonLat }
    *  zoom   Zoom series        { Integer }
    */
   zoomToLonLat: function(lonlat,zoom){
      var p=lonlat.transform(this.displayProjection,this.getProjectionObject());
      this.setCenter(p,zoom,false,true);
   },
   CLASS_NAME:"SimpleMap"
});
```

Where CENTER_LONLAT is a longitude-latitude coordinates array. ZoomToLonLat is a function for the transformation of coordinates, which requires downloading the projection packet Proj4j.js. this.getProjectionobject returns the function of the wanted projection. The present map in the example is displayed using Mercator projection. Its coordinates need to be transformed to the default projection.

6.4.3 Data preparation

Data layers and graphic layers

As mentioned in previous sections, the GeoServer can be constructed in a relatively straightforward way with rather modest system requirements. Although its stability needs further improvements, it can meet the requirements of usual applications for data dissemination. Meanwhile, Openlayers can also implement calls to distributed data and explore geography information on the client side. For the case study, some city blocks in Tianjin area are selected and processed with the desktop GIS ArcMap. The main layers are listed in Table 6.2. Besides, with the help of the super edition of Geoserver, graphic layers can be generated as shown in Table 6.3.

Table 6.2 The main information layers of the test bed

Data describe	PostGIS		Geoserver	
	Table	**function**	**Name**	**Title**
Administration region of China	Ch	Basis layer	Tianjin:ch	Ch
Administration region of Tianjin	Tianjin_districts	Basis layer	Tian-jin:tianjin_districts	Tianjin districts
Tianjin Traffic	Tianjin_street	Basis layer	Tian-jin:tianjin_street	Tianjin street
Tianjin water	Tianjin_rivers	Basis layer	Tian-jin:tianjin_rivers	Tianjin rivers
Tianjin total population	Tianjin_population	Demographic information	Tian-jin:tianjin_population	Tianjin_population
Time 7-18 reference people in earthquake	Tianjin_population_7-18	Demographic information	Tian-jin:tianjin_population_7-18	Tian-jin_population_7-18
Time 18-21 reference people in earthquake	Tian-jin_population_18-21	Demographic information	Tian-jin:tianjin_population_18-21	Tian-jin_population_18-21
Time 21-7 reference people in earthquake	Tianjin_population_21-7	Demographic information	Tian-jin:tianjin_population_21-7	Tian-jin_population_21-7
7 Intensity district trapped population	Tian-jin_population_7_18_Inte7	Demographic information	Tian-jin:tianjin_population_7_18_Inte7	Tian-jin_population_7_18_Inte7
6 Intensity district trapped population	Tian-jin_population_7_18_Inte6	Demographic information	Tian-jin:tianjin_population_7_18_Inte6	Tian-jin_population_7_18_Inte6
Epicenter location	Area_earthquake	Epicenter geographic location	Tian-jin:area_earthquake	Area_earthquake
6 Intensity district	Shock-grade6_area_earthquake	Intensity region size	Tian-jin:shockgrade6_area_Earthquake	Shock-grade6_area_earthquake
7 Intensity district	Shock-grade7_area_earthquake	Intensity region size	Tian-jin:shockgrade7_area_earthquake	Shock-grade7_area_earthquake
8 Intensity district	Shock-grade8_area_earthquake	Intensity region size	Tian-jin:shockgrade8_area_earthquake	Shock-grade8_area_earthquake
9 Intensity district	Shock-grade9_area_earthquake	Intensity region size	Tian-jin:shockgrade9_area_earthquake	Shock-grade9_area_earthquake
10 Intensity district	Shock-grade10_area_earthquake	Intensity region size	Tian-jin:shockgrade10_area_Earthquake	Shock-grade10_area_earthquake

6.4.4 Post-quake rescue information system

Once the GeoServer and the Internet collections are prepared, data are ready to be accessed and distributed to the target groups involved in rescue work. The configuration of the distributed GeoServer for post-quake rescue work in Tianjin is demonstrated in the Figure 6.11 The usage of a post-quake rescue information system.

The rescue work supported by the information system typically involves several aspects.

