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A UIS-based System Development to Express the Damage History Information of Natural Disasters

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ABSTRACT

The damage of natural disasters has occurred on huge scale more frequently than before. The damage caused by the disasters are summarized and are analyzed, and are managed as a very general type of documentation, not showing the position of previous damage records and related information such as weather, facilities of CCTV, hospitals, and gas station on the maps. Therefore, it needs to provide map-based searching systems considering damaged area as well as search key-words. This paper focuses on the development of a search system based on the map to manage previous disaster records and related information each disaster using spatial databases. This system consists of three modules, which are databases to store disaster data, the SQL procedure-based search module to extract needed information from the constructed databases, and the map module to express the search results on the map. This paper will contribute to provide framework of a system development for managing the disaster information according to each year and disaster based on the maps and to be utilized as the basic framework in developing damage prediction and prevention systems for disasters in future.

Key words: Disaster Management Systems, GIS, Spatial Databases, ArcGIS, Urban Safety

1. INTRODUCTION

The damage from natural disasters such as flooding, wave-storms, landslides, and windstorms has recently increased. In a short period, massive flooding by a localized torrential rainfall occurred in 2009 is a case of inundation disasters in Busan Metropolitan City, Korea. The heavy rainfall for the day was about 350 mm per hour. The downpours have flooded many houses and roads, so the expansive flooding has damaged people's lives and estates in many places[1].

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GIS-based systems such as hazard maps and disaster prevention systems to prepare for the damage have consistently been developed, but most domestic research has mainly supported simulation model-oriented services for analyzing flooding and land predictions. Many countries have tried to research systems for the reduction of the disasters. The disaster center of Federal Emergency Management Agency (FEMA) [2] and U.S. Geological Survey (USGS) in USA provides services showing occurred areas of natural disasters and related situation information on the real-time. In Japan[3], services of flooding hazard maps with the information of flooded area and evacuation were started by local government agencies in 1993. Recently, GIS-based flooding systems have been developed to provide rainfall and water levels at rivers on the real-time.

In Korea, disaster management systems focus on the disaster countermeasure and recovery services rather than prevention services with analysis and prediction[4,5]. Therefore, we must change disaster recovery management systems into disaster prevention management systems with scientific analysis like other advanced countries. The previous damage records and related information needs to be constructed to do the prevention systems of disasters. Most current systems mainly provide weather information based on the real-time monitoring systems, not providing search function of previous disaster records with the key-words because it is difficult to construct geographical data on time. Therefore, our paper develops a damage history system to search attributive and geographical data of previous disaster records on spatial databases.

The rest of this paper is organized as follows. In section 2, we describe disaster management systems and ESRI's ArcGIS system as a part of related works. Next, we present a design of the GIS-based damage history application and describe the system with four implementation modules. In section 4, we present the construction process of spatial databases and parts of screen shots of the implemented system. Finally, we summarize our system and describe future works.

2. Related Researches

2.1 Disaster Management Systems

Kim et al. [4] forecasted area flooding by calculating direct runoff by the Soil Conservation Service (SCS) curve number method and presented potential disaster areas in large regions. Kim et al. [5] constructed a Web-based GIS system to manage a damage information system for natural disasters. Although the system has demonstrated better response in rapid situations with GIS systems on real-time communication, various searching functions were not supported because the disaster data was constructed on the spatial databases.

Web-based map systems of disasters are serviced in some districts of Korea. According to the some ranges of rainfall, predicated flooded area are displayed on the map [6,7]. The systems provide information of flooded area, landslides area, and predicated flooded area with key-words such as district area, damaged area and causes, and ranged rainfall. The services have limitations not providing detail information such as rainfall, damage and recovery amount, and photo images because of being constructed from contraction data, being not constructed from occurred damage history each disaster and year. On the other words, the spatial database are not stacked up attributive data based on the geographical layers every year.

2.2 ArcGIS Systems

A GIS system is defined as a computer system for capturing, managing, integrating, analyzing, and displaying data that is spatially referenced in the world [8,9]. The current trend of spatial database focuses on the methods of how to efficiently handle geospatial data and how to provide analytic results combined with attributive and geometric data like the oracle spatial databases.

