DATA BASE GENERATION SYSTEM FOR COMPUTER GENERATED IMAGES AND DIGITAL RADAR LANDMASS SIMULATION SYSTEMS.

By Lt. Col. Manfred Haas,
Diether Elflein and Peter Gueldenpfennig

ABSTRACT

The paper deals with a semi-automatic, interactive system to generate data bases from Digital Landmass System (DLMS) Data, for Computer Generated/Image Visual Systems (CGIVS) and for Digital Radar Landmass Simulation (DRLMS) Systems.

Terrain information and certain culture features can be gained from DLMS data automatically for CGIVS and DLRMS data bases. Additional information is prepared by interactive methods, including the use of model library for CGI data bases developed by batch procedures. Data bases can also be developed solely by batch procedures.

INTRODUCTION

In 1975 the German Airforce and Navy decided to use a Computer Generated Image Visual System (CGIVS) and a Digital Radar Landmass Simulation (DRLMS) System for the TORNADO Operational Flight Training and Tactics Simulator. The development of the prototype CGIVS demonstrated that in order to fullfill the operational requirements for this type of simulator, a substantial increase in scene content would be necessary. Therefore, the CGIVS production units have a much higher data processing capability than the prototype. Table 1 shows a comparison of the capabilities of the prototype CGIVS and production units.

	PROTOTYPE CGIVS	PRODUCTIONS CGIVS
EDGES/SCENE	2000	8000
POINTLIGHTS/SCENE	1000	4000
FACES/SCENE	500	4000
REAL TIME DATA BASE CAPACITY	10,000	40,000* Plus Dynamic Reloading
TV-LINES	525	875
RASTER ELEMENTS/TV-LINE	512	1000
TEXTURING	NO	YES
CURVED SURFACE SHADING	NO	YES

Table 1.

Comparison of Prototype and Production CGIVS for the Training Simulator TORNADO

The increased scene content for the new CGIVS had substantial impact on data base generation. For the prototype system, the CGIVS data bases had been generated manually by batch operation. The areas and models had been derived from geodatic charts, areal photographs, blue prints, and normal photographs. The scene content of this material was reduced and manually transformed into graphic vectors. The coordinates of the vertices of the edges were defined on punched cards. Only after the coordinates of the vertices had been defined on the punched cards automatic data processing could be used for operations such as reading-in, testing, scaling and computing of face normals and seperation planes.

The high information density of the data bases for the new CGIVS led to the necessity for use of automatic and interactive procedures for the development of data bases. For this new CGIVS, Messerschmitt Bolkow-Blohm (MBB), designed the Data Base Generation System (DBGS). This DBGS will not only be used for the design of data bases for CGIVS, it will also perform generation and modification of data bases for the DRLMS system. It is worth mentioning that all DRLMS for the German and Italian TORNADO simulators have an update console with which small modifications to the data bases can be performed. One system out of the six ordered by the German Government and one of the Italian Airforce systems has additional computer peripherals used to transform source material into online data bases. The source material for this transformation program is cartographic information in digital form in accordance with the product specification for Digital Landmass System (DLMS) Data Base/ICD/100 1. Edition, July 1977.

DEVELOPMENT OF VISUAL DIGITAL DATA BASES

Structure of The Visual Data Bases

The data base for the CGIVS represents the mathematical description of the stylized world. This description is in coded form on a storage medium, so that the CGIVS can read it out in an online process and can perform further data processing tasks.

The geometry of the "world" is defined by points, lines and faces. A point is defined by storage of its X-, Y-, and Z-coordinates. Two points define a line. By the use of several lines a closed polygon can be developed which represents a face. The CGIVS shows points and faces which are described not only by their geometrical position, but by other attributes like color, texturing, or curved surface shading.

