

## COMPUTER-ASSISTED TERRAIN ANALYSIS ON A MICROCOMPUTER

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### ABSTRACT

Prediction of cross-country movement rates for vehicles is one of several topics of considerable concern in both military and civilian applications. Algorithms have been developed by a number of organizations that predict speed based on vehicle characteristics and detailed terrain data. Sufficiently detailed terrain data are not readily available in digital form for most areas of interest. A microcomputer-based system has been developed for encoding existing analog (hardcopy) terrain data bases and processing them into a gridded data base. The databases thus created can be used to generate a number of cartographic products of which cross-country movement is one example. The system makes use of a low-cost, commercially available computer-aided design (CAD) program to provide both input and output to a wide variety of peripheral devices. Intermediate processing of the data is accomplished by custom programs developed by the author.

### INTRODUCTION

#### Military Terrain Analysis

The primary function of the Army's field Terrain Analysis Detachments is to provide rapid response terrain analysis products to the field commanders. These products have been standardized by the Defense Mapping Agency (DMA) through the introduction of several procedural guides and an analog data base of terrain factor overlays. These overlays, known as tactical terrain analysis databases (TTADB), contain detailed information about the terrain with separate overlays for soil types, slopes, vegetation types, and others.

An example of a terrain product is the cross-country movement (CCM) map. Since a vehicle's capability to move off-road is influenced by several factors, most notably vegetation, slope and soil type, manual preparation is very tedious. An officer with recent service in a field terrain unit has estimated that while approximately 50% of the production effort made use of the terrain factor overlays, the terrain teams did not usually have the time required to create some of the more complicated terrain analysis products. Tactical terrain analysis is a prime candidate for automation. DMA is working toward the automation of topographic terrain analysis data, but it will be several years before such data are available for wide areas.

### System Concept

The goal of the project described in this paper, named DigiTAS for Digital Terrain Analysis System, was to develop a low cost system of off-the-shelf hardware and internally developed software in order to automate the creation of standard DMA terrain products. Unlike previous programs to introduce automation to terrain units in the field, the proposed system would be capable of directly supporting the units' day-to-day mission. Further, the system is based on two separate modules, the first of which allows field creation of a terrain data base and the second of which manipulates that data. When DMA fields a digital terrain data base, the first module will become somewhat superfluous, but the second, with slight modifications, will be able to handle DMA produced data.

The algorithms for creating the terrain products have been well documented and are not presented here. The thrust of this project, as with much of the effort in automating cartography, is not in manipulating the data but in acquiring it to begin with. This paper deals with the design and development of a specialized terrain analysis system.

## SYSTEM DESIGN CONSIDERATIONS

### System Functions

Four functional requirements were identified for the DigiTAS system:

1. Digitize currently available DMA produced terrain factor overlays, converting the analog data into a gridded digital data base compatible with existing digital terrain elevation data (DTED).
2. Store digital data in as compact a form as possible, making use of data compression techniques and bit-mapping of data. Desired goal was to have all data for a 1:50,000 topo sheet on a single 1.2 MB floppy disk.
3. Support interactive manipulation of the data using algorithms that automate the DMA procedural guides to create DMA standardized terrain analysis overlays (e.g., winter concealment, cross-country movement).
4. Create hardcopy output overlays to existing map sheets.

### System Hardware Configuration

The hardware configuration developed for the system is shown in Figure 1. All components of the system are readily available commercial products consisting of the following:

1. Microcomputer. An MS-DOS based microcomputer with high resolution graphics display. The programs developed support several types of input and output hardware, recognizing and making use of the maximum capabilities of the host system (e.g., high resolution displays, math co-processors, extended/expanded memory).

2. Input. A digitizing tablet to allow encoding of the terrain factor overlays. Different size digitizers are supported with paste functions allowing a small (12" x 12") pad to be used for digitizing an overlay in sections.

3. Output. A printer or plotter for output. Several types of output devices are supported from small format dot-matrix printers to large format plotters. All are capable of generating output which can yield the standard products, albeit some output may require limited manual drafting.

