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Design and Implementation of GIS Based Automatic Terrain Analysis System for Field Operation

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Abstract

A GIS based tactical terrain analysis system named ATTAS (Army Tactical Terrain Analysis Software) has been designed and implemented to support the field commanders for enhancing the capability of their unit and efficiency of weapon system. This system is designed to provide computer graphics environment in which the analyst can interactively operate the entire analyzing process such as selecting the area of interest, performing analysis functions, simulating required battlefield operation and display the results. This system can be divided into three major sections; the terrain analysis modules, utilities, and graphic editor. The terrain analysis module includes surface analysis, line of sight analysis, enemy disposition, 3D display, radar coverage, logistic route analysis, shortest path analysis, atmospheric phenomena prediction, automated IPB (Intelligence preparation of Battlefield), and other applied analysis. A combination of 2D and 3D computer graphics techniques using the X-window system with OSF/Motif in UNIX workstation was adopted as the user interface. The integration technique of remotely sensed images and GIS data such as precision registration, overlay, and on-line editing was developed and implemented. An efficient image and GIS data management technique was also developed and implemented using Oracle Database Management System.

1. Introduction

A GIS based automatic terrain analysis system can assist military commanders in exploiting and assessing the terrain and other elements' effects for tactical advantage in areas such as ground mobility, counter mobility, weapon system performance, aviation, and environmental impact (Capps, et al., 1989). The application of this system has been very active in advanced countries and some examples are as follows:

o Integrated Training Area Management (ITAM) program which is an organized approach to total military land management (Goran and Finney, 1991),

o AirLand Battlefield Environment (ALBE) program to assess and exploit battlefield environment effects (Capps, et al., 1989),

o Tactical Decision Aids (TDAs) program to assist the commanders in exploiting and assessing weather and terrain effect for tactical advantage (Capps, et al., 1989),

o Evaluating sites for assault landing strips for cargo planes,

o Assessing the environmental impact such as soil erosion, landslide risks, water quality in the operation field (Goran and Finney, 1991; Ji and Johnson, 1994; Merry and Wu, 1994),

o Assessing the impact of the morphological and physical characteristics of urban terrain to support Military Operations over Urban Terrain (MOUT) (Ellefsen and Liu, 1994),

o Assessing usage, standardization, and impact of Digital Terrain Elevation Data resolution on terrain visualization (Fatale and Messmore, 1988; Podczasy, et al., 1994),

o Arms control assessments (Johnson and Malzahn, 1993).

Seventy percent (70%) of Korean terrain is rugged mountain area and Korean army has recognized the need for the GIS based terrain analysis system which can support fields commanders in assessing the related factors and simulating operation. A prototype system named Army Tactical Terrain Analysis Software (ATTAS) has been developed and being tested for the field applicability.

This paper describes the concept of the system design and techniques used in the implementation of the ATTAS system.

2. System Design Concept

2.1 Design Considerations

The ATTAS has been designed as a high performance, interactive environment for access terrain data, management, analysis, and display tools. Many GIS and terrain analysis tools have been developed and being used in advanced countries (Niedzwiadek, et al., 1989; Dilks and Finney, 1994). However, they are not well suited for the readily use in Korea since the terrain analysis system should be tailored to Korean morphological and terrain characteristics in addition to satisfy the field commanders' requirements.

A complete survey for the existing GIS and terrain analysis software packages such as FULCRUM, TerraBase (US Military Academy, 1988), CAMMS, GRASS (USACERL, 1993a; 1993b), ERDAS (ERDAS, 1991), and ARC/INFO (ESRI, 1990) was performed to analyze each system's functions and architecture, which were used as references for the design of ATTAS System.

An intensive survey was performed to understand the requirements of the field commanders (Yang, et al. 1992). The results showed the request for the surface analysis was the highest, visible area analysis was the next, and the logistic route analysis / atmospheric phenomena and other functions are little bit lower. The ATTAS system was thus designed to handle the major terrain analysis functions such as surface analysis, line of sight coverage, logistic route analysis, and enemy information management.

Design emphasis was put on the "user-friendliness", good visualization and expansibility to ensure the good use of the system and the smooth expansion to the more advanced system in the future (Hibbard, 1988; Dueck and Wells, 1988).

