DEVELOPMENT OF FOREST FIRE RISK INFORMATION MANAGEMENT SYSTEM USING GIS TECHNOLOGY

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ABSTRACT:

This study is aimed to develop forest fire risk information management system using GIS, remote sensing, statistics and computer techniques. This system can be used by forest managers in each province to plan extinguishment of a fire and to mange comprehensive forest fires work. Thus in order to develop the system, we first, constructed the geographic information related to a forest fire, and next, developed spatial analysis techniques using likelihood ratio and conditional probability. for analyze forest fire hazardous area. The forest fire information management system will be use to for manage and utilize the constructed information related to a forest fire. risk analysis technology so that those in charge of forest fire control in cities and counties particularly in the Yeongdong Province of Gangwon-do, Korea where the frequency and damages of forest fires are quite high can carry out forest fire prevention, forest fire fighting and resource management efficiently.

1. INTRODUCTION

Forest fire is one of natural phenomena that has been occurring unceasingly on earth since much earlier than the birth of human culture using fire. Forest fire burns various light and heavy fuels including fallen leaves, fallen branches, withered trees, grass and woods. There are various causes of forest fire. Although different depending on local custom, practice and economic level, most of causes are directly or indirectly related to human acts particularly human faults. The United States, which has vast wild forest areas, planned Joint Fire Science Program centering on USDA (U.S. Department of Agriculture) Forest Service and USGS (U.S. Geological Survey), and is conducting joint researches together with relevant specialists and research institutes [1]. FARSITE (Fire Area Simulator) [2] developed by USDA Forest Service is a forest fire simulation application programs based on GIS technology. It can calculate the intensity of forest fires, expected routes of fire development, the speed of spread, etc. using data such as topographical information (altitude, gradient and exposure), spatial information such as fuel distribution maps, water maps and soil maps, and property data such as weather, wind velocity, wind direction and fuel humidity. In Canada as well, research on forest fire has been made systematically, and currently an integrated system for forest fire risk forecasting has been developed and being operated. Recently, Canada developed Spatial Fire Management System (SFMS) based on 75-year-long researches on forest ecosystem and forest fires [3, 4]. In Australia, Stephen R. Kssel, et al. developed a model of forest fire risk areas using data on forest fires in the past and the model is providing various types of information for forest fire forecasting, fire prevention policy making, environmental influence evaluation, forest fire pattern analysis, etc. [5]. S. Sauvagnargues-Lesage, et al. proposed a methodology for the application of GIS in forest fire fighting [6]. In Korea, the history of forest fire research is short and the importance of the research is not recognized properly and, as a result, there have been few systematic researches on forest fire.

Recently, research has been made on factors related to the occurrence and spread of forest fires but it has been merely based on weather information and data on forest fires in the past. That is, it has not considered GIS materials including topographical information and stock maps, which are major factors of forest fire occurrence and development.

This study designed and implemented GIS-based forest fire risk information management system that can establish geographic information related to forest fires and integrate established databases so that those in charge of forest fire control in cities and counties particularly in the Yeongdong Province of Gangwon-do, Korea where the frequency and damages of forest fires are quite high can carry out forest fire prevention, forest fire fighting and resource management efficiently.

2. ESTABLISHING GEOGRAPHIC INFORMATION DATABASE RELATED TO FOREST FIRES

We established GIS-based database related to forest fires for the analysis of forest fire risk areas and forest fire risk information management system, centering on six cities/counties in the Yeongdong Province of Gangwon-do where the frequency and damages of forest fires are highest in Korea. Geographic information related to forest fires was built up using Arc/Info, ArcView and PCI software, and the constructed materials are listed in <Figure 1>. For this, we used 1:25000 digital topographical maps published by National Geographic Information Institute. From the digital topographical maps, administrative maps were derived in the detail of cities, counties and sub-counties. In addition, using contour lines extracted from the topographical maps, we made 10m-resolution DEM, slope maps, slope exposition maps and shaded relief maps.

Furthermore, we extracted road networks (ordinary roads, village/town roads, and narrow paths), residential areas, farmlands, the locations of public offices, etc.

In order to analyze forest fire risk areas, road networks, residential areas and farmlands were converted into 10m-resolution GRID format through buffering at regular intervals (25m, 50m, 75m and 100m). This study also used 1:25000 digital stock maps, dividing them by forest type, diameter class, age class and density and converting into vector format and 10m-resolution GRID format. In addition, Landsat satellite images were produced for the east coast of Gangwon-do before, just after and one year after the great forest fire in April 2000. Data on the occurrences of forest fires during the past 10 years were collected from materials kept at the Forest Government Information Agency and the relevant cities and counties. Data on the locations of forest fire breakouts with geographical coordinates were obtained from the Provincial Office of Gangwon-do. Data on forest fire fighting equipment and manpower by city/county were obtained from forest fire prevention plans issued by the cities and counties. Data on the locations of freshwater bodies, heliports, landfill areas and forest fire observation facilities were collected from materials at the Provincial Office of Gangwon-do as well as city and county offices.