- Information retrieval

By means of functions embedded in OpenLayers, relevant data for rescue work can be retrieved from the available GeoServer and Google map server. The retrieval is for example reflected in the following script:

Table 6.3 Graphic layers of the test bed

Layer name	Layer describe	Including layer	
		Name	**Title**
Tianjin earth-quake position China	The location of the earthquake in the country	Tianjin:ch	Ch
		Tianjin:area_earthquake	Area_earthquake
		Tianjin:shockgrade6_area_earthquake	Shockgrade6_area_earthquake
		Tianjin:shockgrade7_area_earthquake	Shockgrade7_area_earthquake
		Tianjin:shockgrade8_area_earthquake	Shockgrade8_area_earthquake
		Tianjin:shockgrade9_area_earthquake	Shockgrade9_area_earthquake
		Tianjin:shockgrade10_area_aarthquake	Shockgrade10_area_earthquake
Tianjin earth-quake shock-area	Earthquake intensity region	Tianjin:erea_earthquake	area_earthquake
		Tianjin:shockgrade6_Area_earthquake	Shockgrade6_area_earthquake
		Tianjin:shockgrade7_Area_earthquake	Shockgrade7_area_earthquake
		Tianjin:shockgrade8_Area_earthquake	Shockgrade8_area_earthquake
		Tianjin:shockgrade9_Area_earthquake	Shockgrade9_area_earthquake
		Tianjin:shockgrade10_area_earthquake	Shockgrade10_area_earthquake
Tianjin earth-quake be-sieged people	All the possible collapse of the building, besieged person and casualty	Tianjin:tianjin_street	Tianjin street
		Tianjin:tianjin_population_7_18_inte7	Tianjin_population_7_18_inte7
		Tianjin:tianjin_population_7_18_inte6	Tianjin_population_7_18_inte6

- Website for rescue work

