STUDY ON PERSONAL COMPUTER SYSTEM FOR THE COMPREHENSIVE ANALYSIS OF THERMAL IMAGE AND GEOGRAPHIC INFORMATION

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Abstract

The technology to observe and process the thermal image has become more common in recent years, and is widely used in the various fields from disaster prevention to diagnosis of buildings. So far, however, the utilization of thermal image has been mostly concentrated unitary on the analytical process of the information obtained from the thermal image, and there has been no comprehensive analysis involving other conditions and information. Under such background, we discussed in this study the process flow of system and system configuration so that the thermal image and map information can be simultaneously analyzed, and at the same time, the observation, analysis and output of result can be performed easily in a short time in a consistent flow of work.

This paper reports on the conception of the system, how and why such system was studied, and the substances of system so far discussed.

KEY WORDS: Thermal, disaster, process, information, analysis

1. Introduction

Due to the improvement of observation and treatment techniques in recent years in our country, the thermal infrared data are used in the various areas for diversified purposes such as grasping of the state of disaster, diagnosis of buildings and plants and inspection of electronic components. In the past, however, the mainstay was the unitary analytical process based only on the information obtained from the thermal images, and there has been no comprehensive analysis involving other related geographical information. Especially in our country where there volcanic disasters and slope land disasters occur rather frequently, it is strongly hoped to apply the thermal image to the site level works where real-time information is necessitated. For this purpose, it is urgent to construct a simple system which can analyze the thermal image from the comprehensive viewpoints jointly using the various geographical information relating thereto.

Based on these backgrounds, we discussed, in our present study, a personal computer system which can analyze thermal image and geographical information comprehensively and produce results comparatively easily.

In discussing the system, our main purpose was to apply it for the disaster prevention, and we placed highest concern to the functions such as the construction of database of thermal images observed through multiple seasons and related geographical information, time sequential analysis using the thermal images of multiple seasons, and overlay analysis/evaluation of the information obtained from other than the thermal images (geographical information, map information). Furthermore, we discussed system processing flow and system configuration which can perform observation, analysis and result output in a consistent flow in a short time and with easiness.

This paper will report on the conception of system, details of system discussion and the details of system which was constructed as a pilot system.

2. Conditions for system discussion

The purpose of this system is to grasp the actual states of volcanic disasters and slope land disasters, conjointly using the thermal image and geographical information in the consistent flow of analysis, observation and analysis result output. Main background reasons why we tried to construct such system are as follows.

2.1 Necessity of analysis function to jointly use the thermal image and geographical information

The application fields of thermal image have been so far confined mainly to the investigation and analysis of small scaled objects which have relative homogeneity, such as the diagnosis of outer walls of building and plant and the inspection of electronic components. Therefore, it was possible to extract the information concerning the abnormality and change of the objects with a high accuracy from analysis results of only the thermal images. In grasping the actual state of disaster, on the other hand, the scale of investigation object is large, and the expression of it and its shape are not homogeneous. Also, since the objects are placed under the natural conditions, they are strongly influenced by weather and sunshine, etc.

Furthermore, the information relating to the disaster cannot necessarily be grasped completely only from the temperature distribution of land surface. Because of these reasons, it is considered difficult to extract the disaster information accurately.

On the other hand, the information concerning the disaster prevention and the actual state of disaster is closely related to the geographical information such as topography and land conditions of the region concerned. Therefore, it is considered possible to grasp more precisely the information concerning the actual state of disaster by adding temperature distribution obtained from thermal image to the geographical information and by overlay analysis of multi-dimensional information. Also, it should be possible to precisely grasp the information of thermal image itself such as temperature distribution by supplementing the topographic information, etc. to the analysis of thermal image.

2.2 Necessity of time sequential analysis of thermal image

The time sequential analysis of thermal image has been so far based on the temperature distribution of single time period, and there are only few instances where such analysis is made on the time sequential changes of thermal images observed over the plural time periods. In the field of slope land disaster, however, it is effective to grasp the time sequential change of temperature distribution to understand the transition of state of slope land or volcanic activities, and there is a limitation in the analysis of thermal image of a single time period. For these reasons, it is considered to be effective to use the system which can perform overlay analysis of thermal images of plural time periods and time sequential analysis of temperature change.

2.3 Necessity of quantitative display, output and summation

The main result obtained from the conventional analysis of the thermal image was the image of temperature distribution. As a result, the users in most cases read the pattern of temperature distribution qualitatively from the displayed/outputted images. By this method, however, it is difficult to grasp the information of thermal image qualitatively and accurately. By compiling the thermal image information and related geographical information as a database under a unified standard, it should become possible to display the map accurately overlaid with the thermal image, and to sum up the area quantitatively. Also, it should be possible not only to display the images but also to output the analysis result onto maps such as topographic map.