ESRI's ArcGIS is a system that developers can build their own application based on the maps and includes ArcGIS Engine, Developer Kit, ArcSDE technology, and so on. Specially, ArcGIS Engine is a collection of GIS components and developers can deploy GIS data, maps, and geoprocessing works in applications using application programming interfaces for COM, .NET, JAVA, and C++. The ArcGIS Engine includes ArcGIS Engine Developer Kit and Runtime. The ArcSDE technology [10] as a core component of ArcGIS products by ESRI manages spatial data in a relational databases systems and clients can access the spatial data such as points, lines, and polygons. The ArcSDE technology supports for multiuser editing environments and provides data integrity and operation based on the specific RDBMS schema. The spatial type is an object type that describes and supports spatial data such as points, lines, and polygons.

ArcObjects [11] library components need to manage spatial data in ArcSDE technology. Developers can use ArcObjects framework, which is an object-oriented geographic data model and an integrated library of software components, to add new tools or work flow to ArcMap and ArcCatalog applications and to create new applications. The API components provide to build GIS-enabled applications, to access spatial data, to create and draw graphic features, and to effectively visualize and analyze spatial data.

3. Design of the GIS-based Damage History Application

3.1 System Architecture

We propose an architecture that describes what data is on the spatial databases and how to search the previous disaster records based on GIS. The system consists of spatial databases, search module, and map module as illustrated in Fig. 1.

The spatial database stores geographical data and attributive data. These are basic topographic maps of Busan Metropolitan City, South Korea and geographical maps needed to search damage history information. The former map of scale of 1:1,000 is constructed by Busan Metropolitan City and the latter map is constructed with our collected documentation data based on the basic topographic map. We draw damage area ranges with surveyed history data and the position information of the facilities such as emergency facilities of hospital and police stations, disaster prevention facilities of pump stations, floodgate, and other main facilities of CCTV, gas station, and power stations. We have researched the system framework with five layers such as raw data collection, data management, analysis models, integrated systems, and required services in constructing a digital hazard map system[12].

The system contains the search module and the map module that provides search results of damage history data and related disaster data based on the geographic information. The search module needs to search and to modify the damage history data of four categorized of natural disasters such as flooding, wave-storms, landslides, and windstorms and the related information such as dangerous area and facility data. In addition, this module includes the routines to manage photos and to provide aggregated statistics related to the damage history data.

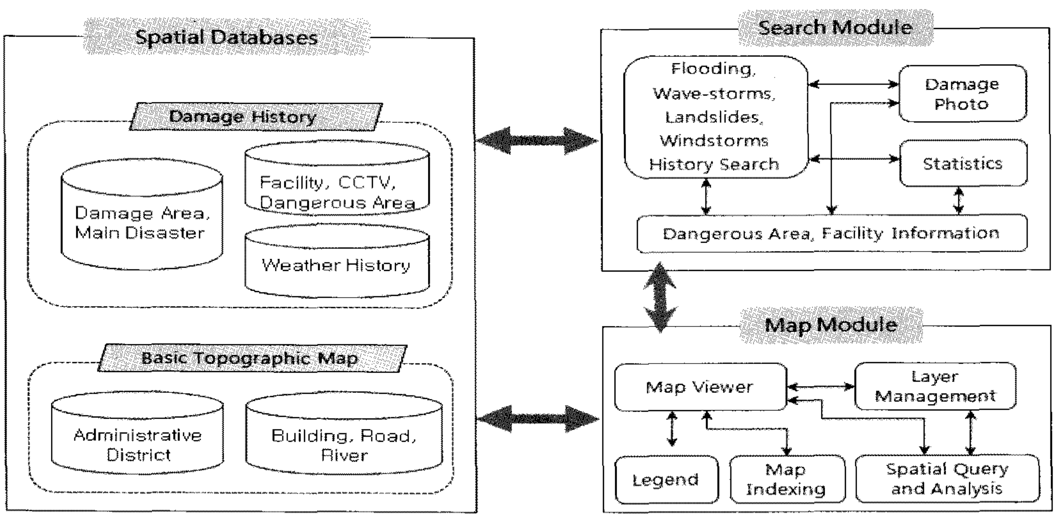

Fig. 1. Architecture of Damage History System.

The map module contains the necessary functions needed to control maps, which are the map viewer, the layer management, map indexing, legend to display the geographical information. Specifically, the spatial analysis needs to provide results of buffer analysis that execute to find the damage area near one kilometer from a dangerous area.

