TITLE: Interactive Access and Management for Four-Dimensional Environmental Data Sets Using McIDAS

INVESTIGATORS: William L. Hibbard and Gregory J. Tripoli

BACKGROUND OF THE INVESTIGATION:

The development of McIDAS (Man-computer Interactive Data Access System) has been a long term project at the Space Science and Engineering Center for managing, displaying and processing earth science data. This grant is part of a series of NASA funded projects to explore technological opportunities to extend the capabilities of the McIDAS system, including animated three-dimensional displays, the use of computing standards such as UNIX and X Windows, the use of commercial workstations, interactive three-dimensional graphics, graphical user interfaces, and visual interaction with computations. The systems developed by these NASA funded projects have either become part of McIDAS, or access data in McIDAS file formats.

The McIDAS-X system released in April 1992 evolved from an experimental version of McIDAS running under UNIX and X Windows, and developed by this NASA funded technology exploration. The VIS-5D (VISualization of 5-Dimensional data sets) system, available as freeware and widely used by atmospheric modelers, was developed as part of this NASA funded technology exploration. VIS-5D provides highly interactive visual exploration of large data sets in McIDAS grid files, such as those produced by numerical simulations and volume scanning radars. The user interface of VIS-5D is specifically designed for earth scientists and, for a given size of workstation, it allows exploration of much larger data sets than other visualization packages.

VIS-5D is being used by scientists at UW-SSEC as a routine diagnostic tool for their model developments, and has had a real effect on the content of their science. It is also being used by scientists at NASA/MSFC and at NASA/GSFC. In addition to the support from NASA for the development of VIS-5D, the French Meteorology Bureau and INPE/CPTEC in Brazil have both funded visiting scientists for periods of six months who contributed to its development.

We have implemented a distributed version of VIS-5D, supported by the Gigabit Testbed Project. This version of VIS-AD accesses very large data sets (10^10 grid points) residing on remote super computers, although it requires extraordinary computational and communications resources.

The current NASA grant combines support for this exploration of technology with support for atmospheric modeling, recognizing the importance of cooperation between scientists and system developers.

SIGNIFICANT ACCOMPLISHMENTS IN THE PAST YEAR:

Enhancements to VIS-5D

During the last year, enhancements to VIS-5D include

A) a significant decrease in the response time to user selection of new iso-level contour surfaces for depicting fields
B) the ability to render plane slices as pseudo-colored images, which is useful for visualizing highly textured radar data
C) the ability to render topographical map backgrounds from user-supplied topography data files
D) a port of VIS-5D to run on almost all models of SGI workstations
E) a port of VIS-5D to run on the IBM RISC 6000 workstations.

Implementation of the VIS-AD system

We have implemented an initial version of the VIS-AD (VISualization for Algorithm Development) system and have demonstrated it at the American Meteorological Society conference in Atlanta in January 1992. VIS-AD lets scientists visualize the results of experiments with their algorithms. It functions somewhat like an interactive debugger, except that it presents graphics of high-level data objects rather than just printing lists of numbers. Its focus is on tracing high-level algorithm behavior rather than on tracking down low-level bugs. VIS-AD provides

A) an editor, compiler and interpreter for a programming language similar to C
B) management of user-defined data structures, accessible as data objects from the programming language

C) support for MISSING data in the programming language
D) an elegant and flexible mechanism for managing finite samplings of continuous quantities, such as the way a satellite image samples earth locations
E) interactive execution controls for setting breakpoints and executing single steps in programs
F) a means to display any combination of data objects in a program.

Scientists at Wisconsin are beginning to use VIS-AD to help them develop algorithms for the GOES Pathfinder project. VIS-AD accesses image data and gridded data in McIDAS data files, so that it can easily be used to access data from the GOES archive and other sources at SSEC.

In order to demonstrate the flexibility of VIS-AD, we have applied it to an algorithm for discriminating clouds in GOES images using infrared and visible data. These image data may be displayed as pseudo-colored images, as two-dimensional contours of pixel values, as three-dimensional surfaces, as two- and three-dimensional scatter diagrams of infrared temperature versus visible brightness versus variance of temperature, and as other formats. These display formats are not hard-wired, but are defined by the user in a flexible language.

Numerical Modeling Applications

The University of Wisconsin Regional Atmospheric Modeling System (UW-RAMS) is being used as a prototype model to test the usefulness of VIS-5D to numerical simulation. The output infra-structure of the UW-RAMS model output was modified to write output of any variable or function within in a large menu of possible functions, to McIDAS grid format where it could be easily picked up by the VIS-5D software for immediate visualization of results. Model output formats for numerical model runs on non-McIDAS computers was also modified to create files which are easily converted to McIDAS files for VIS-5D applications.

