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Earthquake Damage Prediction System Based on WebGIS

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Abstract: In order to solve existing problems in current earthquake damage prediction systems, for instance repeatedly functional construction, data updating hardship, an earthquake damage prediction technical service system with online service function built based on WebGIS is developed. This system adopts B/S architecture and a three layer mode, considering service-oriented thought. The database follows the earthquake industry code, employing oracle relational database and spatial database engine to manage and store basic data. The system is constructed in modularization development mode, applying enterprise service bus to integrate business functions. The system output could provide technical support and scientific basis for urban earthquake disaster prevention and mitigation, earthquake emergency management, urban construction and renewal and earthquake insurance.

Key words: Earthquake damage prediction, earthquake disaster prevention and mitigation planning, WebGIS, information management system

INTRODUCTION

Earthquake damage prediction is an important part of earthquake disaster prevention which is equivalent to estimating the probability of certain building damage degrees, casualties and economic losses under possible earthquake actions of various strengths, as well as comprehensively evaluating harm scopes and social impacts (Earle *et al.*, 2009; Erdik *et al.*, 2011). China has developed the research of earthquake damage prediction and disaster prevention countermeasure for large and medium-sized cities and the demonstration research of earthquake disaster mitigation for capital area since the 9th Five-Year plan. Over thirty cities and enterprises have finished their earthquake damage prediction work and built up the information management and decision making systems for disaster prevention and mitigation, with the guidance of the first national code (GB/T 19428, 2003). However, all these systems were delicately developed with decentralized functions and could only be applied in particular areas. Universal earthquake damage prediction technical service platform has not been developed.

The mass basic data was collected with long period and could hardly been updated. The systems could only calculate and show the results based on pre-stored database including building earthquake damage matrixes, but non-support for real-time fragility computing

(FEMA, 2003). Therefore, the author puts forward to build a unified HAZ-China Earthquake Loss Estimation System based on WebGIS platform (Chen and Sun, 2013). This system is set to integrate functions such as earthquake damage prediction, earthquake emergency response, earthquake field loss assessment, building safety appraisal, post-earthquake scientific investigation and post-earthquake rehabilitation. This study briefly introduces the overall function design and system architecture of Earthquake Damage Prediction System (hereinafter referred as EDP system) and the functional design and implementation thoughts for basic database and modules.

OVERALL DESIGN

Overall design: EDP system could serve for various professional and public users through internet as a universal public service platform. It provides basic data and scientific basis for urban disaster mitigation planning, earthquake emergency management, post-earthquake rehabilitation and earthquake insurance, as well as popularization and publicity of earthquake damage prediction knowledge for public. The system is mainly consisted of functional modules of earthquake influence field, geological disaster assessment, building earthquake damage prediction, lifeline engineering

