CIG DATA BASES; WHERE ARE WE HEADED?

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ABSTRACT

The rapid advancement in capabilities of computer image generation (CIG) visual systems has resulted in increased application of such systems from take-off and landing training to full-mission simulation. These full-mission applications dictate a need for the creation of high-fidelity data bases covering large geographical areas on the order of multiple thousands of square miles. As a consequence, the manual techniques employed in the past to create small, airfield vicinity data bases are not practical for generation of very large data bases. Clearly, some type of automated data base generation technique is required. Current trends are aimed at utilizing the Defense Mapping Agency (DMA) digital data base as source data and applying to it a computer transformation in order to arrive at a real-time CIG data base. However, current limitations of the DMA data, CIG system constraints, and training utility of the end product limit the amount of automation possible in the data base generation process. This paper discusses the evolution of the CIG data base generation process from totally manual methods to current trends toward full automation. Practical limits of automation and potential future developments are examined.

INTRODUCTION

Since late 1973 when the cost of aviation fuel began to rise and availability became less certain, the Air Force has endeavored to reduce the number of training hours in the actual aircraft. Accordingly, the full-mission considerations of simulator training have become more important. Visual simulation has become a major contributor to the full-mission training capability in simulators. The most widely used method for generation of the visual imagery for Air Force simulators is that of Computer Image Generation (CIG). This technology employs high-speed, special purpose computational logic to generate perspective imagery using a mathematical model of the real-world as input data (data base). The problems encountered in determining the content of the data base, as well as limitations in the generation of the data base and the resulting impact on training capability are the subject of this paper.

WHERE HAVE WE COME FROM?

In the Beginning

A classical measure of the processing capability of the CIG system is the edge capacity. An edge is defined as the boundary between two separate surfaces in the displayed imagery. CIG systems acquired during the infancy of the technology (roughly 1962-1972) by NASA and the U.S. Navy could generate on the order of 240 to 512 edges. The data bases used by these systems were thus very small and low in detail. These data bases were all hand-modeled at relatively low cost in manhours. Their small size and simplicity made testing and debugging (correcting anomalies which cause the generation of incorrect scenes or distracting effects) a relatively simple task. However these early CIG systems, because of their limited power, were used for training only basic flying maneuvers such as take-off and landing.

In the late sixties and early seventies the dramatic progress in the electronic microcircuit industry was beginning to reflect on CIG technology. Image generators capable of processing 1000 to 2000 edges became available. Along with this growth in image generator capacity came the attendant growth in edge density and in the geographical area of coverage of the data base. The Air Force's Advanced Simulator for Pilot Training (ASPT) was perhaps the premier system developed during this time. The ASPT visual system had the capability to process up to 2500 edges from an originally delivered data base containing approximately 100,000 edges. The initial ASPT data bases covered an area of 500 square nautical miles and yet were still generated by hand using engineering drawings, blueprints, photos, maps and personal observations. Those features or objects which were deemed significant as cues for training were manually extracted one-by-one from the source data. The time required to intelligently fill a data base of this size with sufficient edges and lights to fully exploit the capability of this more powerful image generator was becoming significant. The ratio of data base cost to the total cost of the visual system was starting to rise.

The Air Force's Advanced Electro-Optical Sensor Simulation system (AEOSS) was developed in the mid-seventies as a tool to investigate not only E-O sensor simulation using CIG, but new image generation techniques as well. Although the AEOSS was a non-real time research oriented device, it had the capability to replay relatively complex imagery (containing over seven thousand edges) in real-time for evaluation. Perhaps the real significance of this system, however, was that it marked the first application of a fully automated technique for CIG data base generation. The terrain definition for the AEOSS data base was derived by fitting surfaces to the terrain elevation data provided by the Defense Mapping Agency (DMA) Digital Land Mass Simulation (DLMS) data base. DMA also provides a cultural data file to describe the topography of the terrain, but for AEOSS it was used mainly to define the locations of large water features (lakes, etc.) on the terrain. Some of the man-made cultural features were also transformed automatically, but this was done using a relatively gross approximation of the features with little detail. All of the detailed culture specifically required for the AEOSS system was modeled and inserted into the data base by hand. This becomes significant when one considers that the geographic area of coverage has been extended to 2500 square nautical miles.

