Design and Implementation of Geological Hazard Data Acquisition System Based on Online Technology

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Abstracts. Based on the working process and technical requirements of geological hazard survey in China, a geological hazard field survey data acquisition system was developed based on online technology. The system, capable of presenting remote sensing images or topographic maps with a scale of 1:50,000 or higher accuracy and providing accurate positioning based on GPS and Beidou system, can satisfy the requirements of geological hazard field data collection. The system provides numerous functions, including data download, survey route navigation, online form filling, graph drawing, photo recording, and data synchronism. The development of the proposed system will provide rapid, accurate, and convenient data collection and information search for geological hazard field survey. The proposed system has been widely applied in practice and has significantly improved the working accuracy and efficiency of geological hazard field survey.

Keywords: Geological Hazard ;Mobile terminals ;Field survey ;Online ;Acquisition system

China is one of the countries that face the most serious geological hazards in the world. Especially since the beginning of the twenty-first century, the frequent occurrences of major geological hazards have contributed to significant damages to project constructions, urbanization process, and social developments.

Geological hazard survey is an important precondition for geological hazard prevention and control and deepens the understanding on the actual situation of geological hazards as well as effectively reduces the risk of geological hazards to lives. In addition, a more thorough understanding of geological hazard distribution also provides support to the establishment of geological hazard monitoring and early warning program and project management and emergency response. Therefore, since 1999, China has carried out geological hazard survey
and zoning (1:100,000) and a more detailed geological hazard survey (1:50,000) with county as unit. Since 2013, the China Geological Survey (CGS) has carried out geological investigation and risk assessment demonstrations on landslides and debris flows in areas prone to geological hazards. Since 2020, a new campaign of field survey of 1:50,000 was conducted, focusing on risk evaluation and providing comprehensive prevention as well as the control countermeasures and a basis for the prevention and management of geological hazards.

The rapid development of mobile communication and Internet technology also improves the working efficiency of geological hazard survey. In the traditional process of geological hazard survey, compass, geological hammer, and the magnify glass, handheld GPS and digital camera are most commonly used in the field for data collection based on topographic map, geological map, remote sensing image map, survey record book, and survey card, among others, in paper format. After finishing the field data collection, informationization and database establishment can be conducted next. Therefore, the informationization degree of the whole survey process is low, and the repeated workload is large, leading to low work efficiency and accuracy. Furthermore, human error is easy to occur in the process of data entry.\textsuperscript{[1-2]}

Digital field mapping started more recently in China, but it has developed rapidly. It has been applied to different fields such as the regional geological survey, mineral resources survey, groundwater resource survey, land survey, and forestry survey, among others. In the field of geological hazard survey, the preliminary exploration of digital field survey has also been carried out.\textsuperscript{[3-4]} Since 2016, in order to support the geological hazard survey with scale of 1:50,000 as the investigation unit, the geological hazard field collection system was developed and replaced the previous paper-based survey with offline geological hazard field data collection based on mobile terminals.\textsuperscript{[5-6]} With the development of mobile communication technology and the popularity of the network, based on the existing geological disaster field survey data acquisition system, this paper develops an online geological disaster survey data acquisition system based on Android terminal.

The system provides numerous functions, including data collection based on mobile terminals, development of the field survey data management module based on Web terminal, realization of the online data transfer and download, digital collection and online upload of the geological hazard survey business data, and establishment of the online work and management mode of “cloud + mobile terminal” for geological hazard survey.

The use of information technology will lead to the collection of relevant synchronized data that is sent to the Web end for more rapid and more efficient search and review. The development of the system is not only for reducing the field inspection task of field personnel but also for reducing the field survey data collection and analysis work and promoting more convenient project management personnel timely query and management. It can meet the needs of field investigators, internal data processing personnel, and project management personnel, improve work efficiency, and has strong practical significance and application value.

1. System design

1.1 System architecture design
This system is composed of two parts, namely, Web data management system and mobile data acquisition system. The Web data management system is used for the data preparation for the survey, as well as the field survey data recovery and conversion in the late processing work. On the other hand, the mobile data acquisition system is used for field survey, mainly for field survey of the survey area, entry of the survey form, entity sketching, and taking field photos, among others.

1.2 System functional design
In view of the traditional geological hazard investigation data preparation, numerous functions were designed and developed to satisfy the working process of field survey, which
include investigative work online management, navigation point, data entry, section drawing, photo, entity drawing, record collection, investigation, route, work summary and management, data upload online etc. functional modules.

2. System implementation
2.1 System development
The system of geological hazard survey data takes the Internet and tablet computer (pad) as the terminal, Android 4.2 as the platform, based on mobile 3S technology and voice input technology. Visual C++ is used to develop and realize all functions of the system design.

