The development of China national geohazard information system

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Abstract. Geohazards caused significant damages to people and economical properties. The prevention and mitigation of geohazards in China is facing great challenges. To solve the problem, establishing a national geohazard information system is important in accessing the distribution of geohazards, optimizing the efforts of prevention and mitigation, and improving the public awareness and risk reduction capabilities. After two decades’ of development, China national geohazard information system have upgraded from client-server (C/S) to browser-server (BS) architecture, and now to the micro-service based architecture, more than 320 thousands of geohazards which were mainly collected through field surveys and the routine field inspections have been saved in the database; through the information system, data acquisition and integration, classified storage, efficient data processing, real-time statistics and data services have been achieved and standardized by numerous technical specifications. In this paper, the current status of China national geohazard information system, including the development progress, database architecture, system functionality and data applications are introduced, and expected to provide references of establishing an efficient and comprehensive geohazard information system to improve the geohazard risk reduction capabilities for the countries or regions suffering from geohazards.

1. Introduction
The large number and wide distribution of geohazard in China claims casualties and causes tremendous economic losses annually. Geohazard database and information system have gained importance in the mitigation by providing data management, data statistics, and public services, etc (Herrera et al., 2018). The rapid developments and innovations of modern information technologies have provided the significant technical support for geohazard database and information system to be more dynamic, elaborated, smart and timeless (Kirshbaum et al., 2009; Van et al., 2012; Pennington et al., 2015).

The establishment of China national geohazard information system started from the year of 2001, and mainly included two aspects: the national geohazard database and information system. First, through the systematically collection of multi-temporal geohazard data, the national geohazard information system were gradually established, and now more than 322 thousands of geohazard events have been recorded; second, to satisfy the needs of governmental management, scientific researches and public on geohazard, the information system were established based on the national database. The national system, which have been improved from client-server (C/S) to browser-server (BS) architecture, and now to the micro-service-based architecture, have provided standardized collection,
efficient mass data integration, real-time online statistics, presentation and analysis. This paper introduces the developments and achievements of the China national geohazard database and information system, and mainly focuses on experiences to achieve an efficient management and dynamic update of the national database, architecture and functionality of the information system, data service and technical support to governmental administrations on geohazard risk reduction, scientific researches, and public needs (Li et al. 2013).

2. Establishment of national geohazard database

2.1. Data resources

The national geohazard database has a wide variety of data resources, and the majority of data was collected through the field surveys and routine inspections in the landslide susceptible areas. From 2001 to 2008, the first geohazard field survey campaign on scale of 1: 100,000 was conducted on county-level. A total of 2020 counties with overall area of 8.34 millions square kilometers were covered. The second national survey campaign has been conducted since 2005, and it comprises a more detailed investigations on the scale 1: 50,000 with the aim to get a more comprehensive understanding on the spatial distribution of geohazards and vulnerable elements in China. Until recently, about 1500 counties have been covered by the second national survey campaign. The obtained data from two surveys formed the foundation of the national database. Meanwhile, the local governments in susceptible regions also conducted inspections with focus on the occurrence and dynamic development of mass movement events during the flooding seasons. The data gained through routine inspections enable an update on the changes in slope stability and controlling factors providing an important supplement to the geohazard databases on the local and national level.

2.2. Data acquisitions

2.2.1. PC-based data acquisition

This method is designed for the professional geohazard surveyors. By using the PC-based data acquisition method, the field data being recorded on paper format forms can be digitized by following a series of specifications for data uniformation and standardization. Documents such as reports, diagrams, production maps and media that were completed can be uploaded directly to the national database. The PC-based method was more widely used before the practical application of field data acquisition method.

2.2.2. Mobile terminal-based field data acquisition method

A field data acquisition system, was developed based on the working procedure and the technical specifications applied in geohazard survey for professional personnel. The utilized hardware is a tablet or mobile phones running the Android operating system. The developed software supports mobile GIS functions and is capable to integrate and process multiple vector and raster data formats featuring topographic and geological maps, and remote sensing images. Incorporated GPS and voice recognition technique, allows efficient survey route navigation and recording, filling the standardized survey forms, mapping the spatial characteristics of a mass movement such as the sliding direction, toe, boundary or scarp, as well as drawing the geological profile and plane graph, and take photos (Figure 1).

2.2.3. Data aggregation through multi-level databases interconnection

Another important method for data acquisition is the data aggregation from provincial, municipal and county-level databases. The local governments including provincial, municipal and county are responsible for geohazard prevention and mitigation within their administrative regions. Above data acquisition methods ensure the continuous growth of the data volume in the database. Consequently, the evaluation of the data quality is another important aspect for national database construction. To
ensure all data stored in the database meet the established quality standards, a verification software was developed to check the quality of both spatial and attribute data.

