DATA BASE GENERATION: IMPROVING THE STATE-OF-THE-ART

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ABSTRACT

The development of data bases for computer image generation systems is a time consuming, labor intensive process. While the last ten years have seen tremendous advances in the capabilities and capacities of computer image generation, comparable advances have not occurred in the area of data base management. As visual systems can output more scene detail, they require data bases which contain more information and so, take longer to build. If some effort is not made to develop methods to build data bases more efficiently, the limiting factor for the amount of detail contained in an environment will be the data base development time. This paper will discuss two projects currently underway at the Air Force Human Resource Laboratory (AFHRL), Williams Air Force Base, AZ, which enable data bases to be developed much quicker by allowing the modelers to utilize work which has been done in the past by AFHRL or other organizations. The first project is the development of software to convert data bases formatted for one visual system to the format required for another visual system. The intermediate steps of this process will utilize a "generic data base," which is simply a data base which contains the minimum information necessary to recreate the environment in any format. The preliminary test of this effort will be to convert data bases between the Advanced Simulator for Pilot Training (ASPT) and the F-111B Visual System Attachment. If successful, the effort will be extended to transform existing data bases from Defense Mapping Agency (DMA) and other visual simulation systems used by the Air Force, Army, and Navy. When completed, this will alleviate the necessity of completely regenerating the same data base by hand when it is to be used on multiple visual systems. The second project is the development of a library of models. This library is an on going effort to create a collection of pre-made models that are accurate, usable, and well documented. An effort is being made to predict which models will be required in the future and to create them before they are needed. The library will alleviate data base modelers having to make every model from scratch every time that model is used in a different data base. These projects and others also under development at AFHRL will allow data bases in the future to be generated much more efficiently and quickly than is currently possible for most visual systems.

INTRODUCTION

When Computer Image Generations (CIG) was introduced, the limiting factor was the processing power and speed of the hardware. Since then, much work has been done in the development of faster and more powerful hardware, and only limited work in the area of data base development. Due to hardware limitations, early data bases were small, covering only a limited area with relatively few visual cues. The increased edge processing capabilities of current systems permit missions to be more complex, requiring significantly larger data bases. It is not uncommon today for data bases to cover areas of several hundred thousand square miles. Although improvements have been made, these data bases still require a proportionally longer time to build and debug. A simpler, faster, and more automatic method of creating and modifying data bases must be found.

The goal of AFHRL/OT is the improvement of combat effectiveness through flying training related science and technology development. To help support this goal, several different computer image generators are used. When a different visual environment is required for a research study, it must be developed from scratch. In order to accomplisth this, it is very important to develop and manage CIG data bases. If two image generators are to display the same visual environment, it must be developed separately for each system. Currently, each image generator has its own unique data base management system for creating visual environments. The data base modeler must learn all these systems and use them to build visual environments as required to support the mission.

There are two ways to speed up the process of data base development. One is to utilize work that has been done in the past. Another is to improve methods that will be used to build new data bases or modify existing data bases. This paper will discuss work currently being done at AFHRL/OT which enables us to save data base development time by using work done in the past.

There are two projects underway which will be detailed. The first project is a set of programs to convert data bases from one real-time visual system to another. The second project discussed is the library of standard models currently being developed.

Definitions

Before describing in detail the work being done at AFHRL/OT, definitions of key terms will be given.

A visual data base is defined as a collection of numerical data which represents a visual environment. This environment may be either an imaginary world or a portion of the real world.

The data base is built by using the following geometric concepts:

Vertex: A point located in 3-D space

Edge: A straight line segment between two vertices

Face: A closed convex planar polygon (includes a color)

2D Object: A set of coplanar faces

3D Object: A set of faces which form a closed convex polyhedron

2D Model: A set of 2D objects

3D Model: A set of 3D objects

Environment: A set of models that represents a visual scene

Level of Detail (LOD): Each model in an environment can be modeled in multiple levels of detail, each with a different amount of complexity. In real time, the visual system displays the appropriate LOD for each model in the environment. Proper use of feature results in the elimination from processing those edges, faces, and objects too small to be perceived.

