

Development of the Graphical User Interface of the Supporting System for the Slope Stability Evaluation and Improving Its Usability

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Abstract : For better supporting to evaluate the hazardous area affected by the slope failures and landslides, we have been tackled to construct the supporting system (termed SSE-Win) for the slope stability evaluation with the userfriendly Graphical User Interface (GUI) based on the window system. In the SSE-Win, the geographical information and satellite remote sensing data were used to produce the slope stability evaluation maps. In the general design of the GUI, the functions corresponding to the operating procedure in the SSE-Win were investigated. As the next stage of the detail design of the GUI, we designed the link-relation between the screens as well as the contents in each screen. The standardized procedure on the GUI design provided in this study might be contribute not only to the reduction of the entire term on the system development, but also to improve the efficiency of the system life-cycle in modifying and adding the further functions.

Keywords : *graphical user interface, slope stability evaluation, geographical information, satellite remote sensing data*

1. Introduction

In order to estimate hazardous areas on slope in a wider range area, the authors have built a model to produce a slope stability evaluation map based on the integrating geographical information such as on surface, geological, and soil, together with satellite remote sensing data, and have shown its effectiveness. This is so called SSE model (SSE model: Slope Stability Evaluation Model using satellite data and geographical information). The SSE model has been prepared to run on both UNIX and MS-DOS environment, and many application cases have been accumulated. However, it was recently necessitated to run it on a mobile system in WINDOWS environment, which has become popular in recent several years.

The SSE model is based on multivariate analysis of which key theory is quantification method. There are many issues yet to be discussed in building the interface, which governs the system performance, in order to operate the model under the new system, such as to select training data which is considered as judgement criteria, or to control causal factors or files relating to the slope stability evaluation map.

After re-examining carefully a series of procedures in the SSE model, the authors have started design and development of a slope stability evaluation support system (called SSE-Win, hereinafter) which could be operated under the Graphical User Interface (GUI) having enhanced operability. During the new system development process, it is necessary to design a GUI which is compatible with the processing based on the SSE model. This study proposes a simple design method to

enhance the efficiency in developing such a specific GUI, and discusses on its effectiveness.

2. Purpose of the Research

The objectives of this study are as follows:

To point out problems in designing GUI for various specific system used in civil engineering, and to propose a simple design method of GUI, which enables to reflect specialists' opinion effectively for the system development.

To study designing within a screen corresponding to each function of the SSE model and link relationship among screens (screen transition design), and to build into a slope stability evaluation system.

To design a GUI having flexibility and expandability to incorporate addition and revision of functions, and to enhance efficiency of the life cycle as a whole system.

3. Features of This Research

3.1 Location of GUI Design in This Research

In construction industry, engineers are involved in various routine works and thus they are not using specific processing systems so frequently as they use word processors or spreadsheet programs. For example, users of various image processing and analysis system as well as those of GIS application software available in the market, understand process and analysis at the time of system installation, and they learn operation as they use it. However, after some interval of not using the system, they frequently experience inconvenience of reviewing the manual again. This is attributed to improper structure of the GUI which was not so built that a series of process and analysis flow was easy to be traced.

When developing such a highly specialized system in a technological field, it is indispensable, as shown in **Fig.1**, to advance stepwise from the design stage of a whole

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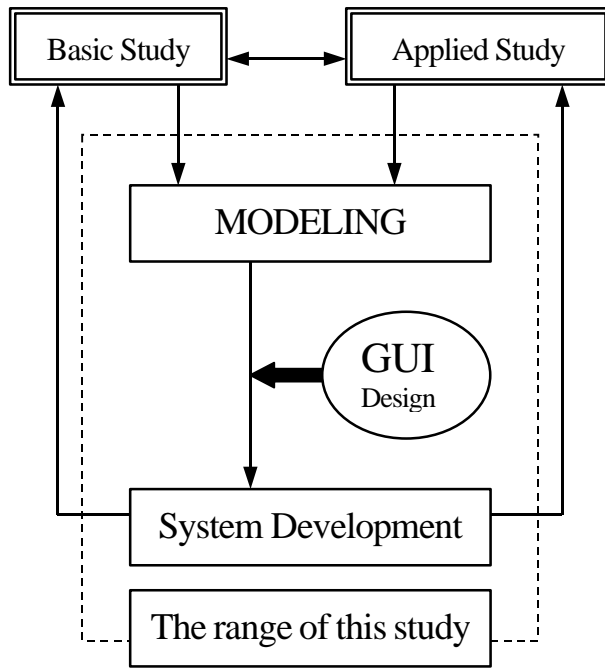


Fig.1 Range of this study

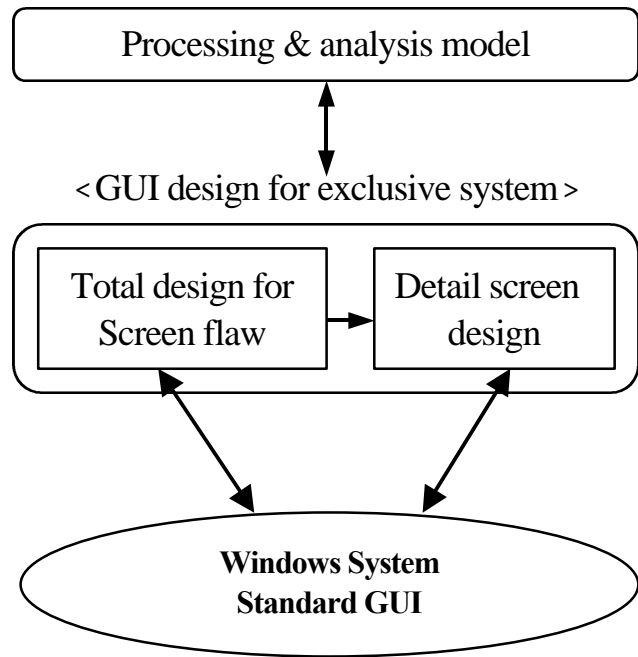


Fig.2 GUI design in this study

system to the detail design stage after modeling a series of process flow in an analysis model obtained from the fundamental research and application research. Therefore in this research, GUI design will be studied by the following two major parts.

