A DYNAMIC VISUAL DATA INSPECTION TOOL

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ABSTRACT

This paper presents a dynamic visual Data Inspection Tool called the DIT. The DIT provides an effective method to visually analyze gridded, multidimensional data and exploit the information contained within them. The DIT has targeted modeled or simulated data fields as the first step in exploring multidimensional data. Modeled or simulated data is typically generated from large complex programs or numerical models that generate weather predictions or other similar analyses. The modeled data often has multiple parameters in the output field, like wind speed, temperature, relative humidity, etc. The Data Inspection Tool tackles how to understand the information contained in the gridded geospatially referenced output from these complex programs in order to make them useful to analysts.

1. INTRODUCTION

Visualizing information is a powerful method of exploiting large gridded data sets that contain multiple variables with spatial and temporal properties. The *Data Inspection Tool (DIT)™* will demonstrate techniques to overcome some of the traditional problems associated with understanding large modeled data sets. Three aspects of the data analysis problem must be understood before the information contained in the data can be useful: 1) the location of the data is critical for geospatial problems, 2) the information within the modeled gridded field must be easily accessible and 3) the time dimension of the problem must be presented in context. Many of the current tools for manipulating modeled data tend to address only one or two of these three key aspects. This poses a dilemma for analysts who must figure out ways to try and comprehend the full complement of information contained within the modeled output. This is particularly true for large temporal-based data sets which show change over time, like the dispersion of a plume for example. The *DIT* attempts to address all three issues.

The *DIT* leverages the *EDGE™* [1] visualization environment. *EDGE™* is a visualization engine that allows the fusion of disparate data types to produce the most realistic and contextual view of the data possible. With the *EDGE™* visual environment, a host of data types and sources can be brought together to generate a contextual view of the situation. The data types include ground imagery, weather imagery, maps, digital elevation models (DEM), gridded data fields, text based data, annotations, etc. By combining the data sets, *EDGE™* can create real world views of the data in as detailed a geospatial context as the data will allow. Figure 1 shows an example visualization created in *EDGE™* using Landsat satellite imagery, a digital terrain elevation model, and weather satellite imagery to generate the clouds in the sky. The *EDGE™* environment also has a clock where the user can control the time step and the time interval over which the data can be animated. The power of the visualization environment combined with analytical data reachback functions for modeled data fields was designed to help solve the three previously mentioned issues.
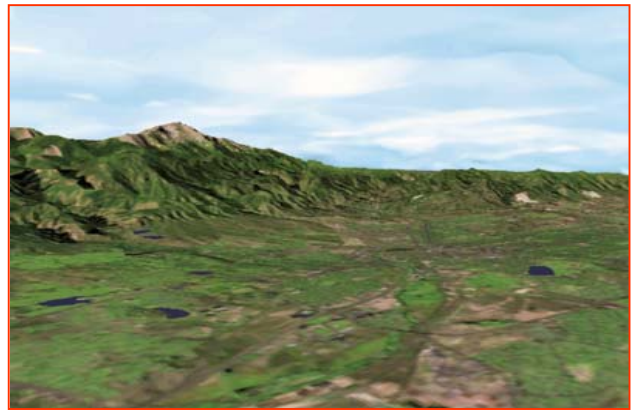
Figure 1. An example of data fusion using the EDGE™ visual environment.

A dynamic visual data inspection tool, the *DIT*, was added to the *EDGE™* environment. The combination of the *DIT* with the highly visual display environment will be the centerpiece of the remaining discussion. The *DIT* functions were designed to reduce complex tasks to a few keystrokes and mouse clicks. The desire to attain both flexible, analytical functionality and minimal interactions to accomplish the functions were often diametrically opposed. However, a balance between functionality and

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[1] Trademark of Boeing Autometric

user interaction was achieved that tends to reduce the number of keyboard and mouse manipulations.

2. RELATED WORK

Other researchers have developed approaches that provide users with intuitive graphical-interfaces to large databases [5][7]. The University of Wisconsin developed the VIS5D/VISAD tools to analyze gridded data fields 'in a box'. A similar commercial tool is the Environmental Work Bench™. [2] While these tools provide sophisticated analyses of gridded data, the data fusion capabilities are currently limited. Interactive environments for data exploration and direct database manipulation have also been investigated. [1][5][10][12] However, the projects tend to target a particular data type or structure which also limits overall capabilities. Other investigations tend to focus on a specific implementation approach which results in the tools working well in particular scenarios. [2][3][6][7] The purpose of this investigation was to generalize the tool set. This tends to make the tool interoperable with other user applications by simply adding data converters to modify the form of the data to one accepted by the EDGE environment.

Previous work in multi-resolution data fusion [4][8], time-dependent visualization [4][8][9], and concept exploration for scientific data analysis [11][13][14] led to the data inspection concept. The basic idea was to allow users to 1) apply data analysis functions, 2) attain data reachback, 3) show graphs for non-literal components, and 4) display temporal visualization while visually integrating the information into a contextual 2D or 3D scene.

