Intelligent Decision Support Platform for Disaster Management in Railways

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ABSTRACT

Information system can support emergency operation in railway by data transmission and process automation. This paper presents an Intelligent Emergency Decision Support Platform in three levels architecture designed for typical disasters in order to promote safety and rescue capability. The platform consists of five sub-systems including monitoring, emergency duty, resource management, commanding and evaluation, and also contains collaborative systems, such as GIS, alert notification and information share. The approach of combining knowledge and case-based reasoning with intelligent analysis is adopted to establish rescue scheme. The components of information share perform a strong role in achieving data interaction and conversion, based on the performance extension of middleware and information processing. Information release is designed to keep continued rescue orders and obtain coordination with related agencies by employing wireless communication and railway private network as well as remotely control and processing. The railway bureau of Nanchang is picked as an example to serve as an application of certain layer in the platform. The results show that the proposed platform can collect information of incidents and start workflow on appropriate rescue stage. It prominently benefits for producing emergency schemes, continuous tracing and feedback.

Key words: Disaster Management, Emergency, Decision Support, Railway

1. INTRODUCTION

As an important bridge to connect different regions, the railway network has covered most provinces and cities in China. Complicate operations in multidisciplinary fields are the basic characteristic in current railway system and it is operating overloaded all the time. Due to potential factors such as equipment failure, natural disasters, especially for the randomness, propagation, and diffusivity of disasters, the railway system is subject to transport interruption, low efficiency, even damage to the network. To date, railway system in China has undergone speed promotion for six times, including heavy load and large quantity of trains, which strictly requires safety and security. With increasing occurrence of disasters, it is vital to improve emergency capability of railway system in that it serves as the main way to convey rescue resources, collocated by government during the period of Catastrophe. The emergency assurance in railway includes two aspects, emergency rescue and network transport guarantee.

The safety greatly depends on disaster preparedness and emergency measures. Pertinently supervising danger zone and facilities by installing sensor devices can improve reliability [1]. Emergency management visualization with hypermedia digital application [2, 3] and available equipments position by employing GIS technologies [4] can assist emergency decision [5]. Moreover, necessary resources like emergency plan and information need to be integrated into the emergency management system, corresponding to emergency process [6]. As for devices and control systems distributed in diversify areas that sustain transport every day, large scale information transmitting in these systems are organized to attain continuance, especially for emergency state. In addition, resources planning and rescue decision are urgently required in the context of disaster. Thus, primary information system can not accomplish this task any more. To meet the challenges, the decision support and information interaction platform is presented.

The rest of this paper is organized as follows. Section 2 summaries railway emergency process and associated management organization. Section 3 presents architecture of an emergency decision support platform and relations of components. Then crucial technologies and principles adopted in the system are explained in Section 4. We describe design of support subsystems with their interactions in Section 5. Section 6 illustrates implementation through a practical example. Finally, Section7 concludes the paper by describing results and deploying observations.

2. EMERGENCY ORGANIZATION

The incidents the railway confronts include four types: (1) natural disaster like earthquake or hurricane, (2) accidents aroused by malfunction or manual fault, (3) public health risk because of illness diffusion or food pollution, (4) crimes and terrorist. All of these are included in the aims of emergency preparedness. As for the variedness of the incidents, we need a general framework to establish unified management as well as according with specialty and complexity of railway system.

The Emergency Decision Support Platform (EDSP) is built in three layers, related to management organization. The railway department is in charge of decision on the top layer, and also commands other layers. The bureau layer is the middle layer that authorizes trains scheduling and stations in certain region [9]. In station layer, rescue tasks will be executed according to
scheme provided by top layer. Therefore, the coordination and information supplied by communication net are basis for EDSP between layers, as well as contact with social institutions, such as police, hospital, etc. The emergency process can be preceded on EDSP in dealing with distinct incidents, which integrates advanced technologies like information analysis and share, supervision and alarm forecast, intelligent decision, and resource allocation.