<u>More Systems</u>

Although CIG technology was struggling to its feet in the early seventies, the impending fuel shortage was about to force CIG to take a giant leap forward. The 1973 Mid-East oil embargo had a significant effect on the price and availability of jet aviation fuel. The immediate reality for the Air Force and the rest of DOD was a gradual yet sizeable cutback in the amount of flying hours normally earmarked for training. The *answer - use simulators to replace the lost training* hours. The Air Force then embarked on a series of new simulator acquisition programs.

<u>More Performance</u>

Since in many cases the new simulators were to replace and no longer simply augment training in the actual aircraft, procurement specifications were written for devices having significantly higher performance capabilities than existing simulators of that time. Inherent in these specifications was a "full mission" training capability; the ability to rehearse a total mission from take-off to landing - all in the simulator. Visual simulation was a key to this capability. Take-off and landing and general cockpit procedures proficiency were no longer the only simulator training tasks to be dealt with. Low level navigation, aerial refueling, visual weapons delivery and aerial combat training via simulators were now firm requirements. Because of its inherent flexibility and rapidly growing capability, CIG was considered the visual simulation technology most capable of meeting these new requirements.

Along with the more powerful CIG systems capable of supporting full-mission simulation, requirements for data bases covering large geographic areas of the world began to evolve. Perhaps the most challenging data base requirements for a CIG visual system are tied to the Air Force's C-130 visual system procurement program.

WHERE ARE WE TODAY?

<u>Larger Data Bases</u>

The C-130 visual system pilot production unit is being procured with three separate data bases. One of these data bases will be a relatively small (2,500 sq mile) area surrounding Barksdale Air Force Base. The other two data bases will each cover 40,000 square nautical miles in the vicinities of Little Rock (Arkansas) and Kirtland (New Mexico) Air Force Bases. The latter two data bases will contain the respective air bases as well as airdrop zones to allow for training in the following areas:

1. Ground operation
2. Takeoff, approach and landing
3. Formation flight
4. Low level navigation
5. Assault landing

It is the low level navigation requirement along with the large area of coverage which necessitates new data base generation techniques.

Since the C-130 flight simulator's radar landmass system was already using the DMA DLMS data base as source data, the decision was made to utilize the DLMS data base as one input for the visual system data base generation process as well. The one obvious benefit to be derived from using the common data source was correlation between the radar and visual subsystems, ie. terrain prominences and cultural features will be portrayed in the same geographic locations in *both systems. The second and perhaps more signifi*cant benefit to be drawn from the use of the DLMS data base is its digital formal. No manual digitization would be required in order to insert cultural features found in the DMS data base into the CIG visual system data base, although the transformation program had to be expanded to provide this capability.

Thus, the complexity of a transformation program which formerly emphasized terrain transformation has been increased significantly with the addition of a more faithful culture transformation and the process of merging the resulting terrain and culture models. Even with this expanded capability, an enormous expenditure in manhours is required to customize the data base for training by manually adding training significant features not found in the DMA DLMS culture data.

<u>Source Data Limitations</u>

Truly, the final data base product can only be as good as the source data used to generate it. In fact the source data is the first problem encountered in the data base generation process. DMA's DLMS data base is the most comprehensive source of data currently available for use as source data for CIG data bases. The DLMS data base is a good source of data because it includes both real-world terrain elevation and cultural data, and will eventually be expanded to cover literally millions of square miles, including the continental U.S. as well as foreign countries.

Although the large area of coverage of the DMA DLMS data base makes it attractive for use as source data for visual data bases, one significant drawback does exist in the fact that, from the outset, the DLMS data base has been created to primarily support radar simulation. Hence only larger "radar significant" features are included in the culture file. Accordingly the DLMS data base does not include many types of features which are very significant from a visual navigation standpoint. This includes such features as roads, overpasses, railroads, and small streams.

Another limitation in the DLMS data base is a lack of any coloration or surface characteristic (texture) information. Also the size criteria which DMA uses to capture features in the DLMS production process limits the resolution of the displayed visual data bases to much less than that which is resolvable in current visual displays. Consequently, any area in the data base which requires high detail must be enhanced via a time consuming manual process using other sources of data.

Thus, there exists no single totally comprehensive source of data which provides the detail and accuracy required to model even take-off and landing type data bases, much less data bases to support the low-level navigation tasks required of the C-130 system. While the obvious solution is to selectively utilize inputs from a combination of several different data sources, it is precisely this solution which introduces some of the major problems currently being encountered in the generation of large data bases.