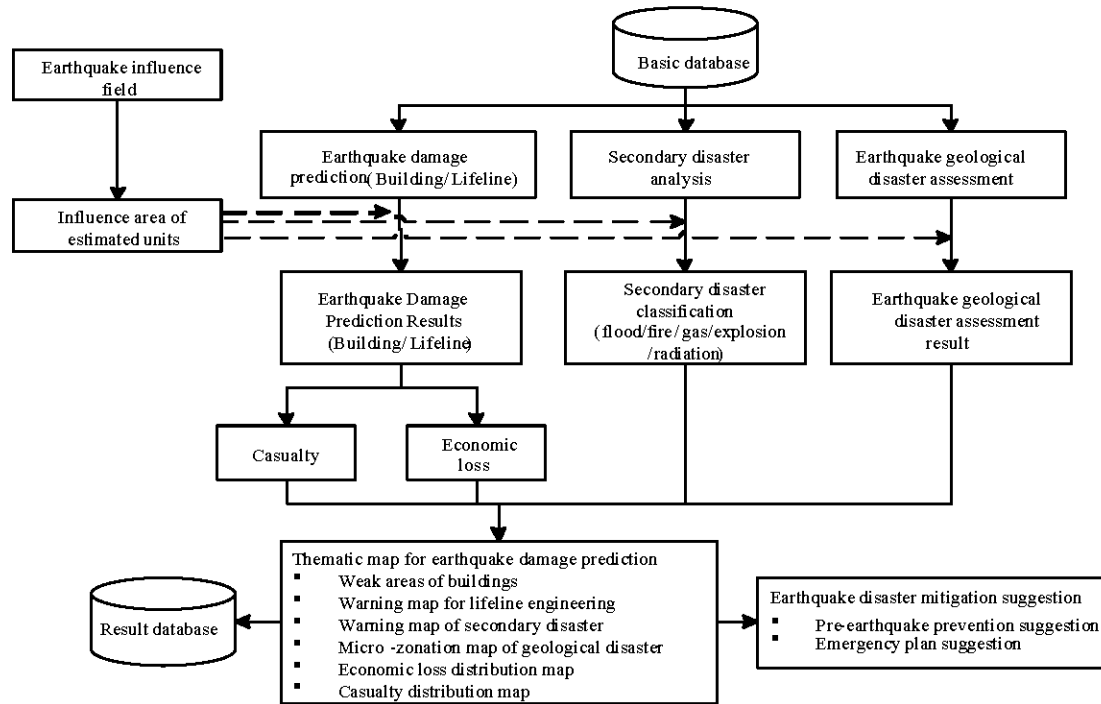


Fig. 1: Technical process of EDP system

earthquake damage prediction, secondary disaster estimation, economic loss estimation, casualty estimation and disaster mitigation countermeasure.

EDP system provides services of three layers: (a) The system offers mature and universal calculation models and basic data as default parameters. Users could calculate and estimate directly with a relatively lower precision; (b) The system provides calculation models of mature and universal, users could adopt local basic data and import which into system database following system defined data format and import interface specification. The result of this layer is relatively moderate; (c) according to local requirements, the system could provide professional customized service of calculation models and basic data and estimation with highest precision would be given. Based on the above thoughts, with the idea of modularization, system modules with “high coherence and low coupling” are developed. Each calculation model function is simplified and couplings between models are reduced in order to realize the “plug and play” module management. Data exchange and calling between different models are realized by adopting WebService Multiple transport protocol. Considering the user’s professionalism; EDP system could be divided into simplified edition and professional edition. The technical flowchart is shown in Fig. 1.

System architecture: EDP system adopts B/S architecture and the thoughts of Service-oriented Architecture. The system development employs WebGIS technology, function module development adopts component-based modular design and software service integration uses the Enterprise Service Bus. The system adopts three-layer architecture, including: Resource management layer, business analysis layer and application layer.

BASIC DATABASE

The basic data of EDP system includes the basic information of nationwide population, economy and environment, the distribution and basic information of all kinds of engineering structures, the structural characteristics, structure types and proportion of each type in various regions and various types of result data from system operation. The data is divided into two levels: detailed data and general data. Detailed data mainly comes from the accomplished earthquake damage prediction work and also the new supplemental data of social service engineering disaster prevention. General data is mainly acquired from new methods such as Google Earth remote sensing image extraction and demographic data deduction. The system gives estimation results of different scales according to data of different precisions. The system database involves varied mass data, manages

and stores attribute data by large-scaled Relational Database Management System Oracle, while using Spatial Data Engine on spatial data. The vector data is stored in common shape data format and the raster data is stored by taking tiff or grid format. Corresponding metadata and data dictionaries are established for all the above data for the efficient query and management of database.

SYSTEM FUNCTIONAL MODULE

Earthquake influence field module: Earthquake influence field which reflects the spatial distribution and spatial correlation of ground motion is mainly used to display the spatial distribution of earthquake disaster. Under any scenario earthquake, earthquake influence field module could generate earthquake influence field layers using GIS and calculate the impact ranges of different intensities by selecting earthquake intensity attenuation model and importing external influence field. By superimposing earthquake influence field and settlements layers, basic data such as buildings, lifeline engineering, secondary disasters, population, economic conditions could be extracted. The basic data would provide basis for following estimation of the secondary disasters, casualties and economic loss. Meanwhile, the module could realize predicting the damage distribution and economic loss of administrative regions by setting the probability intensity of entire work area as a certain intensity degree range from VI to X.

