Spatial Data Software Integration: Merging CAD/CAM/Mapping with GIS and Image Processing

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ABSTRACT: Over the past several years the three basic spatial data mapping technologies (CAD/CAM/Mapping, geographic information systems, and image processing) have undergone an evolutionary maturation. Today's challenges, however, require that these three technologies be fully integrated. There are several possible approaches to resolving the technology integration problem, the most practical, perhaps, being development of software interfaces between the three technologies. This paper focusses on merging CAD/CAM/Mapping with image processing using geographic information systems as the primary interface technology. The basic applications bias is towards Earth resources, the military, and space science problems. The software systems involved include the Jet Propulsion Laboratory's VICAR image processing and IBIS raster-based geographic information system, and Intergraph Corporation's CAD/CAM/Mapping system.

INTRODUCTION

THE GEOGRAPHIC INFORMATION SYSTEM (GIS) is the fundamental technology for merging various independent spatial *data* (maps) into a form that represents *information*. Within a serial computing architecture, this is performed using "polygon overlay" and "query" software technologies.

Spatial data come in many divergent and often incompatible formats. The three basic formats are vector (graphics), raster (image), and tabular (attribute), which correspond to the internal formats, respectively, of CAD/CAM/Mapping,[1] image processing, and geographic information systems. These three technologies have evolved as unique sets of software procedures for preprocessing their respective data types. Comparable preprocessing techniques transcend the technologies, typically including some form of reformating, reduction, standardization, enhancement, and final editing.

A geographic information system, however, also seeks to link data with spatial attributes (e.g., geographic locations) to create information with which managers and scientists can interact (Dangermond, 1986). The GIS may be vector oriented, such as Environmental Systems Research Institute (ESRI) ARC/INFO system and the Harvard Laboratory for Computer Graphics and Spatial Analysis ODYSSEY system. The GIS may also be raster (image) oriented such as the Jet Propulsion Laboratory (JPL) Imaged Based Information System (IBIS) and Electronic Systems Laboratory (ESL) Interactive Digital Image Manipulation System (IDIMS) systems. The orientation is a function of application. Water and power utilities largely deal with pipes, wires, and right-of-ways which are linear features best represented by points and lines (graphics). For these applications, vector/graphic GISs are most useful. Resource managers, defense, and many space scientists deal with areal data often provided by satellite imagery. For these interests, raster GISs are more appropriate.

Most GISs contain preprocessing capabilities specific to their technology orientation. As a result, they are integrated with CAD/CAM/Mapping or image processing technologies, but not both. JPL's IBIS for example, is wholly a subset of the Video Image Communication and Retrieval (VICAR) image processing system. The challenge is to make GISs equally compatible with both vector and raster technologies because present and future information requirements demand integration of all data regardless of format.

[1]CAD/CAM/Mapping is an acronym for mapping oriented Computer Aided Design (CAD) and Computer Aided Manufacture (CAM) technologies.

At the Jet Propulsion Laboratory's Multimission Image Processing Laboratory, data integration and information extraction is a constant concern of Earth resource, space, and defense interests. Considerable effort is underway to broaden JPL's raster oriented VICAR/IBIS geographic information system to incorporate fully integrated vector/graphics processing capabilities. The options for accomplishing this software integration are few: (1) Develop a wholly new raster/vector GIS (the preferred, but not necessarily the most economical approach); (2) develop interfaces to a standard interchange format (egalitarian, but not necessarily the most efficient); and (3) develop interfaces to specific existing software systems (probably parochical, but efficient and cost-effective in the near term). For practical economic reasons, the latter two options are of most interest, with option 3 presently implemented.

This paper describes the technical aspects of the option taken at JPL, specifically, development of software interfaces between the VICAR/IBIS raster-based GIS, and Intergraph Corporations's CAD/CAM/Mapping system. The experience, however, should be comparable for most complex spatial data software interface situations.

BACKGROUND

Two challenging issues confronting the growth and operational use of raster-based geographic information systems are vector data capture ("digitization") and data editing. Data entry (both vector and raster) is typically the most labor intensive and time consuming phase of any GIS project --- yet also the most important. GIS computer processing cannot produce quality information from substandard digitized data.