3.2 Implementation Module

3.2.1 Search Module

The natural disasters are categorized into Flooding, Wave-storms, Landslides, and Wind-storms. The damage data is constructed using documents surveyed on the field when disasters occurred.T he spatial databases include new layers with geographical information about weather, CCTV, facility, and dangerous area as well as the related attribution.

This search module supports to search general key-words such as district area, disaster types, occurred dates, categorized rainfall, damage cause and category, and so on. The photo management needs to store, to search, and to delete related damage photos into the databases. The photo information includes the identification related to history information, file names, taken dates, and photos description, disaster types, and so on. The statistics provide the count of the damage records according to disaster types, administrative district, and categorized rainfall. The statistics show where more dangerous districts are located in and are how different according to categorized rainfall.

3.2.2 Map Module

The map module supports to operate map functions such as to magnify, to zoom in and out, and to pan maps. In addition, there are functions to display legend of maps, to manage layers, to show a map extent to be drawn in the window, and to provide geographic analysis.

The map-viewer is connected to the sub modules such as layer management, map indexing, legend, and spatial query and analysis, which are an essential function in controlling maps. The basic topographic maps are loaded as defaults and the damage history maps are managed by adding and deleting layers as occasion demands. The layer management includes functions such as keeping default layers, adding or deleting layers, and keeping folders of layers. The map indexing operates selected features in its window to be connected to the same location in the main map window. The legend needs to show the color and label of layers. The spatial analysis provides the geographic operation such as nearby or within a distance of each other and buffering with a single straight line distance for all features.

4. System Implementation

4.1 Implementation Environment

We implement a damage history application on the designed platform based on the .Net Environment as shown in Fig. 2. The amount of the geographical and attributive data are stored in Oracle databases systems and the ArcSDE technology. The ArcSDE technology manages spatial data in a relational database management system and enables it to be accessed by ArGIS Clients. We provide the data needed by clients using PL/SQL Language of oracle database systems, C# language, and ArcObjects Component. We uses to manage geodatabase, to place labels, and to adjust scales on the maps using the ArcMap and ArcCatalog tool. The ArcGIS Engine developer kit is a toolkit that can be used to build map applications for the Windows platform using the Microsoft Visual Studio development environment. Users need the installation of oracle client and the ArcObjects run-time to execute the map applications developed by the developer kit.

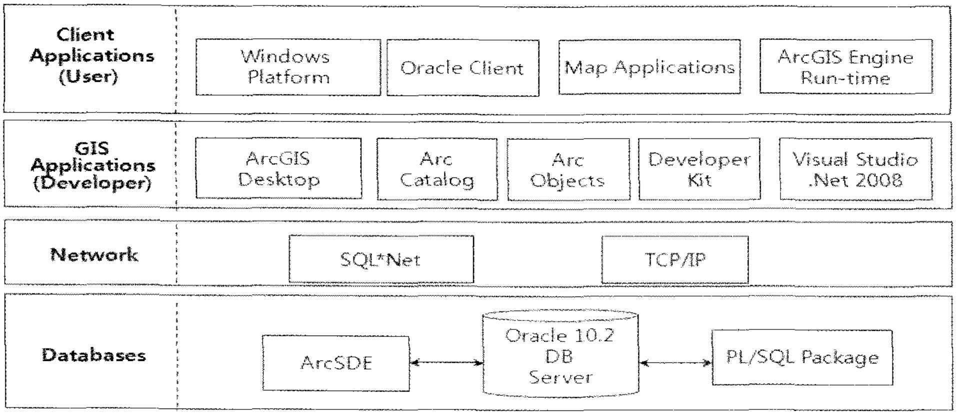

Fig. 2. Implementation Environment.

4.2 Spatial Databases

The damage history contains contents such as the damage types and names, dates and occurrence causes, addresses, damage area, rainfall, damage contents, amounts of damage and recovery, and so on. The dangerous area ranges appointed by Busan Metropolitan City are constructed including disaster types, name, address, and grade of dangerous area, appointed start and end date, and so on. Facility includes attribution information such as the code, name, type, and address of facilities as well as geographical information of the point layers. The CCTV point layers include attributive data such as name, purpose, URL address, port, management name, identification, password of each CCTV to display services on the real-time from installed CCTV. The weather information contains rainfall, wind speed, temperature, wind direction, humidity, and atmosphere each hour for ten years attained from meteorological agency.