Key technologies adopted in system development include the following: (1) optimization of the compression, decompression, and spatial index method of raster data and improvement of the efficiency of the mass data storage, fast loading, and smooth display of raster image data; (2) on the basis of supporting massive raster images, the geological hazard data acquisition system improves the accuracy of GPS coordinate solution and the retrieval efficiency of navigation target points and optimization of the dynamic navigation and positioning function; (3) development of a series of graphic editing tools, including automatic tracking and capturing common edges, graphic segmentation and cooperation, island area adjustment algorithm, and line and surface layer mixing processing, which strongly supported the realization of entity mapping function of geological disaster points; and (4) use of the SharedPreferences provided by the Android system to save the custom table as string data and then analyzing and loading the display when you need to call the table to realize the intuitive and standardized collection and storage of survey data.

2.2 System function realization
2.2.1 Data preparation and delivery
Through the Web-side data management subsystem, the system integrates the basic and standardized geographic data (DLG, DEM, DRG, DOM) of the State Bureau of Surveying and Mapping, geological maps, high-precision remote sensing images, geological disaster distribution maps, field investigation planning road map, etc. The relevant data is transferred online to the tablet computer (pad) through the network, which could be used to generate a map of geological hazard for field investigation. Meanwhile, the system provides high-definition images and elevation data and other shared resource download services based on the network (Fig. 1).

2.2.2 Manage geological hazard survey online
Through the Web end, the basic information of the project can be set, the scope of the work area is configured, and the data resources are configured, which are pushed to the field.
investigators. The roles of the project participants are configured, the geological disaster investigation points are counted and inquired, the investigation routes are planned and set, and the location of the investigators is checked in real-time (Fig. 2).

![Fig. 2 Managing geological hazard survey online](image)

2.2.3 Navigation point function
Using GPS positioning technology, based on mobile GIS and a picture of field survey, the real-time dynamic guidance of field survey route can be achieved by taking point or coordinate navigation. Combined with the identification of topographical objects, the location of investigation points can be determined quickly and accurately. According to the different types of investigation points, the construction points such as landslide point, collapse point, debris flow point, and special engineering geological point can be classified (Fig. 3).

![Fig. 3 Navigation point](image)

2.2.4 Data collection
According to the technical requirements of geological hazard survey, the standardization and complete input of field investigation record form information have been achieved, and allow the replacement of the paper format to digitalized format. Moreover, the system provides tools
such as measurements of distance, area, slope, and lithology information check to assist in the collection of survey data. Voice input is provided to improve the efficiency of descriptive information in the field.

2.2.5 Graph drawing function
The method of combined point, line, and polygon drawing is adopted to mark all kinds of geological hazard observation points such as boundary, fracture, and lithology. Geological hazard structures such as landslide back wall, boundary line, sliding direction, accumulation body, damage range, debris flow source area, flow area, and accumulation area were drawn, and the information of basic elements of point, line, and plane was input to realize the correlation collection of spatial vector data and professional attribute data. At the same time, to assist in the realization of geological disaster field investigation, the geological hazard data acquisition system improves provides powerful graphic editing functions, such as graph deletion, node movement, node deletion, node addition, surface segmentation, surface merging, surface common edge processing, and attribute modification.

2.2.6 Plane section drawing work
Using high-precision remote sensing image, geographical base map, and DEM data, through screen capture and terrain line extraction, and the standard drawing MiG paper mesh, with the help of professional drawing software, on the tablet computer (PAD) to achieve the detailed drawing of plane and section.

2.2.7 Photograph recording function
In the process of geological hazard field investigation, the geological hazard data acquisition system improves can realize the automatic correlation between geological hazard survey points and photographic records and can record the location, mirror image, and related description of photos.

2.2.8 Survey route collection function
Using GPS positioning technology, according to the sampling mechanism and sampling interval, the field investigation route can be automatically recorded to facilitate the inspection of the investigated route.
2.2.9 Work summary and management function
To summarize the working progress based on the system, the system could provide the summarized record of the field work according to the day or different time periods. The completed geological hazard survey points are classified, summarized, checked, and counted in real-time.

2.2.10 Data online upload function
The system also provides data upload and synchronization function, allowing all different types of information, which include media, documents, graphs, as well as the vector data such as the SHP or raster format files, database, etc., to be updated to the server. The data synchronization can be very important to improve the overall working efficiency.

