Research on Remote Cooperative Plotting System for Power Emergency Commanding

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Abstract. Geographic information system (GIS) platform is one of the most important tools in electric emergency command area to improve the command efficiency. The GIS systems available only hold basic data and mainly used to browse, therefore can’t show the information and situation in the process of emergency command. This paper proposes a remote collaborative consultation system architecture for power emergency based on GIS. The collaborative plotting on the same GIS platform through computer network remote terminal is realized, using the GIS map plotting technology and XML symbols drive technology. System plotting symbols situation shows the time series mode based on event driven, can be displayed in chronological order and calculate the huge amounts of information along with emergency events. It can get the emergency situation quickly, and promote emergency command efficiency significantly.

1. Introduction

With the application of state grid geographic information system (SG-GIS), the use of GIS system in the fields of grid maintenance, marketing, infrastructure and security has significantly promoted the management efficiency. Power emergency command is closely related to geographic information, and the effective use of GIS system to assist it can significantly improve the efficiency of emergency response. However, the emergency command GIS system available only provides the display, inspection and statistics of power grid facilities information, lack of real-time disasters, resources, commands and other key elements of emergency command, which is difficult to fully show the emergency situation. In addition, emergency commanding usually occurs at multiple remote locations, the use of GIS in a single location alone will result in emergency information incomplete. Therefore, how to update the data cooperative dynamic plotting of GIS emergency commanding at multiple remote locations simultaneously, and show the emergency response situation completely, is the new direction for electric power emergency commanding GIS system to be practical.

2. Power Emergency Cooperative Plotting Demand Analysis

2.1. Basic Information Interaction and Display of Emergency Command Based on GIS

The primary work of power emergency plotting is to divide the area and process basic geographic data such as power grid facilities, road traffic, satellite images, terrain and landform, etc. The plotter determines the plot area according to the task, and plots the early warning, disaster situation, emergency events, command, etc. in the area. The plotting objects are substations, power transmission
lines, electricity units, roads and other disaster-bearing bodies, floods, earthquakes, freezing and other disaster-causing factors, rescue workers, equipment, materials and other emergency resources, as well as assembly, evacuation, repair and other emergency actions. Due to the characteristics of uneven distribution, group relevance and individual integrity, and change dynamically with the emergency response process, it is necessary to design the relevant graphic symbols of emergency command based on grid GIS to plot on the base-map using human-computer interaction interface, with the functions of modification, movement, deletion, etc., which can display the geographical location and influence range of various types of plot symbols on the map, so as to fully know the emergency situation.

2.2. Visual Display of Power Emergency Command Graphic Symbol Plotting

Currently, the geospatial information of the power grid, such as power facilities, roads and satellite imagery, is carried by the two-dimensional GIS platform, which is highly efficient and relatively simple to operate, and its geospatial information can meet the needs of emergency command in the macro-scope. The power emergency command graphic symbol based on the 2D platform contains three types: point plotting, line plotting and surface plotting. Point plotting can describe the site, resources and other point-like targets, composed of image vector symbols, line plotting can describe the transmission line and other line-like targets, composed of vector segments, surface plotting can describe the disaster range, inspection interval and other regional targets, composed of the circular, rectangular or irregular polygon and other closed surfaces. External and internal attribute data should also be designed for each kind of plot. External attributes refer to the size, shape, color, filling, transparency and other visual properties of plotting symbol, which are closely related to the meaning displayed by plotting symbols, such as using different color to express the urgency degree of a disaster. Internal attributes such as the number, profession, unit ownership, person in charge and contact information of a rescue team are hard to display directly on the visual platform, it can be displayed by checking the plot and looking up the details. For each plot symbol, its internal and external attributes should be designed to facilitate a more intuitive and accurate understand of the meaning of the symbol.

2.3. Multi-party Remote Collaborative Consultation Demand

Disaster emergency response has the characteristics of multi-factor, wide-ranging and group decision-making, and the command process is usually coordinated by many people. However, these decision makers are often distributed in different space areas, from rear command centers, field commands at all levels to the first site. They have part of the information, and integrate, share and coordinate the information distributed in different spaces, which is an important means to improve the scientific nature of emergency command decision. Therefore, the geographic information platform needs to adopt the cooperative plotting system based on remote network communication. No matter where the plotting operators are, they can add, modify and delete the plotting symbols through the remote plotting system. At the same time, the plotting symbols in different locations will be displayed on the same map, which enables multi-plotting and collaborative consultation based on “emergency one map”. Based on multi-party information, it can directly show the disaster area, rescue force material distribution, rescue operation plan and other timely thematic information, providing a fast and powerful basis for scientific emergency response decision.

