INTEGRATION OF IMAGERIES IN GIS
FOR DISASTER PREVENTION SUPPORT SYSTEM

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ABSTRACT:

This paper presents the results of imagery integration in disaster prevention system for the project of "Special Project for Earthquake Disaster Mitigation in Urban Areas". The proposed approaches differ from existing ones as follows: support registration and spatial-temporal management of (a) original aerial imageries, (b) images of other resources, such as raster result of all kinds of manual or automatic analytical results of the original aerial imageries, (c) video and snap images. Functions for vector conversion for images analytical result, such as extraction of changes, are also provided for further analysis with GIS functionalities. For imageries of high resolution and therefore huge size, they are hierarchically restructured for high access speed. Initial evaluation tests with the prototype system of the above specifications show that the system can build up multimedia database within a few hours for timely spatial decision support. The accessibility and comprehensibility of multimedia database is superior to those of the existing systems.

1. INTRODUCTION

Recently orthogonal images as background information of GIS have been very popular, as long as the budget allows. While orthogonal images offer precise correspondence between symbolized ground features, they require long processing time, in addition to their high costs. When a natural disaster happens, ground investigation of damages might be difficult without indirect means of survey, such as comparison of high-resolution imageries taken before and after the disaster. The project of "Special Project for Earthquake Disaster Mitigation in Urban Areas" is initiated by The Research and Development Bureau of Ministry of Education, Culture, Sports, Science and Technology (BMECSST, 2002). It started from August of 2002 and is scheduled for three years, extensible to five years.

The authors' research team belongs to the third core project and emphasizes on data collection and information retrieval. Here, data collection aims at registering and managing live data collected during disaster management activities. Data can be either multimedia data such as aerial imagery, satellite imagery of high resolution and video data, or document files as generated by DTP or spreadsheet applications. Information retrieval aims at providing user with data inputting, searching, analysing environment, based on the results of data collection.

The authors have performed fundamental analysis of system requirement and specification design in the first year of the project (Lu 2003).

This paper presents the specific design and implementation for the integration of imageries in the decision support system as a means of dynamic information generation, in combination with both existing ground feature information and the analysis result obtained through automatic or semi-automatic comparison of temporal imageries. It differs from existing usage of imageries simply as background orthogonal images in the following ways:

(a) Functions for registering and managing original aerial imageries. Tie points are registered, and the original central projected images are transformed with projection transform. In this way, with little delay of time, the aerial imageries confirm with GIS vector data with the precision of its DSM. To absorb the displacement of image due to variation in DSM, function for adjusting image display position is also implemented.

(b) Functions for registering and displaying images of other resources, such as raster result of all kinds of manual or automatic analytical results of the original aerial imageries, especially change detection in the case of a disaster. To make the reference of background images, as mentioned above, or other geo-spatial features, functions such as transparent display, alpha blending, flood filling with selectable patterns, classification according to selected features and so on.

(c) Functions for registering and managing video and snap images, with geo-spatial keys for spatial searching and visualization.

Functions for vector conversion for images analytical result, such as extraction of changes, are also provided for further analysis with GIS functionalities.

All the multimedia objects are managed in spatial-temporal space, so that comparison between situations before and after a disaster becomes handy. For imageries of high resolution and therefore huge size, they are hierarchically restructured for high access speed.