ASPT Visual System

ASPT has a 2,500 edge monochrome visual system. It uses seven CRTs to display a 300° horizontal by 110° vertical field of view. The environment can be as large as 1256 x 1256 nautical miles. In a visual environment, there may be at most 300,000 edges, 40,000 objects, and 2,000 models. The real-time visual system can display at most 2,560 edges, 512 objects, and 200 models per frame. The ASPT visual system allows three levels of detail per model. The switching distance from one level to the next is a function of the aircraft altitude above ground, the distance to the center of the model, and the size of the model. ASPT uses shades of gray for painting the displayed faces. The scale goes from 0 (very black) to 63 (very white).

DIG Visual System

The F-111 DIG has an 8,000 edge color visual system. It uses three channels to display a 125° horizontal by 36° vertical field of view. The environment can be as large as 600 x 600 nautical miles. In a visual environment there may be at most 2,680 models. The DIG Visual System Attachment (VSA) allows 32 levels of detail per model. The switching distance from one level to the next is specified by the data base modeler. The DIG has 4,096 different colors available for real-time use.

Data Base Modeling

Modeling is the art/science of defining the visual environment which will become a data base. The data base modeler, in conjunction with the researcher, is responsible for identifying the important visual cues in the environment. The modeler then defines them in terms of a three-dimensional coordinate system and submits them to a set of modeling programs. These programs take this input data and generate a data base which can be used in computer image generation.

Until recently, the following procedure was used to build data bases: The modeler would manually digitize source information (such as maps, photographs, etc.) and then punch that information on to computer cards. The cards would be run through several offline programs, and the data base would be output to a disk file. The modeler would then have to use the real-time visual system to look at the data base and check for errors such as wrong colors, models placed in the wrong locations, or other mathematical errors. If any errors were found, the source data would be changed and the entire process repeated. Figure 1 illustrates this process. Although improvements have been made in most data base modeling systems, the same basic procedure is followed.

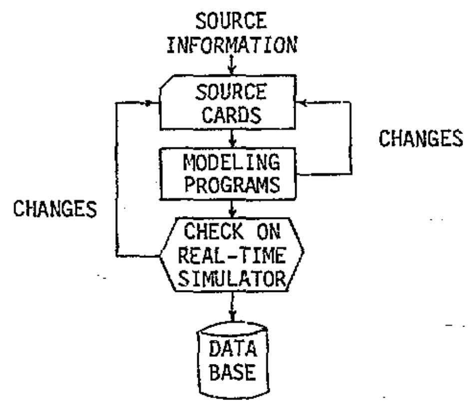

Figure 1 Typical Data Base Modeling Procedure

DATA BASE CONVERSION

Currently each real-time visual system uses a data base with a unique format. This is necessary to allow it to retrieve the information contained in the data base most efficiently. However, although different formats are used, the various system data bases contain the same basic information. This information includes the definition of the shape, location, and color of each object in the environment. Thus, it should be possible to use the information contained in the data base of one visual system to create a data base formatted for another visual system. This is the idea behind the data base conversion project; to utilize work done in the past.

Two different approaches to this conversion process were considered. The first was to develop software which would directly convert the data base of one visual system to that of another. This was rejected since the number of programs required to do this would grow almost exponentially as more visual systems were added. The second approach involves the use of a data base with a generic format as a kernel or core. Two programs would have to be written for each visual system that a data base is to be converted to or from. The first program would convert the data base from its native format to the format of the generic data base. The second program converts from the generic data base to one used by that visual system. The second approach was chosen since it has the flexibility built in to allow the number of visual systems to expand. Figure 2 illustrates this concept.