3. System Architecture and Key Technologies

3.1. System Overall Architecture Design

The overall architecture of the remote collaborative plotting information system is divided into three layers which are listed in Figure 1:

1. Application layer: achieve remote information share with emergency plotters in different regions and disaster relief workers on site through the function of consultation plotting and decision directing.

2. Service layer: realize the general tool function of the system, play an important role in the process of consultation plotting, in which the collaborative management module controls the whole plotting process and manages all the plotting system users, it provides users with consultation plotting
map tools. GIS map can visually show the terrain and landforms of the affected areas, it make various impact analysis and trend judgment combined with map. Data sharing services, including real-time information sharing and all kinds of data information map visualization, which can implement information instruction transmission, it is easy to access all kinds of disaster information.

(3) Data layer: store and manage all relevant data of disaster emergency remote consultation, including basic geographic information data, real-time data, disaster analysis data, etc., provide information service data support for the application.

![Diagram of Remote Collaborative Plotting Information System](image1)

### Figure 1. Overall architecture of Remote Collaborative Plotting information system.

### Figure 2. Illustration of Plot Data Structure.

#### 3.2. Basic Geographic Information Data Distribution and Data Communication Mechanism

The system uses C/S architecture to publish basic geographic information data, and ArcGIS map slicing technology to improve the efficiency of data distribution. The whole system is set up in the grid information intranet, the server is located in the III/IV area, the client is located in the intranet office computer of the emergency command center, and the geographic data in the GIS server is viewed through the network. The client mode can not only efficiently invoke the GIS functions and services provided by the server, it also provide features such as layer management, data retrieval, spatial analysis, graph plotting, graph marking, thematic map making, collaborative plotting results storage that are more functional than B/S architecture.

#### 3.3. Emergency Plotting Graphic Symbol Attribute Architecture

According to the power emergency command requirements, emergency plotting symbols include events, disaster situation, sources of danger, protected objects, emergency resources, emergency operations, etc. However, there is no graphic symbol standard for electric power emergency command, the plotting symbols in existing emergency system generally serve as a schematic diagram and usually displayed in the form of picture symbols plus text description. Although relatively intuitive, it lacks the function of finely show emergency command situation. In order to achieve a more accurate and detailed emergency command situation, the system designed a structured data architecture for each plotting symbol, which is used to realize more extensive data statistics, presentation and query.
functions on the client side. Figure 2 is an example of structured data for the “emergency repair team” graphical symbol. Each plotting graphic symbol corresponds to four parts: display information, basic information, attribute information, and unstructured data. Among them, display information control the visualization of plotting symbol in the GIS system; basic information reflects the maintenance information of plotting symbol; attribute information controls the relatively standardized and quantifiable specific professional information in plotting symbol; unstructured data is all kinds of text, pictures, videos, files that can be associated with plotting symbol. After a plotting symbol is structured, the contained information will be much larger than a picture in traditional system. Structured database can provide great convenience for emergency situation statistics, query, classification and analysis.

3.4. Multi-party Collaborative Plotting Technology for Remote Communication Based on XML

Remote multi-party collaborative consultation plotting is an important prerequisite for “emergency map” to play its role. In an emergency event, plotter in different locations plot and upload information they know, then the integrated emergency situation formed after gathering all kinds of information, which is the basis of emergency command decision. In the practice of power emergency, remote plotting can be carried out at different locations and by personnel with different tasks, such as command centers at all levels, front-line headquarters and first site. The transmission and aggregation of plotting information can be realized through optical fiber, satellite, wireless self-organizing network and other communication means as shown in Figure 3.

The ultimate goal of the remote multi-party situation collaborative plotting system is to unify the visual thematic map of emergency situation, show the emergency site situation in an intuitive form, and ensure the integrity of detailed information. Therefore, all kinds of symbols must be stored in a structured data architecture to facilitate information transmission, display, statistics and analysis. XML language is very suitable for the remote network communication of plotting symbol.