Initial evaluation tests with the prototype system of the above specifications show that the system can build up multimedia database within a few hours for timely spatial decision support. The accessibility and comprehensibility of multimedia database is superior to those of the existing systems.
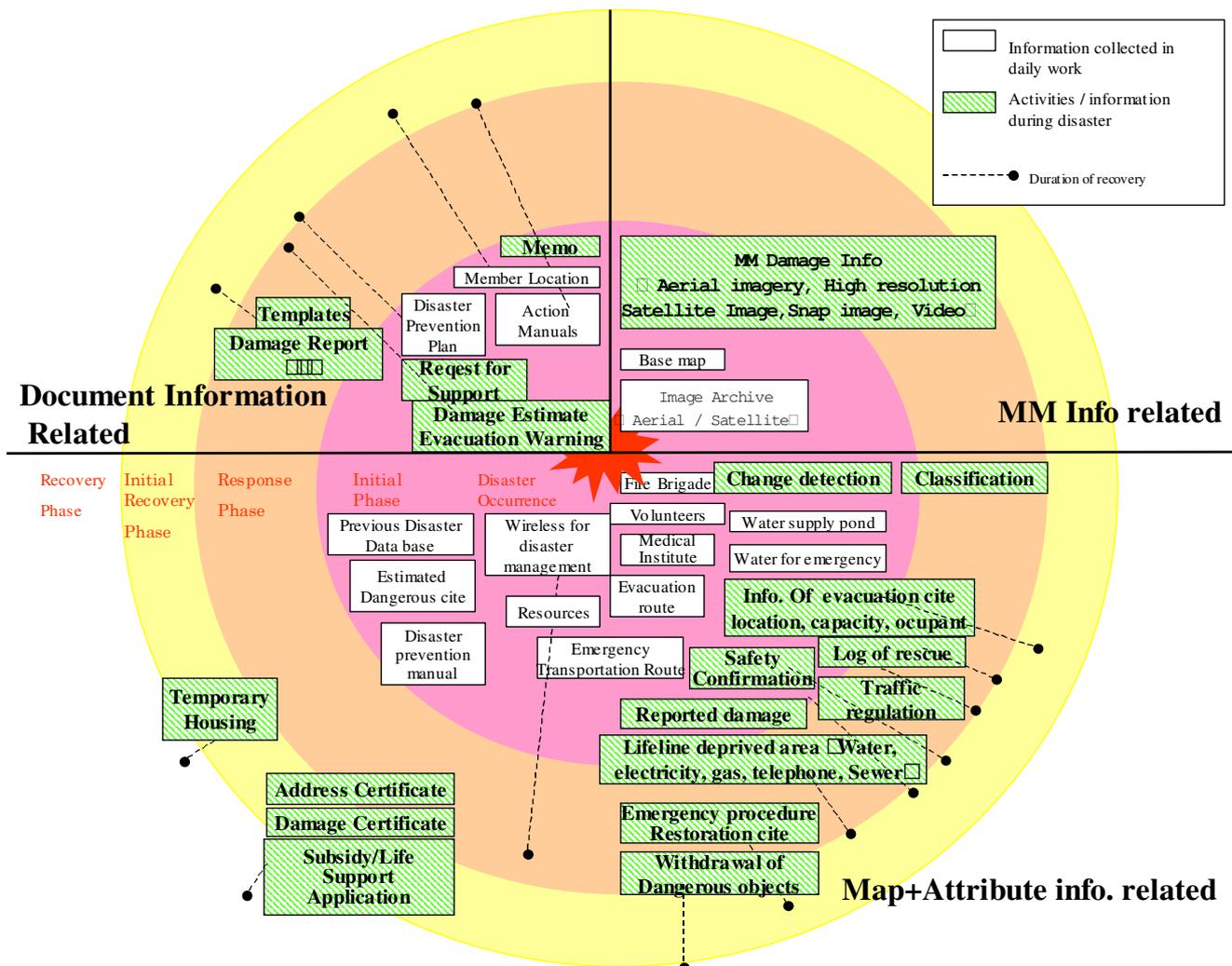
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Document Information Related

MM Info related

Map+Attribute info. related

Information collected in daily work

Activities / information during disaster

Duration of recovery

Recovery Phase Initial Recovery Phase Response Phase Initial Phase Disaster Occurrence

Memo
Member Location
Disaster Prevention Plan Action Manuals
Templates
Damage Report
Reqest for Support
Damage Estimate
Evacuation Warning

MM Damage Info
Aerial imagery, High resolution
Satellite Image, Snap image, Video
Base map
Image Archive Aerial / Satellite