Fig. 3 shows a process of geographical data construction. We gather related disaster data and create tables using ArcMap and oracle database systems. Next, we add a geometry column and set its geometry type, and spatial reference into the tables using the ArcSDE utility. Then, the geographical data is registered for full participation in the geodatabases using the ArcCatalog. Last, we create layer files to manage the information of maps on the ArcMap. We constructed about 1,700 records of damage areas for the typhoon named MEMI occurred in 1993 and the flooding occurred in 2009, Busan Metropolitan City.

Fig. 4 shows a Entity Relationship Diagram (ERD) of the designed databases for implementing damage history systems. The table names beginning with the letter "TB" contain only attributive data and the table names starting beginning with "LY" contain geographical data as well as attribu-

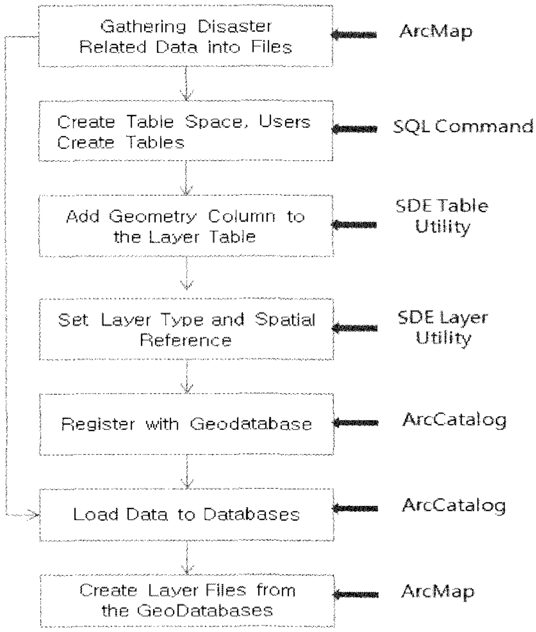

Fig. 3. Process of Geodatabases Construction.

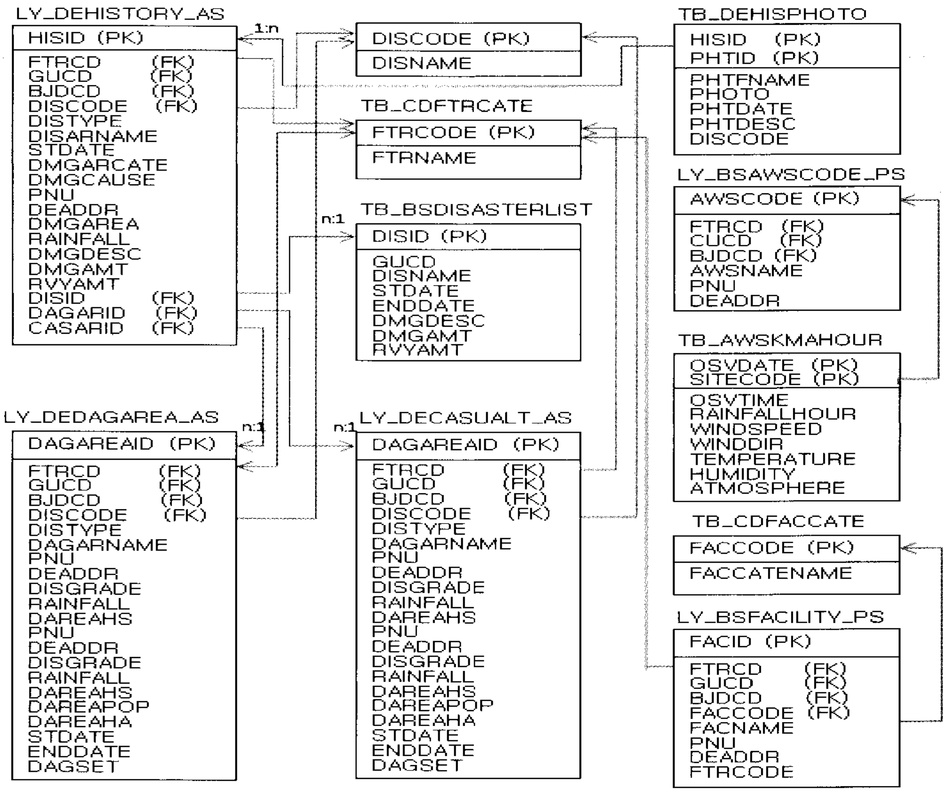

Fig. 4..Database Logical Diagram.

tion data. We call the geographical data as layers and the layers were largely classified into point, line, and polygon. The end letter "AS" of layer names means polygons, "LS" means lines, and "PT" means points.