2.4 Necessity of simple system which has consistent processing function

Among the conventional systems which handle the thermal image, there are few systems which can perform observation, analysis and result output as a consistent flow. Especially when to make highly leveled analysis to the thermal image, it is necessary to process the data obtained by an observation system by inputting them into large scaled analysis system by off-line. Thus, it has a defect to take long time as the observation, analysis and result output cannot be processed efficiently as a consistent flow. Especially in case to grasp the situation of disaster, it is necessary to obtain the analysis result in a short time. It is also necessary to carry the analysis system directly to the disaster area, and to process the data on the site. For these reasons, it is necessary to develop compact and simple system which can perform the observation, analysis and result output efficiently as a consistent flow.

3. Basic conception of system

We discussed the basic conception of system basing on the conditions for system construction as stated in the above. Fig. 1 shows the system conception. Here, we discussed the concrete conditions to be satisfied concerning the hardware, software and database. The details of discussion for each item are as follows:

3.1 Conditions of hardware

3.1.1 Easy, compact and divisible equipment configuration: When considering the requirements of the system that it can be carried to and operated at the site, the system must have easy and compact configuration of equipments. In this case, therefore, it is effective to configure the system mainly around the small sized sensors and personal computer. On the other hand, high compactness is the prerequisite condition for observation and analysis machines because of the necessity of urgent observation and analysis at the time of disaster. In addition, on the other hand, it is also necessary to place peripheral equipments and high speed processing machine in order to analyze the detailed information of disaster and to process the highly leveled information of thermal image. Therefore, it should be effective to divide the system into a number of modules, and and to construct the system so that it is possible to operate either the single module unit or all the modules as a total system. In this case, it is necessary to maintain the compatibility of data among the modules.

3.1.2 Employment of large capacity, high speed processing machine: The volume of data and volume of calculation are large because large number of data are used including image data mainly of thermal image as well as geographical information. Considering the necessity of real time analysis at the time of disaster, the data processing speed should be fairly high. Since the processing speed of personal computer has been rapidly improved in recent years, it is effective to use the latest 32-bit machine (mounted with i486DX). Also, it may be necessary to use the large capacity storage equipment such as hard disc and optical-magnetic disc.

3.1.3 Equipment of diversified I/O device: In order to input the diversified information such as image data mainly of thermal image, geographical information and observation details, the system must be equipped with input/output devices which can cope with these data. Also, the output device must be able to handle the various forms because the format of output should be diversified into image, vector value and list.

3.2 Conditions of software

3.2.1 Software must have good operability: Considering the necessity of rapid analysis at the time of disaster and the use of this system at the disaster site, it is necessary that the software should have a good operability. It should be necessary to construct the software effectively using the windows and icons.

3.2.2 Equipment of function to effectively process the thermal image with high speed: It is necessary that the observed thermal image data are coordinated with geographical information and compiled in the database under a unified standard. Especially when time sequential observation is made, the volume of data will become huge and the observation conditions will also be diversified. As a result, therefore, it is necessary to provide the function to coordinate the positional relation with the geographical information and to unify the standard for temperature. It is also necessary to provide the highly advanced function such as to overlay the thermal images each other which are stored in the database, and to perform the time sequential analysis of temperature.

3.2.3 Equipment of function to integrate thermal image and geographical information: It is necessary to provide the function to combine the thermal image and geographical information and integrate them each other. Namely, functions are necessitated such as to display the thermal image and geographical information overlaying them each other as well as to evaluate the degree of disaster risk using the both information. Also, it is necessary to have the function to make calculation basing on the geographical information, such as to work out the disaster area by each region (by river basin or by administrative districts).

3.2.4 Optimal use of graphic function: While the thermal image is image data, the geographic information is arranged as another data which has forms of image and vector. Therefore, it is necessary for the system to be able to display the various kinds of data on the screen using the graphic function of personal computer. It is necessary provide the system with the function of screen display such as overlay display, parallel display and time sequential switching display.

3.3 Conditions of database

3.3.1 Integral management of diversified data: The data used for this system have the diversified forms such as image, vector, mesh and value list, etc. It is necessary to compile into a database and manage them under the unified standard. Especially in order to overlay the geographical information and thermal image, it is necessary to consolidate them by the unified coordinates value. At the time of emergency or for the observation and analysis at the site level, it is difficult to individually manage the huge volume of file such as the thermal images which are observed time sequentially. Therefore, it is necessary to provide the function to automatically manage the individual files inside the system.

3.3.2 Systematic conversion of data format: As stated before, the data used in this system have diversified formats. It is therefore necessary to systematically convert the data format so that these data can be combined functionally. Specially important is the conversion function between image data and vector data

4. Analysis of required functions

When taking the conventional analysis of thermal image as an example, the general flow of its processing will be as shown in Fig. 2. Following this flow of processing, and referring to the existing examples of thermal image analysis, we analyzed the concrete functions required for each step (observation, preliminary processing, analysis, and result output).