![Figure 1](image1.png)  
*Figure 1.* The user interface of field data acquisition system based on mobile terminals (Left: Geohazard distribution; Right: mapping of the landslide)

2.3. *The architecture of the national database*  
By collecting the geohazard data into the national database, establishing a proper database architecture is the foundation of efficient data storage, rapid data quarries, data mining and maintenance (Van et al., 2012). The national geohazard database mainly consists of three types of data: the attribute data which are mostly from the geohazard survey forms; the spatial data, which are mostly spatial features of the investigated geohazard s as well as the mapping productions in vector format; the production data, consisting of derived products such as maps, documentations and media data (Figure 2).
Figure 2. The architecture of national database

2.3.1. Attribute data
The attribute data mainly consists of the descriptions of geohazard properties. The attribute data can be divided into four perspectives, and each perspective represents for one category of information regarding to a specific geohazard event. Among the various categories of information, an unique ID number of geohazard is used to interconnect all of the information being generated from the four perspectives. Users can access all information regarding a specific geological hazard efficiently.

2.3.2. Spatial data
The spatial data consists of both vector and raster data. Vector data include the spatial characteristics of geohazard s such as location, geometry etc. Raster data include a series of multi-temporal remote sensing images and InSAR, etc, especially for regions of high susceptibility or risk level. The vector data can be classified into three different categories: the spatial features of geohazard, geographic elements and geological conditions. The spatial distribution and plane geometrical features of geohazard are the major contents of geohazard vector data. Presented by the combination of point, polyline and polygon elements, a detailed descriptions of the spatial distribution and plane geometrical features of geohazard s such as the sliding boundary, scarps, deformation direction, influencing area, and any observation that could be relevant to the geohazard occurrence can be characterized and presented on different vector layers, which to be saved in vector database. The vector layers including geographic elements such as rivers, transportation infrastructures, residence areas, plantation and land use, etc, are most obtained from the geographical conditions census data. The national database also have established the data sharing mechanisms with different types of database (social, economic and population census; remote sensing data; InSAR; etc), therefore a comprehensive collection of vulnerable elements, remote sensing images, 4D (DLG, DEM, DOM, DRG), and InSAR data in the susceptible regions can be accessed through the national geohazard database. The technical specifications of spatial database construction have been established to ensure the standardization of vector and raster data. In the specifications, the elements appeared on different layers, contents and formats of attribute tables and name of spatial data layers, etc are clearly specified to ensure the standardization and uniformity of the spatial database.
3. Establishment of geohazard information system

3.1. The architecture of the national database
The system is developed based on the database, and designed for database management and providing efficient data service, mainly consists of the infrastructure service layer, data service layer, platform layer, and software layer. The four-layer architecture is a typical architecture of an information system built based upon database: IaaS (Infrastructure-as-a-Service); DaaS (Data-as-a-Service); PaaS (Platform-as-a-Service); SaaS (Software-as-Service).

3.2. The application of micro-service in the system
As the demand for information services requested by the prevention and control of geological disasters has become more refined, online, and intelligent, the scattered and redundant data management methods, simple and solid query statistical analysis functions as well as the single and static information service results have not been able to meet the requirements. The information system needs to be continuously improved in terms of professionalism, interactivity, open and flexibility. Therefore, the system uses micro-service architecture technology to develop multiple platform functions such as statistical analysis of massive data, query geohazard information, spatial vector data overlay and statistics, online analysis and mapping of geological disaster areas and data sharing with third parties. The above functions were splitted into a series of micro-service function modules, which is convenient for efficient development and perfection, online deployment, upgrade and optimization, third-party sharing, and effectively improves the timeliness, practicality and expandability of research results.

3.3. Primary functions

3.3.1. Working supervision for governmental administration
The latest geohazard distribution, vulnerable elements statistics, spatial distribution and rating of geohazard risk areas, etc, can be accessed in real-time; the working conditions of monitoring devices installed in different regions, monitoring data reception of these monitoring devices, as well as the early warning results based on the monitoring data can be presented in the system; any emergency event such as occurrence of geohazard and sudden loss of vulnerable elements would be reported by the local government through the information system, and real-time information update can be provided to support the ministerial administration on decision making. Therefore, through the supervision function, users, especially for the administrative staff can access a comprehensive understanding of the overall picture of geohazard condition in China, and keep track of all important activities in geohazard prevention and mitigation.

3.3.2. Full-life cycle management of geohazard
A massive amount of data could be generated throughout the process, from identification to mitigation. Therefore, the full-life cycle management of geohazard in the database is defined as the management on the data of all aspects of risk reduction activities for the geohazard, including information collected during the field survey process, monitoring data and early warning, any engineering mitigation activities and/or relocation applied. All above data related to one single geohazard can be interconnected through the unique identification number assigned in the phase of geohazard survey. Therefore, users can access these information directly by scanning the code, which is directly correlated with the identification number of geohazard.