3. *DATA INSPECTION TOOL (DIT)*

The *DIT* was designed looking forward to other user applications that could leverage the basic capability of the underlying architecture. Consequently, the initial *DIT* design encompassed several basic components. The components include the ability (1) to extract data from three-dimensional and time sequenced gridded data fields (data reachback), (2) to display the spatial and time histories of the data in graphs, (3) to associate the data with objects in the viewed scene (4) to animate the

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[2] Environmental Work Bench is a trademarked product of SSESCO, Inc.

information over time at the users discretion and (5) to use the extracted information in associated applications,. Using these capabilities, users will more efficiently visualize and understand complex data. A short explanation of each basic feature follows.

3.1 Data Reachback Interface

The data reachback interface allows users to access the information along slant path or vertical profiles over selected locations. The path profiles require that start and end points of the paths be determined based on the user application. The *DIT* extraction algorithm computes the nearest grid points along the path between two locations or the nearest point for a location specified by the 3D cursor. Most of the data reachback is accomplished without direct user intervention. The reachback is simply accomplished based on the type of interaction specified by the user from the display. Once information is extracted from the underlying gridded fields, users typically want to peruse the data. Graphical displays work as traditional data exploration tools to assist user in understanding the data
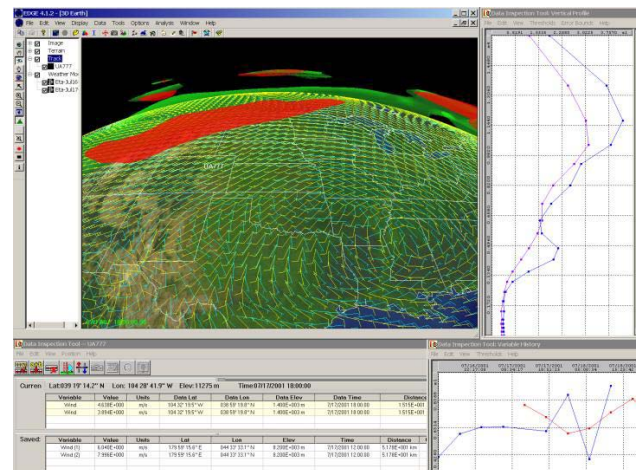

Figure 2. Shows a gridded weather model in the viewer window with the jet stream core (red) and the wind vectors (green). The graphs display a comparison of the vertical temperature profiles for the same location from two distinct model forecasts (top) and the comparison of a single location within both models over time (bottom). Note, the models were from successive forecasts and the second model (red line) starts at a later time than the first model (blue line).

Most gridded fields contain multiple variables. For example, a typical weather forecast field may contain the temperature, relative humidity, wind speed/direction, pressure, etc. at every point in the grid. Users may

specify only the variables of interest for use. This reduces access time and helps improve the *DIT*'s performance.

Due to the number of variables in the data sets, visual clutter can result. In the first version of the *DIT*, visual clutter is controlled by the user. However, the EDGE™ environment provides methods of assisting the user in controlling clutter. For example, visual objects that represent the data set (isosurfaces, vectors, contours, etc.) may be toggled on/off individually to allow the user to rapidly view the information visually. The visual 'objects' representing the data provide maximum clarity and understanding when coupled with the graphing capabilities of the *DIT*. Both the visual 'objects' and the graphs correspond spatially and temporally to help the user analyze the situation. To assist with specific analysis, the DIT can be associated with geospatial objects like a cursor or path object.

3.2 Association with Geospatial Objects

Users may specify the data reachback in one of several implicit modes. The three modes are the cursor mode, the attached object mode, and the path mode. In the cursor mode, a 3D cursor can be manually moved around the display. The extracted data for the cursor position can be shown in a table or graph by variable, time and location.

The cursor mode may show the data only for the specified location of the cursor or the user may choose to display an entire vertical profile at the cursor location. In the attached object mode, a 3D cursor is essentially attached to an object in the display. An object may be the position of an aircraft, ship, or other moving or stationary object for example. All the 3D cursor functionality carries over to the attached object mode. In the path mode, users may be interested in unique geometrical views between two points. In this mode, the data is extracted along the slant path specified by the user. A typical application of the slant path mode would be to determine whether a satellite can see a particular location on the ground given the latest weather forecast field for example. (See section 3.5) This application would assist with cloudfree imagery collection for example.

3.3 Multiple Interactive Graphs

Once users have selected the modes of operation and the variables (Section 3.1 and 3.2), the data can be displayed in graphs or passed to other applications. Since multiple variables may be selected from the data, users may determine whether the variables are drawn in the same graph or different graphs. Figure 2 shows two

graphs. Each contains only one variable; the top graph shows a vertical temperature profile and the bottom graph shows the concentration of a substance released into the atmosphere over time for a particular location (latitude, longitude, and altitude). Users may accept the default scaling of the graphs or choose their own. To the right of the graphs, users may view the actual values contained in from the gridded field by viewing the text output of the graphed values.