Topographical map	, administrative map	cities, counties	1:25000	line, polygon
	contour	DEM	10m x 10m	Grid
		Slope	10m x 10m	Grid
		Aspect	10m x 10m	Grid
		Shaded Relief	10m x 10m	Grid
	Road netwok	Road	1:25000	line, grid(buffering)
	residential area		10m x 10m	line, grid(buffering)
	Farmland		10m x 10m	line, grid(buffering)
Forest map	type		1:25000	polygon, grid
	diameter class		1:25000	polygon, grid
	age		1:25000	polygon, grid
	density		1:25000	polygon, grid
Satellite imagery	Landsat	2000.3.6 2000.6.18 2001.8.24	30m x 30m	Grid
Occurrences of forest fire	occurrence			table
	location			point
Monitoring facillity	camera			point
	Watch tower			point
	manpower			point
Firewater body				point

Fig. 1 GIS based thematic maps

3. DESIGN AND IMPLEMENTATION OF FOREST FIRE RISK INFORMATION SYSTEM

3.1 Design of forest fire risk information system

The system was designed for forest fire controllers to search various types of resource information necessary for fighting forest fires and to utilize fire-fighting equipment and manpower efficiently. In addition, it can be utilized to make forest fire risk maps (for vulnerable areas) using statistical probability models such as likelihood ratio, conditional probability, Bayesian, regression and certainty factor to support decision-making on the optimal deployment of forest fire observation facilities and personnel and policy-making for efficient forest fire prevention.

<Figure 2> is a class diagram showing basic classes forming the forest fire risk information management system and their relations. There are 13 representative classes and user commands are processed by CCommand Classifier. User commands include data input, data output, map search and statistics output, and a command input through the command handler branches into routines in relevant classes.

CResourceManager contains the definitions of search and update tasks, which are operations related to forest fire fighting equipment and manpower. Data are loaded using operations defined in CLayerManager and CDataLoader.

CLayerManager contains the definitions of layer overlay operations and the variables of the currently selected layer, and the definitions of basic operations to upload data and display on the screen and variables to specify layers.

CDataLoader contains the definitions of operations to upload data according to data type. Particularly for points, there is an operation defined to match with the symbol table and display on the screen.

CSpatialStatistics contains the definitions of operations to view statistic data in various forms using constructed information of forest fire history.

CSpatialDMEngine contains the definitions of operations to product forest fire risk maps using constructed thematic maps related to forest fires. Moreover, in order to apply specific statistic techniques, CCertainly, CLikelihood, CRegress, CCondition and CBaysian contain operations inherited from their parent classes as well as operations defined in each of the classes. CModelValidator contains the definition of operations to verify the results of execution by model.

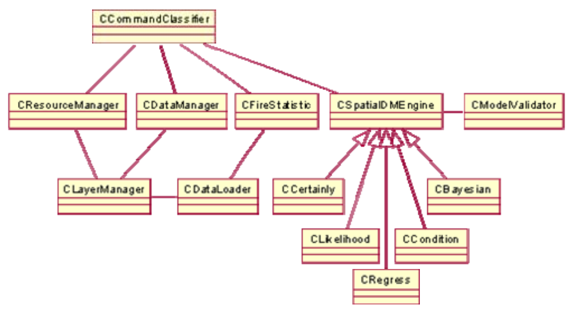

Fig. 2 Class diagram of the forest fire risk information management system

<Figure 3> is a schematic diagram of the forest fire risk information management system, which is composed of application programs to be used by forest fire managers, meta-data for managing and accessing collected data, and various forms of datasets.
Application meta-data is accessed and managed using SQL queries using ODBC, and other images are loaded to the system through access paths stored in the meta-data. Meta-data is composed of dynamically structured system menu, data access paths, and a part for roles according to files. Command Classifier classifies various commands including statistic data search, spatial data statistic probability analysis and calculation, map handling and data input, and applies the commands to maps. By users' request of spatial data analysis, Spatial Data Analyzer finds places vulnerable to forest fire using probability techniques such as logistic regression and joint conditional probability according to input parameters. Layer Manager plays the role of mapping loaded images and property data and producing maps in easily understandable forms.