4.1 Observation function

4.1.1 Picture taking of each kind of image: In case of emergent observation and taking aerial photograph at the time of disaster, it is necessary to collect image information such as thermal images efficiently with high maneuverability. Since there are frequent instances when the photographs are taken from oblique direction especially at the time of volcanic disaster and slope land disaster, it is necessary to provide the observation function with high maneuverability. Also, since the thermal image has inferior quality compared with aerial photograph, it is difficult to grasp the positional relation among the objects on land. Therefore, in order to grasp the positional relation between the thermal image and objects on land, it is effective to take color aerial photograph (or color aerial video) as supplemental data. In that case, it is necessary to have a function to synchronize the both sensors and take picture from the same angle.

4.1.2 Collection of observation details: In case of aerial photographing, it is difficult to confine the photographing scope comparing with the observation made at fixed point on land. Especially in an emergent case such as disaster, there is no room to choose the flying course, and as a result in many cases, it is difficult to determine the positional relationship at the time of analysis. Therefore, much time is consumed for the preliminary processing to match the positional relation with the map, disturbing the efficient, rapid and correct analysis of data. To solve this problem, it is necessary to provide the function to measure the positional relation between the photographs taken and objects on land. Therefore, it is effective to provide the function to add and automatically record the observation details such as temperature calibration information and observation time onto the information stated before which is necessary for grasping the positional relation.

4.1.3 Database of time sequential thermal image: Since the obtained images have not been arranged in time sequence in the conventional observation of thermal image, much labor was needed for arranging them at the time of analysis. It si therefore necessary to automatically establish the database of time sequential thermal image including the observation position and time using the observation details as mentioned before. Fig. 3 shows the concept of time sequential database of observation time.

4.2 Function of preliminary processing

4.2.1 Conversion of each information into digital data: The thermal image is required to have high

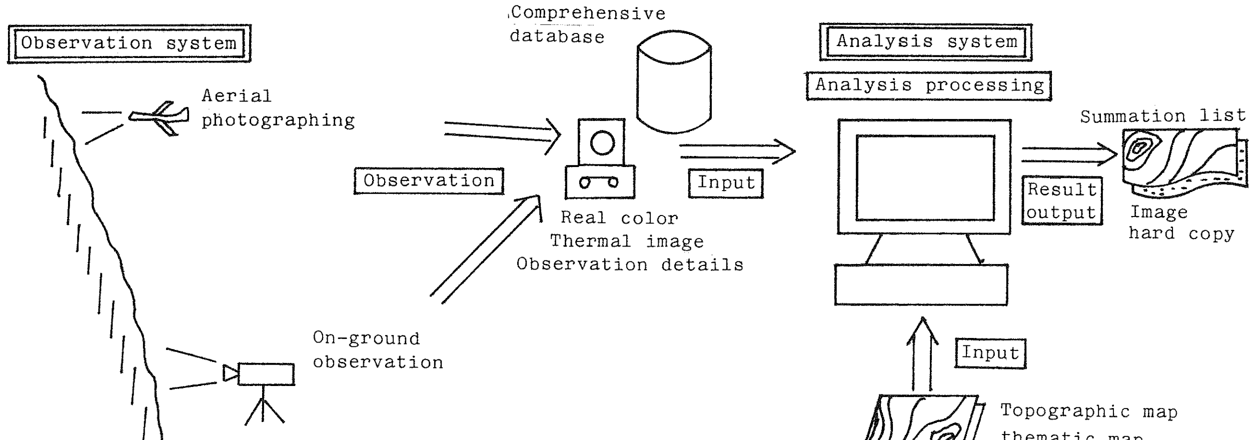

Fig. 1 Diagram of system configuration

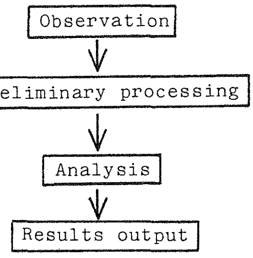

Fig. 2 Flow of processing

real time nature, and is in most cases recorded at the time of observation. Considering the numerical value processing at the later stages, it is necessary provide the function to convert these analogue image to the digital image data. In this case, it is also necessary to provide the function to add above-mentioned observation details to each image. In order to perform integration processing of thermal image and geographical information, the function to convert the geographical information such as topographic map and thematic map into digital data will be also indispensable. For reference, the thermal image is a data which have diversified format such as image, vector and mesh, etc. It is necessary to provide the function of mutual conversion between these data format in order to perform systematic analysis.