A second equally challenging requirement is that the data flow be bi-directional. Data typically flows only one way, from the digitizer to the GIS system. Rarely do present day systems allow data to flow from the GIS to the digitizer workstation for editing or enhancement. The interfacing of CAD/CAM/Mapping, GIS, and image processing software on the same computer can provide an opportunity for data capture, data integration, and GIS processing in both the graphics and raster domains (Faintich, 1986).

JPL's VICAR/IBIS software system has the capability to accept existing data in many formats, but formerly lacked the capability to easily capture and edit large quantities of raw graphics data. This deficiency has been overcome by acquiring an Intergraph Corporation CAD/CAM system and developing the necessary interfaces to directly accept Intergraph formated files. The VICAR/IBIS experience is a useful tool for discussing the spa-

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tial software interface problem because it is a neutral system, i.e., a non-commercial research and development system available through the U.S. Government's COSMIC software repository facility (University of Georgia, Athens). These systems are briefly described.

VICAR

The Video Image Communication And Retrieval image processing system (Castleman, 1978; Colwell, 1983) is a flexible image processing software system developed in 1966 by the California Institute of Technology's Jet Propulsion Laboratory for the National Aeronautics and Space Administration (NASA). Initially developed for the computer processing of imagery returned from the unmanned Ranger, Surveyor, and Mariner space exploration programs, VICAR has become a full featured image processing system with over 350 programs (approximately 615,000 lines of code) available to support a wide variety of remote sensing, Earth resources, geologic, biomedical, forensic, planetary, astronomy, and commerical applications. VICAR is also one of the most widely used non-commercial image processing systems, with installations in many governmental, academic, and commercial organizations around the world (Colwell, 1983).

IBIS

The geographic information system component of VICAR is the Image Based Information System (Bryant and Zobrist, 1976; Bryant and Zobrist, 1981). IBIS is unique in that it is the only raster based GIS of significant size and complexity (Colwell, 1983). Most spatial data entered into IBIS are rasterized, but the system easily handles tabular and vector formats. In the simplest case, IBIS databases are composed of multiple layers of raster "data planes" (Figure 1) generated from satellite or vector data sources. The key data plane is the "geo-reference" which contains the spatial dimensions of the management regions (e.g., census tracts, counties, administrative zones, etc.) to which all tabular and statistical information are referenced. Figure 2 provides an example of the IBIS tabular and raster data interface. As a functional subset of VICAR, the full power of image processing can be brought to bear upon the IBIS data planes.

GRAPHICS EXCHANGE STANDARDS

One of the available spatial data software interface options (option 2) is to utilize an existing graphics exchange standard

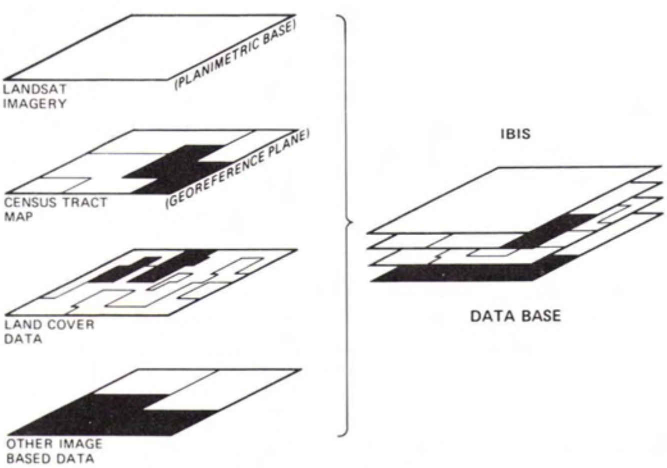

FIG. 1. A simple IBIS database characterized by several layers of coregistered data planets.