For small earthquakes, earthquake influence field module commonly adopts round attenuation model. While for large earthquakes, earthquake influence field module will employ oval attenuation relationship and fault distance attenuation relationship because the destruction is usually caused by fault fracture. Earthquake influence field mapping adopts the following methods: (a) Using interface input, (b) Reading intensity preliminary data from seismic monitoring stations and networks, (c) Obtaining the external influence field directly, (d) Hand-drawing earthquake influence field and (e) Drawing intensity anomalies. For the generation of earthquake influence field, the key issue is to determine its spindle axis direction and the system can realize it by operation interface input and mouse selecting. There's also another way to achieve the goal: the direction could be calculated by automatically identifying the orientation of the nearest active faults from the epicenter, without default spindle axis parameters. The main interface of the system is shown in Fig. 2.

Building earthquake damage prediction module: Building earthquake damage prediction module contains earthquake damage prediction of single building and building groups. Building earthquake damage prediction module gives out earthquake damage prediction result of single building and fragility matrixes of building groups by selecting rational fragility analysis method and deposits the results into the basic database of earthquake damage prediction and attribute list corresponding to building layers (Chen and Sun, 2010; Sun and Chen, 2008, 2010; Sun *et al.*, 2012). By overlaying the earthquake influence field layer and administrative boundaries and building layers generated by GIS, this module generates the damage quantity and degree of different types of buildings in various intensity areas and shows the damage condition by thematic maps, statistical graphs, tables, etc. Moreover, the module comprehensively evaluates seismic capacity of buildings, points out the high risk areas, main problems and weak links and provides chart derivation of which. Different mode, sampling rate, fragility analysis method and earthquake damage prediction results display is separately defined for different investigation levels.

EDP system provides default models and detailed model to support the building earthquake damage prediction calculation. The default models are based on the existing universal building earthquake damage matrixes and the detailed models provide operation windows for users to directly input local earthquake damage data including building earthquake damage matrixes or earthquake damage prediction results of single buildings. Then the building earthquake damage matrixes could be obtained by real-time fragility calculation method given by the system.

Lifeline engineering earthquake damage prediction module: Lifeline engineering is the umbrella term of energy (electricity, gas, oil, heat) supply, communication, traffic and water supply engineering systems. This module mainly realizes the earthquake damage prediction of all kinds of engineering structures, equipment, systems in lifeline engineering, gives out fragility analysis results, network function failure analysis result of the whole system and earthquake influence scope analysis results, as well as the spatial distribution map of lifeline engineering damage under scenario earthquake and analyses the weak link of each system, combining with earthquake damage prediction results of key projects such as dams and nuclear facilities to provide corresponding cautionary suggestion when necessary. Different



Fig. 2(a-b): Earthquake influence fields of EDP system (a) Scenario earthquake and (b) Actual earthquake

assessment methods and output results are defined for different classes and types of lifeline engineering.

SUMMARY

EDP system using WebGIS put forward in this study is trying to provide a uniform researching and application platform of earthquake damage prediction for public

service, considering problems existed in former ones. In accordance with “Code for earthquake disaster evaluation and its information management system”, together with China’s actual demand and objective status service object, main functions, system structure, database and function modules are presented in this study. It’s necessary to point out that the methods used in modeling and calculation of Lifeline engineering systems damage

and secondary damage is still not sufficient and further development should be accelerated. With the booming of digital city, it is a trend to construct a uniform forecasting platform. Not only the achievements can be shared and budget can be considerably saved, but also the industry related field like city earthquake damage reduction, land utility, earthquake insurance will be paid more attention and further long-term investment.

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