Registration

Since certain areas of CIG data bases often contain navigationally significant features which are not completely defined in the DMA DLMS data, these features must be obtained from a different source. There are alternate data sources such as Joint Operation Graphics (JOG) charts, Tactical Pilotage Charts (TPC), photos, etc. However, when additional features are extracted from any of these alternative data sources and inserted into the previously transformed data, registration with other features in the data base can become an almost insurmountable problem unless proper care is taken at the correct stage of the data base generation process. A case in point is the C-130 visual system data bases in which bridges are extracted from the DMA data, and streams and roads are placed in the on-line data base using JOG charts as source data. When extracting features from two different sources, each with its own accuracy tolerance, the result is predictable. For instance, a road may run up to a stream and miss the bridge by several hundred yards, if in fact the bridge traverses the stream at all. Several other such misregistration situations are possible, such as:

1. Dams to lakes
2. Streams to lakes
3. Roads to water features

These irregularities are unacceptable for navigational training and potentially require significant numbers of interactive manhours to insure proper registration. Manual interaction is a leading contributor to data base production costs, but at present there is no clear alternative to resolve these types of problems.

Real-Time Constraints

On the other end of the data base generation issue is the capability of the image generator to handle the data base content. Data bases must be generated with consideration of the target image generator's processing capacity. Failure to do so will more than likely result in system overload which is characterized by unacceptable streaking or breaking up of the video image. Thus, the goal in the development of any particular CIG system is to create a uniformly dense data base that will, in general, be tailored to load the image generator to an optimum percentage of its capacity without overloading it. This is not typical of past approaches where the image generator has been sized to handle the most dense, worst case areas of the data base which usually constituted a relatively small percentage of the entire geographical area of coverage. This approach guaranteed waste of a large percentage of image generator capacity whenever sparsely populated areas of the data base were traversed.

Several performance parameters of CIG image generators need to be considered during the data base generation process. The most important of these is the number of faces or edges which the system can handle. This, in conjunction with the field-of-view of the visual system, leads to an understanding of the edge or face density required in the data base to properly load the image generator. The number of edge crossings per raster line that the image generator can handle is also a parameter that influences allowable edge density in the data base. Finally, there is the consideration of mass storage for the data base. While not a problem at present, future systems with larger capacity and higher fidelity image generators and more complex data bases will impose new and more challenging requirements for data base storage and real-time retrieval. The only real concern is that the stored data base is adequate to optimally load the image generator and is capable of being accessed rapidly enough to allow real-time generation of the required scenes.

Other Considerations

Generation of acceptable on-line data bases is not assured by simply creating mathematically correct object definitions and avoiding conflict with image generator capabilities. Indeed a displayed data base may, upon initial static evaluation, look very acceptable. However, when the data base is applied to a real-time training scenario, the same displayed data base may be judged to be unuseable. When dealing with CIG systems, the relative acceptability of a data base and the concept of "realism" are not necessarily related. In order to accomplish training, the data base must, in conjunction with the image generator, provide adequate and "proper" visual cues to the aircrew. The proper cues vary for each different task. For take-off and landing, the relationship of the runway to the surrounding terrain and culture and the texture or character of the terrain surface may be most important. For low level navigation however, the occlusion of cultural features by other cultural features and the terrain profile is more significant. Also a low level navigation data base must include a sufficient number of cultural features to clutter the scene in order to train the navigator to discriminate between similar features in establishing checkpoints.

Another requirement for navigational training is consistency which can be exemplified by the ability of a student navigator to look at his chart and base the determination of a checkpoint on a feature on the chart, with full confidence that the feature in question will appear in the CIG data base for every occurrence on the chart. Dealing with this problem properly entails numerous hours devoted to manual processes. The pain involved can be eased by intelligently determining what features are navigationally significant and including all such features at the cost of eliminating other features whose presence makes the data base look more realistic, but adds no training value. Of course the determination of what is navigationally significant needs to be determined separately, to some extent, for each different data base area. This is illustrated on the C-130 by the fact that the Little Rock area is tree covered with numerous lakes and a moderate amount of man-made cultural detail. The Kirtland area, on the other hand, contains very sparse cultural content (approximately 8% of the number of features found in the DMA data base for the Little Rock area for roughly the same geographical area). In the Little Rock area, the lakes and trees are navigationally significant, while such features as farms and ranches are useful for their clutter value but are of secondary importance for overall navigation. In the Kirtland area, however, isolated ranches and windmills comprise a large percentage of the cultural detail and are primary navigational cues.