2.2 GUI and System Integration

The X-Window based OSF/Motif was selected as the main Graphic User Interface (GUI) because of its unique nature of strong network orientation and device-independence characteristics (Nye and O'Reilly, 1990; Quercia and O'Reilly, 1991). These characteristics enable all the geoprocessing and database analysis be performed either in the host (server) or at the local workstation(client). In this way the usage of the server and client hardware can be optimized. A customized Korean Character ("Hangul") menu-driven GUI was adopted since the capability of the "Hangul" processing is very important for the Korean commanders.

The ATTAS system has a large group of graphics and application libraries that are layered to provide the software developer with a variety of programming implementing tools. The libraries for the GUI and visualization functions rely on X Window (X11R4 or X11R5), the X toolkit and Motif widget set. All of the ATTAS codes have been extensively modularized in order to minimize the hardware dependency and maximize the expansibility.

3. ATTAS System Implementation

3.1 Hardware Configuration

SUN Sparc 470 workstation equipped with a digitizer, an image scanner, a film recorder, a cartridge tape drive and an erasable optical disk drive was used as the platform and its hardware configuration is as shown in Fig. 1.

3.2 Software Overview

The ATTAS system is built on top of the Oracle DBMS. Fig. 2 shows the schematic diagram of the functional modules of the system. The system management tool is the X-window based user interface containing menu bars and buttons labeled in Korean. The main menu program controls the flow of the process and supervising the connection among the analysis modules.

Both raster and vector image handling capability have been implemented. Raster images can be easily retrieved and extracted by defining the area of interest on the screen with mouse and the desired analysis can be performed by selecting the proper function in the menu. Vector data such as roads, bridges, unit symbols, troop movement route can be drawn and saved on the disk. Polygonal data also can be generated, filled, and overlayed.

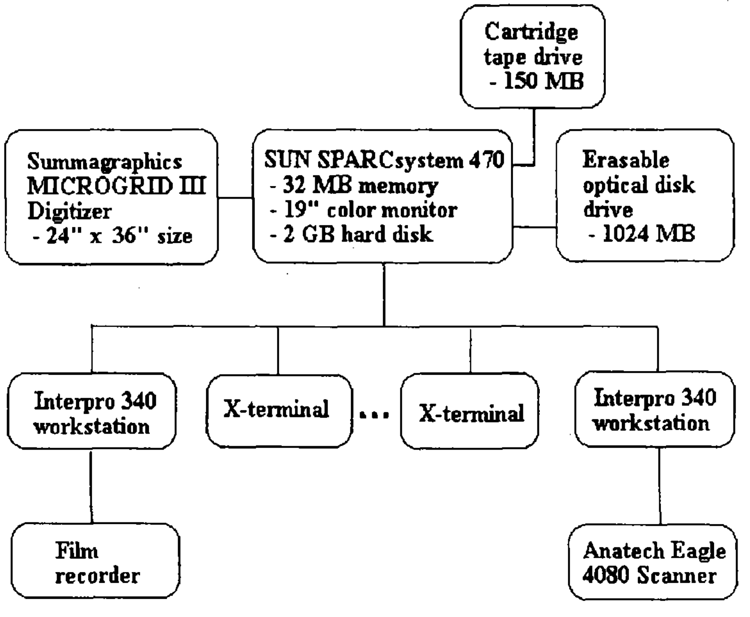

Fig. 1 Configuration of ATTAS Hardware System

The integration technique of remotely sensed images and GIS data such as precision registration, overlay, and on-line editing was developed and implemented. The GIS analyzing algorithm for the multi layered data such as digital elevation model, soil, land cover, slope-gradient, slope-aspect, etc. have been implemented. These algorithms include weighted boolean arithmetic, spatial interpolation, polygonal operation, and user defined functions (Laurini and Thompson, 1992).

4. System Functionality

The software can be divided into three parts: terrain analysis modules, utility modules, and graphic editor modules.