The fast and accurate transmission of information to rescue teams is decisive. Therefore, a simple and easy-to-update website which can be accessed by various client terminals with LAN and wireless connections is a must. The main contents that should be transmitted through website include: The location of epicenter in a map with accessible geographical coordinates and happening time; Zones of earthquake intensity and their relative distance to the epicenter; Distribution of casualties with information about collapsed building, population; Distribution of the trapped people and so on. Figure 6.12, Figure 6.13, Figure 6.14, Figure 6.15 demonstrate a number of maps embedded in the website. By linking the layers, further information can be derived and transmitted to people equipped with mobile devices in the disaster area.

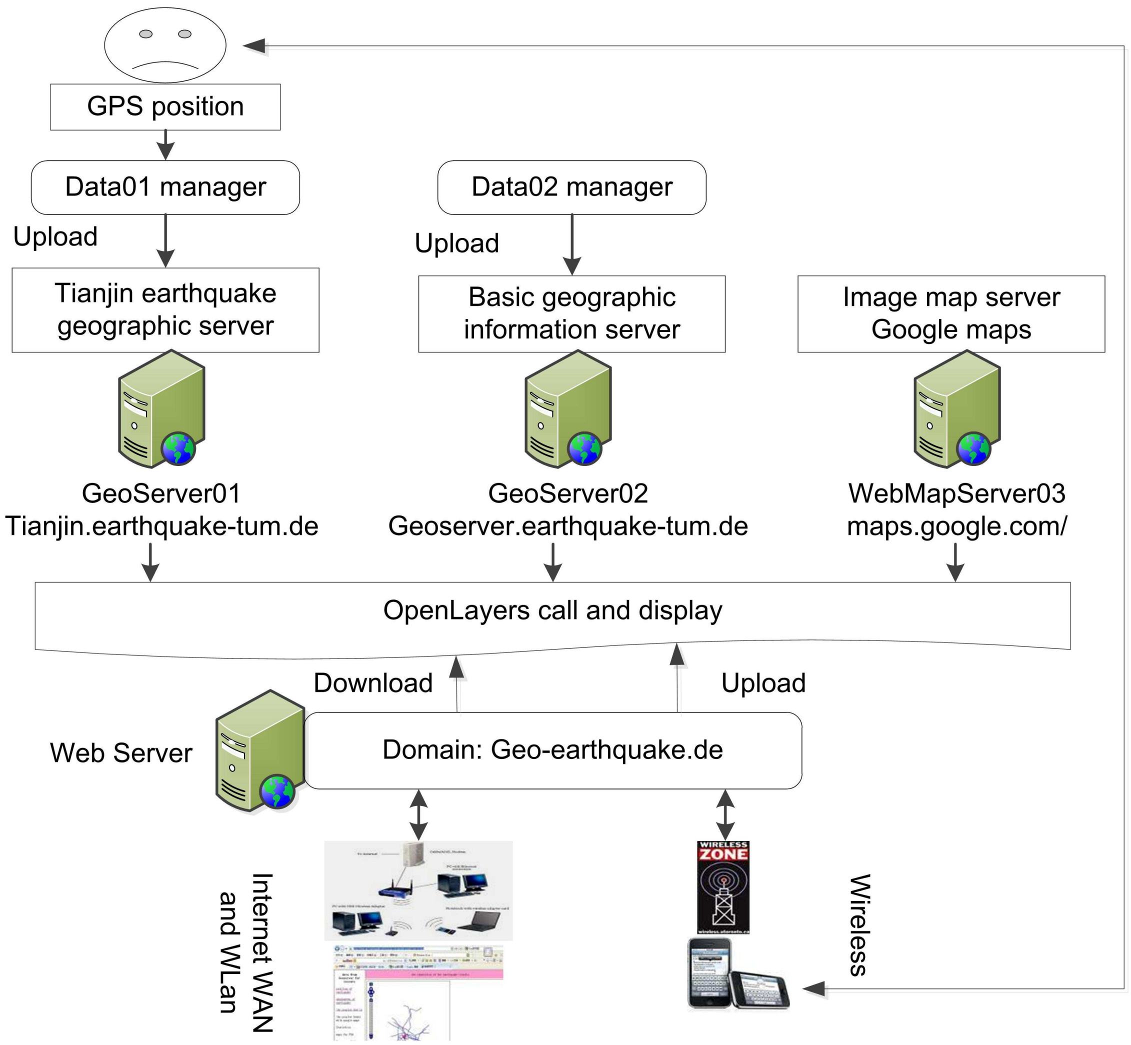

Figure 6.11 The distributed GeoServer of Tianjin for post-quake rescue

call tianjin.earthquake-tum.de data in geoserver01：

http:// tianjin.earthquake-tum.de:8080/geoserver/wms

call geoserver.earthquake-tum.de data in geoserver02：

http:// geoserver.earthquake-tum.de:8080/geoserver/wms

call the data in Google map server：

var googlesatellite = new OpenLayers.Layer.Google("Google Satellite" , {type: G_SATELLITE_MAP, 'maxZoomLevel':18});

map.addLayers([googlesatellite]);

var googlebybrid = new OpenLayers.Layer.Google("Google Hybrid" , {type: G_HYBRID_MAP });

map.addLayers([googlebybrid]);

var GMapsStreets = new OpenLayers.Layer.Google("Google Steets" , {type: G_NORMAL_MAP, 'maxZoomLevel':18});

map.addLayers([GMapsStreets]);

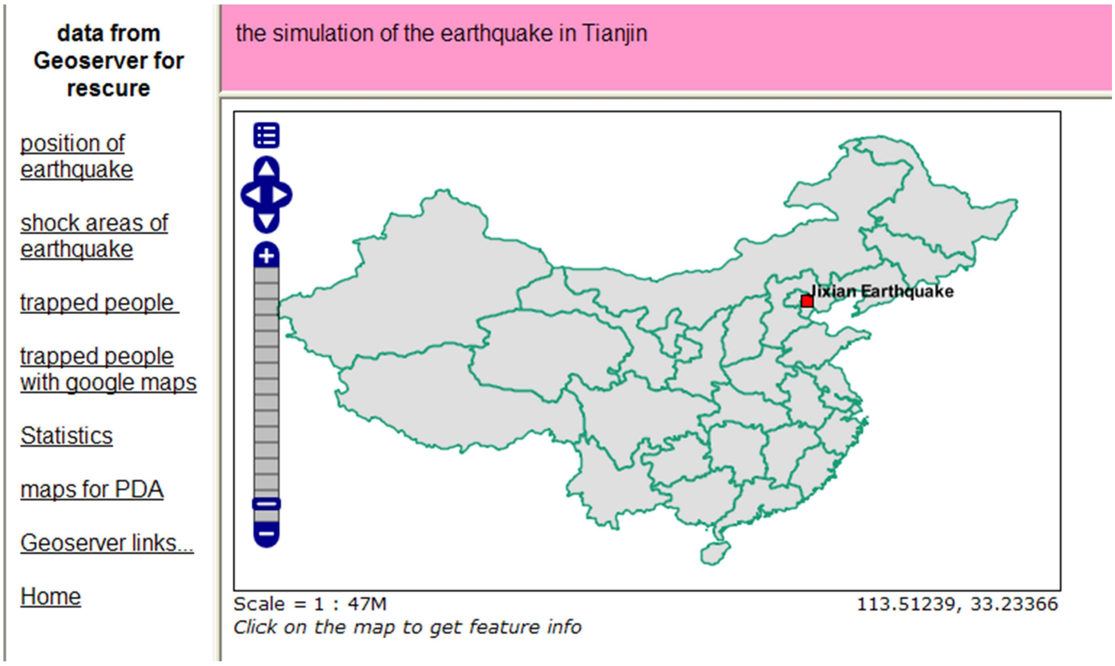

Figure 6.12 Web map showing the epicenter

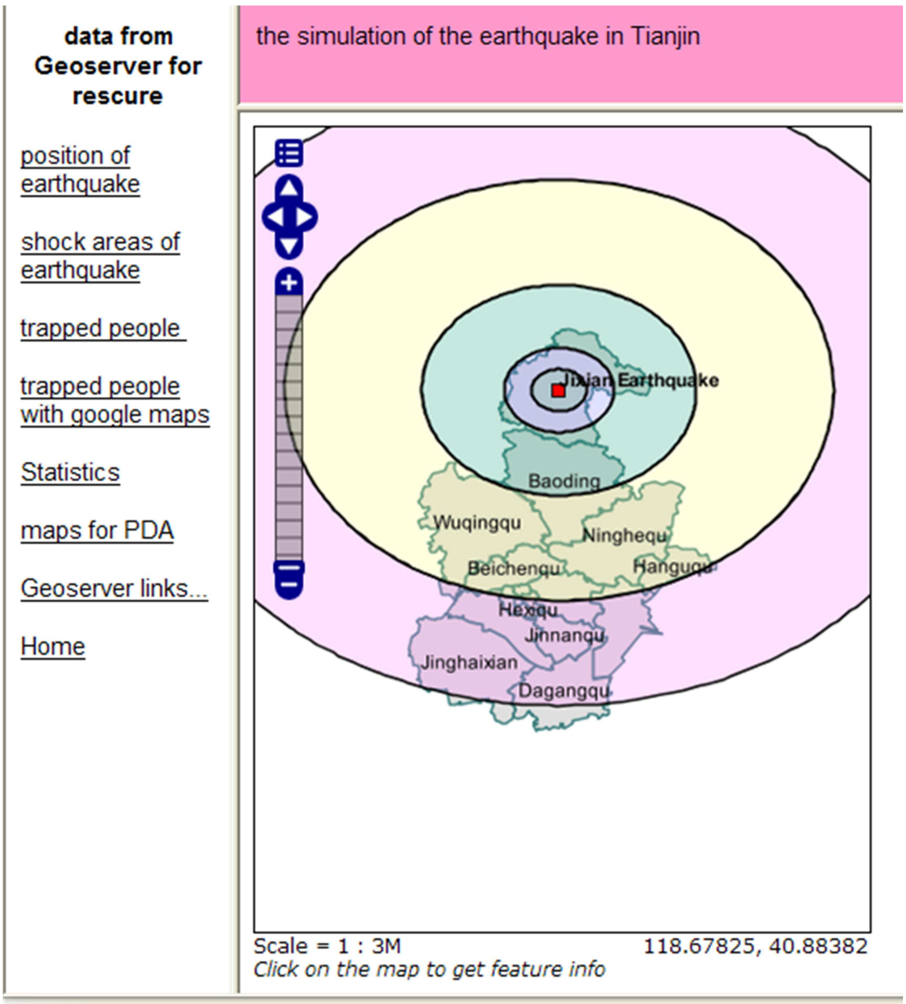

Figure 6.13 Zones of earthquake intensity