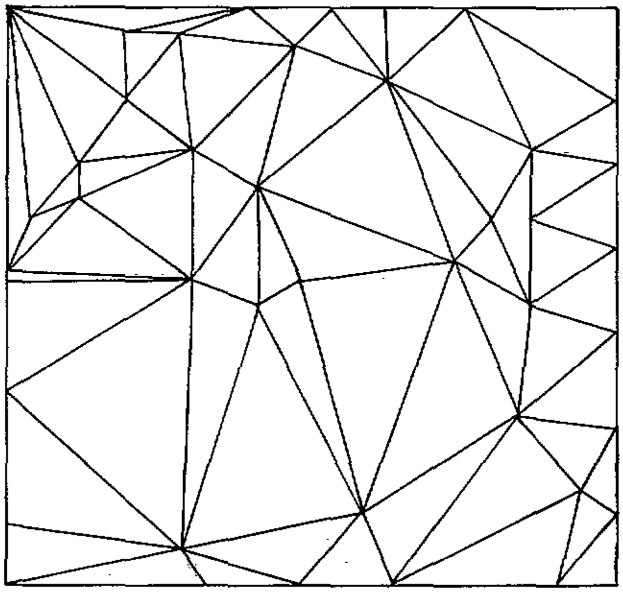

Figure 1. Terrain Approximation

The morphology of the terrain is approximated by triangles. (See figure 1.) Outlines and position of the triangles are matched to the terrain in an optimum manner. The number of triangles, and therefore the information density of the data base, is a function of the roughness of the terrain. This means that the information density of a planar landscape is relatively small, and for mountainous terrain, it is very large.

It is possible to divide these triangles into more faces, in order to show changes of ground vegetation and culture features by the means of different attributes.

Three-dimensional objects can be built out of these faces. These objects, in turn, form more complex models. Objects are always convex, while models can also have a concave character. Objects and models can represent houses, towers, bridges etc., which are positioned in the terrain.

In principle the DBGS enables three methods of data base generation: Automatic transformation, interaction and batch (See figure 2).