4.2.2 Position coordination, mosaic: Since the thermal image observes the objects from various angle, it does not have conformity with the coordinates on land. When assuming the integrated analysis with geographical information and time sequential analysis of thermal images of different time periods, it is considered effective to have the function to coordinate the various combination of positions among the data such as thermal image and real color picture, thermal image and geographical information, etc. In this case, it is necessary to configure the functions so as to perform the automatic processing (rough geometric correction) using the position information among the observation details mentioned above, and the precise geometric correction using GCP.

In most cases, on the other hand, the thermal images generally take up the object dividing it into several parts. For the sake of efficiency of analysis, it is desirable to have smaller number of processing units of image. Mosaic function is needed to integrate the plural number of images into one image.

4.2.3 Calibration of temperature level: The thermal image observed is a light-and-shade picture which indicates the high and low temperature. It is necessary to convert these light and shade into the image which shows the actual temperature values on land. Also to perform the time sequential analysis of temperature distribution of different time periods, it is necessary to convert them into temperature image under the unified standard. In case of a disaster, it is difficult to measure the actual temperature of the object at the disaster area. For this reason, it is necessary to have the function to calibrate the temperature using the temperature calibration information of sensor among the observation details. Also, in order to grasp the temperature in more detail, it should be necessary to have the functions of atmospheric correction and radiation rate correction.

4.3 Function of analytical processing

4.3.1 Temperature analysis: Temperature analysis requires the function to quantitatively analyze the temperature information through the operational processing, and the function to visually grasp the temperature information by displaying it on screen with various combination of information. As for the operational function of thermal image, it is effective to analyze the temperature information using the thermal images of plural time periods. For example, it is necessary to have the function to calculate the temperature difference between the two thermal images of different times for grasping the transition of volcanic activity. Also, in order to eliminate to influence of sunshine at the time of observation and to grasp the regular distribution of temperature, it is necessary to provide the function to calculate the average temperature using the thermal images of plural different times. Furthermore, in order to grasp the temperature characteristics in more detail, it should be necessary to prepare the map of time sequential map of temperature change at a specific area among the thermal images of plural times.

As for the screen display functions, it is necessary to provide the basic display function for individual thermal images as well as the simultaneous display function of plural images which enables the time sequential comparisons.

Basic display function should involve the functions to display the temperature distribution image and operation results image as a light-and-shade image or level slice image. In addition, it should be necessary to have the functions to display the individual thermal image, analysis result image and real color image in parallel on the same screen as well as the function to display the temperature distribution images of plural time periods continuously switching them one by one. Fig. 4 shows the concept of screen display function used for temperature analysis.

4.3.2 Integrated analysis: In the integrated analysis, it is necessary to have the function to grasp the relation between the thermal images and geographical information by combining together the thermal image itself, temperature information image obtained from the operational processing of thermal image, and geographical information (topographic map, thematic map, etc.). It is also necessary to have high analytical function which can evaluate the degree of risk at the time of disaster and also provide the evaluations for the prevention of