Coloration of features is a significant navigational cue and therefore is also an important consideration in data base generation. Subtle color differences between features cannot always be successfully inferred from source data but instead must sometimes be gleaned from personal observation or color photography.

One last consideration in the generation of large area data bases is the concept of homogeneity. The displayed data base must possess a distribution of features (detail) which is analogous to the real world. Concentration of features in an area of the on-line data base where the same relative concentration does not exist in the real world can lead to artificial cueing. Corridorizing of a data base is the practice of concentrating data base detail along a pre-determined flight path. While corridorizing can help to reduce the number of manhours required to build a data base, it does tend to limit the flexibility of use of the data base and can also result in artificial cueing; if most of the detail is clustered around one predetermined path through a data base, other missions with other routes of flight cannot be readily accomplished. Also if, while flying a mission along the preselected corridor, the pilot begins to inadvertently diverge from the prescribed path, the crew will immediately be alerted to his error by the sudden reduction of scene detail away from the corridor.

In many regards data base creation is as much an art as it is a science and the above comments are intended to illustrate that a rigid, cookbook approach to data base generation is not usually sufficient. Even if all the mechanical registration type problems are eventually solved, it appears a certainty that some amount of modeler interaction during the data base production process will always be required. The objecttive, then, must be to minimize modeler interaction by maximizing the amount of automation used in the basic feature extraction process and leave any manual interaction to debugging and fine tuning enhancements.

WHERE ARE WE HEADED?

It is clear that there are many unsolved problems in the visual data base generation process. Furthermore, the current problems are only likely to worsen as technology advances and image generator capacity increases along with the demands on the data base. Thus, data base production costs can only be expected to keep rising. What can be done about it? The Air Force is currently pursuing several efforts in order to deal with these problems.

Data base commonality is one potential solution to the problem. In past systems, radar and visual data bases as well as any sensor data bases have all been developed independently of each other. The hand-modeled areas and processes that require manual interaction are and will continue to be fairly expensive parts of the process. It is possible that generating these areas once and including appropriate features/descriptors for visual, sensor, and radar all in the same data base could ease the data base generation manpower requirements. The tradeoff potentially involves more storage for the on-line data base if parameters which are not being used for a certain application are built in. However, a secondary translation program could be applied to extract a specialized data base from the universal common data base and thereby eliminate the overhead.

Data base portability is another idea under consideration by the Air Force for use in future systems. This concept would require that all future data bases be generated to the highest detail or fidelity possible and described in a high-order type data base language. This data base could then be compiled (or filtered) for other simulators or for other types of missions in the same simulator by specialized software which uses the high level description as input and develops a tailored data base for a particular application on a target visual system. Each feature in the high-level data base would contain appropriate importance descriptors for filter survival based on the type of mission to be trained and the capacity of the intended image generator. This technique, combined with a discriminator capability in the image generator to monitor image generator loading and select features from the on-line data base in priority (or importance) order, should save on data base generation expense and at the same time provide for better image generator loading and overload prevention in CIG visual systems.

There is also the consideration of future alternate data sources. Although at present the DLMS data base is the best source of information available for CIG data bases, there is the possibility that new and better sources of data may be developed in the future. One must keep in mind, however, that it will probably take requirements by potential users other than the simulator community to make the development of such a "customized for training" data base worthwhile, considering the great expense involved in data base construction.

One future possible source is the DMA level V (for visual) data base currently being planned. Level V will involve the addition of features and descriptive parameters to the DLMS data base for the purpose of better defining features and surface characteristics which are navigationally or perceptually significant for visual system use. Level X is a planned extension of Level V which will provide relatively small areas of high detail within Level V. However neither Level V nor X is expected to be implemented (except possibly for demonstration purposes) for approximately ten years.

In summary, the technology of computer image generation and attendant advances in data base generation for CIG has seen tremendous advances. Many more advances are currently being envisioned, planned or implemented. But in the final analysis, it is probable that some degree of manual enhancement or editing will always be required no matter what the capacity of the target image generator or the intelligence of the transformation program is.

ABOUT THE AUTHORS

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