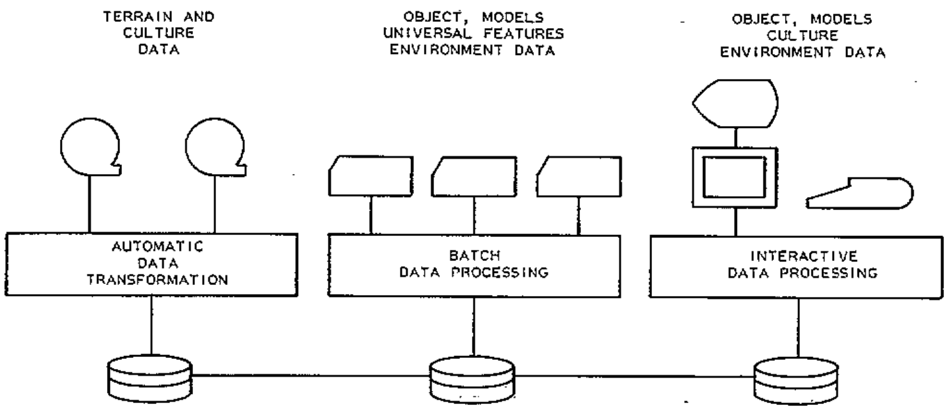

Figure 2. Data Base Generation System

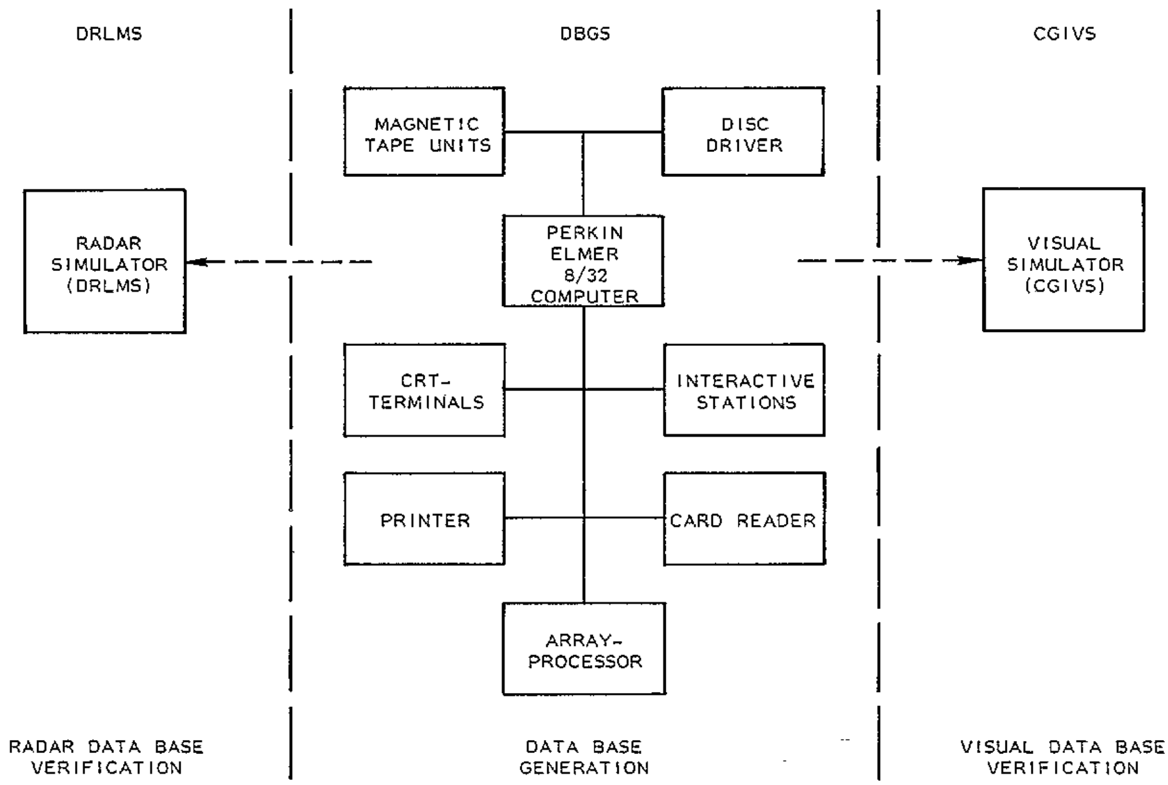

Figure 3. Hardware Configuration

Hardware Configuration (See figure 3)

The Data Base Generation System is a stand-alone computer complex with computer peripherals. It can be operated independently from the simulator and consists of three main groups: Computer System, Display System, and Interaction System. Only commercial hardware is used. The system has the following configuration:

a. One Perkin Elmer 8/32 Minicomputer with 1 MB Functional Storage, Writable Control Store and Floating Point Unit.

b. One type AP 120b Array Processor developed by Floating Point for parallel performance of time comsuming procedures.

c. Two Perkin Elmer Type 550 CRT terminals which enable simultaneous communication with the computer.

d. One card reader (1000 CPU) and one line printer (300 LPM), developed by Perkin Elmer as additional input/output peripherals.

e. Two 9-track, 1600 bpi mag-tape units for the input of large amounts of data.

f. Three magnetic 300 MB disc drives for the storage of completed data bases.

g. Two interactive stations, each consisting of one Tektronix 4014-1 graphics terminal, and one Tektronix 4954 digitizing tablet for parallel graphical data processing. The picture content of one graphics terminal can be documented using one Tektronix 4631 hard-copy unit.

This hardware configuration enables the transformation of DMA data, interactive data base generation and modification, as well as batch processing for the generation and modification of data bases for CGIVS and for DRLMS.

VISUAL SIMULATION SYSTEM/DATA BASE GENERATION

Data Base Sources

The source material for the Data Base Generation System is digital landmass data. To satisfy the tremendous requirment for such data, the military geographical agencies of the NATO-countries have defined one standardized format in which the information on geographical charts is digitally stored.

There are two types of DLMS data: terrain data and culture data. This information for the same area is stored on two different magnetic tapes. The terrain data represent altitude data at the cross-points of a grid system. The grid systems are divided into five different zones according to latitude, so that each square has an edge length of 100 meters for the coarser level of detail (level 1), and 30 meters for the finer level of detail (level 2).

The culture data describes the natural terrain structure and the artificial cultural features of the terrain. There are points, lines, and faces defined, which are numbered by an analysis code. Information concerning the geographical position and dimension, as well as the material category and the identification code, is attached. Thirteen different material categories represent, for example, water, earth, rock, metal, etc. By the use of the identification code, characteristics can be differentiated in very great detail. For example, different shapes of roofs or bridges can be discerned.

Terrain Transformation

An algorithm is used in the Data Base Generation System which enables the triangulation of DLMS terrain data in a way that the advantage of variable information density can be used. The logic of this algorithm is based primarily on "trial" and "error". The trials are performed for a certain number of DRLMS grid-points, for which the standard deviation and maximum error in comparison with the triangulated terrain is computed and is compared with defined maximum values.

Culture Transformation

The DLMS face characteristics are projected on the triangulated terrain so that a face subdivision is performed. The attributes of these faces can be gained from the information on the material category and the identification code. For point features, only the positions will be transmitted during transformation. During the interaction it must be decided whether a line feature describes, for example, a river such that a long stretched face has to be projected into the terrain, or only a bridge has to be shown, which is called up from the model library.

Further data on texturing and curved shading are allocated interactively.

Interaction

In order to correct the deficiencies in the digital source material and those which have been introduced during the transformation program, it is necessary to perform interaction during the different phases of the data base generation. One starts with non-digital source material, as for example geodetic charts, air-photographs, etc. The information of those data mediums are brought into the data bases by use of the interactive station.

