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

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SIGNIFICANT ACCOMPLISHMENTS IN THE PAST YEAR:

Enhancements to VIS-5D

The VIS-5D (VISualization of 5-Dimensional data sets) system provides highly interactive visual exploration of large gridded data sets such as those produced by numerical simulations and volume scanning radars. VIS-5D can accomodate data sets containing up to 50 million grid points in a five-dimensional rectangle. For example, these 50 million points can be factored as 50 latitudes by 50 longitudes by 20 vertical levels by 100 time steps by 10 physical fields (pressure, temperature, specific humidity, U, V and W wind components, etc.). VIS-5D was written as a subsystem of McIDAS, and accesses data in McIDAS file formats, including 3-D grid files, map boundary files, and topography file.

Recent enhancements to VIS-5D include:

A) vertical cross sections that can be moved through a three-dimensional spatial volume interactively

B) an interactive three-dimensional cursor that can be used to retrieve earth or grid coordinates of depicted data

C) interactive placement of wind trajectories using the three-dimensional cursor, with trajectories calculated both forward and backward from a user specified space/time point.

Other enhancements are designed to support production of publication quality images, such as:

D) 2-D text labels which the user can place over the VIS-5D display, and which can be individually moved or deleted

E) the ability to select ribbons for depicting wind trajectories

F) the ability to select high-quality calculation of transparency and anti-aliasing.

VIS-5D is being used by scientists at UW-SSEC and at NASA/MSFC to view the output of their numerical simulations. Greg Triploi is using it to help develop a hurricane simulation running on the Stardent GS-2000, monitoring the simulation as it runs, diagnosing problems as they develop, and using the insight gained to modify and restart the simulation. VIS-5D is also distributed as freeware.

Development of the VIS-GI application

The VIS-GI (VISualization of Global Images) application has been developed around the MSU temperature anomaly data set produced by Roy Spencer and John Christy of NASA/MSFC. It stores the images in a compressed format, and decompresses them and remaps them in real time for animation. Thus it is able to store two channels of data over the 12 years from 1979 through 1990 in 5 day steps (876 total time steps) with global coverage at 2.5 degree resolution in about 22 megabytes of memory.

The global images are displayed in either a Mollwiede projection or mapped onto a sphere. The user can switch between these map projections, as well as enable/disable animation, enable/disable map boundary overlays, and select between channel 2 and channel 4 with immediate response. The images animate at up to 10 frames per second.

The application provides a color widget for interactively adjusting the false coloring of the two channels. The mouse may be used to control panning and continuous zooming of the Mollwiede projection, and rotation of the spherical globe. The mouse can also be used to select and drag a geographical point for calculation and display of a time series of image values. The time series display also serves as a context for mouse selection of animation bounds and current displayed time.

Design of the VIS-AD system

The VIS-AD (VISualization for Algorithm Development) system will give scientists the ability to interactively develop and modify algorithms for analysis and diagnostics of spatial data sets such as images and grids. In particular, the VIS-AD system will provide interactive visualization of internal data structures of the user's algorithms, interactive control of algorithm execution, and interactive modification of algorithms. Thus VIS-AD will function somewhat like an interactive debugger, but will provide visualization of data rather than simply printing numerical values. VIS-AD will access McIDAS data files, and will adapt VIS-5D as a basis for its displays.

We have completed a detailed design for the data type definition and data display functions of VIS-AD, and have begun implementing these functions. We have also developed preliminary designs for the algorithm modification and execution control functions of VIS-AD.

Whereas VIS-5D and VIS-GI are highly optimized for particular types of data sets, VIS-AD will provide a very general analysis and visualization tool, as well as a tool for interactive development of algorithms for processing images and other geometric data sets.

Numerical Modeling Applications

The University of Wisconsin -- Regional Atmospheric Modeling System (UW-RAMS) has been fully implemented on the Stardent GS-2000 VIS-5D workstation to both execute numerical simulations and then visualize results. This was accomplished by adopting the McIDAS format as a standardized model output and then building software so that the model users can design visualization to meet their needs. The output may consist of any number of the basic predicted variables or functions of those variables. The output software was also designed to build the McIDAS output stream from any specified spatial increment of any specified subgrid area of any of the model's nested grids. This provides the flexibility to output highly detailed data for short high resolution visualization sequences or longer less detailed sequences. Several scientific experiments have already been run on the Stardent GS-2000. These experiments include the numerical simulation of polar lows, tropical cyclones and the Kuwait fires. The tropical cyclone studies were the first to utilize VIS-5D as an interactive tool for model analysis with startling success. In fact, a visualization of the model simulation was presented to the 19th Conference on Hurricanes and Tropical Meteorology held on 6-10 May, 1991 in Miami Florida to show how vertically propagating internal gravity waves influence hurricane genesis. The comments from scientists at the conference were unanimous that the 5D visualization helped them see things they previously labored to imagine or else never even considered. Since it has been implemented for routine use with UW-RAMS, the VIS-5D software has grown to be a tool which we can no longer live without. The VIS-5D software has also been implemented by Prof. John Anderson (of SSEC) as a routine output from his group's numerical simulations of convective downbursts and by Dr. Robert Auney of CIMMS for visualization of synoptic scale 4D satellite data assimilation model.

FOCUS OF CURRENT RESEARCH AND PLANS FOR NEXT YEAR:

Further enhancements to VIS-5D

We will work with scientists to define useful new features for VIS-5D. Some possibilities include:

A) decrease the response time to user selection of new iso-level contour surfaces for depicting fields

B) interactive retrieval of field values using the 3-D cursor

C) render plane slices as psuedo-colored images rather than as contour lines, which would be useful for highly textured radar data

D) render satellite images onto surfaces in the 3-D box

E) render 3-D grids as transparent fogs, as faster workstations become available

F) provide more flexible map projections in the 3-D box

G) provide arithmetic, differential and integral operators on 3-D grids to compute interactive diagnostics
H) increase the size of data sets which VIS-5D can address, though the development of a distributed VIS-5D which can directly access data stored on a supercomputer

Generalize and enhance the VIS-GI application

We will generalize VIS-GI so that it may be applied to climate data sets produced by scientists at MSFC and other institutions. We will also work with scientists to define interactive statistical capabilities for VIS-GI, such as:
A) the ability to select a geographic region and integrate values over the region
B) the ability to correlate values from different points and regions.

Implement the VIS-AD system

We will implement an initial version of the VIS-AD system, including data type definition, data display, interactive algorithm modification, and execution control.

Because of its ability to display arbitrary data types and its support for interactive modification of the algorithms which compute those data types, VIS-AD promises to be an extremely flexible visualization tool. Thus VIS-AD will give us a very quick way to implement many of the enhancements which we may define for systems like VIS-5D and VIS-GI.

VIS-AD is possible because of the constant increase in performance of workstations. However, we will work to optimize the efficiency of the VIS-AD data type definition and data display functions, and begin work toward an implementation suitable for massively parallel architectures.

Plans for Modeling Applications

As we gain experience using VIS-5D as the primary analysis tool, we expect to learn more of what will be needed to improve the VIS-5D software for use as presentation graphics and as an interactive analysis tool. One such improvement will be to enable the VIS-5D program to use high resolution topography of model simulations. The implementation of VIS-AD will enable us to restrict VIS-5D output to primitive variables while derived quantities are calculated on the fly by VIS-5D. These derived quantities will include all of the individual tendency terms important to the evolution of the simulation. Animated sequences of physical processes will provide new insights into the relationship between individual processes and storm evolutions and will doubtlessly power a revolution in the understanding of phenomena ranging from dynamic scale interaction to the formation of hail in thunderstorms.

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