This scheme is oriented by damage history layers, which are related to other tables such as code, facility, and weather information. Also, in the connection among tables, the system provides that damage area is to which disaster list is related, as well as search works of basic keyword and photos. Table 1 summarizes the description of defined tables.

4.3 Searching Scenario

We present an example of the searching scenario using the developed program. This system shows the keyword search action on the left-side screen and the map control- based search on the map of the right-side screen with two windows, which are indexing map and legend. Users can extract needed information with the key-words such as categorized administrative district, type and name of disasters, dates, damage cause, and so on. Also, the geographical area of queried results is shown on the map as shown in Fig 5. Users can magnify, reduce, pan, and do full extent in the map window with the map controls on the top of the right.

There is detail information of a damage history with photos, damage types, dangerous identification, damage causes, and so on as shown in Fig. 6. Users can modify and delete the damage history data and manage photos related to the history data.

Also, users can analyze how many records are within a dangerous area. The Fig. 7 shows damage area has ten records in a Haeundae area and six records of them are within the dangerous area.

In addition, there are keyword search functions

Table 1. Table Description

Category	Table Name	Description
Code	TB_CDDISCATE	Categorized Codes of Natural Disasters
	TB_CDFTRCATE	Categorized Codes of Layers
	TB_CDFACCATE	Categorized Codes of Facilities
Damage History	LY_DEHISTORY_AS	History Data of Natural Disasters Related to Disaster Identification and Danger Area
	LY_DEDAGAREA_AS	Appointed Disaster Danger Area Data
	LY_DECASUALTY_AS	Appointed Disaster Danger Casualty Area Data
	TB_DEHISPHOTO	Photo Images for Damage History Data
	TB_BSDISASTERLIST	Occurred Disaster Lists with Disaster Name, Damage and Recovery Amount
Facility, Weather	LY_BSFACILITY_PS	Facilities with Position of CCTV, Gas Stations, Hospitals, Schools, Police Stations, Pumps
	LY_BSAWSCODE_PS	Categorized Codes for Position of Observed Weather
	TB_AWSKMAHOUR	Observed Weather with Rainfall, Wind Speed, Wind Direction, Temperature for Hour

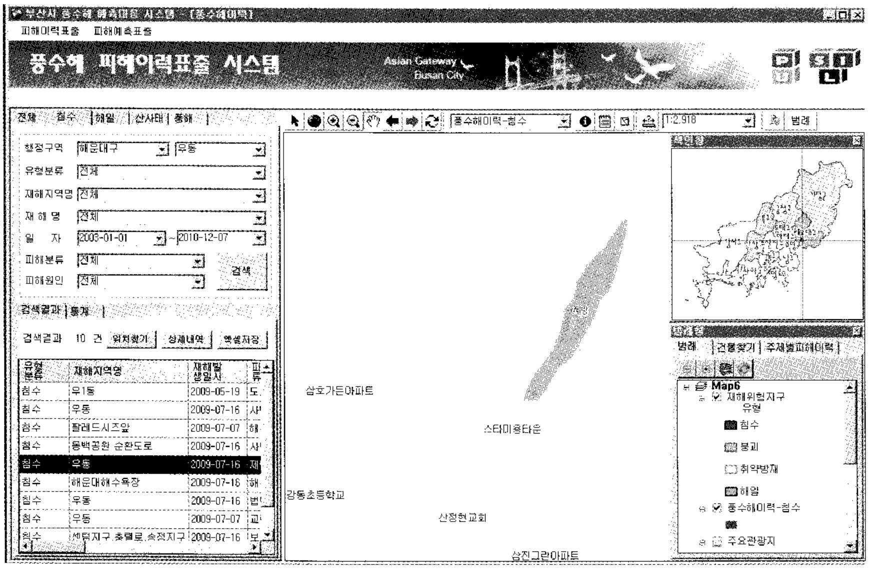

Fig. 5. Damage History Search Flooded in Haeundae Area.

such as disaster grades, appointed dates, disaster types, and so on in search of the dangerous area. We provide the disaster lists with the start and end dates, damage and recovery amounts, weather history information with rainfall, wind speed, and temperature per hour. The position of facilities such as CCTV, hospitals, hotels, pumps, gas stations, and so on is shown on the maps.