3.3.3. Meteorological early warning of national geohazard
The national geohazard information system can directly access to the early warning results including predicted risk rating and spatial distribution of the confirmed early warning areas that are published by each province. Through the system, administration users can access the highest rating of risk warning areas as well as its spatial and temporal distribution in each province. In addition, the system could
automatically conduct the overlying analysis using the geohazard distribution and meteorological early warning results, a list of geohazards that are located inside the early warning areas can be provided and additional attention may be requested in case of emergency. The national information system can access the real-time monitoring data and working status of the monitoring devices from approximate 8500 monitoring stations all over the country. The monitoring data including real-time video, precipitation, and crack deformation, etc. In the future, the connections between the national information system and all of the active monitoring stations in China will be established.

3.3.4. The data browse and real time statistics
Online data search, retrieve, browse, and statistics are important functions of the national information system. For instance, based on the user-defined area, the information system can present the spatial distribution of geohazard within the area based on the spatial analysis function as being built in the system, and show the spatial characters of geohazard distribution. Also, to help surveyors to identify the development of geohazard based on multi-temporal remote sensing images, the system can show the high-resolution remote sensing images from different periods on the same display.

![Figure 3. Geohazard distribution](image)

3.3.5. Online analysis and mapping
An analytical tool for regional susceptibility mapping based on information system platform was developed. The calculation process by using the analytical tool can be divided into four significant steps: (1) users can define the analysis area based on interest of concern; (2) the analytical tool can automatically extract the data of geohazard distribution as well as geological and geoenvironmental parameters, human engineering activities, geographic and geomorphic parameters that are available within the defining area from the database; (3) the analytical would provide a default setting or allow users to set the reclassification for each possible parameter manually; (4) the analysis tool would conduct spatial overly analysis (using weight of evidence method principle) based on the reclassified parameters, and present the results of quantitative weight values for each parameter. The weight value of each class of the analyzed parameter would be used to show the influence of each parameter on geohazard formation and development. This is also an essential step for developing the susceptibility analysis function, which will be developed in next phase of information system development.
Figure 4. The statistical analysis of the major geohazard formation conditions based on the weight of evidence method through the information system

3.3.6. Information services based on mobile terminals
Improving the application and service of geohazard information in public daily life can be an efficient way to improve public awareness and capacity for landslide risk reduction. To achieve the objective, a navigation service tool considering the landslide distribution is designed and developed for providing navigation service to the public. The navigation service tool can be installed on android system-based mobile terminals (PAD or smart phone) and provide multiple functions including route planning to avoid potential risk from landslides in highly susceptible region, voice reminding when users approaching landslides unconsciously, information reporting of any observed landslide, etc. When the user turns on the navigation service tool, the tool will keep track of its current geographic location and the moving trail, and continuously send the positional information back to the national database, so that the information system would search for any existing landslide in the surrounding area. When the users approach any pre-identified landslide, the navigation tool would automatically turn on the voice reminding and inform the user to make detour or leave the risk area immediately. The function can provide an efficient, direct, economical and convenient service to daily public life to improve the public awareness and capacity of landslide risk reduction.

4. Discussions
After two decades of developments, the national geohazard information system have played an increasingly important role in geohazard mitigation and prevention in China. Multiple technical specifications, standards, hardware, software, and practical applications have been generated, and the comprehensive working mechanism has been established. To ensure the quality of recorded data into the database, it is critical to continuously optimizing and expanding the establishments of technical standards and specifications, data acquisition technologies and continuous data dynamic update is vital for national geohazard database. Also, the design and optimization of information system should focus on the needs of geohazard prevention and mitigation and maintain the compatibility with advancements of new technologies to achieve the open, joint construction and mutual sharing, so the system should follow the service and need-oriented concept for the design and development of the system, and always maintain a good compatibility for its continuous innovation by involving the cloud computing, artificial intelligence or micro-service technology.

Through years of efforts, geohazard prevention and mitigation in China has made tremendous progress, but the increasingly serious condition has set the new and higher objectives geohazard prevention and mitigation work, which also requires more comprehensive and efficient data service of
the national geohazard information system. Therefore, for the next phases, the database and information will be improved from numerous perspectives: (1) the capacity of data mining and analysis will be further improved, and the timeliness, efficiency and accuracy of the information service provided by the system will be continuously strengthened; (2) the rapid advancements of modern information technologies provide the reliable technical support for the national database and information system to be more accurate, efficient and timeliness, so that will improve the governmental administration on geohazard prevention and mitigation to be more standardized, accurate, precise and timeliness.

5. Conclusion
The establishments of China national geohazard database and information system have mainly focused on the needs of administration of geohazard prevention and mitigation. A system of unified technical specifications for data collection and integration, numerous tools and software for data acquisition, quality check, and data input have been completed, which formed the comprehensive technical support for the dynamic update of database and information system. The construction and application of China geohazard national database and information system over the past two decades have been proved to be a feasible way for improving the geological hazard prevention and mitigation in China. It is expected that this study can provide accessible and mature experience for any other countries or regions that also greatly suffering from geological hazards, and contribute to the improvement of geological hazard risk reduction in the world.

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