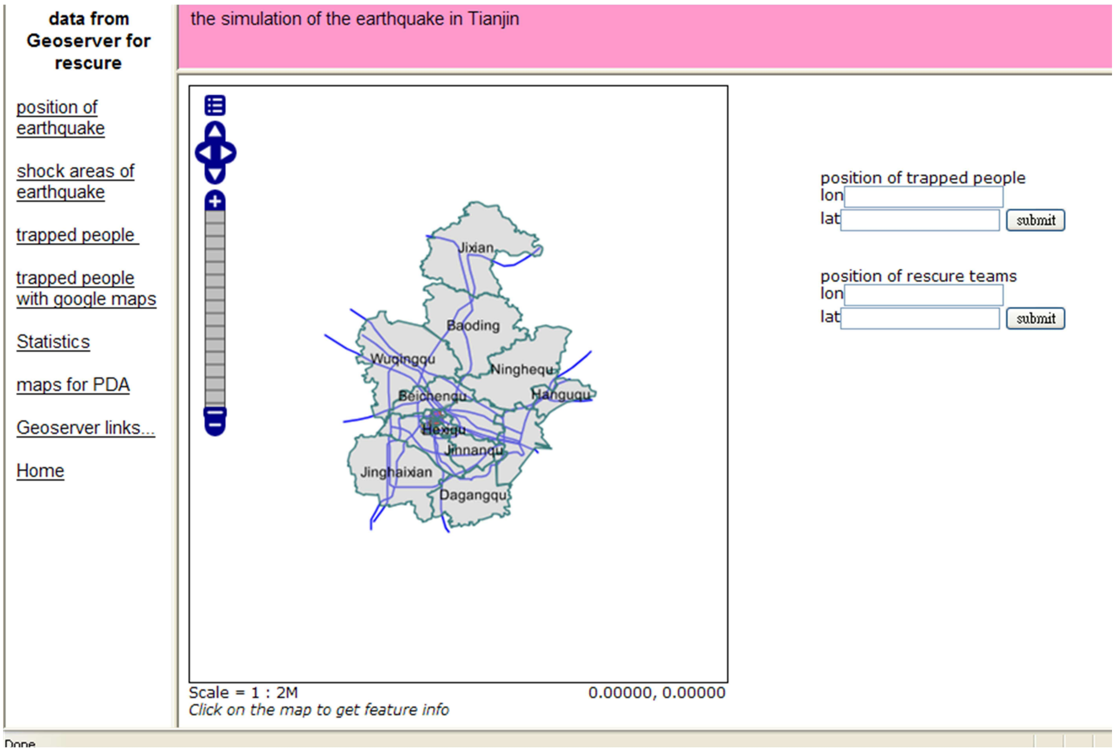

Figure 6.14 The positions of trapped people waiting for rescue

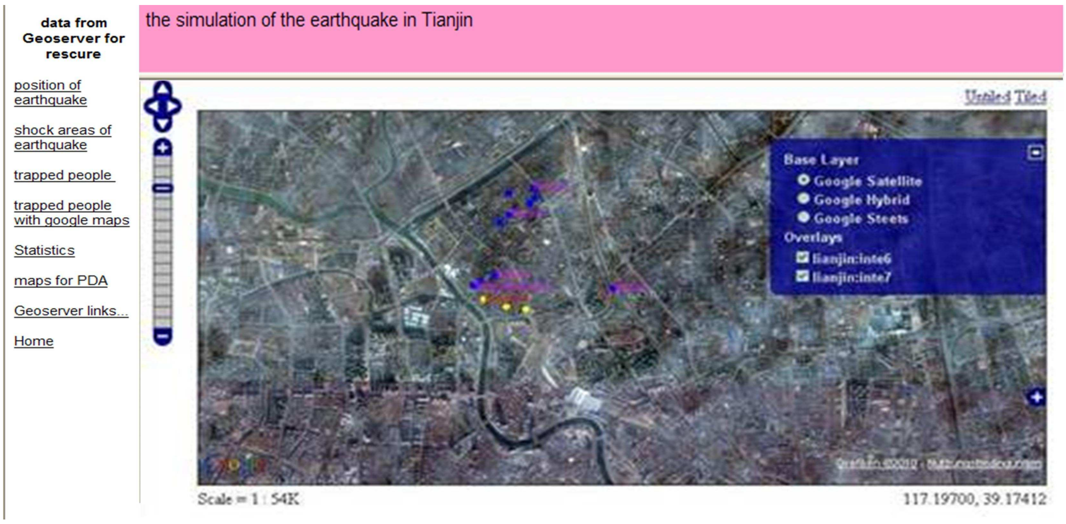

Figure 6.15 The positions of trapped people overlaid on Google Image

6.5 The realization of wireless communication

For the post-quake rescue operations, the most urgent task is to find the locations of besieged people. The principle of GPS is useful for this purpose. The American company SiRF and German company Infineon developed GPS receiver chip with millimeter precisions (Su, 2007a). With these chips and A-GPS service, the people and things can be effectively positioned under difficult conditions such as within the collapsing houses (Preis 2005； Xue et al. 2002； Nourbakhsh et al. 2006).

Cell phones equipped with GPS receiver and / or A-GPS constitute a convenient infrastructure for the transmission of location information to rescue center and can thus facilitate the searching work. Cell phones with A-GPS service are still rather expensive. For example, the gpsOne[98], an AGPS service of QUALCOMM charges rather high fees. Consequently, the number of AGPS-enabled handsets is limited. With the further development of telecommunication and mobile technologies, especially with the smart fusion of phone chips and GPS chips, positioning functions will soon become an integrated part in cell phone. At the same time, along with the upgrading of GPS of USA, other Global Navigation Satellite Systems such as GLONASS of Russia, Galileo of EU, and Beidou of China are complementarily enhancing the coverage and precision of positioning function (Su 2006; Su 2007b). All these existing technologies will efficiently support the tracking and rescuing work.