GUI design under standard WINDOWS system

GUI design as specific program system

In early researches with regard to GUI design, their major objectives of study were design methodologies of the interface, such as man-machine interface, i.e. how to point or operate icons on the screen or the screen itself with a mouse or a tablet. This study focuses not on these kind of GUI design under standard WINDOWS system, but on a specific GUI design as slope stability evaluation support system, from a viewpoint of the compatibility with target process and analysis method.

In practice, as shown in **Fig.2**, GUI design process problems in the specific GUI design process will become clearer, and lead to design and development of a GUI with enhanced operability. Including the location of the GUI design in a specific system development, those problems can be pointed out to be not yet cleared.

3.2 Features of This Research

Features of this research is summarized into the is divided into two stages: whole system design and detail design. The whole system design takes care of screen transition design, and the detail design takes care of design

within a screen. In this approach, it is expected that following two points.

(1) Development of GUI in the SSE Model

The SSE model originally contains specific process and analysis function needed for making a slope stability evaluation map. Examples are designation of the hazardous area which will be the criteria for selection and judgement of causal factors, and various analysis functions based on quantification method type II, and mini-max second group discriminant method. In order to execute these functions in a GIS application software or image processing analysis system available in the market, it is necessary to create a number of intermediate files, and to process and manage all these files troublesomely, including their input and output operations. To solve these problems, a GUI with enhanced operability is designed and developed in this research for easy execution of a series of process in the SSE model.

(2) Efficiency Improvement of System Life Cycle

Aiming for efficiency improvement of life cycle in system development and utilization, many researches have been conducted on GUI design methods under standard WINDOWS system, and on design supporting tools. In addition, there are some researches on GUI design issues for GUI design support system itself. When a highly advanced technology is required in a system development, its designer and developer are rarely the same. This will lead to the reason why researches