3. System characteristics

3.1 Real-time, accurate, and efficient positioning and navigation
The system utilizes the Beidou/GPS satellite positioning technology and uses the registered remote sensing image or scanned topographic map as the electronic base map to display the current position and trajectory of the investigators, effectively improving the accuracy and efficiency of field positioning.

3.2 Use of GIS resources and functional services anytime and anywhere
In the process of geological hazard survey data collection, the offline map can be used at any time, and all kinds of functional services of GIS system can be used, so that the field work is more convenient, and the efficiency and accuracy of field work are improved.

3.3 Replacing paper-based workflow
The system could provide the paperless operation of the whole work, allows the superposition of remote sensing data and vector data, and directly uses it as the base map, without printing paper topographic map and remote sensing image. The system is embedded with a full set of forms, cards, and charts for geological disaster investigation and can be effectively expanded to achieve a paperless working procedure.

3.4 Fast data acquisition process
Using mobile devices and embedded GIS system, embedded data forms for different types of conditioning factors of geological disasters survey can be quickly selected and filled in the field, and the overlaying relationship between the survey data can be checked to ensure the accuracy and efficiency of field survey. At the same time, the photos taken by the survey equipment can automatically be associated with the geological disaster information, saving the trouble of manual matching. Moreover, the card content can be printed out at any time.

3.5 Meeting the full set of working procedures
The system can meet the requirements of field survey workflow: navigation and positioning, questionnaire filling, entity drawing, work summary, and workload statistics, among other work, can be completed by the system. In addition, the system is designed in strict accordance with the geological disaster investigation business process, in line with the habits of the frontline staff.

3.6 High-quality survey results
The system can automatically check the data quality at any time and greatly reduce the work and risk of retest. Creating a backup of the original data at any time can avoid the probability of data loss that could be induced by various problems. In addition, the system provides a standardized data conversion function, and the output data can be directly stored and shared into the standard database.
3.7 Track record to ensure the authenticity and reliability of the investigation process
Using satellite positioning, the system can effectively monitor whether investigators have access to the target site. Through the track recording function, it can display the track that field investigators have traveled to ensure the authenticity and reliability of the survey data.

3.8 Upload survey data in real-time and provide data results in a timely and rapid manner
Through the Internet, the data that has been investigated can be uploaded to the database in the case of data loss and provide to the staff in a timely manner, which is convenient for the work to inquire, browse, and data processing. Within the same investigation group, the data can be shared through the system, improving the working efficiency rapidly by preventing the repeated investigation.

3.9 The Web terminal displays the real-time location of field investigators to ensure the authenticity of the survey and the safety of personnel
In the case of network in the field, the location of field investigators can be returned in real-time and displayed on the Web to ensure the authenticity of the investigation work and the safety of investigators.

4. Application of the proposed system
At present, the system has been officially launched in May 2020 and has been promoted and applied throughout the country, including Sichuan, Shanxi, Shaanxi, Gansu, Yunnan, Xinjiang, and Guizhou, among other areas with severe geological hazards. The system was applied in different fields, including the first national comprehensive risk survey of natural disasters, national 1:50,000 geological hazard risk survey, geological hazard survey projects deployed by the CGS and other geological hazard survey-related work. In the application process, a large number of detailed, reliable, and accurate survey data have been obtained, fully meeting the design expectation and greatly improving the work efficiency of field investigation and internal and external industries. A complete field basic data collection database is constructed.

5. Conclusions
This study proposed a new online geological field survey system for geological hazard survey, involving numerous functions. The proposed system could provide significant support to field working requirements and provide rapid and efficient data information to technician and management personnel. The system could provide authenticity, timeliness, and reliability of data.

The following aspects should be considered by using the proposed online system for a more efficient and accurate geological field survey based on the relevant technical requirements and can be more beneficial to the wider range of applications and promotion prospects.
(1) Before the survey: All electronic data to be used in the survey can be downloaded and stored on mobile devices through the Internet for more rapid browsing regardless the time and location.
(2) During the survey: The positioning, multimedia, network transmission, and other functions of mobile devices could greatly reduce the interval time of various related operations.
(3) After the survey: The survey results can be uploaded to the server in time, and the Web client can be managed in real-time to improve work efficiency.
(4) Data security: The on-site survey data is recorded electronically and is transmitted to the indoor server, which can effectively avoid the loss of data and data.
(5) To facilitate the filing of data and the preparation of reports: The data, photos, video, and audio recordings collected on-site are sent back to the indoor server database, which can be directly exported for use in accordance with the previous paper form format.
(6) To facilitate the standardization and standardization of the investigation process: Through the built-in standardized and standardized data collection operation process on the mobile
platform, the operators are guided to collect survey data in accordance with the standard process and format.

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