3. SYSTEM ARCHITECTURE

The EDSP builds in distribution structure, which means enterprise servers and storage devices are used to integrate specific data, application and service for railway department and 18 bureaus, aiming to transaction together and share resource within subsystems. Due to station layer is mainly responsible for sustain and update data, it is required to visit bureau layer in Browse/Server but without server stalled in. The three layers are linked by internal communication network, and the end of mobile can interact with any layers through public wireless net. Users in top layer and middle layer can operate respective applications by self LAN.

The EDSP consists of two categories of components: one is operation application including five subsystems: supervision, emergency duty, resource management, commanding, and evaluation, the other is support application including three subsystems: information share, railway GIS, and alert notification. Especially, the information share is the core of information and data interaction which depends on data federation and web service [7], as shown in Figure 1. The metadata is collected and converted into multiple forms like files or pictures from database installed in servers and sent to different hardware.

![EDSP structure](image)

**Figure 1. EDSP structure**

**Supervision and forecast**

The monitor and CCTV system are used to supervise and submit real-time data for daily operation and disaster management. The tasks also include potential danger objects and critical protected facilities, such as exploder, flammable material, chemical product, danger cargo, and gasoline nearby rail lines. These static data will be collected and shown in GIS graphics. Another important performance is alarms for abnormal status, which need to contact with special monitor systems, i.e. SCADA, BAS. The EDSP elicits advanced alert information to compare with information of running trains, captured from automation transport control (ATC) system. In case abnormal signal appears, the system will alert to decision makers by supplying features and evolution of incident. Original data comes from special systems, i.e. 5T systems, train monitor, geological subsidence monitor in Qinghai-Tibet railway, video watch-control system, storm warning system, rainfall monitor system. The metadata acquisition demands collaboration of subsystems for automatic data processing, and then essential data will be transferred to analysis and risk assessment on current status. Consequently, the results determine whether alarm should be started and in what level.

In order to obtain correct and effective scheme, most of work is to identify and extract information to deliver to receivers of modules. Once alarm happened, EDSP is started and incidents situation is collected from supervision subsystem, also include report submitted from bureau or station. The alert notification subsystem is appointed to inform decision makers and relevant personnel. GIS system is used to seek available resource and transport tools in appointed region and make out reasonable deployment scheme [8], i.e. routes of rescue team from salvage agencies.

**Emergency process and command**

The subsystem builds in the mode of workflow management in view of emergency treatment could be separate to a few continuous but independent stages [9], and the purpose is to achieve automatically execution of each stage in appropriate time, attributing to the chain of stages, designed in pattern of successive running and driven by exterior engine. Concerning emergency plan built beforehand can not meet with disaster background, the treatment depends much on layout and circumstances of scene, thus, intelligent decision is used to establish rescue scheme with information disposal in GIS and resource management subsystem.

**Concurrent multi-event management**

The EDSP allows treating several incidents simultaneously, named concurrent queue, which allows switch state between current dealing and suspending. If the system is in the process of incident, any details and proceedings of other incidents will be completely recorded until treating status comes back. The emergency workflow of EDSP can be terminated only if user inputs password that starts up system processing and pass-through authentication. After treatment, the EDSP
automatically produces an assessment report in the light of records of incident, so that experience analysis and comparison could be carried out.

## 4. CRUCIAL TECHNOLOGIES

### Intelligent decision support

Search for emergency plans fits the principle of Case Based Reasoning (CBR) \([10]\), since treatment of incident relies heavily on past experience, frequently improving old methods or assembling parts to construct new ones by knowledge reuse. At first, the plan is defined as a contextualized piece of knowledge representing an experienced situation, formed by two components: problem description and solution. The approach of establishing scheme specifies the model, while data and parameters used to instantiate execute process. The set of attributes, elicited from common descriptions of event, is crucial for quality of our retrieval algorithm and acts as a first filter over the plan set to accelerate retrieval. In order to connect with attributes query, indexes are appended by constructing a set of data structures linkages to the plans. The chain of operation steps are matched to duties, involved in emergency plans, to form knowledge net of contents for similar incidents, in which the duty is treated as nodes. Consequently, a chain table of duties can be attained and serves as essential index to describe model and metadata used to express problem. The similarity evaluation method adopts the nearest-neighbor idea \([11]\):