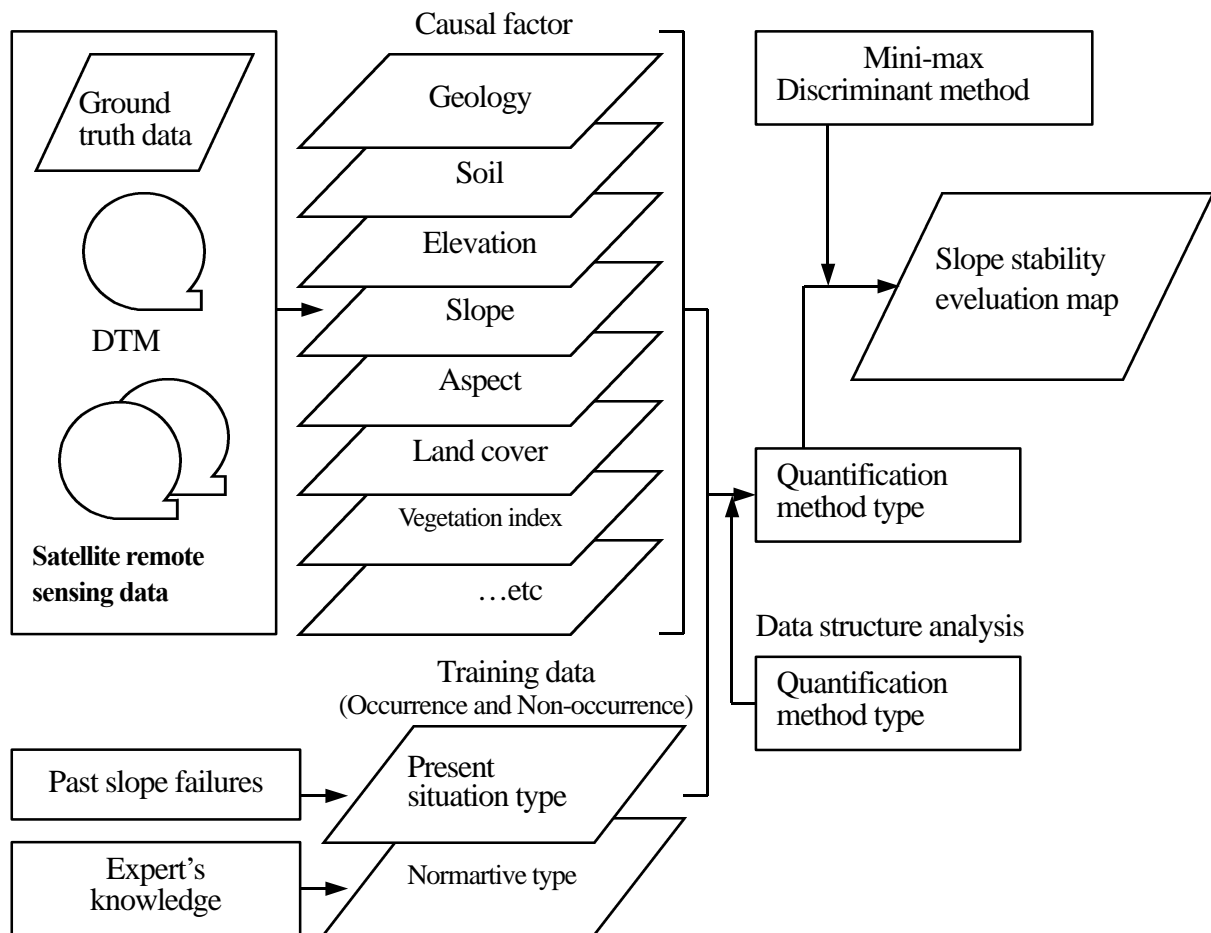


Fig.3 Constituent of SSE model

relating to the GUI design supporting tools have been tried to improve efficiencies in communication and design work between designers and developers. However in reality, many cases were found difficult due to its time and cost, that designers sophisticatedly use the GUI design supporting tools by themselves, and establish an ideal system development method such as designing interactively with the developers. As the contents of the system is more specialized, this will cause more problems. For the systemization of the SSE model studied in this research, the same kind of situation applies. Especially, in case the process flow and handling of the data are highly complicated, it is not recommended to design and develop all the function to be equipped systematically from the beginning. It is rather recommended to develop only essential functions, and also to give flexibility with which additional functions are able to be installed after the system is in service.

Considering the above points, this research proposes a design method of GUI which enables to incorporate designer's opinion easily by a simple procedure. In practice, it shows the process function of the SSE model and information regarding screen transition (event

information) on the same flow chart simultaneously, and it proposes how to write a design specification easy to be understood. Without installing any special GUI design method or design supporting tool, this design method sufficiently works for design of a specific GUI, and it contributes to improve efficiency in the life cycle of the whole system including system development and utilization such as addition and revision of functions.

4. GUI Design and Development

4.1 Environment of the system Development

Assuming that everybody can easily operate the slope stability evaluation support system, system development has been carried out based on a portable, personal computer. OS used was WINDOWS 98, and programming language used was Visual Basic of Enterprise Edition.

4.2 Design of GUI

(1) Whole System Design

Structure as a whole of the SSE model is shown in Fig.3. Basically, it is a model to make a slope stability evaluation map, by using geographical information and

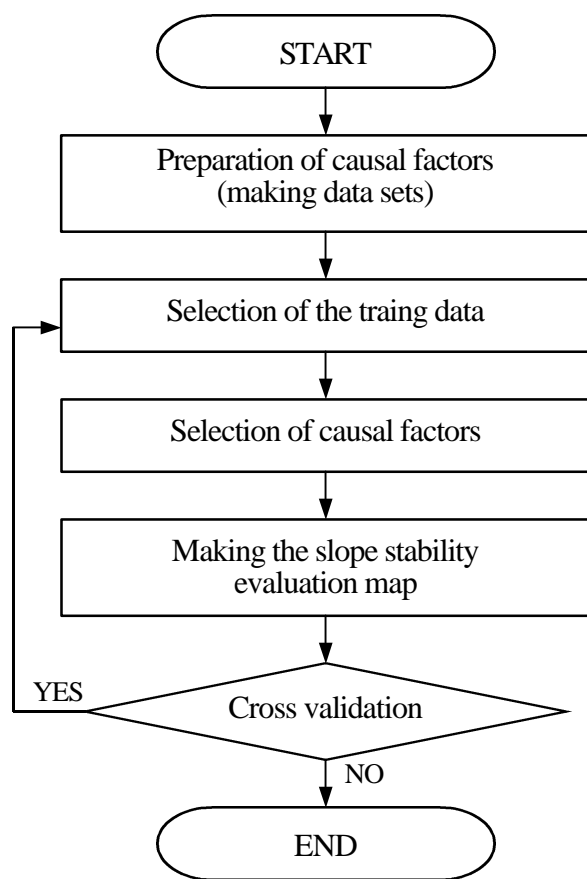


Fig.4 Procedure of SSE model

hazardous area to be used as criteria (termed training data). As detail of the SSE model was published by literature No.1 ~ No.3., it is not mentioned in this paper. Whole system design of the GUI in this research consists of the following two steps.

a) Study on Function Structure

A series of process procedure of the SSE model is summarized as shown in Fig.4. In addition, basic requirement for the GUI necessary to achieve this process on the system, was studied. Table 1 shows main study results. Especially, functions to make data sets and functions to select training data, require the GUI specific to this system, and intensive study has been done at the next step, i.e. detail design stage.

b) Screen Transition Design

There are ongoing researches on making a design specification of GUI or its supporting system development. However, from reasons that description of the design specification is very much detailed, and that specifications are broken and arranged, new problems such that it becomes harder to understand the whole structure of the GUI, are pointed out.

To respond for these problems, this research proposes

Table1 Items of GUI design

Function		Requirement of GUI
Data sets making and management		<ul style="list-style-type: none"> • Data sets management by JOB unit • Selection same kind of causal factor
Displaying geographical infomations		<ul style="list-style-type: none"> • Simplify Data sets selection • Simplify causal factor celection
Making slope stability evaluation map	Training sample preparation	<ul style="list-style-type: none"> • Selection of the hazardous area with mouse • Auto save training data
	Selection of causal factors	<ul style="list-style-type: none"> • Select causal factor through the list-box • Automatic grouping causal factors
	Making slope stability evaluation map	<ul style="list-style-type: none"> • Output sope stability evaluation image • Use the result by spread sheet software • Sensitivity analysis on the causal factors

a screen flow chart as shown in Fig.5. It is to draw flow chart based on the function structure as shown in Table 1. Characteristics of this flow chart can be summarized into the following three points.

It consists of 4 kinds of information, i.e. standard dialogue box (WINDOWS system standard GUI) , original window (necessary functions: from specific GUI), event (process flow), and input operation, and it is able to be described by very simple symbols.