The hardware of the interactive station consists of a graphics terminal, a digitizing tablet, and a hard-copy unit. The source material is positioned on the digitizing tablet and is scanned by means of a digitizer. The digitizing process is traced on the graphics display. A cursor defines the position of the digitizer unit. With a menue attached to the digitizing tablet, or by means of the alphanumeric keyboard of the graphics terminal, additional information can be put in. The interactive station is supported by a complex software package which allows one to select certain data as well as to change or input new data. This software package limits the menue effort to a minimum and is user friendly.

Correction of DLMS-data

Before the transformation process starts, it has to be ensured that the available DLMS data are in accordance with the convention of the DLMS specifications. Experience has shown that the number of errors which have to be corrected interactively varies according to the care with which the data was collected. In this phase, single characterstics can be changed or completely new characterstics can be added to the DLMS format.

Correction of the Online Data Bases

All necessary information which can not be gained from the DLMS data bases must be added interactively after the transformation has been performed. These are primarily the lines of communication which, to a certain extent , are not existent in the DLMS data bases. Further data on new faces or models has to be added where the transformation program shows only non-identified lines or point features. Additionally, more models can be superimposed. Finally at this stage, interaction is necessary in order to allocate specific attributes such as color, texturing, or curved surface shading as well as the creation of universal features.

Generation of three-dimensional Objects and Models

For the model library a complex store of objects and models is created. This is necessary in order to describe the different culture features in the terrain. The basic forms of simple objects are read-in on the digitizing tablets from construction drawings. These objects can be varied by simple geometrical operations like scaling, mirror inversion, rotation, etc. Complex models can be built up interactively from different objects. The German Airforce and Navy require a complex model library. The models include a drilling platform, mine shaft superstructure, chemical plant, coke plant, refinery, transformer yard, processing industries with different shapes of roofs, scrap yard, rotating cranes, railway stations, different types of bridges, open-ended stadiums, family houses, castles, residences, hospitals, different types of church towers, airport control tower, runways, aircraft parking areas, taxi ways, drydocks, navigation light ship, light houses, etc.

Data Base Verification

The completed data bases are demonstrated on the graphics display of the Data Base Generation System. The geometrical construction of the data bases can be evaluated. However, all attributes are only numerically indicated (code tables). In order to get a complete impression of the data bases with respect to texturing, curved surface shading, color and the three-dimensional relationships, it is necessary to demonstrate them on an actual CGIVS. By performing this verification, the data base will also be evaluated with respect to the dynamic appearance. The verification might result in the need for corrections, which can be accomplished in one of the above mentioned steps.

Verification of data bases on the real CGIVS is now used only temporarily. In order to prevent use of the simultors at the squadrons for data base generation, it is planned to extend the Data Base Generation System by adding a non-real-time Computer Generated Image System.

German Data Base Visual Requirements

For the time being the German Airforce and Navy require the following complete data bases:

a. Navigational area of upper Bavaria, including an airforce base and a NATO-standard bombing range

b. Sea area with a coastline

c. Seaport

d. Complex model library - The generation of simple objects and models has been mentioned before. More complex models to be designed are:

- Fighter aircraft
- Transport aircraft
- Tanker aircraft
- Typical kinds of ships
- Ground vehicle (heavy)
- Ground vehicle (medium heavy)

By the mid 1980's the German Airforce and Navy will create their own data bases in a common data base generation center using the equipment here described.

RADAR SIMULATION SYSTEM DATA BASE GENERATION

The Data Base Generation System also makes it possible to generate data bases for the Digital Radar Landmass Simulation (DRLMS) System. In order to gain a DRLMS data base, a transformation of United States Defense Mapping Agency (DMA) source data is performed. The system allows interactive modification of the DMA data bases or the generation of new data bases from topographic charts. The same hardware is used for generation of both the radar and visual data bases. Verification of completed data bases is performed on an actual DLRMS, at least for the time being.