\[
\text{Similarity}(I, P) = \sum_{i=1}^{n} w_i \times f(I_i, P_i)
\]

where \(i\) is an individual attribute; \(f\) is a similarity function defined for computing similarity between the input plan \(I\) and a stored plan \(P\); \(w_i\) is the importance weight. If outcome indicates no available plan, the transference approach aimed to adjust relevant parameters is applied to extract reusable parts from chosen plans and create candidate scheme. Furthermore, a new plan should only be retained if it is sufficiently different in semantics in order to avoid excessive expansion of plan base. The process to intelligently produce emergency scheme are shown in Figure 2. The Base packaging operations to database provides a fundamental interface to execute data visit and operation logic; other packages are used to build interfaces defined in this package.

The analysis is started to pick out the most prominent difference between results and the goal, and also includes reusing parts, to match with subject through dynamic study. The strategy that conversion and parameters alteration are used to modify primary plans to gradually fit for actual incident. The retrieval mechanism starts through driving scheme workflow and the result is regarded as candidate scheme. In the next step, it is supplemented by scheme of scenarios, based on collaboration of GIS, to establish final scheme for rescue.

As for rescue focuses on passenger evacuation and resource allocation, math algorithms to improve rationality are employed in our project. For other region in the railway network, there is need to prepare scheme to assure trains running and avoid disturbance to schedule because of dissemination of trains delay. EDSP calculates time that trains could be interrupted beforehand in the light of incident location in rail net, and analyzes which trains and related rail lines could be affected. The alert notification subsystem starts alarm in advance to inform passengers abiding by rescue request. Moreover, stations in other regions prepare to evacuate large scale passengers will be reminded.
Client/Server, Browse/Server, and mobile. In C/S, performance covers browsing map, creating and modifying data, spatial modeling, and dynamically displaying objects in two-dimensional or three-dimensional. The maintenance of geographic spatial database that allows multi-user concurrent access is also involved. According to treatment request, custom applications are created as form of document or catalog for geographic data set or GIS service. In B/S, clients visit server through web browser to attain GIS services, such as spatial search, object properties, span and zoom of map.

The mobile client is necessary for emergency, which installs GIS in devices like PDA or notebook PC. EDSP separates applications into simple tasks to support GIS operation outdoors by wireless connection to GIS web server. In the side of mobile client, all sustaining information can be downloaded from server, and correspondingly, the data in the scene could be collected. Thus, accurate data helps to figure out resolution of cartography and navigation.

5. SUPPORT SYSTEMS

Information Share System (ISS)

ISS is regarded as hinge of exchanging and sharing all sorts of information among specific systems in EDSP that utilize uniform interface so as to reuse modules. ISS has developed in standardized communication architecture and demonstrated solutions for overcoming interoperability challenges like data integrity and consistency in multiple layers.

ISS builds on share of database grade that means information can be directly attained on the level of databases, and united view is constructed for multiple databases in the circumstances of distinct structure called data federation. Moreover, the functions that can be shared in subsystems are converted into form of service to recombine by adopting service packaging technology, in which the definition and registration of service are required, also need service queue management and decomposition. Especially, in order to dynamically identify and comprehend messages, the middleware is used to provide reliable service and intelligent route for target system to carry out correct data exchange. The principle of data transmission in ISS is shown in Figure 3.

EDSP sends emergency orders to supervision system and command system to coordination, based on services offered from ISS that executes data transition in various format on the basis of XML application. The share database serves as knowledge resource to support decision and offer web service. The alert notification subsystem is composed of application server, database server, message server, CTI server, and the end of management, shown in Figure 4. The CTI server applies resolution of united calling based on distribution IP to achieve stability, reliability, and flexibility. The message server deploys in message modem or pool that links 8 SIM cards in series to receive or send message. The systematic data is recorded in servers of application and database so that users can conveniently manage and look over information in special systems. Actually, the three servers have respective functions but share a common server in the light of request of disaster management.