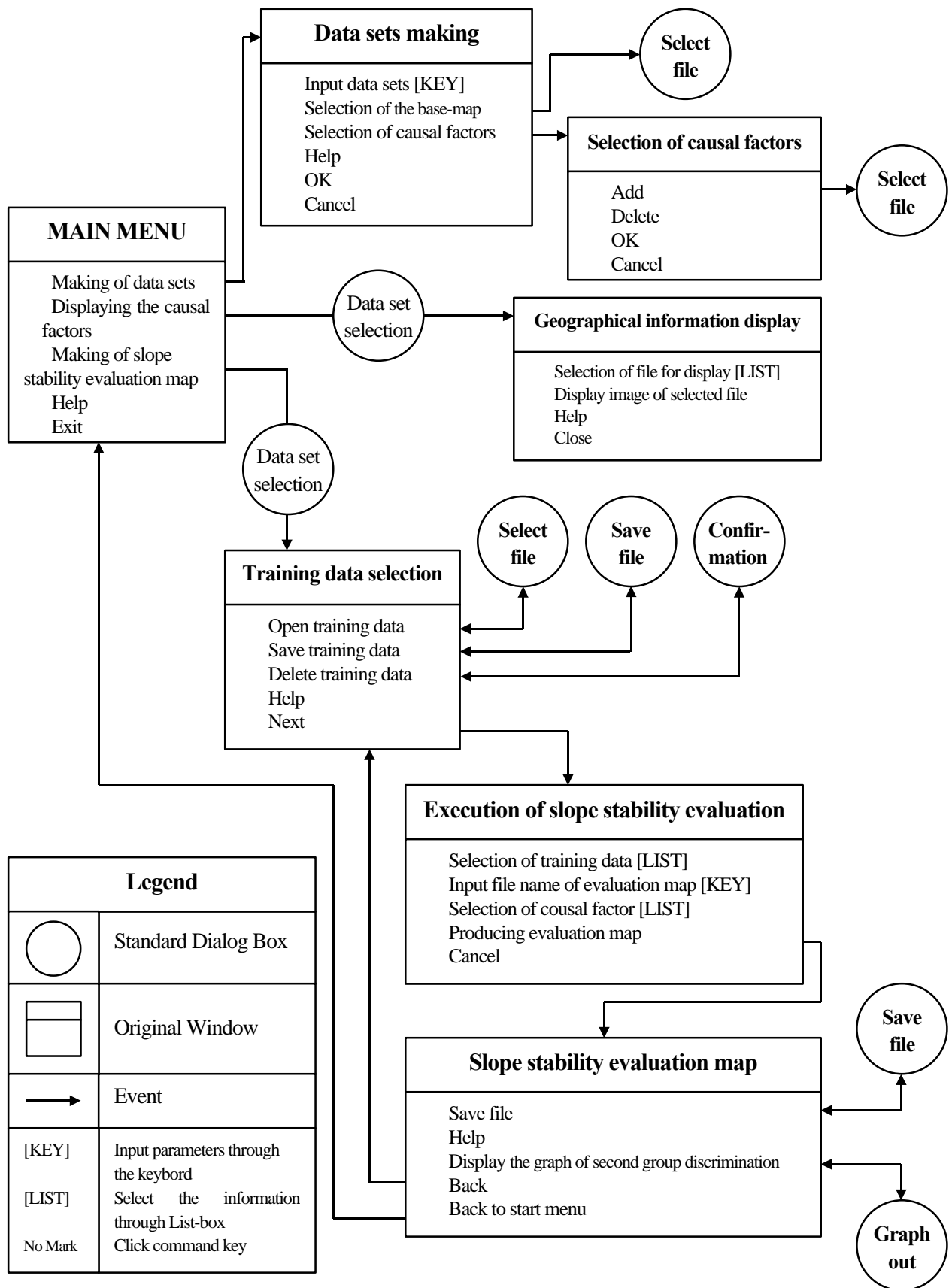
Without introducing any special GUI design supporting tool, design and development can be efficiently carried out. Whole system structure of GUI ,which designer has to transfer correctly to the developer, can be made clear.

Design scope by a standard WINDOWS GUI and by a specific GUI, has been clearly defined. Accordingly, the designer can concentrate on the specific GUI design, and efficiency in GUI design is expected to be enhanced.

(2) Detail Design

When a whole structure of the screen flow chart is finalized, it continues to the design within a screen. Actually, it comes to the design work, such as how to develop a standard WINDOWS GUI system within a screen. Information required for building a standard GUI, will be shown on the screen. For example, on the flow chart shown in Fig.5, at a frame of the screen indicated as “Making Slope Stability Evaluation Map”, the following five functions are shown,

- select training data file
- input file names of evaluation map



Legend	
	Standard Dialog Box
	Original Window
	Event
[KEY]	Input parameters through the keyboard
[LIST]	Select the information through List-box
No Mark	Click command key

