A positioning system for forest diseases and pests based on GIS and PTZ camera

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Abstract. Forest diseases and pests cause enormous economic losses and ecological damage every year in China. To prevent and control forest diseases and pests, the key is to get accurate information timely. In order to improve monitoring coverage rate and economize on manpower, a cooperative investigation model for forest diseases and pests is put forward. It is composed of video positioning system and manual labor reconnaissance with mobile GIS embedded in PDA. Video system is used to scan the disaster area, and is particularly effective on where trees are withered. Forest diseases prevention and control workers can check disaster area with PDA system. To support this investigation model, we developed a positioning algorithm and a positioning system. The positioning algorithm is based on DEM and PTZ camera. Moreover, the algorithm accuracy is validated. The software consists of 3D GIS subsystem, 2D GIS subsystem, video control subsystem and disaster positioning subsystem. 3D GIS subsystem makes positioning visual, and practically easy to operate. 2D GIS subsystem can output disaster thematic map. Video control subsystem can change Pan/Tilt/Zoom of a digital camera remotely, to focus on the suspected area. Disaster positioning subsystem implements the positioning algorithm. It is proved that the positioning system can observe forest diseases and pests in practical application for forest departments.

1. Introduction
Forest pests are one of the three major disasters for forest resources and ecology in China, which lead to more serious damage than forest fires and deforestation. In recent years, the situation of forest pests become more severe. On the one hand, the occurrence area of frequent diseases and pests remains high. On the other hand, the invasion of exotic pests is becoming more and more serious. In 2011, the occurrence area of major forest pests in China reaches to 175,220 thousand mu[1].

To reduce the loss of disasters, multi-level forecast stations of provinces, cities and counties for diseases and pests have been established in China. However, they mainly use artificial investigation method to collect the information of forest diseases and pests and to report level by level. The ground investigation is characterized by artificial walkthrough and on-site judgment, so it is difficult to collect disaster information comprehensively and timely, especially in the areas with complex topography and inconvenient traffic. In order to further improve the monitoring coverage and timely rate, researchers explore the use of remote sensing technology to monitor and forecast diseases and pests. Recently,
remote sensing technology has been applied to monitoring forest pests. Remote sensing has a high recognition rate only for a few diseases and pests by literature retrieval and analysis[2-5].

In the forest industry, remote video monitoring technology is mainly used in forest fire monitoring and assist to direct fire-extinguishing[6-10]. Wireless local network, high-definition camera and digital PTZ are main hardware equipments of the technology. Through improving existing equipments, the disaster positioning algorithm based on DEM is developed to realize effective monitoring and tracking the diseases. The video positioning system can monitor pests that make tree defoliating, withering and changing of tree crown. The video positioning system will reduce the workload of forest investigators.

2. Monitoring pattern of forest pests supported by video positioning

In forest pests information collection field, the data recording system of forest pests monitoring based on GIS/GPS has been popularized preliminarily[11], which forms the survey mode using PDA to collect data instead of paper and pens. Although this mode ensures the accuracy of information collection and high efficiency of data processing, it still depends on artificial walkthrough and has much potential space to improve at the degree of coverage and timeliness of investigating. Remote video monitoring is able to complement each other with the mode.

![Figure 1. The investigating mode supported by video positioning.](image)

Remote video monitoring system can scan the area in a short period of time and achieve positioning of diseases and pests with visual characteristics, to form thematic maps of disasters to provide navigation for ground surveyors to verify on site. And then the verified disaster information is fed back to the system for remote re-examination and tracking spread trends. The collaboration of remote video monitoring system and ground survey improves the agility of the process and significantly saves manpower. Figure 1 shows the business process of the synergy of remote video monitoring system and ground survey. The key to support this process is to build the software system of remote video positioning.

3. System design

Driven by business requirements, the design principles of accuracy and visualization are used to build the system. Accuracy: disaster positioning is the core function of the system, whose accuracy is a key issue for applicability of the system. The positioning algorithm is developed to ensure that the accuracy is within the available range. Visualization: 2D GIS and 3D GIS subsystems are developed to assist positioning with spatial visualization, and the usability of the system is improved.