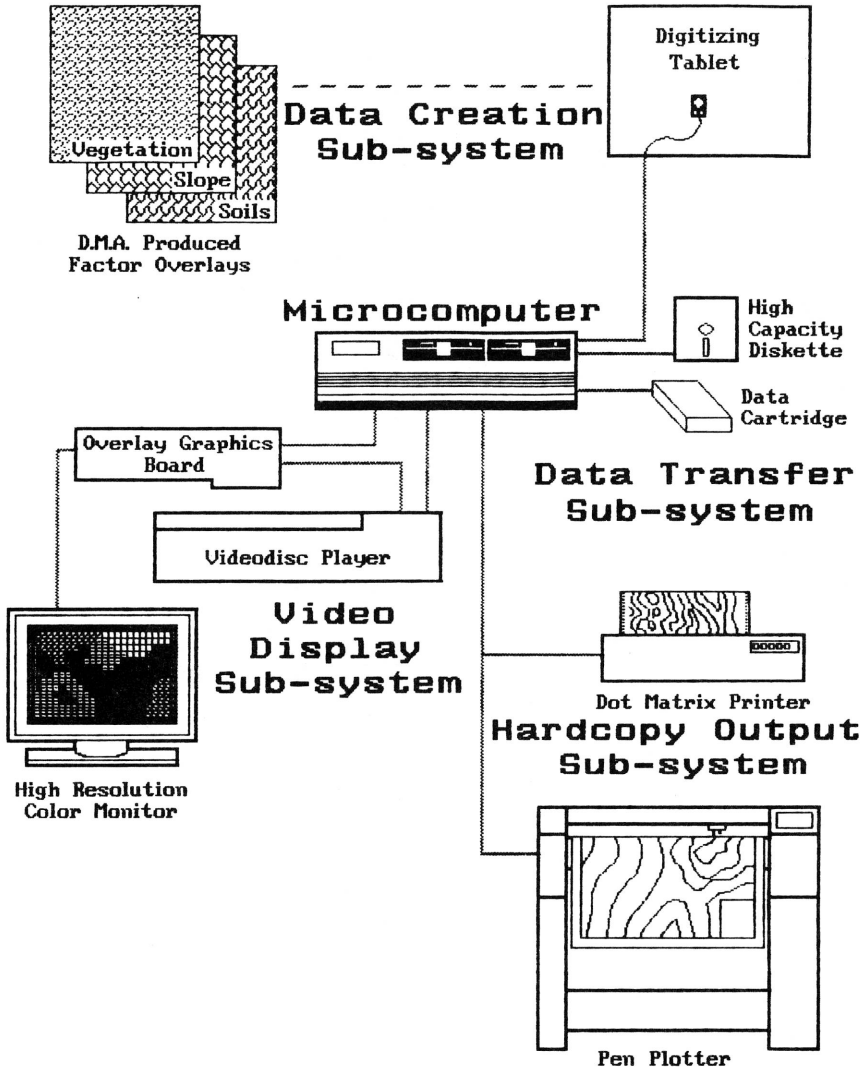


Figure 1: System Hardware Configuration

### Specific Programming Requirements

At the start of the project, the specific programming requirements were identified:

- support for general purpose digitizing
- conversion of digitized vector data to a gridded system
- transformation of the data into the DTED-compatible coordinate system
- pasting together individually digitized segments of the terrain factor overlays
- bit-mapping the gridded data in as compact a form as possible
- implementing the DMA procedural guides as programming algorithms
- implementing device-independent display routines
- creating multiple output device drivers

To avoid the major task of developing the device-independent input/output drivers, the use of a commercial computer-aided design (CAD) program was investigated. Many low-cost high-performance CAD packages have recently entered the marketplace. Several were examined and most proved suitable for providing digitizing and editing support for encoding the terrain factor overlays. In addition, the programs could also handle output of the final products on pen plotters and pieced dot-matrix printers. Importing and exporting data to and from the CAD environment is usually accomplished via a translation program.

### General Scheme of Operation

The data flow through the system is illustrated in Figure 2. The sequence is:

1. DMA produced terrain factor overlays are digitized. The digitizing scheme is the "spaghetti" approach with each line segment being digitized once.
2. The vector "spaghetti" generated by the digitizer is processed by a conversion program that accomplishes three tasks in sequence: building the line segments into polygons, tagging the polygons with the feature attribute code, and converting the polygons to a gridded database.
3. Depending on the standardized product desired, the data base is manipulated to provide an on-screen representation of the terrain product. If hardcopy is desired, the terrain data processing program converts the gridded overlay to a vector representation in the exchange format for the CAD program.
4. The CAD program generates plotter output on high end systems with full-size registered overlays. Low end systems can generate a series of true-scale sectionalized dot-matrix printouts which can be registered and traced to produce a full-size overlay.

Items 1. and 2. above constitute Module I of the system which will ultimately be superceded by DMA produced digital

terrain analysis data.

Items 3. and 4. above constitute Module II of the system which can be modified easily to support DMA supplied digital terrain analysis data when it is defined and available.