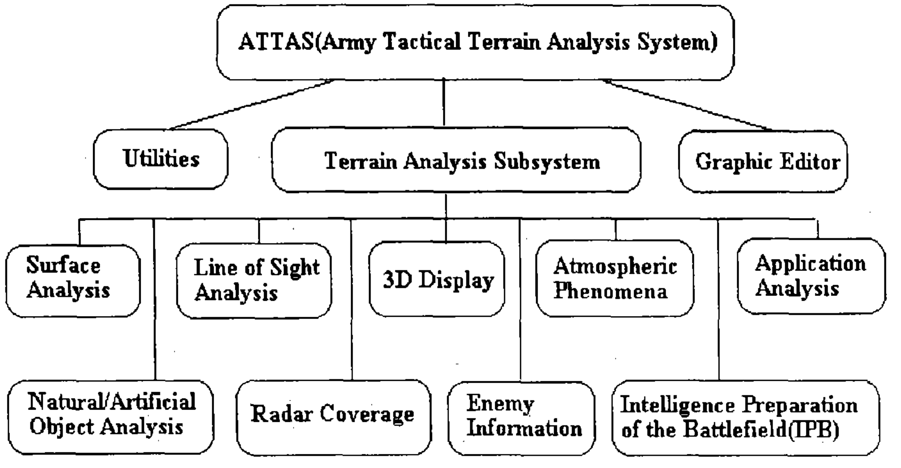

Fig. 2. Functional Modules of the System

4.1 Terrain Analysis Subsystem

The terrain analysis subsystem is composed of the modules for the surface analysis, natural/artificial object analysis, line of sight coverage, 3D display, radar coverage, logistic route, atmospheric phenomena, enemy information and applied analysis (Fig. 2). The detailed content of the implemented functions are as follows:

o Surface Analysis: analysis of covered area, concealed area, slope gradient, contour, elevation, and field mobility (Fig. 3).

o Natural/Artificial Object Analysis: analysis of logistic routes, natural and artificial objects such as bridges, rivers, and roads.

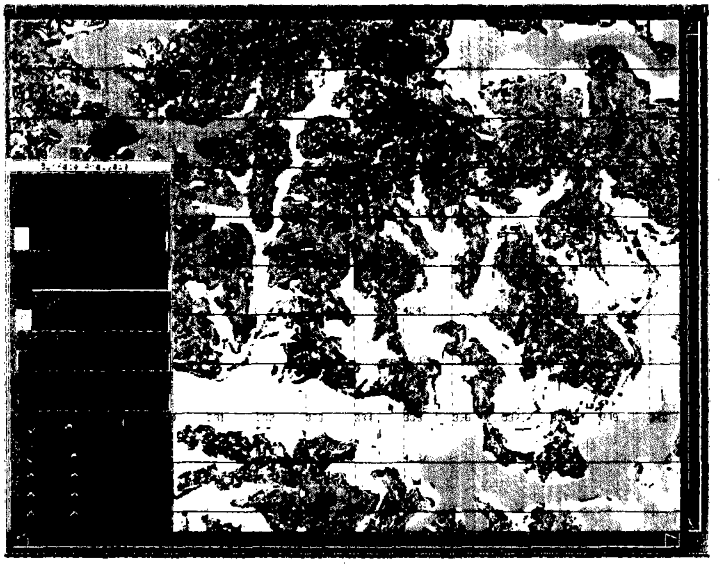

Fig. 3 Field Mobility Map Depicted in Color Levels. White represents good mobility, green and yellow for average, and light brown for bad, and brown for immobility. Menu is labelled in Korean characters for user-friendliness.

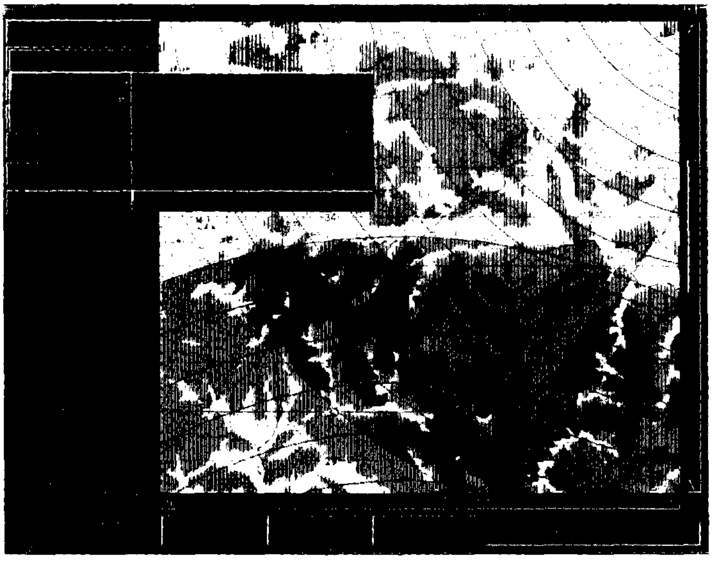

Fig. 4 Communication Relay Station Site Analysis. Pink and gray represent the area covered by one of two stations and the dark red represents the area covered by both of the stations. Menu is labelled in Korean characters.

