The AirLand Battlefield Environment Program and the Visibility Model

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INTRODUCTION

Terrain and environmental factors have long played a critical role in determining the success of an army in battlefield conditions. A ground forces commander can gain a considerable advantage by being able to better predict the effects that terrain and weather will have on visibility, ground mobility, and weapons systems. The advanced knowledge of environmental effects can be used to better distribute and utilize available personnel and assets to counter the enemy's actions. The objective of the AirLand Battlefield Environment (ALBE) program is to provide topographic and environmental expertise in the form of graphic map overlays produced by tactical decision aid (TDA) software models.

The U.S. Army Corps of Engineers (COE) initiated the ALBE program to coordinate the efforts of the Corps laboratories with support from the Army Materiel Command (AMC). The ALBE Tactical Decision Aid Technology Demonstration program is conducted under the auspices of the Corps of Engineers Directorate of Research and Development. Participating laboratories include the Cold Regions Research and Engineering Laboratory (CRREL), Waterways Experiment Station (WES), Topographic Engineering Center (TEC) (formerly the Engineer Topographic Laboratories), and Battlefield Environment Directorate (BED) (formerly the Atmospheric Sciences Laboratory).

PURPOSE

The ALBE program has two major goals:

(1) to provide materiel acquisition, training, and doctrine activities with the capability of assessing and exploiting realistic battlefield environment effects
(2) to provide the field Army with the operational capability to assess and exploit battlefield environment effects for tactical advantage

To accomplish these goals the various ALBE laboratories coordinate and integrate candidate TDA software models onto a common hardware platform. The software is presented to cross-service users through demonstrations, evaluations, and training sessions that occur both in the laboratory and in the field. Based on the received responses and recommendations, the software is modified to best meet the users requirements. The ALBE software and algorithms are then transferred to system developers for refinement and inclusion into their fielded software configurations. This approach allows fielded systems to acquire software that has gone through iterations of testing and improvements and provides battlefield commanders and their staff with the ability to better exploit the

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Terrain and environmental factors have long played a critical role in determining the success of an army in battlefield conditions. A ground forces commander can gain a considerable advantage by being able to better predict the effects that terrain and weather will have on visibility, ground mobility, and weapons systems. The advanced knowledge of environmental effects can be used to better distribute and utilize available personnel and assets to counter the enemy's actions. The objective of the AirLand Battlefield Environment (ALBE) program is to provide topographic and environmental expertise in the form of graphic map overlays produced by tactical decision aid (TDA) software models.

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combined effects of terrain and environment in the decisionmaking process.

ALBE SYSTEM

Operating Environment

ALBE is currently operating on 386 and 486 Personal Computers that use the SCO UNIX V.3.2.2 or V.3.2.4 (SCO Open Desk Top 1.1 or 2.0) operating system and X-windows (X11 Release 3 or newer) with MOTIF. The software requires 16 megabytes (MB) random access memory (RAM), a minimum of a 300 MB disk, and a 256 color graphics card. TEC, as the designated executive agent for the ALBE program, coordinates software distribution. The majority of the code is written in the C and FORTRAN programming languages and is government owned.

Data Requirements

Data sources used by ALBE include Digital Topographic Elevation Data (DTED), Arc Digitized Raster Graphics (ADRG), Interim Terrain Data (ITD), historical climatology, rain gauge, airfields, and miscellaneous vehicle, bridge, personnel, and military equipment data files.

The Defense Mapping Agency (DMA) generates a majority of these data bases. DTED Level 1 is a uniform matrix of terrain elevation values spaced at 3 arc seconds or approximately every 100 meters. ADRG is a digital raster representation of a paper graphic product. ITD consists of vector feature and attribute information contained in six separate files; soils, slope, vegetation, surface drainage, obstacles, and enhanced transportation. The information contained in the ITD digital data base is analogous to the content of the 1:50000 scale Tactical Terrain Analysis Data Base (TTADB).

The baseline data set accessed by the ALBE TDA software models consists of DTED, ADRG, and processed ITD. Four of the original vector ITD files; the soils, slope, vegetation, and obstacles, are combined into a single raster data file. This complexed file allows for rapid access and analysis of the data within these four themes. The transportation and drainage files are maintained in a vector format.

The ALBE software manages all of the baseline data in a coherent, seamless data base. There are no implied edges at map sheet boundaries. This allows ease of data access and manipulation over large user defined areas of interest. Analysis of the data can be user defined to occur anywhere within the geographic confines of the imported data.