Fig.5 Screen flow chart

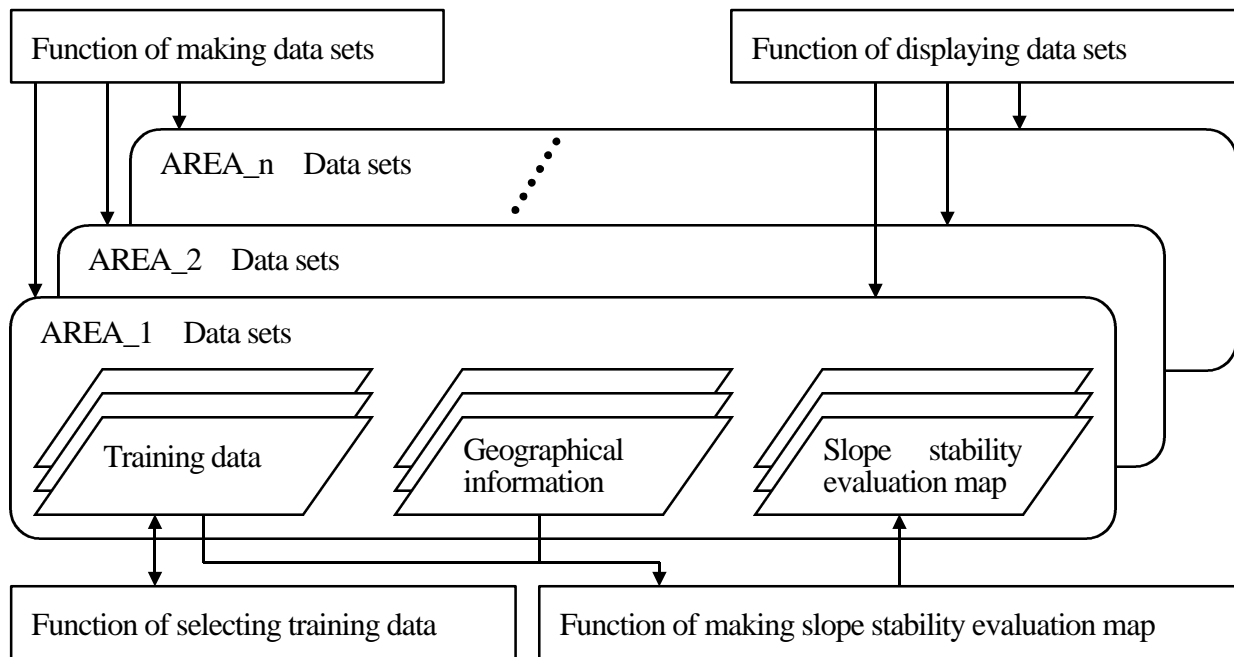


Fig.7 Data set structure and transaction processing

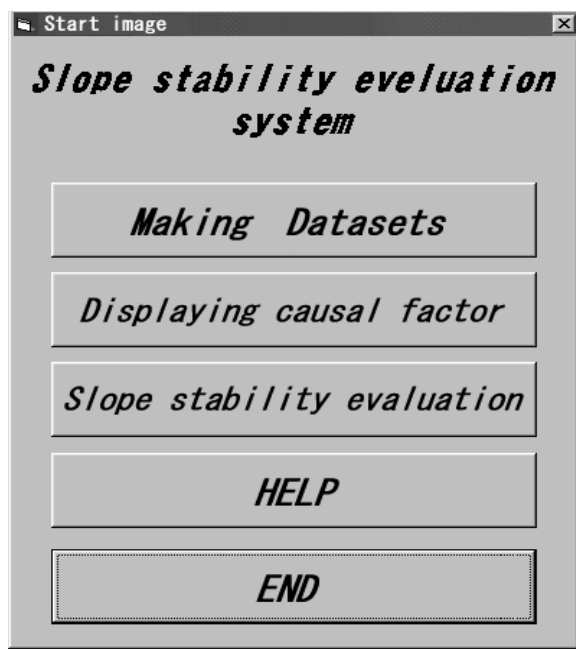


Fig.6 System main menu

select causal information to be used
 execute
 cancel

These items from top to bottom, correspond to the process flow in the SSE model. In addition, it is indicated as an event information that it can transfer from the location “execute”, through the arrow mark, to the next process of “Save/Analyze Evaluation Map” screen. It is important in the detail design step that the relationship between the necessary function and the event to be shown on the screen must be checked carefully, and then written.

Although the flow chart shown in Fig.5 is drawn according to a very simple drawing rule, it helps to understand the whole system, and also to point out issues to be discussed actually when standard WINDOWS system GUIs are installed in the process of screen transition design.

5. Building Slope Stability Evaluation Support System

5.1 Main Menu of the System

When executing the slope stability evaluation support system, a main menu as shown in Fig-6 is presented. The menu consists of the following four functions.

- Making data sets
- Displaying causal factor
- Slope stability evaluation
- Help

Users first use “ Making data sets” in order to transform causal factors to be used for making a slope stability evaluation map, into data sets. Then, users can look and check the information transformed into data sets by “ Displaying causal factor”. After completion of data set making, users can make a slope stability evaluation map by using “ Slope stability evaluation” function.

5.2 Data Set Making and Management

In the SSE model, when slope stability evaluation is executed as shown in Fig.7, it is necessary not only to