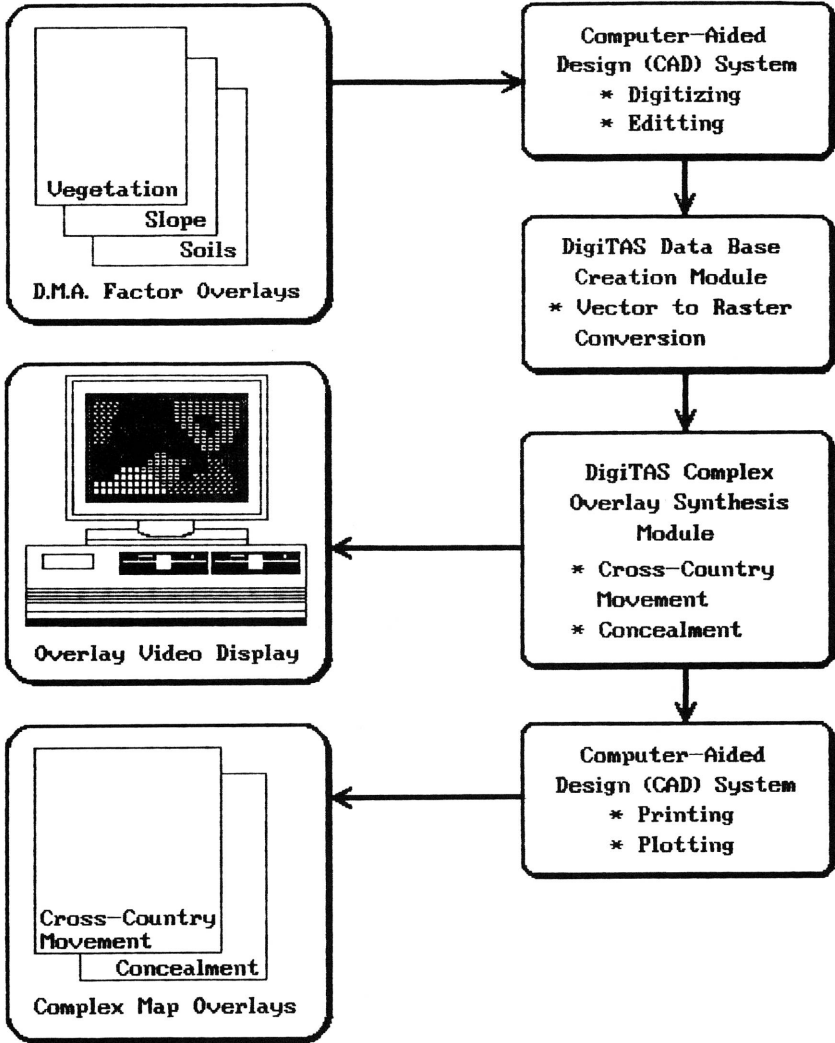


Figure 2: Data Flow through DigiTAS

#### DigiTAS Data Structure

Two approaches were considered in selecting the DigiTAS data structure, the first being to design a data structure optimized specifically for DigiTAS and the second being to base the design on the proposed DMA terrain data structure. The second approach was adopted to make the system as compatible as possible with the proposed DMA product as

well as making interim use of data derived from DMA's terrain factor overlays. The design of the data structure for DigiTAS is therefore driven by several goals:

- retain all information content of the planning and tactical terrain analysis overlays that are digitized
- adhere to the proposed tactical terrain data (TTD) specifications to allow data to be easily subsetted from TTD when available
- balance the tradeoff between data compression and data manipulation

There are two basic components of the issue of data structure: data record structure (data content per unit area) and database structure (unit area content per cell). These are essentially independent of one another and are addressed below.

Data Record (Unit Area)

Factor	# of Categories		# of Bits
	TTADB	TTD	DigiTAS
1. Vegetation			
a. type	24	26	5
canopy closure			
b. summer	5	5	3
c. winter	N/A	5	3
d. height	10*	11	4
e. stem diameter	LUT	13	4
f. stem spacing	LUT	15	4
g. roughness	LUT	11	4
h. undergrowth	2	2	1
i. misc. other	N/A	?	0
2. Surface Configuration	8	9	4
3. Surface Materials			
a. type	20	21	5
b. state of ground	3	5	3
c. depth of material	2	3	2
d. surface roughness	5(LUT)	21	5
e. misc. other	N/A	?	0
†Total bits to encode			47
LUT - factors determined from a look up table			