Besides the positioning of cell phones, many GPS trackers are available on the market. For the case study, GPS tracker developed by an electronic company in Shenzhen China is adopted. With a size of 64x46x17mm, a weight of 50g and a high precision chip in SiRF III GPS, it has the sensibility of 159dBm and contains 2000 oscillators (Wunderlich 2004). With the positioning precision of 5m, GPS tracker has a velocity of capturing GPS signal which is hundreds or thousands times faster than the general GPS chips (Eisfeller et al. 2005).

The working principle of this tracker is rather simple. The communication between the tracker and the cell phone number can be realized by inserting a SIM card and using the frequency range of wireless net GSM\GPRS 850/900/1800/1900MHZ or GSM\GPRS 900/1800/ 1900MHz. The location information can be divided as positive and passive position. In case of passive positioning, the authorized cell phone calls the tracker number which then sends its location information back to the authorized cell phone. For active positioning, the tracker sends by pressing its SOS emergency button its location directly to the authorized cell phone without being called (as seen in Figure 6.16).

Figure 6.16 Location position that can be sent via a wireless tracker with an SOS button

This location information can be then transmitted to the rescue center or teams through wireless communication. As illustrated in Figure 6.17, this location appears in the map on a rescue client terminal, at the same time the positions of trapped people are also displayed.