Fire Brigade
Change detection   **Classification**
Previous Disaster Data base
Volunteers   Water supply pond
Wireless for disaster management   Medical Institute   Water for emergency
Estimated Dangerous cite   Evacuation route
Resources   **Info. Of evacuation cite location, capacity, ocupant**
Disaster prevention manual   Emergency Transportation Route
Safety Confirmation   **Log of rescue**
Traffic regulation
Temporary Housing   **Reported damage**
Lifeline deprived area Water, electricity, gas, telephone, Sewer
Address Certificate
Damage Certificate   **Emergency procedure Restoration cite**
Subsidy/Life Support Application   **Withdrawal of Dangerous objects**

Figure 1. Information and actions for disaster management

2. OVERVIEW OF THE JOINT PROJECT

The project of "Special Project for Earthquake Disaster Mitigation in Urban Areas" is initiated by The Research and Development Bureau of Ministry of Education, Culture, Sports, Science and Technology. It started from August of 2002 and schedule for three years, extensible to five years. It consists of three core projects as follows.

(a) Prediction of quake pattern
Studies the crust structures of metropolitan cities.
(b) Improvement of quake resistance
Studies the technologies for improving quake resistance using shock stand of large scale, with the cooperation of ten sub-teams.
(c) Optimisation of rescue strategies
Optimises the strategies for rescuing victims (19 sub teams), the infrastructure with rescue robot (11 sub teams).
(d) Integrated earthquake disaster management
Study the policies and regulations related to earthquake disaster prevention for integrated earthquake disaster management

The authors' research team belongs to the third core project and emphasizes on data collection and information retrieval. Here, data collection aims at registering and managing live data collected during disaster management activities. Data can be either multimedia data such as aerial imagery, satellite imagery of high resolution and video data, or document files as generated by DTP or spreadsheet applications. Information retrieval aims at providing user with data inputting, searching, analysing environment, based on the results of data collection.

3. CONFIGURATION OF THE SYSTEM

Figure 1 is the result of researches by author's group during the first stage of the project. It shows the information and actions for disaster management. Especially during the initial stage of a disaster, the most direct and informative resources are all kinds of imageries including video. The functionalities of imagery integration proposed and implemented in this paper facilitate the usage of imageries, either by independent view, or integrated with vector data in a GIS. The functions also include image processing modules that convert simulation or analysis result in raster image format into vector format, for more efficient and precise analysis with existing GIS functions.

Since both geographical and temporal factors are as important for observation and analysis of events after a disaster, all the imagery information is registered as spatial-temporal objects. To enable the coexistence of imageries of different resource, and for the same area, all the coordinated imagery objects have the attributes of transparency and mask colour.
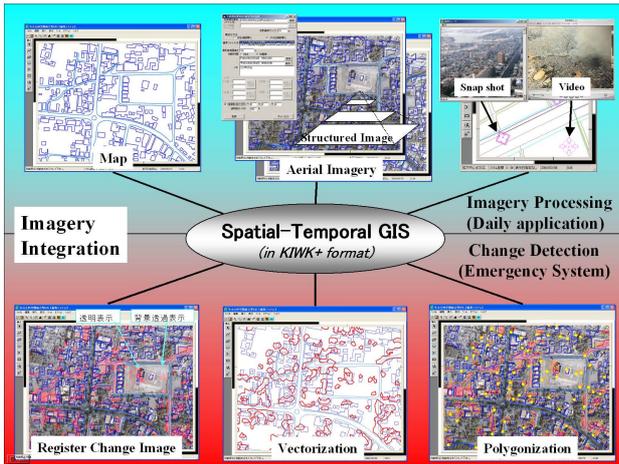
Figure 2. Configuration of the system

Figure 2 shows the configuration of the proposed system. The Spatial-Temporal GIS is the system designed and developed by the consortium of DiMSIS, which is a GIS for managing disaster information (Kakumoto 1996). The imagery integration system is an extension of DiMSIS, including the support of KIWI+ format (KIWI+ 2003). It contains registration modules for the following sources:

a. Aerial photo; with or without orientation data
b. Orthogonal or satellite imagery
c. Snap photo
d. Video
e. Simulation or analytical imagery; such as those from change detection systems

4. DETAILS OF INDIVIDUAL MODULES

The imagery integration system consists of graphical user interface (GUI) and image processing modules.