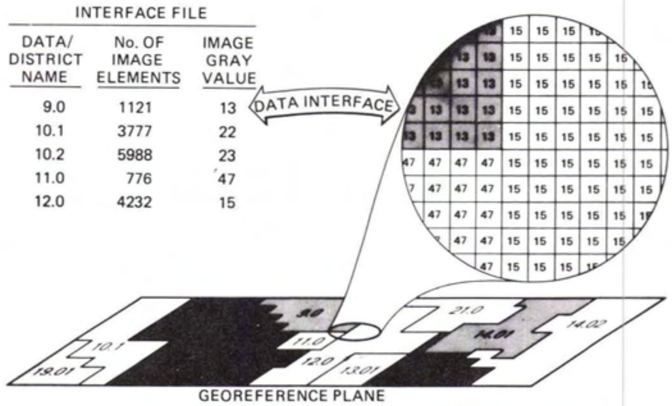

FIG. 2. The IBIS tabular and image raster data interface.

such as IGES ,[2] GKS,[3] or EDIF.[4] Interfacing with one these standards was not initially undertaken because of the perceived expense involved with intimately learning their format after the formidable expense of learning Intergraph's format. The graphics standards may also not be entirely suitable. For example, Zeiler (1987) found IGES to be "inadequate for cartographic applications," and storage inefficient because of its mechanical engineering heritage. Given the necessary project requirements, VICAR/IBIS may be interfaced with IGES in the future because of its military and NASA support. Currently, the direct interfaces between VICAR/IBIS and Intergraph's CAD/CAM format have been developed and are described in the following section. Interfaces with other CAD/CAM/Mapping systems (e.g., Synercom, IBM, AutoTrol) may also be developed given the necessary project-specific requirements.

CAD/CAM/IBIS (GRAPHICS) SOFTWARE INTERFACES

Two IBIS software programs, DGN2GRAF and GRAF2DGN, were written to facilitate the interfacing of Intergraph Interactive Graphics Design Software IGDS "design" files with IBIS "Graphics-1" files. The programs were written on an Intergraph workstation powered by a Digital Equipment Corporation 11/730 computer with concurrent resident VICAR/IBIS software. The IBIS Graphics-1 format is a simple file with a repetitive set of variable size and number of (user defined) elements separated by a "0,0" code.

DGN2GRAF converts either two-or three-dimensional Intergraph design files to IBIS Graphics-1 format. The program can handle most Intergraph elements including point, line, arc, shape, text, line string, curve string, and cell designations. All design levels can be combined for output as a single file, or up to 20 levels can be output into separate files at a single time. Text is output in IBIS "tabular" file format, which can be conceptualized

[2]IGES (Initial Graphics Exchange Specification) is an evolving graphics format strongly supported by military and NASA interests. Other supporters (of various intensity) include GE-Calma, Computervision, Intergraph, Applicon, McDonnell Douglas, Control Data Corporation, Autotrol, IBM, and General Motors (Fallon, 1986). When its evolution is completed, IGES is scheduled to become PDES (Product Data Exchange Standard).

[3]EDIF (Electronic Design Interface Format) is oriented more towards electronic CAD/CAM activities, but is also supported (in various intensities) by a large number of corporations including Motorola, National Semiconductor, and Texas Instruments (Fallon, 1986). EDIF is a committee effort which could become more mapping-oriented in the future.

[4]GKS (Graphic Kernel System) is an international system consisting of a number of utilities that interface graphics data with many graphics display processors. GKS is more a programmer's tool chest than data depository, but is supported (again in varying intensities) by Digital Equipment Corporation, IBM. GE-Calma, and Tektronics (Fallon, 1986).

as a file of equal length data "columns," where each row in the IBIS tabular file corresponds to a unique georeferenced text string (or set of numeric values). Other IBIS programs allow complete conversion between IBIS Graphics-1 and tabular file formats. DGN2GRAF has provisions for adding an X and Y offset, and a divisor for adjusting (X,Y) scale. Because conventional cartesian coordinate systems operate with the origin in the lower left corner, and image processing systems assume the origin is in the upper left corner, DGN2GRAF parameters allow the output data to be written "Y,X" ("Line, Sample") with the origin moved to the upper left corner.

GRAF2DGN converts IBIS "Graphics-1" (and "tabular" attribute) files to Intergraph IGDS two- or three-dimensional design files. An existing IGDS file must also be input to provide a proper IGDS "Terminal Control Block" for the output file. The user specifies the format type of the input IBIS files (multiple "Graphics-1" and "tabular" files are permitted) and the column numbers of the "X,Y" and text data if such data are being provided from IBIS. Other parameters allow changes in text height, line weight, color, origin, and scaling of the "X,Y," and "Z" data values.