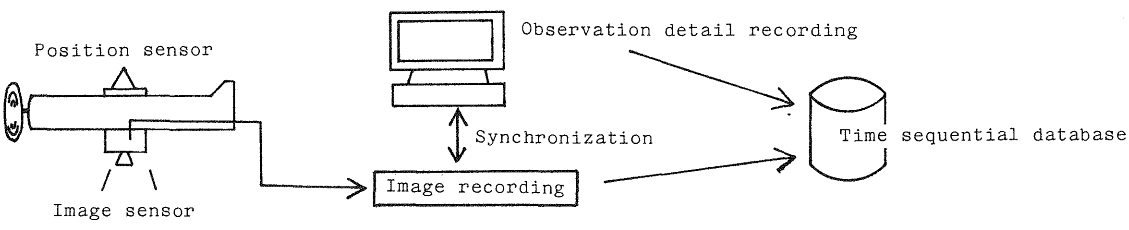

Fig. 3 Concept of time sequential database at the time of observation

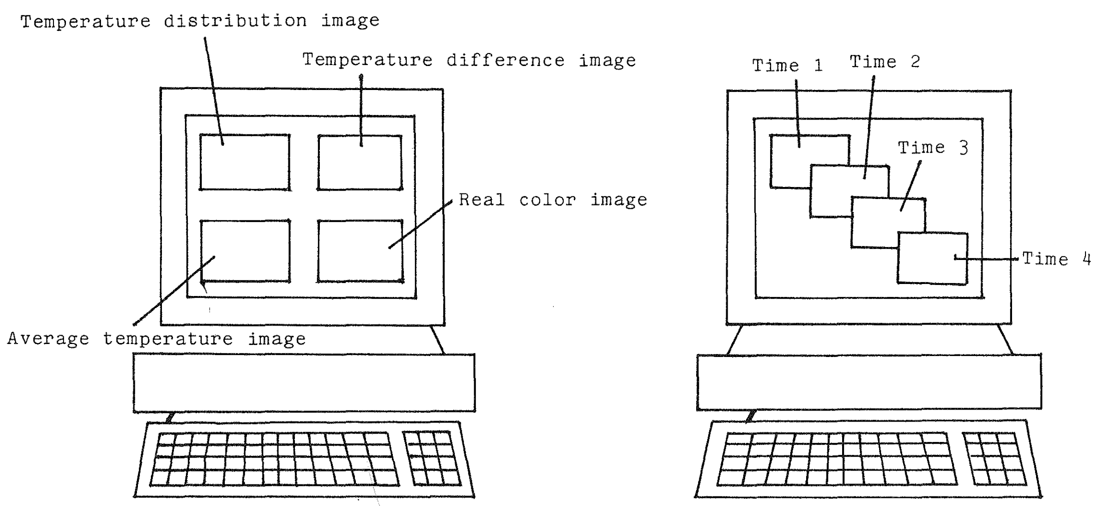

Fig. 4 Screen display function used for temperature analysis

secondary disaster. In case of volcanic disaster and slope land disaster, for example, it is necessary to have the function to estimate, evaluate and classify the expansion of disaster and the hazardous areas in the future by combining the regional characteristics (topographic characteristics and geological characteristics) and the actual state of disaster.

As for screen display functions, it is necessary to have the functions to display topographic map and thermal image, real color image and thermal image, etc. overlaying them each other. In addition, it should be necessary to provide the function to display the individual thermal images and analysis result images three-dimensionally on latitude images and real color images.

4.4 Result output function

The result output function should include the image output function, diagram output function and value (area calculation result, etc.) output function. The image output function should be able to produce the hard copies of individual thermal images and overlaid images of real color image and thermal image as they are used at the disaster sites. diagram output function must include the function to output the thermal image distribution and analysis results on the topographic map and thematic map using plotter, etc. This will be helpful for grasping the disaster state more in detail and understanding the relation between regional characteristics and disaster state. The value output function must have the functions to calculate the area and output the calculation results on a list to grasp to which region and in what scale the disaster is expanding.

5. System configuration for the purpose to grasp the actual state of disaster

Basing on the analysis result of required functions as stated in the above, we were able to discuss the draft of system which is comprehensive, idealistic and feasible in the future. We discussed the system (hardware and software) placing the focus on the grasping of actual state of disaster. Basing on the results of system discussion, we constructed the pilot system to grasp the actual state of disaster at the time of emergency. We will introduce some cases where this pilot system was applied.

5.1 Hardware configuration

Referring to the result of function analysis for system construction made in chapter 4, we discussed the configuration of hardware limiting the purpose to grasping of actual state of disaster. Fig. 5 shows the configuration of hardware. The hardware configuration was designed as compact as possible so that it can be used at the disaster site still being able to perform analysis comprehensively integrating geographical information, etc. The area enclosed by dotted line in Fig. 5 shows the pilot system constructed to grasp the disaster state at the time of emergency.

Video sensor was considered most suitable as the equipment to shoot the thermal image due to its maneuverability and easy operation. Since it is difficult to grasp the positional relation between thermal image and objects on land as stated before, we added real color video device. We also provided VTR to record the photographed pictures. The data recorded on VTR cannot be directly processed by the personal computer. It is essential to provide A/D converter to convert video signal to digital data to allow the personal computer to perform numerical processing.

In analyzing the observed data, we employed a personal computer considering the size, processing capacity and easy operation. We selected 32-bit desk-top type personal computer which has sufficient processing ability, capacity and number of interface. As for CPU, the latest one such as i486DX is considered desirable due to its high speed in processing.

Full color image memory was added as a device to display images. It is possible to use the graphic function of personal computer, but in that case, the observed image may not be displayed clearly because the display color range is generally limited to 8 - 16 colors. By adding the full color image memory, it has become possible to display the overlaid image of map and thermal image by conjointly using the display of full color image and graphic function of personal computer. We arranged the high resolution color display and color hard copier to display/output the thermal images observed and the analysis result images.

It is necessary to have the large capacity recording equipment such as hard disc or optical disc to store thermal images of plural time periods and plural seasons, as well as the many items of map information. We also equipped the system with a printer to output the analysis result of disaster state as a numerical value. We also added scanner, digitizer to input the geographical information.