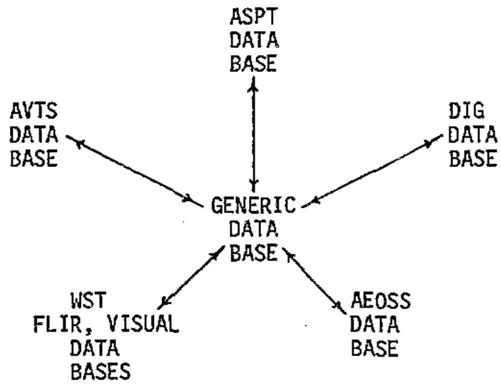

Figure 2 Data Base Conversion System

It was decided to use several phases in the development of this project. Phase 1 would allow the conversion of data bases between two specific visual systems. The visual systems selected were the General Electric Advanced Simulator for Pilot Training (ASPT) and the Singer-Link Digital Image Generator (DIG) for the F-111B Visual System Attachment. This is shown in Figure 3. These systems were chosen for two basic reasons. First, they were both on site at AFHRL which allowed for more convenient testing. Second, there were significant differences in the format of these data bases, so that a good test case could be provided. Details on these two visual systems can be found in the Introduction.

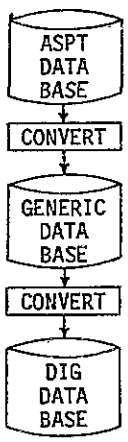

Figure 3 Phase 1 of Data Base Conversion

<u>Phase 1</u>

Phase 1 would be used to demonstrate the feasibility of the concept. It would also be used to explore different formats of the generic data base as well as different techniques to perform the conversion.

Phase 2 would take the lessons learned in Phase 1 and develop a more general format. This would allow the conversion of features not found in either the ASPT or DIG.

The first step of Phase 1 was the *development of a generic data base format. What* was required for this data base was enough geometric information to describe the visual environment exactly. This information was obtained by means of a thorough analysis of the two visual systems to be converted. The data base formats of several other visual systems were also reviewed at this time so that the generic format could be easily modifiable.

The generic data base contains enough information to allow the creation of a data base for either the ASPT or DIG visual systems. Basically, this data base can be thought of as having two parts. The first is a directory which contains the model name and disk location of its information. The second part is the *geometric data of each model. This data is* composed of general model data, general object data, face data, and vertex data. Examples of the type of data in the generic data base are given in Figure #4.

<u>Model Data</u>

Name
Level of Detail
Description
Geocenter
Switching Distance
Object Count
BIT Flags:
  Moving Model
  2D/3D
  Time of Day

<u>Object Data</u>

Name
Geocenter
Face Count
Vertex Count
Light Information
BIT Flags:
  2D/3D
  Time of Day
  Type of Light
  Sun Illumination
  Curved Surface Shading
  Type of Object

<u>Face Data</u>

Geocenter
Normal
Color
Edge Count
Vertex List

<u>Vertex Data</u>

Coordinate
Normal

Figure 4 Generic Data Base Information

The rest of Phase 1 is concerned with the development of a set of programs to perform the conversion of a data base between the two visual systems chosen. This consists of four programs which perform the following functions: convert an ASPT data base to the generic format; convert a DIG data base to the generic format; convert a generic data base to the ASPT format; and convert a generic data base to the DIG format.

Currently, two of the four programs have been written. The first allows the conversion of an ASPT data base to the generic format. The second allows the conversion of a generic data base to the DIG format.

The programs have been designed so that they will not have to be completely rewritten if the format of the generic data base is changed. When the programs were coded, an effort was made to insure that the programs were modularized. Also, each routine has been well documented to make any future changes easy to implement. The programs are written almost entirely in FORTRAN. The only assembly language routines perform tasks such as disk I/O. These programs are also relatively short, each being less than 1000 lines of code.

Once the data base has been converted, there is still work for the modeler to do. The differences between different computer image generators must be accounted for if the environment is to make maximum use of the capabilities of the visual system. The most common task to be performed is the addition or deletion of models. If the receiving system has a higher edge capacity than the originating system, then models should be added to the data base. However, if the receiving system has a lower edge capacity than the originating system, models should be deleted so the image generator is not overloaded constantly. Colors of faces may also have to be adjusted. This is most important when the originating system is monochrome and the receiving system has full color. However, some adjustment will also be necessary in the conversion between two color visual systems since their color tables will probably be different. In addition, some "tweaking" will need to be done on the real-time variables in the data base. These real-time variables include such things as the distances at which models appear and disappear in the visual scene. The conversion program computes default values for these and places them in the data base. However, the defaults will occasionally need to be adjusted.