5. CONCLUSION

We implemented a damage history information system to express previous disaster records based on the map using ArcSDE technology and Oracle RDMS. The architecture of our system consists of spatial databases, search module, and map module. In spatial databases, there are the basic topological

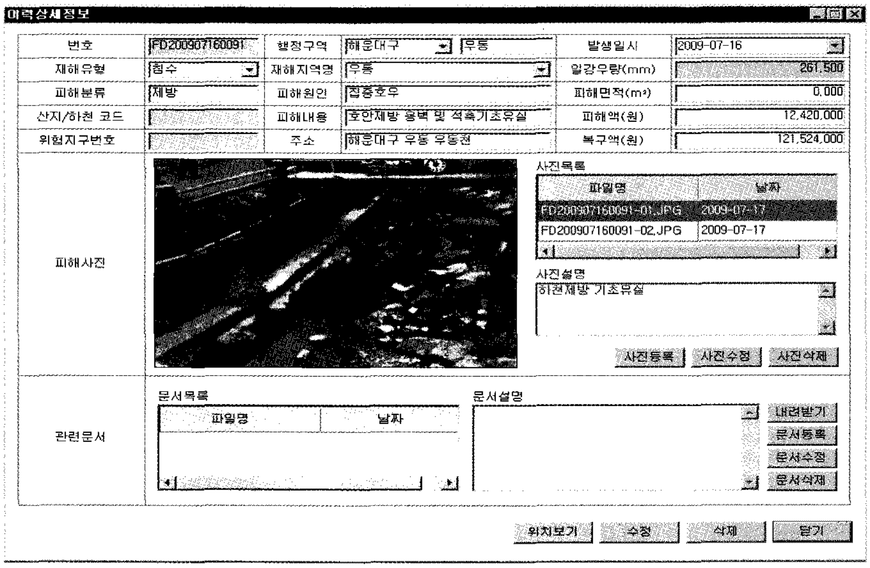

Fig. 6 Detail Information of Damage History.

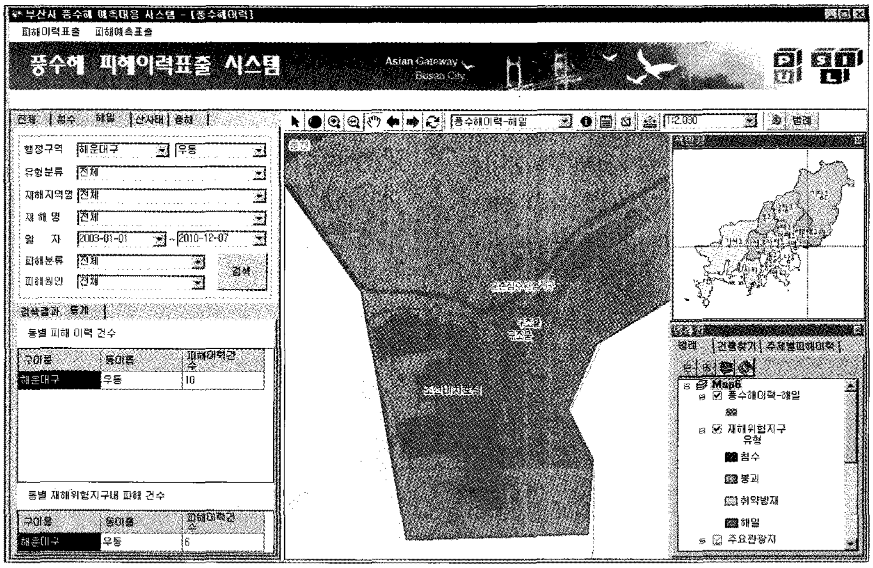

Fig. 7. Analysis for Damage History Records.

maps on the scale of 1:1000 created by Busan Metropolitan City and we constructed about 1,700 records of damage area from documented disaster records occurred in 1993 and 2009. The system supports map-based search with the key-words such as district area, types and names of disasters, occurred dates, categorized rainfall, causes and category of damage area, and so on.

We implemented a map-based search system using previous records of disasters. It is needed to develop upgraded system with analysis and predication functions using the constructed history information to respond the damages in urgent situations caused by the sudden occurrence of a disaster.

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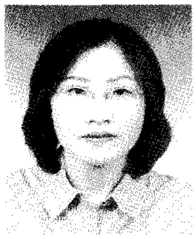

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