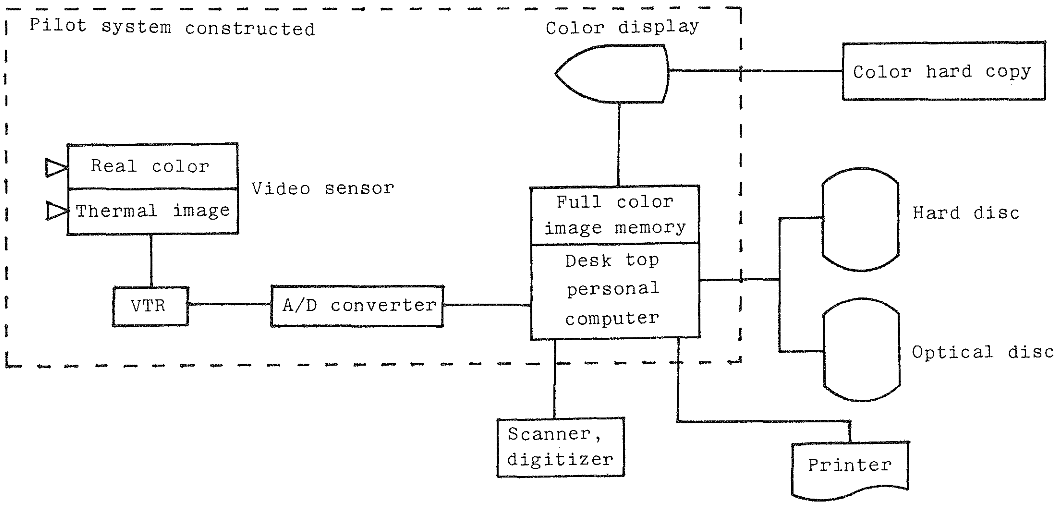

Fig. 5 Hardware configuration

5.2 Software configuration

Basing on the function analysis as stated in the above, we classified the software into preliminary processing, analysis processing and analysis result output, and discussed the functional configuration at each stage of processing. The configuration of software is shown in Fig. 6, the flow of processing in Fig. 7. The areas enclosed by dotted line in the Figures are the functions constructed as the pilot system.

In constructing the software, we placed an emphasis on the easy operation considering the use at disaster site, and used icons, menus and key functions as much as possible. In developing the individual programs, we used C-Language considering the transplantation of program, processing speed and use of graphic library. The details of each function are as follows.

5.2.1 Preliminary processing function

(1) Data input/preparation is a function to input the observed video image and geographical information through the A/D converter, scanner and digitaizer. Video image A/D conversion is a