98 http://www.cdmatech.com/download_library/pdf/gpsone.pdf

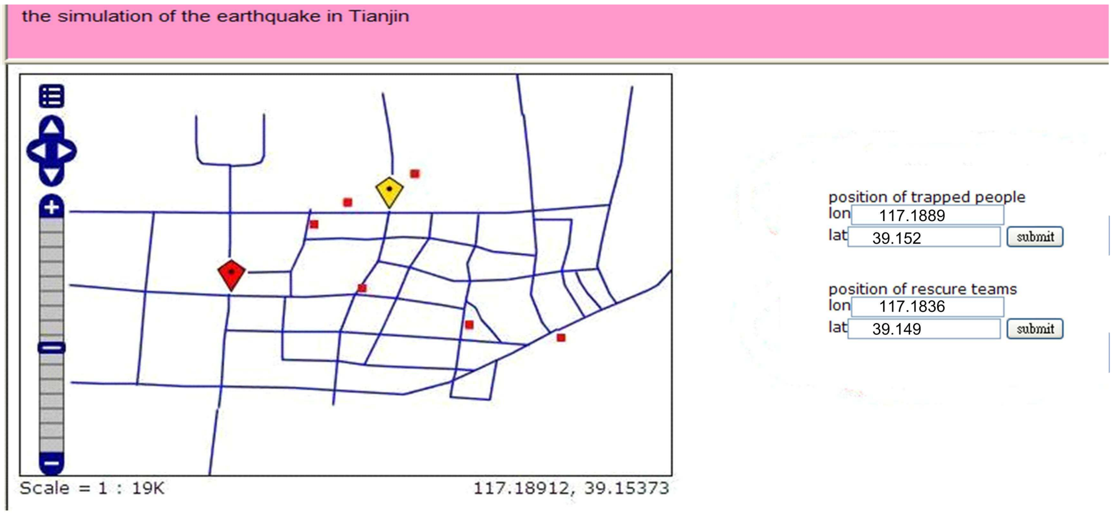

Figure 6.17 The positions of trapped people illustrated on the GeoServer.

The large red symbol stands for position of rescue teams, yellow one stands for position of trapped people)

The above case study has confirmed the feasibility of using ArcGIS[99] and the open source PostGIS for the acquisition and processing of rescue-relevant geo-data in a test area. Trough the open source GeoServer in line with the OGC service standards, at the same time through the peanut shells services, the connection between GeoServer and Webserver has been realized. A straightforward earthquake disaster assessment and rescue information system has been set up for the post-earthquake actions. The test with simulated datasets shows that the system meets the current and common professional standards, can find positions of the people trapped in collapsed houses, conduct the necessary analysis and query in a comprehensible way and transmit the results to the rescue teams in the shortest time. The working principle can be directly applied and adapted to any available real data resources with the purpose to minimize casualties and economic loss caused by an earthquake or other natural disasters. The rescue information server in connection with a Google map server and a communication server leads to an efficient practical information system shared by all who are involved in post-quake rescue work.

[99] http://www.mapcruzin.com/free-wireless-gis-maps/free-wireless-gis-maps.htm

Chapter 7

Conclusion and prospects

7.1 Conclusion

Based on wireless technology and open source web geo-services, the author has established and implemented a post-quake rescue information system for both trapped people and rescue teams, using simulated data from the test area Tianjin from China.

The thesis is essentially composed of a conceptual part and an implementation part. Starting from the existing study on the multi-parameter post-earthquake assessment, the author proposed a comprehensive and open source rescue model which can be shared by all users involved in rescue tasks. Being aware of the fact that the efficiency of the rescue work depends largely on the availability of freely accessible geospatial information from multiple sources and its distribution over the wired or wireless web, the author gives an in-depth analysis of the relevant data sources and their processing methods guided by seismological knowledge. A multi-tiered architecture of data model and methods of how to access distributed geographic information in a GIS application server were elicited. Along with the introduction of the Web GIS concept, the principles of designing web maps and organizing hypermap contents for distributed usage are explained and demonstrated with the examples of SVG maps. Furthermore, the structure and components of wireless GIS as well as its special constraints for rescue work are outlined.

To realize the concept of post-quake rescue information system, the author analyzed WMS, WFS standard of OGC, made a comparison of existing open source programs based on NET and Java, and constructed an open source GeoServer. The necessary database and analytical functions for rescue work were created using the open source software such as GeoTools, OpenLayers, PostGIS. With the help of Google Earth KML in GeoServer, thematic data can be overlaid as OpenLayers on Google image maps. In this way, the epicenter, the coverage of earthquake and locations of trapped people can all be geocoded and displayed over the background of Google images. These maps on GeoServer can then be conveniently transmitted to mobile devices and thus trigger the necessary rescue operations.