Table 1: Data Content of Terrain Databases

The DigiTAS encoding scheme aligns the categories described above as closely as possible with individual bytes in the data record to facilitate access to any specific item while keeping the data as compact as possible:

byte:	1   2   3   4
bit:	01234 567 012 3 4567 0123 4567 0123 4567
category:	1.a. 1.b 1.c h 1.d. 1.e. 1.f. 1.g.  2.
	Vegetation  Surf
	Conf
byte:	5   6
bit:	01234 567 01 23456 7
category:	3.a. 3.b 3c  3.d.
	Surface Materials

Table 2: DigiTAS Bit-mapped Data Record

### Database Structure

Currently, DMA-produced digital data comes in two distinctly different forms: gridded elevation data (DTED) and polygonal feature data (DFAD). The question of gridded versus polygonal data structures is well-argued and has vociferous supporters on each side. For DigiTAS, the decision was made to use gridded data for computational efficiency on the microcomputer host. The basic tradeoff is a larger mass storage requirement for gridded data but simpler processing of algorithms requiring determination of the intersection between various terrain factors. In the last decade, microprocessor power has improved by about two orders of magnitude from a 1MHz 8080 to the 16MHz 80386. In that same period, microcomputer mass storage has gone from 80 KB floppy disks to 500 MB write once read mostly (WORM) drives, an increase of almost 4 orders of magnitude. Therefore, the decision was made to opt for ease of processing over storage volume.

The next design consideration was the choice of reference grid and grid interval. Several possibilities were examined: registration to World Geographic System (WGS) coordinates, local spheroid geographic coordinates or the military standard Universal Transverse Mercator grid system. Each of the choices has advantages and disadvantages:

1. Latitude/longitude grid for 15' x 15' WGS cell  
advantages:
  - matches DTED data location
  - world-wide coverage without edge matching problemsdisadvantages:
  - difficult to register to base map or factor overlays
  - multiple cells to cover one map sheet
2. Latitude/longitude grid keyed to 15' x 15' base map  
advantages:
  - easy registration to base map or factor overlays for both input and output
  - one cell (or integral number of cells) per base mapdisadvantages:
  - requires transformation of WGS-based DTED to local datum
3. UTM grid keyed to base map  
advantages:
  - constant size unit area on the ground
  - precisely aligned with UTM griddisadvantages:
  - usually skewed with respect to map neatlines
  - considerable matching problems at edges of grid zone
  - requires transformation of WGS-based DTED to local datum

The current DMA produced gridded data (DTED) is referenced to the WGS at a geographic interval (3 arc seconds for low latitudes). The source materials for the DigiTAS data, the terrain factor overlays, are registered to base map sheets on a local spheroid. Since the desired end products are complex overlays keyed to base maps, the grid reference

chosen for DigiTAS is registered to the base maps. The grid interval adopted matches that of DTED, 3 arc seconds of latitude and longitude at low latitudes shifting to 6 arc seconds of longitude by 3 arc seconds of latitude at higher latitudes. A simple local datum transformation and interpolation would allow DTED to be merged with DigiTAS data.

The final consideration was total data cell size. Since the unit area coding scheme generates 6 bytes per unit and there are 90,000 units per nominal 1:50,000 map sheet (15' by 15'), the DigiTAS data for each cell is approximately 540,000 bytes in size. This is an unfortunate size as it will neither fit on a MS-DOS standard floppy disk (360 KB) or in the microcomputer's RAM. This can be resolved by breaking the data cell into several files by either factor category or area. Since vegetation data alone account for 3-1/2 bytes, the only breakdown by factor category would be vegetation/surface configuration in one file (360 KB) and surface material in a second file (180 KB). Splitting the data in this fashion complicates the synthesis of certain terrain products that are dependent on all factors.

Alternatively, the file could be broken into subareas. Although it would only be necessary to divide the file in two to allow it to fit into memory or on a floppy disk, a more practical approach is to use a 5' by 5' cell size. This allows easy registration to the base maps as the internal 5' intersections are marked. Each cell is 60,000 bytes in size; coverage for a standard map sheet can be disseminated as 6 cells on one disk and 3 cells plus any miscellaneous files on a second disk or all files on one high-density disk. This is the structure that has been adopted for DigiTAS.

#### CONCLUSIONS

A microcomputer based terrain-analysis system offers a low-cost alternative to the manual methods currently employed by Army terrain analysis units. Creation of a terrain database from currently available terrain factor overlays is a practical task. Commercial computer-aided design software can be employed to provide input and output support and provide a standardized user interface for a wide variety of operations. Special purpose programs can transform the polygonal terrain factor data into a computationally more efficient gridded data structure. Interactive manipulation of the terrain database can produce standard terrain products such as cross-country movement maps in near real-time.