o Line of Sight Analysis: analysis of visible area, communication relay station sites, (Fig. 4), and RASIT capability.

o 3D Display: The 3D topography projection algorithm generates the 3D perspective view. Satellite images, maps, vector line data can be displayed on the top of the elevation data. Color interpolation scheme helps generating a realistic reproduction of the satellite view. The perspective views of 3D surfaces provide a significant aid to appreciating the spatial nature of image data represented in the form of a surface (Fig. 5).

o Radar Coverage Analysis : analysis of the radar coverage by considering the radar beam pattern.

o Atmospheric Phenomena Analysis: analysis of the atmospheric phenomena by using the past atmospheric data, prediction of the sunset and sunrise time.

o Intelligence Preparation of Battlefield (IPB) : analysis of the battlefield preparation by analyzing line of sight, covered area, concealed area, obstacles, important object, movable space, and easiness of disposition.

o Enemy Information Analysis : analysis of the enemy troop disposition by tracing the information of a battlefield.

o Application Analysis: analysis of the shortest path, shortest supply route (Fig. 6), the optimum site for surveillance equipment and the helicopter landing place.

4.2 Graphic Editor and Utilities

The graphic editor functions include graphic devices and environment initialization, file manipulation, basic graphics primitives, annotation, symbol drawing, image manipulation and setting the color, font and zoom factor of the vector data. The utility modules conduct various file conversions and general functions such as load, store, and delete of the files. Utility software also has time conversion function, special unit and data format conversion (length, area, volume, weight, temperature, pressure, and speed).

Fig. 5 Perspective 3D Image. Russian satellite image and DEM data were resampled, registered, overlayed, and used as input data. The color interpolation scheme was applied for the realistic scene display.

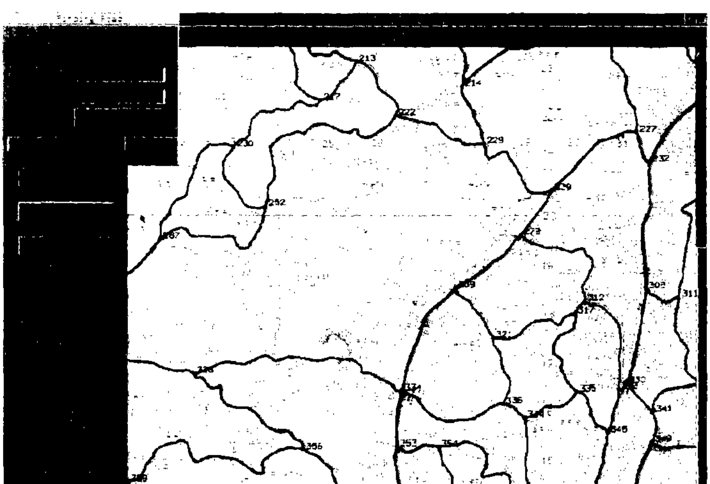

Fig. 6. The Shortest Supply Route Analysis. The shortest supply route is selected by considering length, widths and the pavement status of the road. The green line represents the shortest path. Menu is labelled in Korean characters for user-friendliness.

5. Conclusions

The accurate and timely information produced by the computerized tactical terrain analysis system can help the field commanders to enhance the combat capability and efficiency of the weapon systems. A GIS based terrain analysis system named ATTAS has been developed for this purpose. The ATTAS system was designed to fulfill the requirement of the field commanders in Korean Army as well as to include most of the well utilized analysis functions available in the existing software packages. The design emphasis was put on the user-friendliness, good visualization, and expansibility. The X-Window based OSF/Motif which became industry standard and has good portability has been adopted as GUI tool for its ease of use, strong network orientation, and device-independence nature. The software can be divided into three major sections; the terrain analysis, utility, and graphic editor subsystems. These modules are controlled by main menu system.

The ATTAS has been developed as a prototype system and is being tested for the applicability in the Korean terrain. The possible future development direction can be stated as:

o development of the more sophisticated user interface in which an intelligent agent agent process queries, identifying the terrain data most appropriate to answering the question and performing the necessary analysis,

o adopting object oriented database, and

o introducing virtual reality technique for visualization.

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