Throughout the thesis the importance of reliable and open source geographic information and its analytical tools for people's daily life has been reiterated. With the widespread Internet and a growing informed society, there is a growing amount of volunteered geographic information. At the same time, the demand on open source and easy-to-access data and information services will continue to grow in parallel to the further development of commercial databases and GIS, leading to increased mutual benefits of information providers and receivers.

7.2 Prospects

Earthquakes are still taking place every now and then with different intensities, causing numerous deaths, Yushu County, Qinghai Province in China on April 14, 2010[100] Tōhoku earthquake[101] in East Japan on March 11, 2011 are among the recent disasters. Although professional and volunteered rescue teams can be summoned to be in readiness within the

[100] http://cryptome.org/info/yushu-quake/yushu-quake.htm
[101] http://en.wikipedia.org/wiki/2011_T%C5%8Dhoku_earthquake_and_tsunami

shortest time, finding trapped people in time and providing them with the first help remain a challenge for the years to come. Coordinated work and shared information among the involved people are necessary. More important is that the information should be disseminated within the shortest possible time to the needy people or agencies so as to save the endangered lives. The establishment of a wireless and open source post-quake information system has marked the first step towards the efficient rescue operations based on the most relevant and up-to-date information.

1. Improvements of the post-quake rescue information system

Due to the uncertainty of the earthquake prediction, the pre-establishment of the rescue information system in the seismically active areas is recommendable. The main tasks include:

- Maintenance of the statistical data about various building structures and their earthquake coefficients;
- Maintenance of the demographic information related to various buildings at different times during day and night;
- Joint operation among the Seismological Research Agencies, Citizen Security Departments, Statistical Department and other data delivery agencies;
- Creation of multiple information release servers that can receive, process and distribute open source information;
- Popularization of built-in GPS chips in SOS function and mobile devices, thus involve all citizens as active information senders;
- Establishment of an Earthquake Management Center to coordinate the data flow and rescue operations.

2. The extended applications of the post-quake rescue information system

The working principles of an open source post-quake rescue information system can be propagated to many other application fields that involve sudden disasters or accidents with hard-to-predict damage to people.

Floods and tsunami

As the result of climate warming, floods and tsunami disasters are increasing from year to year and require flood disaster assessment and emergency management systems that should support the rescue operations of trapped persons.

Forest fire

Forest fires can break out all of a sudden and spread to a hard-to-control scope. An open source rescue information system may provide a great help to harness the fire and reduce the damage.

Heavy snow

Heavy snow for days and weeks may typically cause disruptions of transportation and travel systems. In such cases, a disaster management system with open source information may support the communications among trapped people and rescue teams.

Elderly care

The aging society urges the enhancement of elderly care systems. Open source information systems are necessary, especially those equipped with location services may help track the elderly people who have mobility problems or may go astray due to dementia problems, thus prevent accidents, injuries or deaths.

7.3 Suggestions for research agenda

Wireless web GIS with open source data and software will continue to play an important role in our daily life. The post-quake rescue information system addressed in the thesis is just one of many examples showing the necessity and usefulness of sharing distributed information for life saving. As wireless web GIS application combines the wireless communication, Internet and GIS technology, its performance relies on all three technologies which are undergoing further developments (Tsou 2004)

Wireless communication

One possible solution to enhance the efficiency of wireless communication would be to utilize broad bandwidth communication systems such as the High Performance Wireless Research and Education Network (HPR[102]) to provide long-distance wireless networking capability in the Wi-Fi mode. In addition, the recent development of the IEEE 802.16 standard may become a potential wireless network solution for mobile GIS. The IEEE 802.16 standard defines the Wireless Metropolitan Area Network (MAN) Air Interface for broadband wireless access in large urban areas[103] with a scalable solution to extend fiber optic backbones. On the software development side, the design of new data compression technologies for both vector data and raster imagery via wireless networks may also facilitate the transmission of large datasets for wireless GIS applications in the future.

Visualization on mobile display devices

Cartographic visualization as a fundamental geo-service faces a number of challenges. First, it should provide a straightforward way to superimpose and integrate distributed thematic layers such as housing, road, and population; Secondly, it should be supported by the SDI (spatial data infrastructure) in distributed GIS and distributed geo-services; Finally, it should be tailored to various output devices.

The visualization of wirelessly transmitted data on small and personalized display devices of clients is characterized by a number of design constraints. Virtual Reality technology that aims to provide naturalistic impression of the earthquake site such as 3D scenes or photos of collapsing buildings is highly desirable for rescue teams. However, it does not make much sense to transmit mass graphic data to clients. Multimodal and multimedia technologies may help overcome some inherent restrictions on mobile devices (Gartner 2003). OpenGIS Location Services developed by the OGC can be integrated in wireless GIS[104]. In addition, generalization methods are needed to support the data abstraction and fast rendering (Fan and Meng 2009).