3.1. Hardware structure of the system

The hardware architecture of the system is showed in figure 2, which consists of monitoring points, wireless networks, servers and clients. High-definition camera, high-precision digital pan tilt, pan tilt decoder and wireless video server are core equipment of a monitoring station. Pan tilt decoder is used to receive PTZ control command. Digital video server is the signal center of a monitoring station, responsible for sending the collected video signal to the client and for transmitting the PTZ control
command to the digital pan tilt. It is required that the digital PTZ used in the system can output the angles of azimuth and pitch. Every isolated monitoring station and application servers are connected through wireless network. The network of the monitoring area is built by microware networks, with low cost, ease of deployment, strong anti-interference and scalability, suitable for LAN construction under complex environment in forest area. Remote video monitoring software system is deployed on the application server to provide service for multi-client. Data server can provide basic spatial data service and pest disaster information storage service for the application server. Video server is used for secondary distribution of the front-end video streaming, to provide load balancing service under the condition of increasing users.

Figure 2. Hardware architecture of the system.

3.2. Software architecture of the system

Forest diseases and pests have strong spatial feature, so the information of diseases and pests needs a spatial method to express and analyze. 2D GIS and 3D GIS are combined in the system to assist disaster positioning, queries and cartographic output. The software architecture is shown in figure 3, which is composed of 2DGIS subsystem, 3DGIS subsystem, video-control subsystem, disaster-positioning subsystem and message routing center.

Figure 3. Software architecture of the system.

2DGIS subsystem: in addition to the basic functions of layer controlling, roaming, zooming and resetting, it also provides friendly monitoring point navigation and PTZ control, auxiliary disasters positioning, disasters query and thematic mapping output. Moreover, eagle-eye map is provided for 3DGIS subsystem.

3DGIS subsystem: in addition to 3D terrain visualization of forest area, it also provides viewshed analysis of cameras and auxiliary disasters positioning with virtual cameras. Furthermore, the navigation of monitoring points and PTZ control in 3D mode are supported.
Video control subsystem: in addition to the control of aperture, focus and magnification of cameras, the rotation, tilt and speed control of digital PTZ are also supported. Moreover, the video window size and video bit-rate can be set, and the operating authorizations of cameras are managed.

Disaster positioning subsystem: using DEM-based disaster positioning algorithm, with the assistance of three subsystems, the positioning of diseases and pests, data save and export can be achieved, and the disaster information reexamined by forest investigators can be imported.

Communication control center: there are frequent calls among various subsystems. For example, video control subsystem requires passing real-time PTZ angles to disaster positioning subsystem in order to calculate the disaster position. Loosely coupled message-based communication mechanism is used. Message routing center adopts unified message scheduling among subsystems, corresponding actions can be executed after receiving the message, and the returned results are also passed through the message routing center.

4. Disaster positioning algorithm

The basic principle of disaster positioning is to construct a ray emitted from the monitoring point according to the angles returned from PTZ camera. From a geometric point of view, the process of positioning is to get the intersection of the ray and DEM. DEM cannot be expressed by any mathematical function. Thus, in discrete space, the disaster positioning is a process of finding the optimal solution, which is also a constraint satisfaction problem. To improve the efficiency of the algorithm, the viewshed analysis of ArcObjects is called to generate viewshed raster layer, which can reduce the search space of the optimal solution. Disaster positioning schematic diagram is shown in figure 4, in which \( O \) is the monitoring point, \( D \) is the disaster point.

Algorithm input: the DEM of the area, the azimuth \( \alpha \) and pitch \( \beta \) of digital PTZ camera, the height \( H_y \) from digital PTZ camera to the ground, the projection coordinates \((X_{O_1}, Y_{O_1})\) and elevation \( Z_{O_1} \) of the monitoring point, and the raster layer of FOV (Field of View).

The steps of the algorithm are as follows.

1) According to the azimuth \( \alpha \) and DEM, a ray \( L \{D_1, D_2, D_3 \ldots D_n, D_{n+1} \ldots D_m\} \) consisted of discrete point set is obtained through Bresenham algorithm, Bresenham algorithm is a classical and effective algorithm to generate lines, the coordinate is expressed by \((X_{D_n}, Y_{D_n}, Z_{D_n})\), as is shown in figure 5.