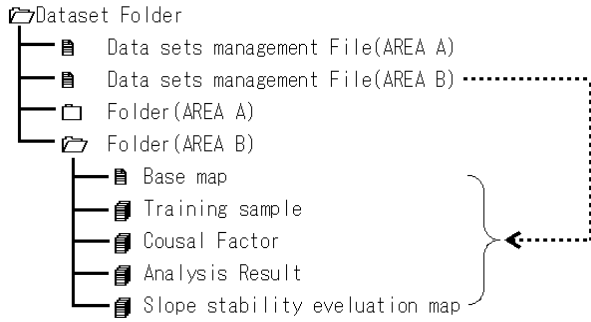


Fig.8 Folder construction

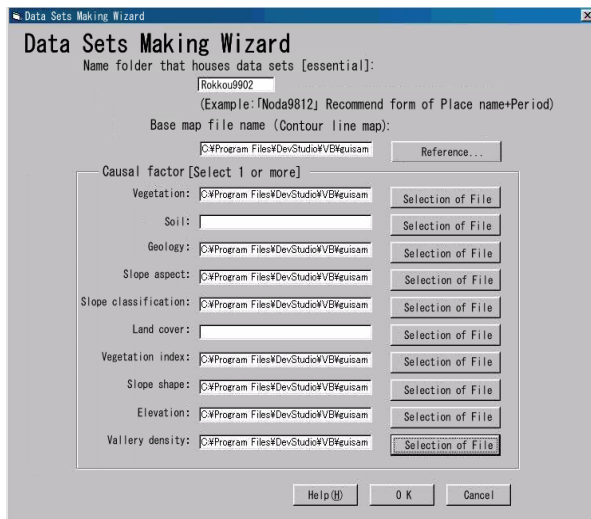


Fig.9 The function for data sets making

make in advance various geographical information (causal information), but to be able to manage those information by job units. Thus the relationship between the data set structure and the process function will be an important element for designing a highly operable GUI.

Data used in the slope stability evaluation support system are, base map where contour lines are written, training data, causal factors, statistical analysis results, graphic information such as slope stability evaluation maps, and figure information. Causal factors can be easily obtained through GIS applications or image processing analysis system available in the market, however, when those are used for the slope stability evaluation, it causes some problems in their management and operation. Then this research studied on the folder structure and the data management method in order to manage those multiple information as a set of data set by each job.

Practically, by using management files on which data set management information is written, data sets are managed centralized by field units (equivalent to a folder

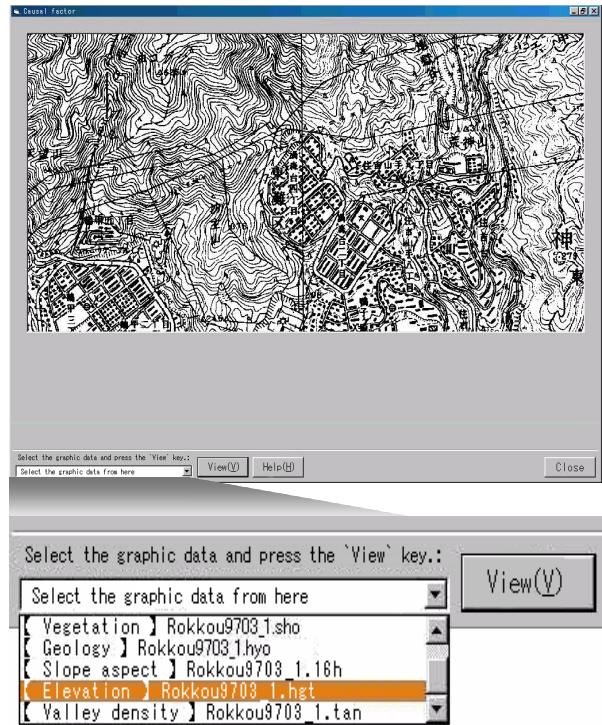


Fig.10 Selection of causal factors

in the system) in the system as shown in Fig.8. Accordingly, it leads to design and development of the specific GUI characterized by unique file access, such as indication of causal factors which will be described later, or selection of training data.

As an example, Fig.9 shows a screen at which data set management is carried out. By only pointing various geographical information made in advance in a certain order with a mouse, data set is made easily by job units. In subsequent operation, users can carry out slope stability evaluation without being interfered with troublesome file management. GUI designed and developed in this research was characterized by those features mentioned above.

5.3 Function Indicating Causal Information

This function is to show and confirm causal information made into data sets. Users do not have to memorize where causal data file is located. It is designed for users to select with a mouse, the causal information already written in a drop down list box as shown in Fig.10. The data set management file shown in Fig.8 works not only to manage data sets, but also to help in designing and developing this kind of GUI

5.4 Function Selecting Training Data

In the SSE model, it is necessary to select hazardous points which are considered to be the criterion of “failure”

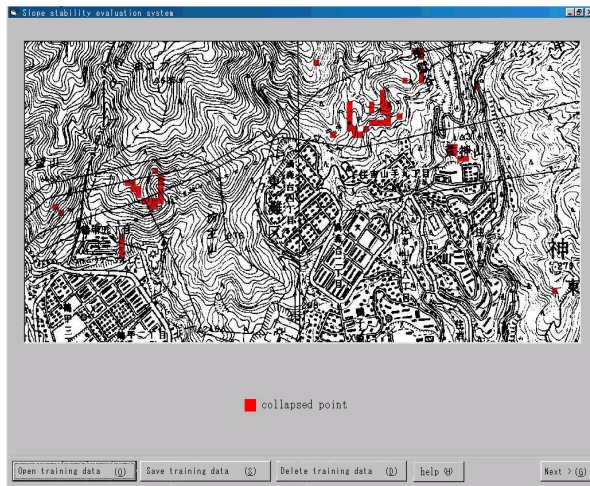


Fig.11 Selection of the training data

or “no-failure”, as the training data. In the screen where selecting the training data, it is so designed that selection or cancellation of the training data can be done by a simple action of clicking the mouse on the map, as shown in Fig.11. When selection of the training data is completed, clicking the push button indicated as “Next” in the lower-right corner of the screen, will make a training data file. As shown in Fig.8, the training data file will be automatically saved into the corresponding job data set folder.