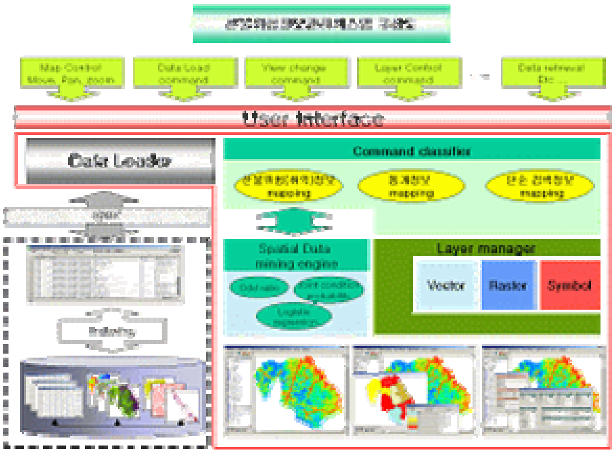

Fig. 3 Conceptional diagram of the GIS based forest fire risk information management system

3.2 Implementation of forest fire risk information system

The forest fire risk information management system was developed using Visual C++6.0, MapObject 2.0, and for operation in MS Windows environment. Using the implemented system, users can search statistic data and maps by locality and on the whole, manage resources necessary for forest fire control, analyze areas vulnerable to forest fire, view information and statistics related to forest fires, etc. The system manager utilizes the system for preventing and fighting forest fires effectively. <Figure 4> shows the representative functions of the forest fire risk information management system. It is a GIS-based application system designed for users to manage and analyze forest fire information conveniently.

A. Map search function

Using the map search function, users can find thematic maps of the entire area of the east coast of Gangwon-do as well as of each city and county. <Figure 4-(a)> is a screen displaying the forest fire risk information management system. It is a satellite image of Samcheok in Gangwon-do overlaid with its roads and water systems.

B. Statistics function

Using constructed information related to forest fires, users can view statistic information such as dates of forest fires, causes, scales of damages and frequencies in the form of chart or map. <Figure 4-(b)> is a map produced based on data on forest fires that broke out in the Samcheok area from 1995 to 2000.

C. Vulnerable place analysis function

<Figure 4-(c)> visualizes places where forest fires broke out using probability-based spatial analysis in order to analyze areas vulnerable to forest fires. In order to analyze areas vulnerable to forest fires, the system used probability techniques including likelihood ratio and conditional probability as explained in Chapter 2. The results of the analysis can be utilized in making decisions on the deployment of forest fire observation personnel in the future.

D. Forest fire information input function

If a forest fire breaks out in a city or county, its information can be entered in the city/county map mode. Input information includes the location of forest fire, date and time, cause and scale, and these data are used in generating forest fire statistics in the future. Moreover, additional information can be entered including information about manpower and equipment committed to extinguish the fire and the personal details of victims. <Figure 4-(d)> is the screen to enter forest fire breakout information.

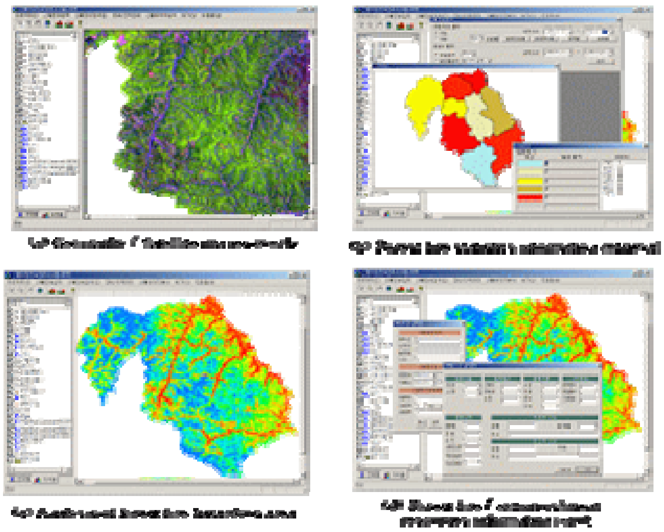

Fig. 4 Function of the forest fire risk information management system

4. CONCLUSIONS

This research built up information on forest fires (forest fire areas, dates of breakout and extinguishment, damaged area, and cause) that had broken out and meteorological data (average temperature, highest-lowest temperature, rainfall, fresh snow cover, average wind velocity, wind direction, and average humidity) in the Yeongdong Province of Gangwon-do, Korea. We also extracted data such as altitude, water system maps, road network maps, administrative division maps, etc. from 1:25000 digital topographical maps, and generated slope maps and slope exposure maps using extracted altitude data. Moreover, geographic information related to forest fires was built up including stock maps, fresh water DB necessary for forest fire fighting,, satellite images before and after a forest fire, forest fire observation facilities, fire fighting equipment/manpower information, heliports and landfill areas.

Using GIS spatial analysis model for forest fire risk areas, we developed a program that produces 1:25000 forest fire risk area maps that can be used by those in charge of forest fire control in cities/counties in controlling and preventing forest fires. In addition, we designed GIS-based forest fire risk information management system using UML (Unified Modeling Language) and implemented it with Visual C++6.0 and Mapobject 2.0 on Windows 2000 platform.

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