A data base originally built for use on the ASPT has been successfully converted to run on the DIG. In spite of the work required to make maximum use of the DIG's capacity, the automatic conversion saved over 50% of the time required to rebuild the data base by hand. If one would be satisfied with seeing a 2500 edge, monochrome scene on the DIG, very little work need be done after the conversion is complete and much more time would be saved.

Currently, the last two programs of Phase 1 are being designed. Once these two programs are complete, a data base created on the DIG will be converted and flown on the ASPT. At this point, we will have the capability to transfer data bases between the ASPT and the DIG.

Phase 2

Once Phase 1 is completed, work can begin on Phase 2. This will be an expansion of Phase 1 to allow the conversion of data bases between any visual system at AFHRL. Phase 2 will use the same approach as Phase 1; the major difference will be in the format of the generic data base. The format of the generic data base will need to be expanded to include information not used by the ASPT or DIG but needed for the other systems. This information includes such things as DMA terrain and culture, texture, and circular features. One area which will require thorough investigation is the role that DMA terrain and culture will play in the generic data base. There are both pros and cons to including this information in the data base. Another area to be investigated is the possibility of converting between visual, FLIR, and radar systems to a limited extent.

MODEL LIBRARY

The second project to be discussed is the development of a model library. This library includes digitized models of various military vehicles and aircraft (mostly Soviet and U.S.). The digitized models are designed to be used on edge/face based aircraft simulation systems. The models are made as edge-efficient as possible while still retaining sufficient detail for vehicle and aircraft identification. Without this library, models were made only when they were required in an environment. When the same model was later required in another environment, the model was essentially remade from scratch. What is normally done is to accumulate models as they are generated for an environment. In addition to this, we are predicting what models will be needed in future visual environments and then developing these models into a readily accessible library. This library will allow data base modelers to generate visual environments more quickly and efficiently.

The models are being created on the ASPT visual system. Therefore, the models are designed and tested to the format and restrictions of the ASPT visual system. These were described in the Introduction.

When creating a visual environment, some models tend to be more of a modeling problem than others, and so, take longer to build. Unlike most models used in an environment, vehicles and aircraft require more modeler finesse to be efficiently and accurately represented. Source data in the form of photographs, blueprints, and dimensions is an absolute necessity. The identifying features for these models play an important role. Relative dimensions and angles require much more consideration than they would for models such as buildings. Since these models tend to be more complicated then others, significantly more development time is required. Assigning gray shades to faces can be tricky. For example, the top of an aircraft's wing should not be the same shade as the side or top of the fuselage. Separation planes required for object priority within the model tend to be a problem for vehicle and aircraft models. Since these vehicles and aircraft are likely candidates for "moving" models, real-time translation and rotation needs to be considered. Having such models premade and properly documented in a model library can decrease the amount of time required to build a visual environment.

The models in the library are designed with three levels of detail. An explanation of levels of detail can be found in the introduction. A typical vehicle modeled in its most detailed version is composed of five to ten objects with about 100 edges. Figure 5 shows a vehicle as it is typically modeled on ASPT, and Figure 6 is a photograph of the actual vehicle. A typical aircraft model in its highest level of detail has 13 to 15 objects composed of approximately 300 edges. Figure 7 shows an aircraft as it is typically modeled on ASPT, and Figure 8 shows the actual aircraft. The intermediate and least detailed levels tend to have respectively 60 and 30 percent of the number of objects and edges compared with the highest level. The lower two levels are designed independently of the highest level and so are not just a stripped down version of the highest level. All models are constructed along the X axis of a 3-D coordinate system with positive Z defined as "up." The center of rotation for modeled vehicles is at the middle of the vehicle on the ground. A modeled aircraft's center of rotation is at the aircraft's approximate geocenter. Aircraft are made in two versions, wheels up and wheels down. Variable geometry aircraft are modeled with the wings in two positions, the fully swept and fully unswept wing positions. The approach typically taken in modeling is to be more concerned with how "pretty" a model is and less concerned with how edge efficient it is. Since our goal is to create visual cues necessary to perform a specific task (and not to sell a visual system), the models are designed to be edge efficient yet easily identifiable. Instead of having one or two "pretty" models in a scene, we can have many less detailed but still useful models. It currently takes about two weeks to design, code, debug, visually test, and document a model.