DGN2GRAF and GRAF2DGN enable the bi-directional flow of data among Intergraph CAD/CAM/Mapping systems and VICAR/IBIS image processing and geographic information systems. Complex data digitized using the full power of the CAD/CAM system can be brought over to IBIS for special GIS processing, be returned to the CAD/CAM system for further editing, then sent back to IBIS for final disposition. By this process, the traditional problems of data capture and editing are significantly reduced. An example of this process can be seen in Figure 3. In this diagram, eleven maps of differing projection were individually digitized and transferred to IBIS. IBIS software re-projected the 11 maps to fit together as a single dataset of common map projection and characteristics. The combined re-projected file was returned to the CAD/CAM system for verification and editing of seams between map sheets. The resultant file (Figure 3) was sent back to INBIS to assume its role as one of several data overlays in the GIS database under construction.

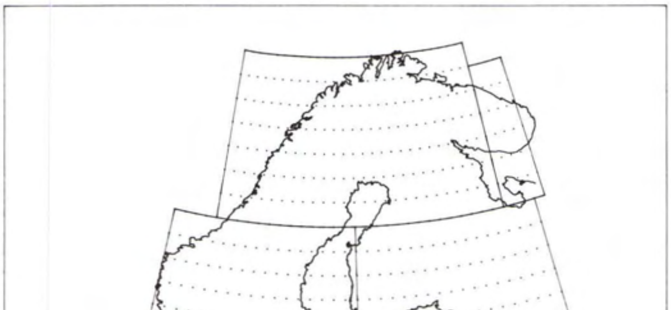

FIG. 3. Vector data from eleven separate maps of northern Europe were digitized on the Intergraphy CAD/CAM/ Mapping system, sent to IBIS for re-projection as a single (new) map projection, and returned to the Intergraph system for verification and seam editing. Dots represent re-projected latitude and longitude control points. The excellent re-projection indicates the accuracy of IBIS mapping techniques, and the powerful synergism of CAD/CAM/Mapping with IBIS GIS technology.

CAD/CAM/VICAR (IMAGE) SOFTWARE INTERFACE

Two VICAR programs, TOXYZ and TOGRD, were written to interface VICAR formatted elevation images with Intergraph's DTMN (Digital Terrain Model Nucleus) software package. Actually, any image dataset that could logically benefit from the Intergraph DTMN package could be transferred to the DTMN system.

TOXYZ converts VICAR electron images to Intergraph "random point" files for subsequent generation of triangulated, gridded, or IGDS design files. Parameters allow the user to subsample the image, exaggerate the Z value, and provide appropriate scalar values.

TOGRD directly converts VICAR elevation images to Intergraph gridded files for subsequent generation of IGDS design and contour files. Parameters allow the user to specify the appropriate scalers, grid cell increment, and Z value range.

Figures 4 through 6 use the Chukchi Sea between Alaska and Siberia to provide a summary example of the CAD/CAM/IBIS interchange capabilities. Figure 4 shows the two dimensional bathymetric contours of the Chukchi Sea as digitized on the CAD/CAM system and plotted. Figure 5 shows the data after conversion to IBIS format utilizing DGN2GRAF, map-projected using IBIS software, converted to the VICAR image (raster) domain, and pixel interpolated (using and inverse-distance weighted nearest-neighbor interpolation algorithm) to produce a continuous (three-dimensional) surface bathymetric map. The raster image (Figure 5) was contoured using different intervals form those used in the original digitizing. Figure 6 shows the final product after using TOXYZ to return the image data to the Intergraph graphics domain (random point format), where it was triangulated, rotated, and displayed in a three-dimensional perspective view.