Figure 4 shows the structure of the remote collaborative plotting management which is mainly composed of user management, network transceiver management, XML file management and collaborative interaction. The main functions of each module are shown below:

1. user management: realize client login control and authority management.
2. network transceiver management: upload, update, or distribute work based on network data input by users.
3. XML file management: save the XML file associated with plotting symbol in the plotting server. XML file management parses and updates the contents of the file after plotting symbol is updated.
4. System Function Design

4.1. Introduction to System Basic Functions

The main function of this system is to create, modify and delete all kinds of plotting symbols in various plotting clients using the client interaction system. Clients can upload voice, pictures, videos, and display it in real time on the GIS platform. In addition, for portable clients, the positioning function of the client hardware platform can be used to display, track record and playback of real-time online positioning information of mobile terminal, including the dynamic GPS location of command vehicles, personnel and nodes, which also support real-time database information interaction. Besides, the platform uses the sliced data published by GIS network server to customize the display layer of various GIS information, it has map situation plotting library and plotting function that meets the criteria of plotting and military standards, which can measure length, coordinates, area, volume, digging analysis, etc., and contains road network data covering all areas of Sichuan province (including provincial road, county and township road), all kinds of important POI data, 2.5 meters resolution satellite image data, 30 meters accuracy digital elevation DEM data. The map layer contains satellite images, road traffic, administrative divisions, schools, hospitals and other points of public interest, its maximum scale is 1:1000, which can satisfy the browsing of geographic information accuracy at the block level.

4.2. Power Emergency Plotting Symbol Design

The various plotting symbols required for power emergency systems are designed to assist power disaster relief decision-making, including text symbols, disaster situation symbols, trend symbols, and resource symbols. The requirements of the disaster-affected symbols are as follows:
- Tag category: different plotting symbols for different categories of objects;
- Mark level: different plotting symbols for different degree of influence;
- Mark range: different plotting symbols for different extents of disasters;

In this system, symbols are mainly presented in the form of two-dimensional symbols including dot symbols, line symbols and surface symbols. Dot symbol is vector symbol. The proportion between basic shape of the symbol and the number remains unchanged, which can show the emergency situation, resources and so on. Surface symbol contains two-dimensional vector symbols with not fixed irregular envelopes (generated by formulas), such as two-dimensional arrows, which mainly show emergency actions, etc.

This system refers to the symbol standard of domestic public safety and electric power related industry, designs a whole set of standardized power emergency plotting symbol library, and designs 84 vector symbols according to 4 categories and 13 types. The details of the symbols are listed in Table 1.
Table 1. Power Emergency Plotting Classifications.

| Category                              | Type                        | number of plotting symbol |
|---------------------------------------|-----------------------------|---------------------------|
| Emergencies and disasters             | Natural disasters           | 7                         |
|                                       | Industrial accidents        | 4                         |
|                                       | Public facilities accidents | 6                         |
|                                       | Personal accidents          | 5                         |
|                                       | Power accidents             | 8                         |
| Sources of danger and hidden risks    | Natural carriers            | 4                         |
| Emergency objects and protection targets | Artificial carriers       | 9                         |
|                                       | Public facilities           | 13                        |
|                                       | Teams                       | 3                         |
|                                       | Power facilities            | 5                         |
|                                       | Emergency sites             | 5                         |
| Emergency resources                   | Emergency teams             | 4                         |
|                                       | Emergency supplies          | 11                        |

According to the different severity of disaster or risk, the symbols such as disasters, risk sources, protection targets, etc. can be classified and identified, which can better reflect the information of emergency situation plotting. For emergency and disaster icons, red, orange, yellow, and blue correspond to the event's particularly significant, significant, large, and general four levels, respectively. For hazard sources and hazard areas, red, orange, yellow and blue indicate the order of risk value from large to small. For the protection target icon, red, orange, yellow, and blue indicate the order of protection importance from highest to lowest.