Enhanced environmental awareness is exploited by accessing climatic information within the Battlefield Environmental Effects Software (BEES) historical climatology data base. The BEES data consists of approximately 580 stations world-wide that are primarily located within the regions of Africa, Europe, and the Middle East. Each station maintains 32 climate parameters from a list of 128 possible climate parameters. Examples of these parameters include relative humidity, average barometric pressure, minimum, maximum, and average temperatures on both a daily and monthly basis, average number of days with blowing sands, and maximum monthly snowfall. A station is included within the BEES data base only if staff climatologists conclude, by observation of previous patterns, that they can reliably represent future weather conditions.

SOFTWARE

The software on the ALBE system can be divided into two general areas. The first is the user interface (UI), geographic information system (GIS), and graphics display software and the second is the TDA application models.

UI/GIS/Graphics Software

The first area --the UI/GIS/Graphics software-- was designed to support the needs of all ALBE developers. This code is structured to provide a top layer of understandable GIS routines that insulate developers from regenerating redundant low level calls. Common usage of routines aids software developers by reducing redundant code development and benefits the user by giving all of the application software a consistent "look-and-feel." The GIS provides for a multitude of abilities including data import, display, and manipulation of both raster and vector formats.

TDA Application Software

The second area --the TDA application software-- consists of over 60 software decision aids that are maintained under eleven ALBE categories:

(1) Army Aviation
(2) Countermobility
(3) Ground Mobility
(4) Maneuver Control
(5) Terrain Factors
(6) Visibility
(7) Weapon System Performance
(8) Weather Effects
(9) Meteorological Analysis
(10) Nuclear Biological Chemical
(11) Utilities

Army Aviation TDAs provide assistance to aviation officers and air liaison officers by contributing to the success of an aerial mission or by determining countermeasures against enemy air activity. TDAs in this category are:

- Airfields of the World
- Landing Sites
- Road Landing Sites
- Aerial Detection
- Helicopter Landing Zones/Drop Zones
- Helicopter Survivability Zones
- Helicopter Mission Planner (HELMS)
- Line of Sight for Obstructions
- Night Vision Goggles
- Aircraft Icing Conditions

Countermobility TDAs evaluate the effect of obstacles on the movement of ground troops. TDAs in this category are:

Obstacle Emplacement
River Ice Break

Ground Mobility TDAs evaluate vehicle ground mobility. Mobility on the battlefield is affected by vehicle characteristics, driver capabilities, road and terrain factors, weather conditions, natural obstacles, military emplaced obstacles and weapons, and the operational scenario. The model used to take these effects into account is CAMMS, the Condensed Army Mobility Model System. Continually monitored and upgraded, software in CAMMS reflects field-proven algorithms developed from analysis of over 40 years of field and laboratory mobility testing. CAMMS provides an up-to-date tool for analyzing all factors that substantially affect mobility, and a method for forecasting the mobility capabilities of both friendly and threat forces. TDAs in this category are:

Cross-Country Speed Analysis
Cross-Country Reason Analysis
Time Contour Analysis
Avenues of Approach/Unit Movement

Maneuver Control TDAs provide supplemental information useful for the planning of any sort of maneuvers. TDAs in this category are:

Annotation
Icon Based Image Retrieval
Bivouac Sites/Assembly Areas
Construction Resources
Concealment
Unit Locations (with icons)
Sun/Moon Illumination

Terrain Factors TDAs define the locations of the particular terrain factor(s) considered and assist the user in making an initial, cursory evaluation of the influence of these terrain factors on the mission of concern. TDAs in this category are:

Off Road
Soil Strength Analysis
Freeze Analysis

Gap Crossing
Tactical Dam Breach

Source ITD Features and Attributes
ITD Soil
ITD Slope
ITD Vegetation
ITD Obstacles
ITD Transportation
ITD Drainage

Individual Features and Attributes
Dam/Lock Locations

- Drainage Network
- Driver Visibility
- Elevation, Linear Contours
- Elevation, Shaded Contours
- Land Classification
- Obstacle Locations and Types
- Railroad Network
- Transportation Network
- Soil Type
- Vegetation Spacing
- Slope Category
- Ground Surface Roughness
- Road Type

Visibility TDAs show graphical results of applying line-of-sight analysis to determine visible and hidden areas from a user identified site location. Observers at the site location(s) can incorporate visual or radio frequency surveillance modes for threat access. The TDAs can also be used as a countermeasure to evade enemy observation. TDAs in this category are:

- Masked Areas - Visible Zones
  - How High to Visibility
  - Masked Area Probability
  - Radio Frequency Loss
  - Free Space Loss
- Masked Point to Point - Visible
  - Radio Frequency

Weapon System Performance TDAs show performance capabilities of friendly and/or threat direct-fire weapons. The current TDA in this category is:

- Weapon Fans

Weather Effects TDAs predict the effects of weather on equipment, personnel, and operations. These predictions include operations assessments, automated warning messages, and estimates of combat system effectiveness. TDAs in this category are:

- Weather Effects Matrix
- Tactical Weather Effects Messages (TWEM)
- Consolidated Weather Effects Decision Aid (CWEDA)

Meteorological Analysis TDAs address the management and analysis of meteorological data. TDAs in this category are:

- Add/Delete/Edit Weather Gauge/Update Weather Report
- Historical Climatology

Nuclear Biological Chemical (NBC) TDAs describe methods for providing NBC decontamination and predict the effects on battlefield conditions caused by the release of NBC agents (including smoke). TDAs in this category are:

- Winter Chemical Decontamination
- Smoke Screens - Mobile Smoke
  - Tube Delivered Smoke

Utilities include:
- Surface Area
- Surface Distance
- Coordinate Calculator

VISIBILITY MODELING

TEC research has mainly focused on the models within the Army Aviation, Maneuver Control, and Visibility categories. In the past years, the models within the Visibility category have received the most attention and will be discussed more thoroughly in the remainder of this paper.

Background

Determining visibility analysis based on elevation data has long been a fundamental requirement for terrain analysts. Doing the analysis in the past without the use of a computer required that the analyst perform multiple, time consuming calculations. Depending on the desired analysis density, a visibility masked area product may consist of anywhere from 30 to 360 vectors (rays) extending outward from the central observation site. With typical distances ranging from 5 to 50 kilometers, calculations of up to 180,000 radial points would need to be made. This can be time consuming. As computer speed has increased, new programming techniques have been developed to provide faster, more accurate visibility analysis.

During the early 1980s, a vector based Radial Terrain Masked Area model was implemented at TEC which accesses DTED. Other closely related "spin-off" models, such as Aerial Detection, which show alternate ways of viewing elevation information were also developed during this time. Although these models were developed and ported to a number of hardware and software platforms, the underlying software code remained essentially the same.

Raster Modeling

In 1990, the ALBE program experienced a significant hardware conversion. During this period of transition, the ALBE software engineers reevaluated the basic vector approach that the visibility model had historically employed. LOS models can take three approaches to perform and display their calculations:

(1) grid to vector
(2) grid to vector to grid
(3) grid to grid

All of the approaches begin with the grid stage since the models all rely on DMA's DTED which is provided as a matrix of elevation values. The grid to vector approach accesses the elevation posts along radials emanating from the observer position, calculates visibility between the observer and elevation postings along each of the radials, and displays the results in a vector format as visible or masked "spokes" centered at the observer. The grid to vector to grid approach is identical to the grid to vector approach with the exception that interpolations are performed afterwards on the radial vector information to portray the visibility information in a gridded format. The grid-to-grid approach (as in the current ALBE LOS model) skips the intermediate step of creating the vector information and stores the visibility results directly into a gridded format. The grid-to-grid approach was deemed the most advantageous because it:

(1) maintains the integrity (resolution) of the source data
(2) generates a product that conforms to the resolution of the source data
(3) eliminates dense coverage around the site location and sparse coverage at the extremities
(4) does not require double interpolation to present the results
(5) is best suited for interoperability and inter-system transfers

The visibility software has since been further modified to provide a better documented and more modular structure. Duplicate code from the various "spin-off" models were combined into single common subroutines to prevent duplication. Variable names are now designed to reflect both their data type and the variable's actual purpose. Introductory paragraphs and descriptive variable declarations were provided for most subroutines. These steps were done to make the TDA application software easier to understand and easier to port to other computer systems.

<u>LOS Analysis Study</u>

Soon after the reengineering of the ALBE software, the Program Executive Officer for the Army Command and Control System requested that TEC conduct a Line-of-Sight (LOS) analysis study to identify a standard LOS algorithm for use within the Army Command and Control System (ACCS) community. The ACCS is an integration of five battlefield automated control systems:

(1) Maneuver Control System (MCS)
(2) Advanced Field Artillery Tactical Data System (AFATDS)
(3) Forward Area Air Defense Command, Control, and Intelligence (FAAD C2I)
(4) All-Source Analysis System (ASAS)
(5) Combat Service Support Control System (CSSCS)

As their names imply, these five systems cover the battlefield functional areas of maneuver control, fire support, air defense, intelligence/electronic warfare, and combat service support. ACCS will link the systems through an interoperable family of common off-the-shelf computers.