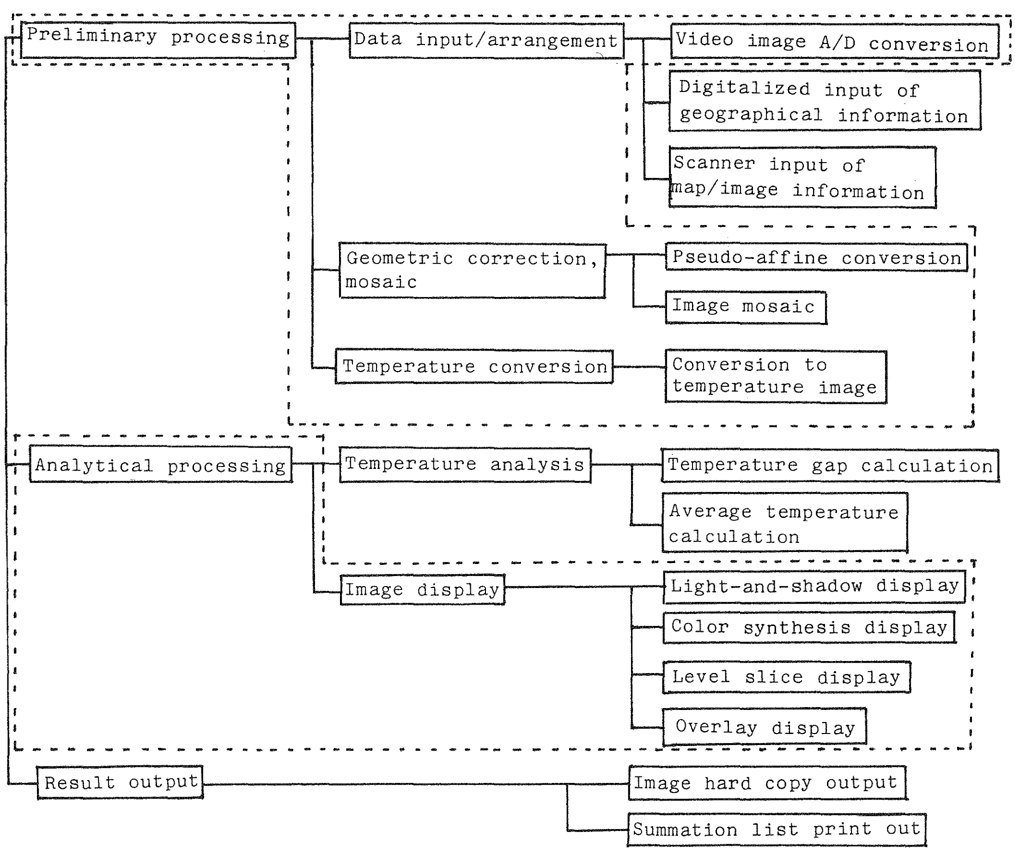

Fig. 6 Software configuration

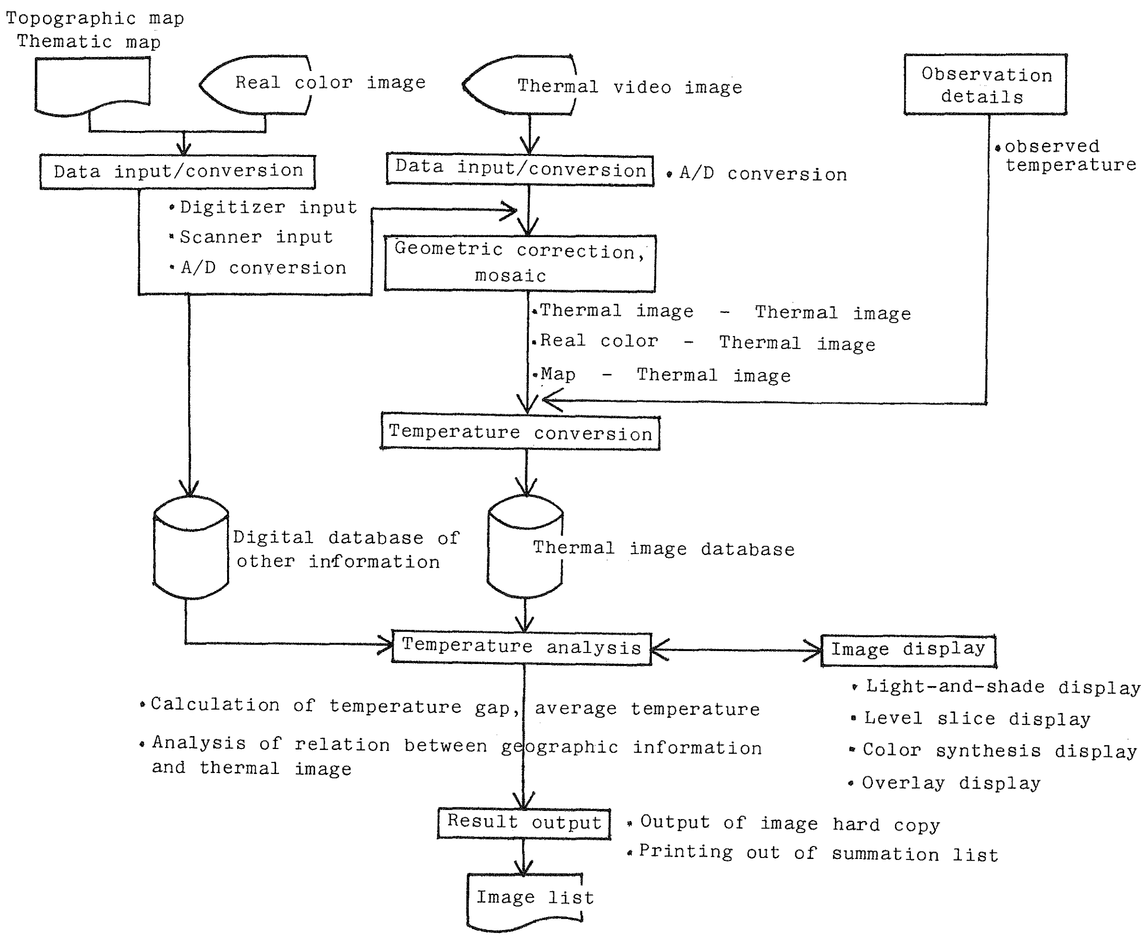

Fig. 7 Flow of processing

function to convert observed real color image and thermal image into digital image data through the A/D converter. Geographical information digitazing input is a function to input the line information (contour lines, etc.) and area information (river basin, etc.) obtained from topographic map and thematic map as vector data such as line form and polygon form.

(2) Geographic correction and mosaic functions are used to coordinate the positions in thermal images with those of real color image and geographic information and enable the analysis processing at later stages such as overlay of thermal images and other information. We also added the mosaic function in order to produce the image which covers wider area by integrating small area images after geometric correction.

(3) Temperature conversion function is a function to convert the observed thermal video image into an image which indicates the correct temperature value. The thermal video images recorded on the VTR is light-and-shade image which indicated the high and low temperatures and does not correspond with the actual values of temperature. Therefore, we devised temperature image conversion function as a function to produce an image which indicates actual temperature value by adding temperature range at the time of observation and applying line conversion method.