In order to distinguish in the non-color system, different shape completeness of each kind of border has different meanings, the shape completeness is divided into four categories: complete border (no gap), two gaps, three gaps and four gaps. The completeness of the border is matched with the color. Red border corresponds to four gaps, orange border corresponds to three gaps, yellow border corresponds to two gaps, and blue border corresponds to a complete border, which can facilitates the logo color recognition, as shown in Figure 5. For non-graded symbol like emergency resource or equipment, it can be represented by square border filled with background color, as shown in Figure 6.

Figure 5. Illustration of Rated Point Symbols.

Figure 6. Illustration of Unrated Point Symbols.
4.3. Plotting Presentation Architecture Technology Based on Event-driven

The main function of the power emergency command collaborative plotting platform is to display the massive emergency information simultaneously on the platform at the same time the emergency event developed, so as to provide emergency command decision-making reference, which is significantly different from traditional emergency plotting systems. Traditional system mainly based on the static display of emergency plans, it is a visual display of the pre-deployment of emergency response, which is difficult to reflect the dynamic process of emergency situation over time. However, the cooperative plotting of emergency command developed in this system is to continuously iterate and update information in the process of emergency response, so as to visually synchronize the real emergency situation on the information platform, which means that the platform's information is driven by emergency events, rather than traditional personnel decision deployment.

Compared with a single static plotting symbol, emergency events focus on the description of event process, including a series of contents such as event type, location, object, event process and processing result. We can understand the process of emergency situation fast and efficient when taking emergency events as a whole. Obviously, an emergency consists of a series of plotting symbols, which is difficult to summarize accurate information of a event in traditional single decentralized mapping system. Besides, in the process of power emergency, a large number of emergency events will be pushed continuously along with the progress of disaster, the use of simple static symbol plotting makes it difficult to effectively distinguish emergency events at different times and places due to the lack of time process elements, and the visual display of information is messy, which is not conducive to the emergency commanders’ quick understanding of the situation.

The event-driven plotting process is shown in Figure 8. After the emergency event plotting is started, the single symbol plotting process is carried out in a cycle to fully present the relevant visual signs in the emergency event. After the completion of all kinds of single symbol plotting, the process will end the creation and modification of symbols and turn to the input of plotting event information, and input related information of events by human-computer interaction or system extraction. Then the complete event data formed and imported into the event database to complete event plotting.
Figure 8. Event-driven Plotting Process.

Figure 9 shows the actual system event-driven emergency command plot event entry. In the system, we can easily browse and query various events, and accurately locate the location of events, view the relevant plotting symbols associated with events by double-clicking the event message bar. Meanwhile, the emergency situation can be tracked and analyzed through the query, sort and statistics of event keywords. The system can play the visual presentation of each emergency event in order, which realize the visual report function of emergency situation.

Figure 9. Event-driven Plotting Illustration.

5. Discussions and prospects

5.1. Enhanced Interactive Consultation Function

Currently, the platform's multi-user operation only rely on the prior fixed permissions for permission coordination. However, in the process of emergency response, this fixed permission setting may be not flexible enough which may cause important information omission or delay. In the future, it is necessary to introduce the dynamic permission management mechanism based on the consultation system to join all participants in the same meeting, and dynamically adjust the plotting permission through setting real-time online communication and permission management, so as to realize more flexible and efficient collaborative plotting.
5.2. LOD Based Hierarchical Display

In large-scale emergency operations, due to massive information input, a large number of plotting symbols may be displayed on the GIS platform, which makes it difficult for emergency commanders to find the key event plotting in the first time. Therefore, it is necessary to introduce hierarchical display based on LOD (Level of Display), make use of all kinds of structured data information in the existing plotting symbol data, and associate it with the scale in GIS information system, so as to display appropriate and relevant plotting symbols on the maps at all levels of measuring scale, which can help commanders understand emergency situation more accurately.

6. Conclusion

This paper introduces the need for emergency cooperative plotting, proposes an event-driven remote cooperative plotting scheme and introduces the overall framework and functional design of the system. A hierarchical plotting symbol library with the characteristics of power emergency is designed to realize the remote “one emergency map” collaborative plotting function with multiple users online at the same time. Moreover, an event-driven collaborative plotting method and process for emergency situations are proposed. The system can provide a rapid, intuitive, accurate and efficient platform for power emergency command, which is of great significance for improving the efficiency of power emergency command.

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