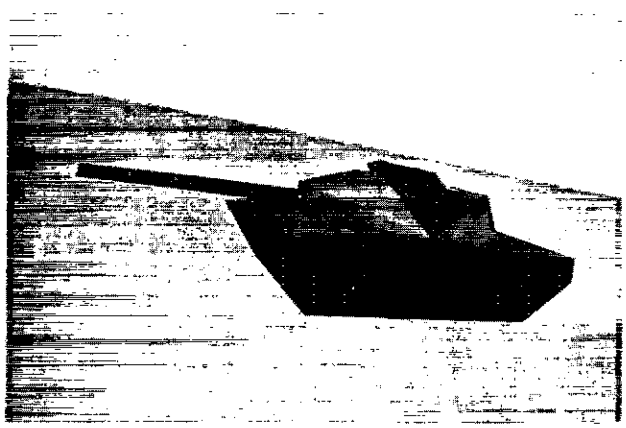

Figure 5 Vehicle Modeled on ASPT

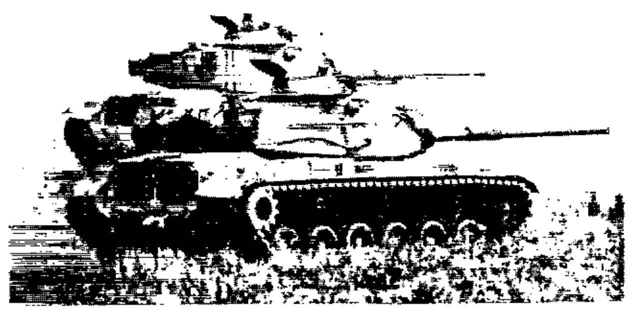

Figure 6 Actual Vehicle

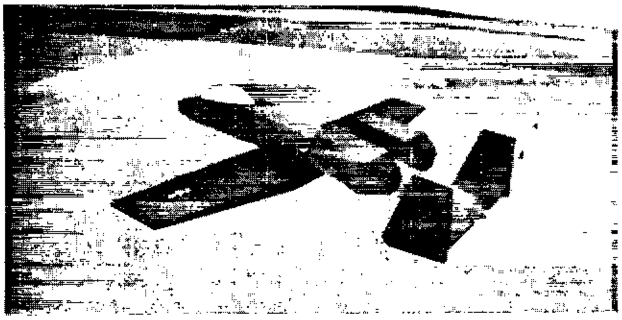

Figure 7 Aircraft Modeled on ASPT

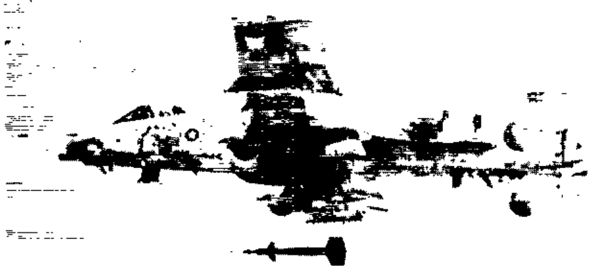

Figure 8 Actual Aircraft

Since it is intended that these models be used for multiple purposes, appropriate documentation is necessary. Documentation for models is available in the form of computer plots, formatted listings of the geometric information describing the model, and copies of the modeler's design sketches of the individual objects and the completed model. Figure 9 is a computer plot of a completed aircraft model. Figure 10 is a typical example of a modeler's design sketch of an object. The models are stored in ASPT modeling source format on a file saved on a computer disk and are easily listed on a line printer. This source data can be easily saved on magnetic tape for transport to other simulation systems. This would allow the vehicle or aircraft to be easily hand coded into the modeling source format of another visual system. In this way, the time consuming design phase of the modeling would be eliminated. When the conversion program is completed, the models could be converted automatically from ASPT format to the correct format of the receiving visual system. Using the same software, models could also be entered directly into the library from a donating simulator system.