5.2.2 Analysis processing function

(1) In order to analyze the temperature, we provided the function to extract disaster information from the temperature information through the processing of thermal images of different plural times. As a basic operational function, we added the temperature gap calculation function which works out the temperature gap between two different times and temperature average function which calculates the average temperature of more than two different times.

(2) We provided the image display function which visually supplements the analysis by overlaying the geographical information and thermal image and by displaying it in various forms.

First of all, provided four functions as basic functions to display the thermal images and real color images in an original state; namely, light-and-shade display, level slice display, color synthesis display and overlay display. The light-and-shade display is a function to display continuous monochrome gradation of thermal image, and slice level display is a function to display thermal images and analysis result images by adding colors according to the temperature ranges. The color synthesis display is a function to display the continuous color gradation of real color image and aerial photograph image. The overlay display is a function to overlay the thermal image with real color image and maps and display it on screen in order to grasp the actual state disaster more efficiently.

5.2.3 Result output function: The result output functions are composed of functions which output analysis result images, etc. to the various kinds of media. As for the output of image and geographical information, we arranged the image hard copy output function which outputs the image on screen directly on a hard copy. We also added the function to output the area summation result of a disaster region as a numerical information.

5.3 Introduction of cases where the pilot system was applied

We will introduce a case where the function of this pilot system was applied taking up the lava dome of Unzen Mountain. The Photos 1 and 2 show the real color image and its corresponding thermal image. These two photos are the images after A/D conversion of the pictures taken by video equipment. Photo 3 is the geometric correction image after coordinating the positions of thermal image and real color image.

Photo 4 is the thermal image after temperature conversion to which colors have been added by a specific ranges of temperature value using the level slice function. From this photograph, we can grasp the state of sphere surface of lava dome. Photos 5 and 6 are the overlaid images of real color and thermal images.

6. Conclusion

The following results have been obtained from the present study.

(1) Basing on the analysis of existing cases, we could materialize the proposal of system integrating the thermal images and geographical information which is comprehensive and feasible in the future.

(2) We were able to make a pilot system to grasp the actual state of disaster.

(3) We applied this pilot system to the actual disaster area.

(4) Basing on the result of analysis of functions which are required for the integrating analysis of thermal image and geographical information, we could summarized the minimum configuration of hardware and software which are necessary for grasping the actual state of disaster.

(5) It is necessary to further develop the system so that more sophisticated analysis (evaluation, classification) can be made in the future.

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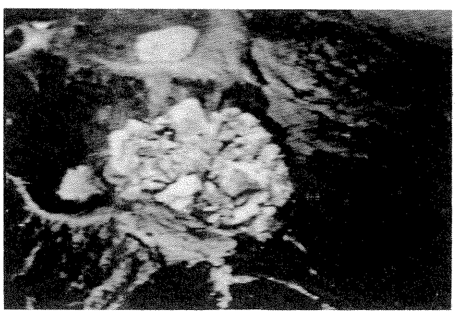

Photo 1: Real color image

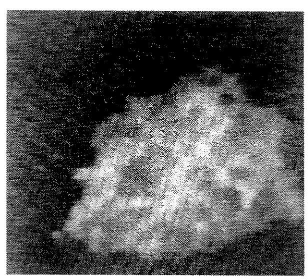

Photo 2: Thermal image

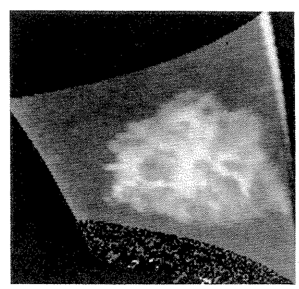

Photo 3: Geometric correction

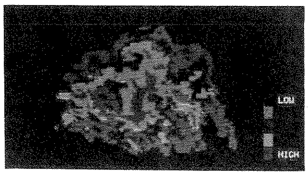

Photo 4: Level slice image

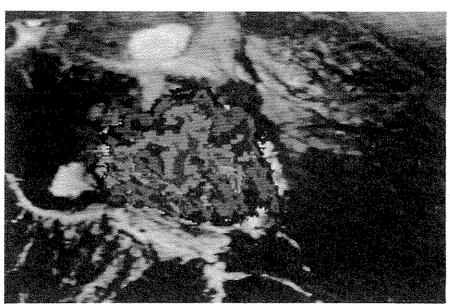

Photo 5: Overlay image

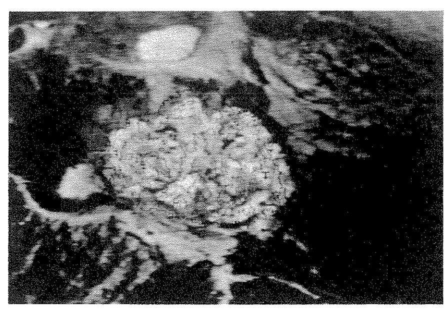

Photo 6: Overlay image