In the SSE model, there are two ways of setting training data, named as “normative type” and “hypothetical type”, and those are called normative type evaluation, and hypothetical type evaluation, respectively.

normative type evaluation

Selecting a point where already slope is failed as training data, and making a slope stability evaluation map, and analyzing it. Normative type evaluation is helpful in analyzing land characteristics in the hazardous areas of which trigger factors are different, e.g. rainfall or earthquake.

hypothetical type evaluation

Based on knowledge of specialists or local residents, a point where slope has not been failed is selected as training data. By analyzing the difference between the slope stability evaluation map based on normative type evaluation and that based on hypothetical type evaluation, potentially hazardous area will be found.

This process of setting training data requiring repetitive trial studies can be done by very simple operation, which is one of the features of the GUI designed and developed in this research.

After making the training data, the screen immediately changes to selection of the causal factors which will be

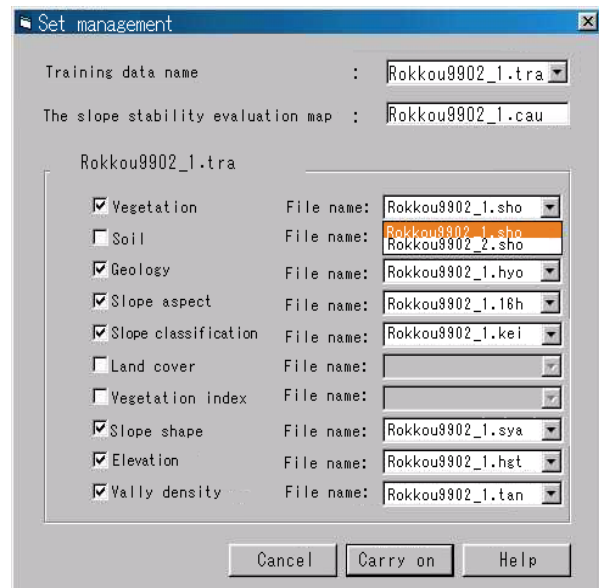


Fig.12 Selection of causal factors

described subsequently.

5.5 Function Selecting Causal Factors

Normative type evaluation and hypothetical type evaluation that described previously, are based on the difference in the type of training data. Whereas for slope stability evaluation using the SSE model, there sometimes carried out such an analysis that evaluation maps are made by taking various combination of causal factors, and compared. This is called “Influence Analysis of Causal Factors” for the hazardous area evaluation, and regarded as an important evaluation process.

In the system developed in this research, causal factors to be used for slope stability evaluation can be freely chosen by marking check box, as shown in Fig.12. Causal factor data files are stored in advance in the list box. Causal factor files to be used for making slope stability evaluation maps can be selected with a mouse from the file list.

Users are relieved from troublesome file operation, such as to memorize or manage the structure of various file groups of which data set consists. It is possible to make slope stability evaluation maps by combining causal factors arbitrarily.

5.6 Making Slope Stability Evaluation Map

After all input parameters selection were done, clicking the push button indicating “Execute” at lower screen as shown in Fig.12 with a mouse, will immediately change to the screen of making slope stability evaluation maps. Then quantification method type II and mini-max second group discriminant method are executed interactively,

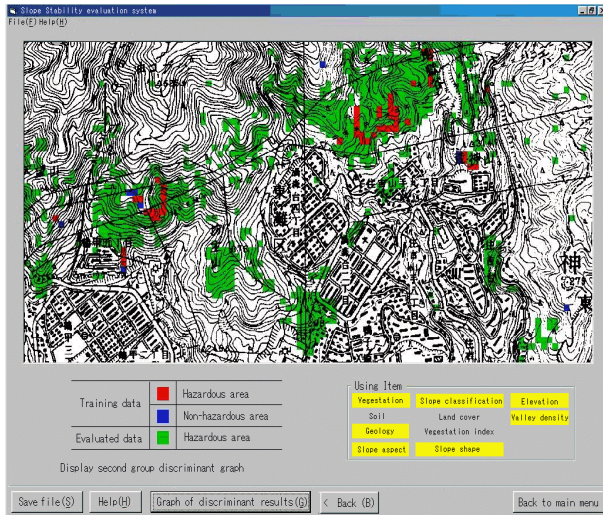


Fig.13 Slope stability evaluation map

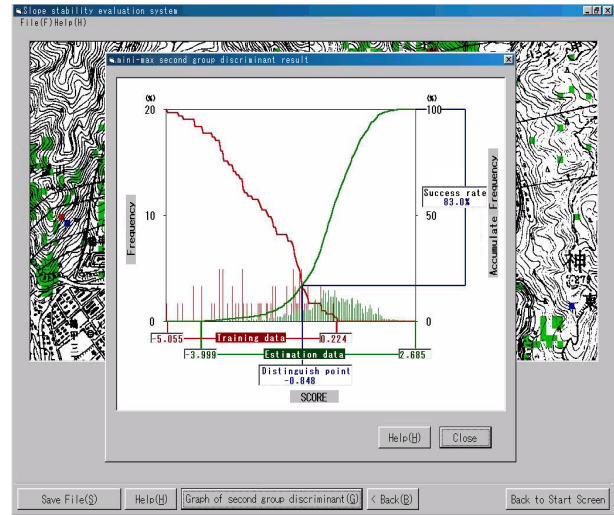


Fig.14 Results of the mini-max second group discriminant method

Table 2 Legend of the slope stability evaluation map

Training pixels	Red	Hazardous area
	Blue	Non-hazardous area
Evaluated pixels	Green	Hazardous area
	White	Non-hazardous area

and a slope stability evaluation map appears on the screen as shown in **Fig.13**. **Table 2** shows the legend for colors of this slope stability evaluation map.

When clicking the push button at lower screen of the **Fig.13** indicating “Graphic Presentation of Second Group Discriminant Method”, results of the mini-max second group discriminant method are presented as shown in **Fig.14**. Distinction between failure group and non-failure group can be easily observed and analyzed at a glance.