GUI includes dialogs for specifying necessary information required by registering all types of imagery into the system. Figure 3 and 4 are dialog examples for registering aerial imagery and video scripts respectively.

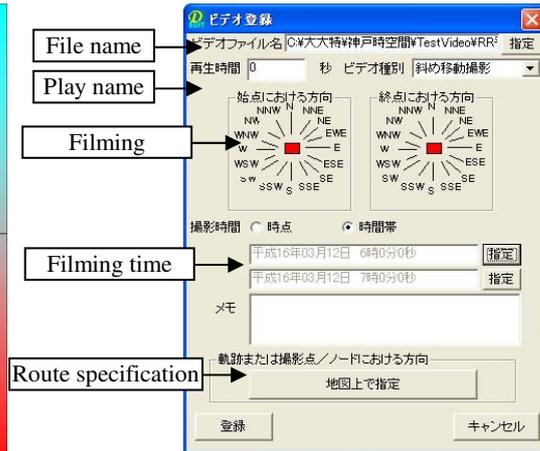Figure 3 GUI for registration of aerial imagery

Figure 4 GUI for registration of video

The information for coordinated imageries is summarized in Table 1. The imageries are restructured in a hierarchical way to ensure efficient display control, such as zoom in/out, pan. Compression option and its ratio can also be specified for saving of storage space.

Table 1. Information for coordinated imageries

Item	Contents
File name	The name of original file
Time taken	The time when the imagery is taken
Tie points	The ground coordinates of points in the imagery. For those without orientation information
Colour mask	For masking out background colour; for overlaying simulation results with imagery
Transparency	For overlaying multiple imageries

Figure 5 shows an example of registered aerial image, overlaid with cartographical map. To absorb the displacement of image due to variation in DSM, function for adjusting image display position is also implemented.
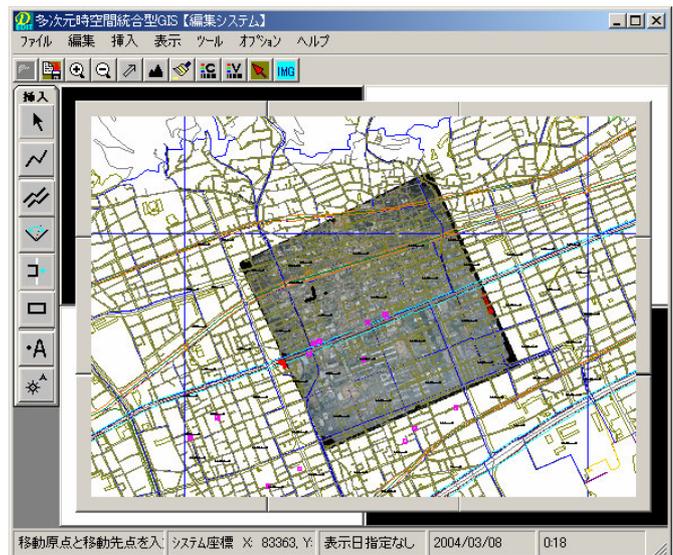