SUMMARY AND CONCLUSION

Several software programs have been written to provide the interfaces between the Jet Propulsion Laboratory's VICAR/IBIS (image processing and geographic information system) software and Intergraph CAD/CAM/Mapping systems. The IBIS DGN2GRAF and GRAF2DGN software significantly reduce the problems of vector (graphics) data capture and editing by providing the linkages for transferring vector data between the GIS and CAD/CAM//Mapping domains. The VICAR TOXYZ and TOGRD software provide the means of transferring raster (image) data between the image processing and CAD/CAM/Mapping domains. Operational experience with these direct spatial data software interfaces has thus far been very positive, but there have been problems. First, two separate systems must be maintained, often at considerable expense (software licenses, updates, special hardware maintenance). Secondly, data formats outside the user's control can and do change, necessitating the rewriting of interface software. The use of a standard graphics exchange format like IGES may help to reduce some of these problems, but with some potential compromise in efficiency and functionality. The long term solution is a fully integrated vector and raster GIS.

In the near term, the bi-directional flow of vector and raster data between the Intergraph CAD/CAM/Mapping and VICAR/IBIS systems, coupled with the existing data flows within the VICAR image processing and IBIS geographic information systems software, have resulted in the creation of a powerful synergism. This synergism greatly expands the capabilities and performance of all systems in an era of increasingly complex spatial problems.

ACKNOWLEDGMENTS

The research and development described in this paper was conducted at the Jet Propulsion Laboratory, California Institute

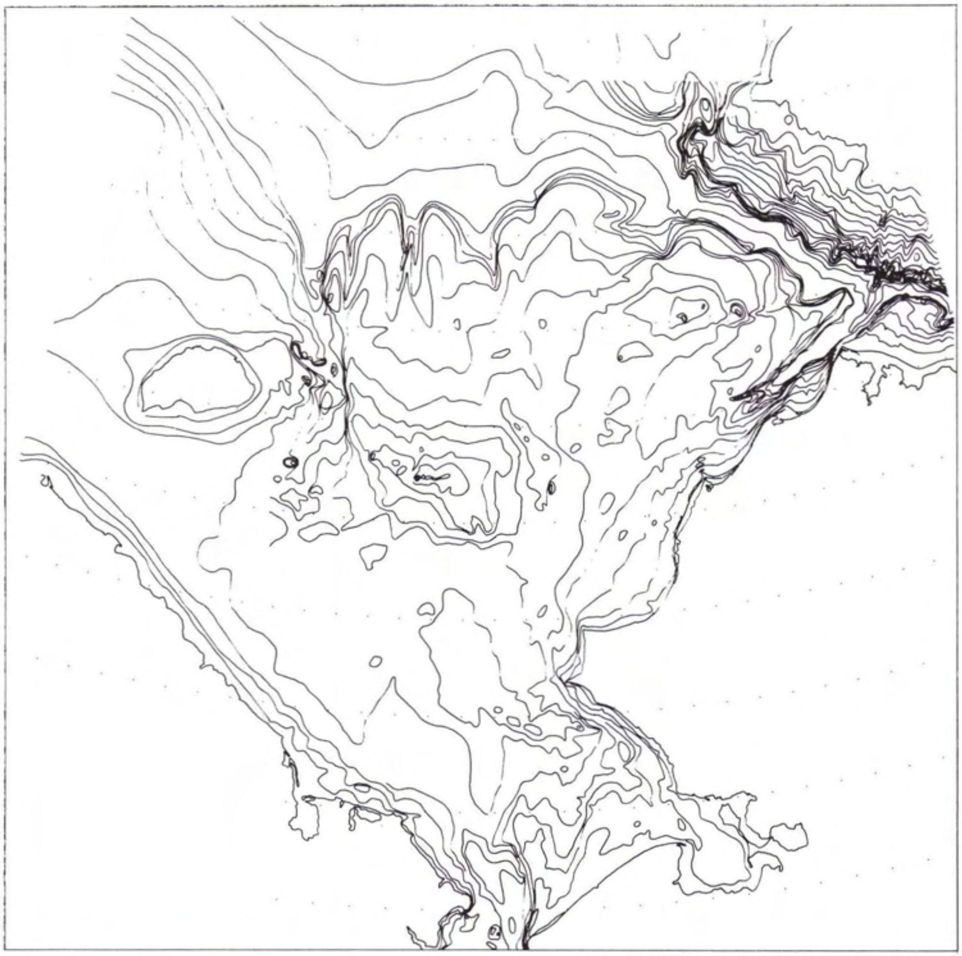

FIG. 4. Two-dimensional bathymetric contours of the Chukchi Sea as digitized on the Intergraph CAD/CAM system and plotted. Siberia is to the left and Alaska to the right.