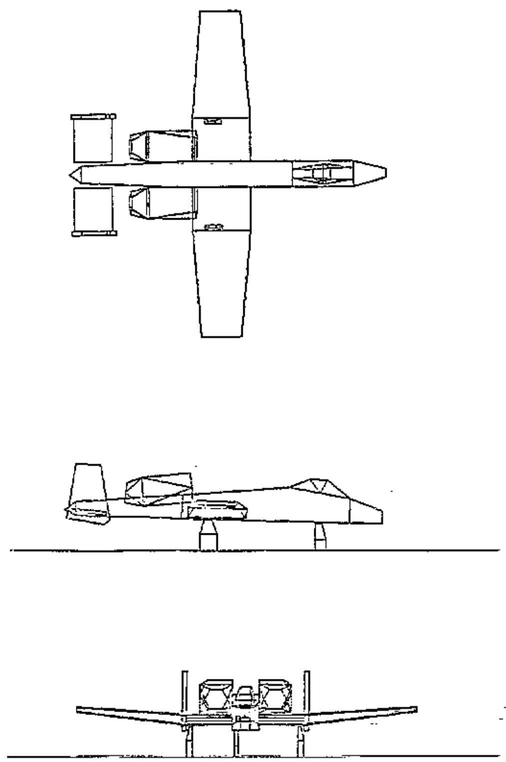

Figure 9 Computer Plot of a Modeled Aircraft

Object Name "2501"

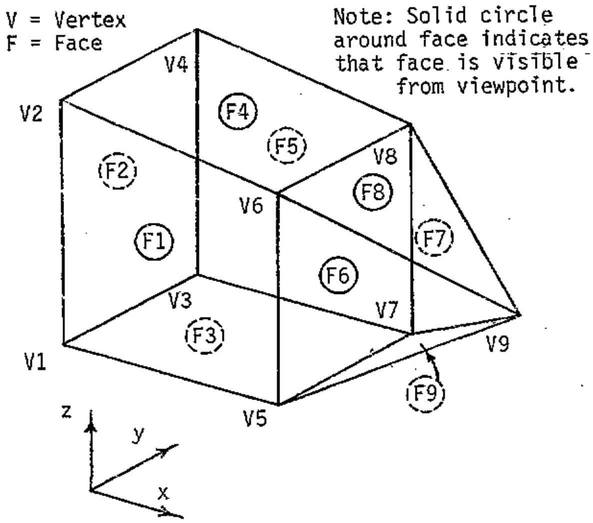

Figure 10 Design Sketch of an Object

The model library currently includes approxiamately 100 completed models. An earlier collection of ASPT formatted digitized models exists on computer cards. An effort is being made to transition these models into the model library. This means insuring that all of the card oriented models meet the standards of the model library (three levels of detail, documentation, etc.). The models in the library are a collection of work done by several modelers. Therefore the style (artistic license) the modeler used to represent the vehicle or aircraft may vary slightly from model to model. The models, when completed, are readily available for future study, test, and training applications.

The library of models is being expanded on a continuing basis.. Although the format of the library models is from the ASPT, the models can be transformed into the format of other CIG visual systems with relative ease. The thorough documentation available makes the models easy to be modified as needed. The library currently exists and is being used for on-going research and development. The models can be used for a variety of purposes. This model library will decrease database development time by about two weeks for each model used from the library.

ABOUT THE AUTHORS

Ms. Patricia A. Widder has been working as a Computer Programmer Analyst with the Air Force Human Resources Laboratory, Operations Training Division, at Williams AFB, Arizona, since 1978. She has worked in several areas including data base modeling software, real-time visual software, and data base modeling. She is currently completing a Masters Degree in Electrical Engineering.

Mr. Clarence W. (Steve) Stephens has been working on data base modeling for the Air Force Human Resources Laboratory, Operations Training Division, at Williams AFB, Arizona, since 1978 and is currently in charge of the data base modeling effort. He is currently completing a degree in Computer Systems Engineering.