Figure 5. An example of registered aerial imagery

For video scripts, types of viewing method, route or filming position etc are stored. Figure 6 shows some typical symbols representing the registered imagery, and overlaid with cartographical maps.
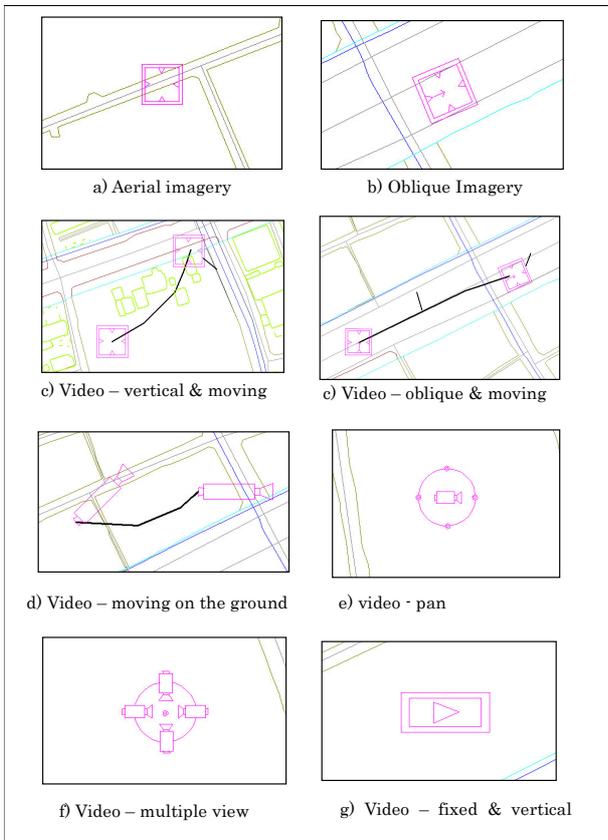

a) Aerial imagery   b) Oblique Imagery

c) Video – vertical & moving   c) Video – oblique & moving

d) Video – moving on the ground   e) video - pan

f) Video – multiple view   g) Video – fixed & vertical

Figure 6 Examples of symbols representing the spatial information of imageries

Besides the original imagery resources, analytical results such as change detection or simulation results are as important for decision support. Therefore the proposed system also provides a group of functions that include binarization, contour tracing, vectorization, and import into GIS. Error allowance for vectorization can also be specified according to the requirement of precision in the GIS operations that will follow.

Figure 7 to 9 show a serious of processing results by the above functions. Figure 6 shows the original result of change detection, proposed by a parallel project group of the author's institute (Sakamoto 2001). Figure 7 shows the result of binarization, by the specified threshold, Figure 8 the result of contour tracing and vectorization, by the specified threshold of error. The small circles are the representative point of the vectorized polygon.

By comparing the degree of overlapping between the changed polygons and those of houses, we can easily identify the damaged buildings. Figure 10 shows examples of such operation by the hashed building polygons.
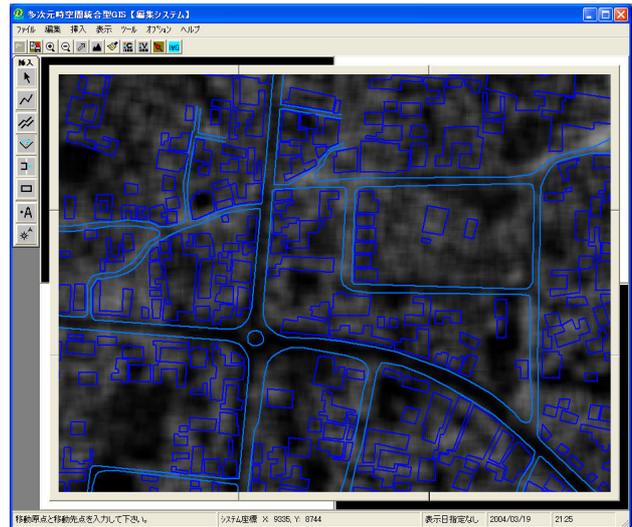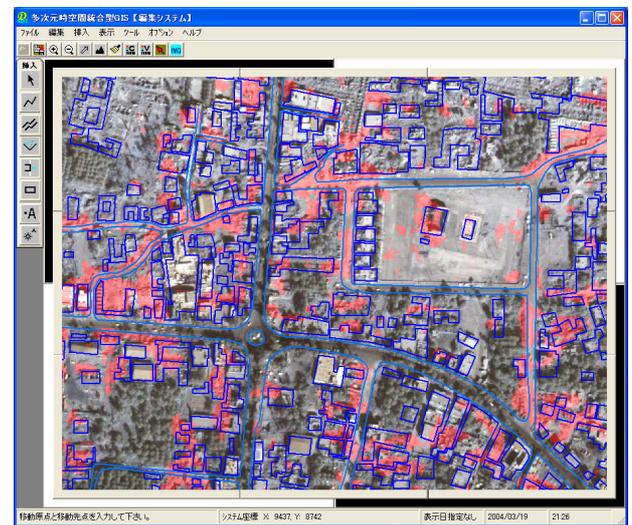