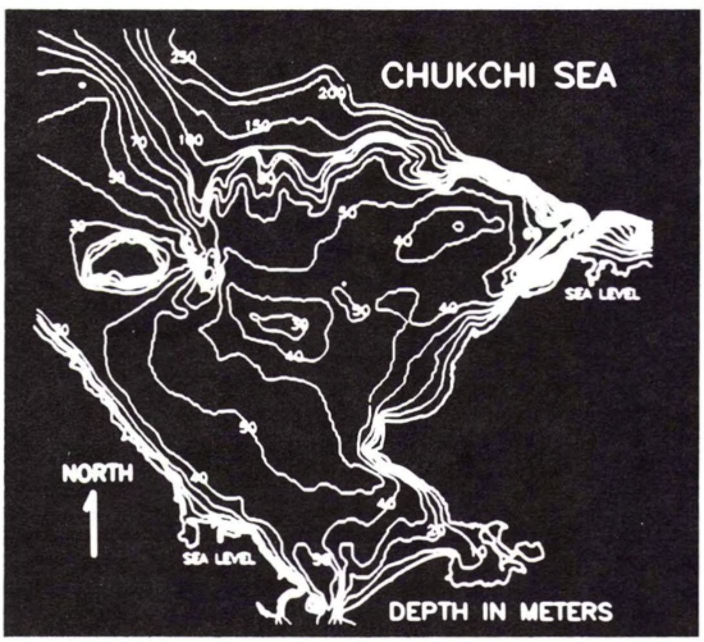

FIG. 5. Chukchi Sea data after conversion to IBIS format utilizing DGN2GRAF, map-projected using IBIS software, converted to the VICAR raster (image) domain, and pixel interpolated to produce a continuous (three-dimensional) surface bathymetric map. Different contour intervals were selected for the raster image, and therefore vary from the original digitized contours.

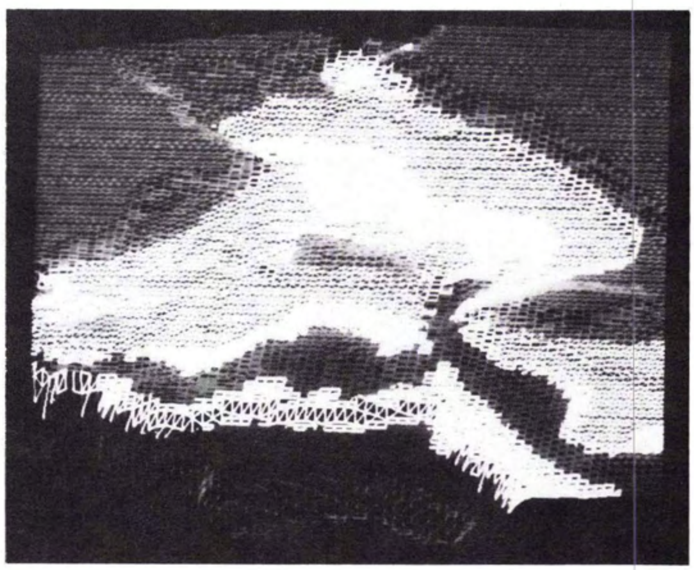

FIG. 6. The final Chukchi Sea product after using TOXYZ to return the image data to the Intergraph graphics domain (random point format), where it was triangulated, rotated, and displayed in a three-dimensional perspective view. The view is from the North Pole looking south towards the Bearing Straits. Alaska is to the left.

of Technology, under contract with the National Aeronautics and Space Administration. The team effort involved in this research included several people, particularly K. Franklin Evans, Richard K. Fretz, Lee F. Johnson, Barbara A. McGuffie, and the authors.

DISCLAIMER

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not constitute or imply its endorsement by the United States Government or the Jet Propulsion Laboratory, California Institute of Technology.

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