Automatic Transformation

The on-line DRLMS data bases are produced from the source material by means of a translator program wherein the grid format is automatically transformed into a compressed vector format. The translator program consists of two parts: the terrain transformation and the culture transformation. Both processes are performed separately and the information is later combined to achieve the on-line DRLMS data bases. The transformation program uses a variable compression technique with the following characteristics:

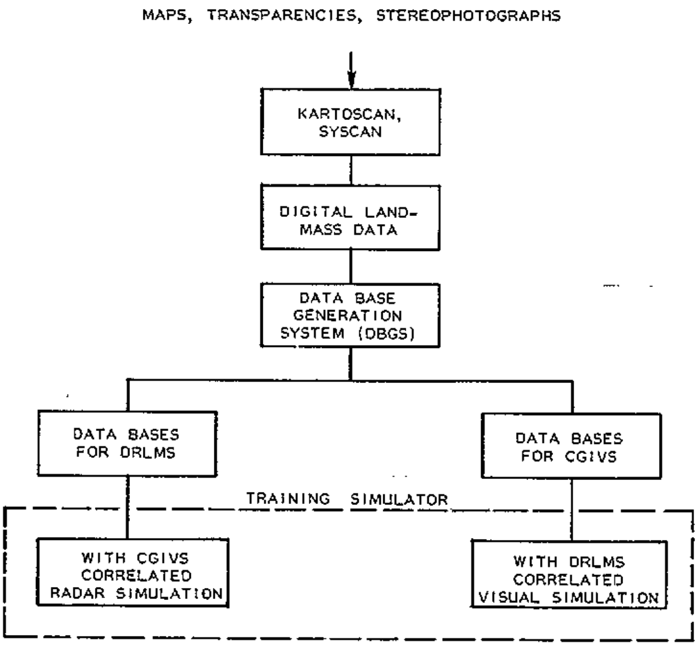

Figure 4. Generation of Data Bases for Training Simulators

The terrain is approximated by plane faces which are constructed with lines (vectors). One vector indicates a change in the elevation. The number of vectors which are necessary to model a given terrain is dependent on the roughness of the terrain and the required accuracy of the image.

Isolated objects such as towers and power pylons are defined as point targets. Point targets can be identified by their radius, their height above ground, and by their directional or nondirectional reflectivity characteristics.

Characteristics with length dimension (e.g., bridges, streets, etc.) are defined by line segments. Height above ground and reflectivity data can be added.

Large area features like lakes, irregularly shaped buildings, etc., can be defined by mulitple line features. Height and reflectivity data are added. Each data point that is stored includes information concerning position and height in respect to the foregoing value. Therefore, all of these values can be defined as vectors. In comparison to code techniques with constant grid distance, the variable compression technique results in a substantial saving of storage capacity. This allows a much better and more realistic image in systems of compariable storage capacity.

Interactive Data Base Modification

After having performed the first step of transformation, the data base can be improved interactively. In addition, there is the possibility of modifying existing data bases by subtracting or adding parts or changing the reflectivity. Dimensional characteristics can be added and features can be changed in respect to length, width and height.

Interactive Data Base Generation

An additional program of the DBGS allows data base generation without using Defense Mapping Agency Data. Interactively generated terrain data are formatted in a way that they are compatible with data received from the automatic transformation program. In addition, interactive generation and formatting of culture feature data can be performed.

Verification and Requirements for Radar Data Bases

The data bases gained from the DBGS process can be verified by means of the actual DRLMS. The same applies for modified radar data bases. Using the DRLMS, the realistic dynamic appearance is evaluated. However, in order to use the actual DRLMS only for training purposes, the Data Base Generation System will be extended by computer peripherals so that the verification process can be performed with the Data Base Generation System.

At present, a realtime DLMS data base is required for upper Bavaria.

Visual and Radar Data Base Correlation

Visual data bases as well as radar data bases are developed by industry with the assistance of the user. Figure 4 shows the data base generation for CGIVS and DRLMS systems. By using identical source material, correlation of the displays for both simulation systems is possible.

ABOUT THE AUTHORS

Lt. Col. Manfred HAAS is assigned to Headquarters, German Air Force, Director Air Armanent, and is stationed at Cologne where he is the officer responsible for simulator programs including F-104, F-4F, RF4E, Alpha Jet, and Tornado. He played an active role in evaluation of the digital visual system and radar system for the Tornado training simulator. Lt. Col. Manfred Haas was formerly an active F-104 pilot.

Mr. Diether ELFLEIN is a senior engineer in the German Government service. He participated in a number of international programs. He is now a member of the Program Office MRCA (Tornado Aircraft) and is responsible, among other efforts, for the operational flight training simulator. Mr. Elflein holds a Masters Degree in Engineering from the Technical University in Munich.

Peter M. GUELDENPFENNIG is Program Manager, Training Systems, for the Dynamic Division of Messerschmitt-Boelkow-Blohm (MBB), based in Munich. Prior to this, he was head of the Navigation Department at MBB and has been actively concerned with simulation systems since 1971. Mr. Gueldenpfennig holds a Masters Degree in Aeronautical Engineering from the Technical University of Berlin.