Figure 7 Original result of change detection

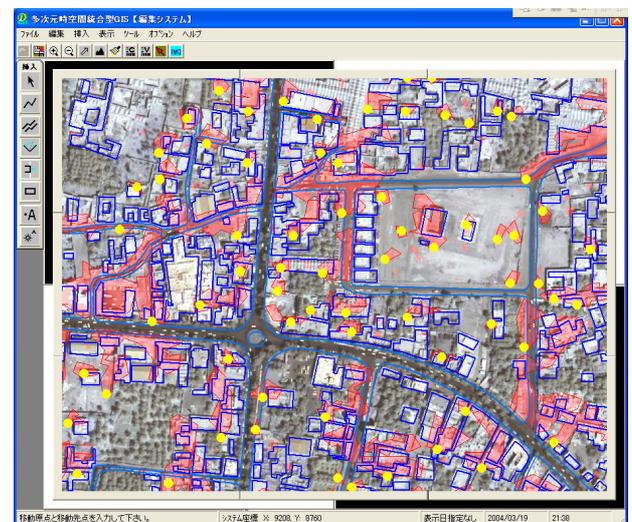Figure 8. The result of binarization

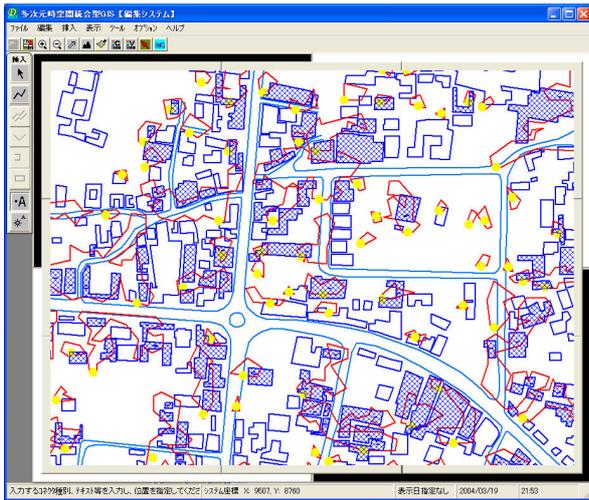Figure 9. The result of contour tracing and vectorization

Figure 10 Examples of extraction of damaged houses based on the overlapping of change detection results with map.

The registered imageries can also be searched by specification of type, name, time, comments, range etc., as shown in the dialog window in Figure 11.

Figure 11. Search setting dialog

5. EVALUATION RESULTS

Using a PC with a CPU of above 2.66GHz, and memory over 512 MB, imagery of about 2GB each can be registered in about 30 minutes. Thus for a total of 5 aerial photos that covers about 10 Km^2, it takes less than 3 hours to register them. When choosing the compressed structured image format, the resulted hierarchical image has a size of about 200MB, which is about one tenth of the original one. At this compression rate, the deterioration of imagery's quality is not obvious, and the decompressing does not affect the system performance.

The change after the disaster can be identified either by alternatively setting the system display time to before and after the disaster, or by overlapping the result of change detection with the imageries and map.

Resources such as snap shot and video are also registered as spatial objects, which can be searched with spatial-temporal conditions.

6. CONCLUSIONS

We have proposed and implemented an image integration system for decision support when disaster happens. It enables registration and searching of all types of imageries including video clips and snap images, both in spatial and temporal space. Imagery of even giga byte size can be displayed without much stress, by using a hierarchical structure, with compression option. Simulation or change detection results of raster format can also be converted to polygons for efficient and precise analysis with standard GIS functions.

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