Data protection in wireless GIS

Some mobile GIS applications may utilize classified or proprietary GIS data gathered from the field or through access to classified databases. The classified information needs to be protected from unauthorized access in both mobile GIS devices and via wireless communication channels. Currently there are very few preliminary solutions for the protection of sensitive GIS data, such as password protection and data-encrypted transmission. The real challenge for securing mobile GIS applications is to create a hierarchical security framework to define different user groups (administrators, special- access users, regular users, guests) with different permissions to access various security levels of geo-data from a single GIS content server. GIS community needs to develop strategic guidelines for the issues of data protection and location privacy.

These aforementioned improvements are anticipated to enrich and elaborate the post-quake rescue information system developed in this thesis.

[102] http://hpwren.ucsd.edu

[103] http://grouper.ieee.org/groups/802/16/index.html

[104] http://www.idsemergencymanagement.com/emergency_management/corporate/OpenGIS_Consortium/Geospatial Geographic/16_0/g_supplier.html

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Abbreviation

ADS: Automatic Data Set

Ajax**:** Asynchronous JavaScript and XML

API: Application Programming Interface

APSDI: Asia-Pacific Spatial Data Infrastructure

AR: Augmented Reality

ASP: Active Server Pages

AWT: Abstract Window Toolkit

BPEL4WS: Business Process Execution Language for Web services

BSD: Berkeley Software Distribution

CDGPS: Canadian Differential GPS system

CDMA: Code Division Multiple Access

CGI: Common Gateway Interface

DCP: Distributed Computing Platforms

DEM: Digital Elevation Model

DGI: Distributed Geographic Information

DHM: Distributed Hypermap Model

EPSG: European Petroleum Survey Group Geodesy

FTP: File Transfer Protocol

GIF: Graphic Interchange Format

GIS: Geographic Information System

GLONASS: GLObales Navigations- Satelliten- System

GML: Geography Markup Language

GNU: General Public License

GPL: General Public License

GPRS: General Packet Radio Service

GPS: Global Positioning System

GSM: Global System for Mobile communications

GUI: Graphical User Interface

HTML: Hypertext Markup Language

HTTP: Hypertext Transfer Protocol
INSPIRE: Infrastructure for Spatial Information in the European Community

ISAPI: Internet Server Application Programming Interface

ISO: International Organization for Standardization
ITU: International Telecommunication Uniom

J2EE: Java 2 Platform Enterprise Edition

JPEG: Joint Photographic Experts Group

JSON: JavaScript Object Notation

JSP: Java Server Pages

KML: Google Earth markup language

LBS: Location-based Services

MAN: Metropolitan Area Network
MGE: Morrowind Graphic Extender

MIME: Multipurpose Internet Mail Extension

MLP: Mobile Location Protocol

MVC: Model-view-controller
NGDF :National Geospatial Data Framework

NSAPI: Netscape Server Application Programming Interface

NSDI: National Spatial Data Infrastructure
ODBC :Open Database Connectivity
OGC: Open GIS Consortium

OMG: Object Management Group

OpenGL: Open Graphics Library

PDA: Personal Digitals Assistant

PHP: Hypertext Processing

PNG: Portable Network Graphic Format
RDBMS: Relational Database Management System

RM-ODP: Reference Model of Open Distributed Processing
SDE: Spatial Database Engine

SDO: Spatial Data Option

SMS: Short Message Service

SMTP: Simple Mail Transfer Protocol

SOA : Simple Object Access

SOAP: Simple Object Access Protocol

SQL: Structured Query Language

SRS: Spatial Reference System

SSI: Server Side Includes

SVG: Scalable Vector Graphics

SVGB: SVG Basic

TCP: Transmission Control Protocol

TDMA: Time Difference Multiple Access

TIN: Triangular Network

TP: Transmission Path Layer

UDDI: Universal Description, Discovery and Integration

URL: Uniform Resource Locater

VGE: Virtual Geographic Environment
VGI :Volunteered Geographic Information

VRML: Virtual Reality Modeling Language

W3C: World Wide Web Consortium

WAAS: Wide Area Augmentation System

WAP: Wireless Aplication Protocol

WCS: Web Coverage service

WFML: Web Form Markup Language

WFS: Web Feature Service

WGIS: Wireless GIS

WLAN: Wireless Local Area Network
WML: Wireless Markup Language

WMS: Web Map Service

WSDL: Web Services Description Language

WSFL: Web Services Flow Language

WSXL: Web Service Experience Language

XML: eXtensible Markup Language

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