The LOS analysis study began by canvassing numerous government and commercial agencies to determine the types of LOS models currently in existence. In all instances, the LOS algorithms for visibility analysis were predominately the same regardless of developer. Differences that did exist ranged from methods of accessing the DTED information to geometric simplicities employed in the LOS algorithm. The algorithms basically employ geometric calculations that compute the angle from the observer to the target at each point along each radial and then compares the result with the relative maximum LOS angle to determine which areas are visible and which are masked. The basic concern with these independently existing LOS models is that the potential exists to generate different results. LOS algorithms are integral to various models such as terrain profiles, masked areas, weapon and sensor placements, target acquisitions, and flight line masking zones. Results from these models may differ from one organization to another depending on the type of algorithm used. Identifying a common LOS routine for use within the ACCS community would eliminate both the potential generation of differing results and the costly duplication of parallel and redundant development.

A conclusion of the study was to acknowledge that no implemented LOS algorithm had the combination of features desired by users. The ALBE grid-to-grid approach was thus recommended as the foundation visibility model to which the desired features found in the other studied models will be added.

Current Visibility Model Features

The ALBE visibility model uses the grid-to-grid approach for the LOS calculations and includes additional features designed to increase the models usefulness. These features include:

(1) a site elevation matrix that depicts the actual values of the DTED in the immediate vicinity of the observation site and gives the user the flexibility to reposition the observer to a nearby or higher point in the area
(2) a how high array that contours the previously defined "hidden" areas to show how high the target would have to be raised in order to be seen by the observer
(3) inclusion of vegetation data, in which vegetation heights are compared with observer and target heights to indicate areas of vegetation obscuration
(4) a visual acuity factor, where a user defined target width must visually subtend at least one minute of arc in order to be considered visible
(5) access to climatic weather data for atmospheric refractivity calculations
(6) ability to locate the observers position using a cursor on a displayed map background image
(7) probability considerations that subdivide the visible and masked areas into definite and probable regions based on a factor representing DTEDs relative vertical accuracy
(8) integration of the Electromagnetic Compatibility Analysis Center (ECAC) Terrain Integrated Rough Earth Model (TIREM3) library for radio frequency and free space loss calculations

ALBE Visibility Based Models

The ALBE models which share features implemented with the new gridded approach can be divided into three groups depending on their output format. Grid and vector based outputs can be used as map overlays. Profiles are vector models that generate cross sectional profiles of the terrain. Groups and models are as follows:

Grid based:
- Visibility
- How High to Visibility
- Visible Probability
- Helicopter Mission Survivability
- Radio Frequency and Free Space Loss

Vector based:
- LOS Obstructions
- Aerial Detection

Profiles:
- Visible Point to Point
- Radio Frequency Loss Point to Point

On-going Research and Future Plans

Most visibility models rely entirely on geometric equations to locate the masked areas which are hidden because of rises in the terrain. Research efforts are currently underway to identify other nongeometric equations which will result in a much more realistic visibility model.

Variable sensor type algorithms will be integrated to handle portions of the electromagnetic spectrum such as the infrared and thermal bands. With this additional capability, analysis can be done for devices such as night vision goggles. The resultant graphics from these calculations would then display the specific ranges that the sensors can first detect and then recognize a potential threat.

Target background and contrast algorithms will also be added. A dark green truck may be easy to detect when parked on a sandy desert, but very difficult to detect when parked near a heavily forested region. The results of these calculations would further enhance the implemented acuity distance algorithm by adding background and contrast considerations to the target width parameter currently being used.

Rather than assuming the atmosphere to be clear or vacuous, effects caused by the absorption and scattering due to atmospheric molecules will be handled by atmospheric attenuation algorithms. These algorithms will give a much more realistic portrayal of fog, haze, and other common effects. Since many of these algorithms depend on factors such as pressure, temperature, and the density of molecules along a path, it is anticipated that more extensive use of the BEES climatic database will be required.

Other additional influences that will affect the results of the visibility model include scattered and reflected solar/lunar radiation, thermal emissions, and enhanced atmospheric refraction routines.

Future research and development are also planned for a site emplacement algorithm. Currently the way a user selects an observer location is through educated guesswork. If a visibility model is run without achieving satisfactory results, the user must try again with a different observer location. Rather than relying on trial and error, site emplacement algorithms will identify to the user prime locations for optimal visibility.

CONCLUSION

The terrain and the environmental effects upon the terrain are key aspects for a successful understanding of the battlefield. Consequently, work will continue within the research and development community to both improve existing and develop new tactical decision aid models based on identified research areas and user recommendations. The ALBE program presented here brings the Army community one step closer toward the timely and accurate acquisition of terrain related information for major command decisions.

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