Figure 3. Communication in ISS

Figure 4. Network and Components of Alert Notification Subsystem

The system offers information announcement, such as voice, broadcast, fax, Short Message Service (SMS) of mobile phone, and records management, so corresponding hardware is needed. For instance, the CTI server can assist telephony; voice fax relies on IVR platform; and SMS requires wireless GSM devices. While the approach of dealing with information received from different equipment is similar that a list of messages should be built, then classify and convert to message that can be recognized, finally returned receipts are reserved for query and check.

Middleware expandability

In order to utilize dynamic information received from other systems, it is essential to adopt web service interface in standard format, in which EDSP acts as applicant of web service and other systems serve as service providers. Once both sides of interface choose input parameters and return values, the provider will put out service to assigned address for visit of applicants.

The subsystems and modules of EDSP exchange data on united transmission of ISS, depending on middleware technology. ISS sets up queue with excellent security measures to assure accuracy of keep and fetch data. When data is obtained, it is right that loading them into queue to wait scan of transmitter by transferring interface. The processes maintain two kinds of disposal. In the process of receiving inspection, the format and content of data is need to be analyzed, and then translated into proper coding to store in database before returning receipt to initial senders. In addition, the sending process includes examining data directory and sheets, then transmits to ISS after verifying exactness in format and coding, then returns successful receipt to inform previous task has finished.
6. IMPLEMENTATION

The Nanchang bureau is picked as experimental unit of bureau layer in EDSP. The system software and hardware are installed with corresponding subsystems: Emergency Duty, Resource Management, Commanding, and Evaluation. In particular, resource dispatch is based on application of GIS, shown as Figure 5. The platform starts appropriate processing on condition of requests and verifies performance of coordination and interaction among components.

![Figure 5. GIS Application of EDSP](image)

The emergency scheme relies much on information collected from special subsystems like GIS. In specific, the location and situation of railway infrastructure such as rails and stations in the range of this bureau are gathered and laid out in maps, besides security information and attributes, i.e. risk units, buildings nearby stations, other transport tools and yards, landform of the scene, etc. Then spatial analysis with introducing assessment models is employed in order to establish rescue scheme that greatly suit for scene.

In order to obtain information of the scene, we pick up some main stations that belong to Nanchang bureau as station layer, which provides video and monitor information, and resource data should be also needed. According to the user, the subsystems of emergency duty and supervision has got good use because of perfect integration with practical operation, which contributes more on defending disaster as soon as possible. An incident of the train breaks out of rails was simulated and EDSP was started to deal with emergency. The result proves the commanding subsystem can play a vital role in decision making and accelerate rescue. Owing to the effectiveness of treatment scheme greatly depends on match of emergency plan and maintenance of resource data, the reliance among multiple subsystem brings a limit for EDSP, which means strict consistency of fundamental data. Moreover, a large quantity of GIS data leads to upload or download slowly, thus, optimizing data read and algorithm is further study for this project.

7. CONCLUSION

Concerning complicate emergency process and collaborative operation of cross department in railway, we design and develop a comprehensive information platform for disaster management and process control. Since diversity of the disasters and related specialty, EDSP is built on a general framework that is divided into 3 stages to construct a closed-loop execution: supervision and alert before incident; collect information for decision support and resource allocation in the course of emergency; analysis and assessment to expand knowledge base for daily training of security. The platform devotes to extraction of monitoring information and dynamic data consistency in multiple layers, in which manage different regions that rails covered. Using web clients, EDSP demonstrates how alerts can be activated after analyzing data and comparing them to standard, and solves critical problems of decision support such as automatically figuring out rescue scheme on the basis of position and navigation, offered by GIS and GPS. In addition, in the research we found that for the range of the railway network, in order to reduce damage, short-term and real time alerts in advance should be distinguished from specific regions, which means on the one hand treatment in the scene need to be emphasized, on the other hand, in potential impact region emergency preparedness is more important. Our work aims at encapsulating special operation and large quantities data interaction into united platform and building a channel for managers to conveniently and visually guide rescue in the spot, and more performance related details will be explored with further observation and long period of practical use.

8. REFERENCES