5.7 Editing Evaluation Map and Statistical Analysis Result

Files for the slope stability evaluation map or statistical analysis results previously mentioned, are saved in standard file forms used in the WINDOWS 98 environment, into a data set folder for corresponding job. These evaluation results are able to be processed by users with word processors or spreadsheet programs, for making reports.

As explained above, by using this system, slope

stability evaluation map can be made or analyzed, with easy operation. The GUI devised in this research contributes in many aspects for improvement of the system operability.

6. Conclusions

(1) Achievement of the Research and Development

Contents of this research will be summarized into the following three points.

Study on the Philosophy of the GUI Design.

Research trends with regard to the design of GUI, a system with which calculation and analysis of highly technical and specialized field in construction industries were surveyed, and importance in studying the methodology of the design and the development of the specific GUI was pointed out.

Proposal of Simplified GUI Design Method

Two objectives were presented (**Fig.2**); one is to design a specific GUI which is required for the system aimed to be developed, and the other is to design a standard GUI for WINDOWS system. A simplified screen flow chart (**Fig.5**) which will support designing of the former, a specific GUI, was presented. This screen flow chart consists of simplified symbols and the designer can be concentrated on the design of the specific GUI during the process of detailing the flow chart.

Building Slope Stability Evaluation Support System

Process procedure and structure of functions of the slope stability evaluation model were made clear, and design within a screen corresponding to each function, and link relationship (screen transition design) were also considered, and slope stability evaluation support system

was built. GUI having flexibility and expandability to incorporate addition or revision of functions was designed and efficiency in the life cycle of the whole system was improved.

(2) Future Issues

In this research, systemization of the SSE model based on a standard WINDOWS system GUI was aimed at first, and effort have been made to design and development of indispensable process function. As it is planned to pick up any problem if occurred in service, and to try to make improvements continuously on GUI, we understand that the following three points are considered to be issues for the future.

Expansion of Function in SSE

The SSE model has an analysis menu of data structure analysis among causal factors based on the quantification method type III, and has various analysis functions such as differential image analysis which extracts the difference among the slope stability evaluation maps made under various conditions. These analysis functions which have not been developed, are better to be added.

Addition of Slope Stability Evaluation Model Other than SSE Model

The authors are carrying out studies on comparison of the solutions obtained by other slope stability evaluation models based on probability theory (Bayesian model, Fuzzy set model, Certainly factor model), in addition to the SSE model, and also on how to apply solutions obtained by multiple slope stability evaluation models. In order to develop these studies further, slope stability evaluation models other than the SSE model shall be equipped with the system developed in this research.

Arranging Data Resource Management Function

In this research, there is no reference to how to process direct information such as photographs or official record books obtained through site investigation. Study on management of various information resources relating to the slope stability evaluation, such as causal factors, training data, slope stability evaluation map, and direct information obtained at site, has to continue. It is necessary to build a total and centralized system which can manage and utilize these information by geographical regional unit.

7. Closing Remarks

As functions of system development tools become more sophisticated, efficiency in system development is being improved. However, attention must be paid to that introduction of a new method for design or development, or of development supporting tool, does not necessarily lead to the system development convenient for the users.

No matter how media, software, or development/design supporting tools evolve to be of higher performance, it is considered essential to go back again to the original point of system design, and to promote the development of specific GUIs through the careful "application work analysis".

Not only for the slope stability evaluation supporting system introduced in this research, evaluation of various specialized system in the construction industries is significantly dependent on the design concept of the specific GUI as shown in **Fig.2**. It is also expected that OS environment will change in many ways. It will be appreciated if this study approach contribute somehow to design and development of a specific system utilizing WINDOWS standard GUI.

REFERENCES

- 1) Obayashi,S., Kojima,H. and Fujii K.: Improvement of the Accuracy for Extracting Areas in Danger of the Landslide Using Satellite Multispectral Data, Journal of construction management and engineering No.534, pp 173-184 1996
- 2) Obayashi,S., Kojima,H. and Murakami, T.:A Proposal on the Evaluation Method for the Dangerous Area of the Steep Slope Accompanying the Erosive Collapse, Journal of construction management and engineering No.567, pp.225-236 , 1997
- 3) Obayashi,S., Kojima,H.:The Evaluation Method Introducing the Ground Characteristics for the Hazardous Slope Affected by The Erosive Collapse, Journal of construction management and engineering No.609, pp.123-136 1998.12.
- 4) Obayashi,S., Fujita,K., Kojima,H. and Fujii,M.: Development and Operational Procedure on the Consulting System for Slope Stability Evaluation , Bulletin of the Remote Sensing Laboratory Remote Sensing Series , No14 , 1993.4.
- 5) Susan Fowler, Kurosu,M. : Dictionary of the Windows user interface, Shoeisha, 1998.8.
- 6) Mayers, B.A.:Tools for creating user interfaces, An introduction and survey, IEEE Software 6(1), pp.15-23,1989.
- 7) Bass, L.J. and Coutaz, J. :Developing software for the user interface,Addison-Wesley, Inc., 1992.
- 8) Ito,J. :Operational flow diagrams(Story boards) Design Support Tool for User Interface Design ,Symposium on Human Interface Society , Vol.12, pp.515 ~ 518, 1996.10.
- 9) Kojima , H. , Chang , C.F. , Obayashi , S. and Fabbri , A. G. : Comparison of strategies in prediction modeling of landslide hazard zonation , Proceedings of the International Association for Mathematical Geo-logy, No.4, pp.218-223, 1998.10.