As a result, essentially all numerical model runs are capable of being visualized routinely, and most, in fact, are. The visualization has become a primary tool for understanding complex dynamical systems. Problems encountered with the prototype visualization software are relayed to the Hibbard-Paul development group, where improvements are made. The visualization has used also for presentation graphics for publication, at conferences, seminars and even graduate student exams. Several examples of its use as an interactive model diagnostic tool and then as a presentation graphics tool are mentioned below.

As an interactive diagnostic tool, the VIS-5D has become a software of central importance. Both numerical studies of tropical cyclogenesis and polar low cyclogenesis used VIS-5D to investigate the details of scale interaction processes, by finding and defining the existence and movement and vertical trapping of outward and inward propagating spiral gravity wave bands, showing the development of a hurricane eye structure, the coexistence of microphysical quantities, the relationship between isentropic surface and momentum surfaces throughout the storm with regard to the existence of conditional symmetric stability, the development of the Ekman boundary layer and so on. Trajectory analysis has been useful in revealing major differences between the dynamical structure of the tropical cyclone at the tropical depression, storm and hurricane stages.

Numerical studies of large eddies in the boundary have used the VIS-5D to demonstrate the tendency toward organized bands in unlikely situations. The animation instills the viewer with a sense of how and why the organization must occur and on what it must depend.

Numerical studies of thunderstorm clouds with UW-RAMS have utilized VIS-5D to depict the updraft organization, existence and development of the mesocyclone and the role of the different microphysical components of the system. Numerical studies of downbursts by Dr. J. Anderson have also utilized VIS-5D to visualize downbursts simulated by an independent model.

The VIS-5D graphics have been employed as a tool for conveying the simulated dynamics to an informed audience at scientific conferences. Presentations of the visualized hurricane at the Miami National hurricane conference and the Atlanta Mesoscale conference were well received and enabled the speaker to demonstrate dynamical principles of scale interaction otherwise difficult to understand or explain. The visualized hurricane was also used in the classroom to explain hurricane dynamics to a senior level undergraduate class.

The visualized polar low simulation was presented at the Atlanta mesoscale conference to demonstrate the influence of inertial stability on CISK induced arctic cyclogenesis and was successful in driving home points which would have difficult to show with two-dimensional graphics. Several papers have been submitted or in preparation utilizing full color or gray shaded VIS-5D illustrations.

FOCUS OF CURRENT RESEARCH AND PLANS FOR NEXT YEAR:

Continued development and application of the VIS-AD system

Because of its ability to display user-defined data structures and because of its support for user-written algorithms accessing those data structures, VIS-AD is an extremely flexible tool for visualizing data and algorithms. It is the appropriate software context for most further work under this NASA sponsored exploration of technology. The development of VIS-AD replaces our earlier plans for continued development of VIS-GI and for providing interactive diagnostics as part of VIS-5D. The most immediate areas for continued development of VIS-AD include

A) labeling display axes with application values
B) labeling the current frame in an animation sequence with application values
C) supporting a variety of map projections
D) supporting satellite navigation and calibration
E) extending the library of intrinsic functions for image processing
F) implementing McIDAS commands as intrinsic functions
G) supporting user-written external functions written in C or Fortran
H) improving the efficiency of the language interpreter
I) providing a translator from the VIS-AD language to C.

We will also continue to support scientists at Wisconsin and at NASA who apply VIS-AD to their algorithm development problems, such as those developing product generation algorithms for GOES Pathfinder.

Further enhancements to VIS-5D

We will respond to scientists' needs to make VIS-5D more useful for exploring atmospheric simulation data sets. Some possible new features include

A) interactive retrieval of field values using the 3-D cursor
B) providing more flexible map projections in the 3-D box.

Plans for Modeling Applications

We plan to continue to utilize the Stellar GS-2000 as a primary modeling workstation and to utilize the visualization capability both for locally run model simulations and runs made on other machines. In this coming year, we will be simulating much more real data including an observed mid-latitude snow storm, the killer tornado of Plainfield, Illinois and several mesoscale convective complexes including one with a strong Derecho. We will also accelerate the tropical cyclone research to investigate external scale interactions with the surrounding circulations and again, VIS-5D will play a central role. In addition, we are beginning plans to develop an operational model of mesoscale weather for which there will be application of VIS-5D. Most likely, VIS-5D will be used as a presentation tool in many more conference papers and publications since we have learned to depend on its presentation power. Because the quality of the presentation and published presentation graphics is a permanent record of the VIS-5D product, we would strongly suggest that the development of VIS-5D should be continued to improve the appearance of the visualizations under these circumstances.

PUBLICATIONS:

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