2) According to the FOV layer, deleting the invisible points in \( L \) from \( O_1 \), a point set \( L \{D_1, D_2 \ldots D_n, D_{n+1} \ldots D_m\} \) is obtained, as is shown in figure 6.

3) Compute the vertical angles of points in \( L \) using formula 1.

\[
\theta_{D_n} = \arctan \left( \frac{Z_{O_1} + H_y - Z_{D_n}}{\sqrt{X_{D_n}^2 + Y_{D_n}^2} - \sqrt{X_{O_1}^2 + Y_{O_1}^2}} \right)
\]  

(1)
4) If the condition \( \theta_{Dn} \leq \beta \leq \theta_{Dn+1} \) is satisfied, and \( |\theta_{Dn} - \beta| \leq |\theta_{Dn+1} - \beta| \), then \( D_n \) is the disaster point, else \( D_{n+1} \) is the disaster point.

5) Continue to step 3, until \( D_n = D_m \), that is to say, there is no solution.

To verify the availability of the algorithm, accuracy verification is conducted in a national forest park. First, differential GPS is used to measure the geographic coordinates of simulated disaster points, combined with local three parameters, which is transformed into projective coordinates. Then the simulated disaster points are positioned through remote video positioning system, and the accuracy is assessed by comparing with the actual measurement results.

Within the range of three kilometers encircling the monitor point, five verification points are deployed in \([1\text{km}-2\text{km}]\) and \([2\text{km}-3\text{km}]\) respectively. Results show that: in \([1\text{km}-2\text{km}]\), the maximum error is 107 meters, and the minimum error is 67 meters; in \([2\text{km}-3\text{km}]\), the maximum error is 223 meters, and the minimum error is 155 meters. The measure error scale is acceptable for forest diseases and pests.

5. System implementation and the effect application

To facilitate the deployment and improve the user experience, B/S mode is used in the system. 2D GIS subsystem which is mainly for query and browse and the disaster positioning subsystem that need small amount of data transmission are developed in pure web mode. 3D GIS subsystem and video-control subsystem were implemented using the ActiveX control, due to the large amount of graphic rendering required. Thus, the system is ensured to be smooth by taking advantage of local resources. Three servers were set up on the server side with a speed of 10GB/S to connect with Ethernet. Data server stores spatial data and disaster attributes database. Map server uses ArcGIS Server 10.0 to publish WMS and WFS services, and the disaster business data is stored in SQL Server 2008. Remote video monitoring server-side is deployed on the application server using a middleware of IIS7.0. The video server uses D-Link DNS-726-4 to provide load balancing services for the front-end video server.

Figure 7. Application pattern of the disaster positioning system.

2D GIS subsystem is developed on the basis of the preliminary work\(^{[12]}\), increasing disaster points adding dynamically, the auxiliary switch of monitoring points and disasters assisted positioning methods, packaged as a Visual Studio 2008 AJAX component. 3D GIS subsystem is developed mainly based on OSG (OpenSceneGraph) which is an open source 3D graphic engine. In the network layer, libcurl7.21.3 network is used to transmit WMS terrain pyramid models and the image pyramid models. In the data layer, GDAL 1.8.0 class library is used to analyze spatial data. In the function layer, libMini10.2 terrain rendering library is used to realize 3D terrain visualization.

The application of the remote video monitoring system is shown in figure 7. Based on the disaster positioning of PTZ camera, through XML data exchange format, the disaster information is transmitted to PDA with GPS, then the forest workers can conduct on-site verification further. Thus,
on the one hand, workload is reduced significantly by using video positioning. On the other hand, the reliability of information is guaranteed.

6. Conclusions
The deficiencies of existing survey modes of forest diseases and pests necessitates the development of PTZ camera based remote video positioning system for forest diseases and pests, according to the business requirements of the diseases and pests monitoring. GIS-assisted visual disaster positioning, storage, query and cartographic output are implemented. Through actual verification, the accuracy and usability of the system can meet the requirement of diseases and pests monitoring.

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