3.4 Time Varying Visualization

The time dimension often presents problems when performing analytical tasks. However, for the *DIT*, time is a straight-forward application of the tool. Users simply set the clock and time step in the EDGE™ environment to access the data at the desired time step.
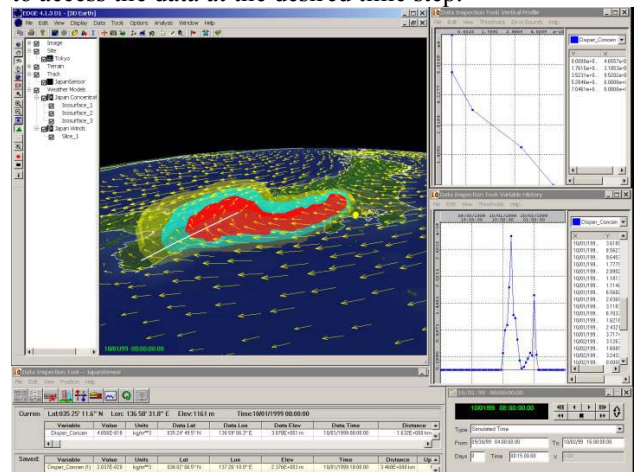
Figure 3. Shows a time varying plume simulation with three concentration thresholds denoted by the red, yellow and blue colors. The two graphs on the right show a temperature profile through the plume (top) and the change in concentration over time (bottom) at a selected location. As the display animates through time, the graphs update automatically.

The graphs discussed will automatically update as the clock time changes. When the *DIT* is attached to the flight track of an aircraft, for example, users can see the vertical temperature or moisture profile change with time and position. This feature is one of the most unique in the tool. An extension to this capability requires the export of the data to applications other than graphs.

3.5 Combining Data Exploration with Applications

Viewing the data extracted from specific locations over time is essential to achieving a basic understanding of the information contained in the gridded field. However, how this data affects user applications is, in

most instances, the real problem to be tackled. The *DIT* was designed to help determine how the user is impacted by the data (gridded forecast field). For example, how does the forecast weather impact the collection of imagery over a particular area?

The *DIT* was extended to operate with a set of atmospheric attenuation algorithms and may be called an imagery collection application. The areas of interest for the imagery collection were identified in the *EDGE™* environment as fixed sites (cities). A sensor was attached to the flight track; the sensor was attached to the *DIT*. As the aircraft or satellite track was flown over time, lines were drawn between the collection vehicles (aircraft) and the areas of interest. The geometry of the view to each area of interest was determined over time by the vehicle's position relative to the area of interest. The atmospheric data along the required slant path to the area of interest was extracted by the *DIT*. The imagery collection application used the *DIT* collected information to determine the likelihood an area of interest was visible based on the forecast weather. Based on the calculated likelihoods, colored lines were drawn between the areas of interest and the collection vehicle. The user could then ascertain whether a particular collection profile would meet the user's needs.

The imagery collection application was the first application to be built on top of the *DIT* architecture. It performed exceptionally well. Other potential applications include flight planning, fuel consumption, and emergency management. The extension of the *DIT* to other applications will also improve the overall functionality contained within the *DIT*.
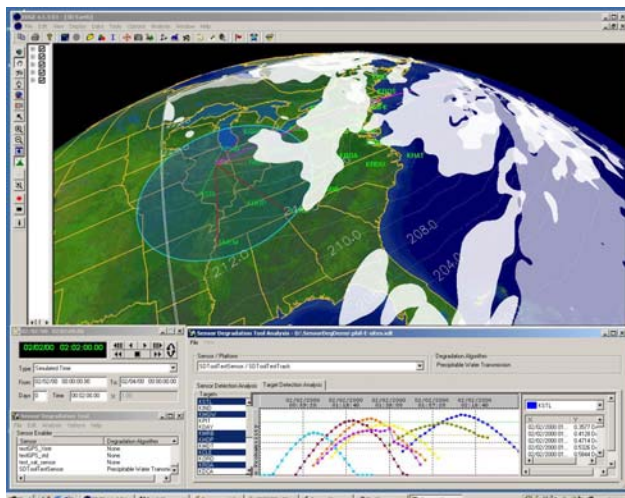
Figure 4. Displays an aircraft with its field of view (transparent blue region) and a gridded forecast weather field. Detection lines are draw in red to cities

of interest. Clouds (white) were determined based on areas of 90 percent relative humidity in the gridded forecast field. The lower right graph shows the probability of detection of different areas of interest (AOI). Each AOI's detection probability graph is shown in a different color.

4. CONCLUSION

The *DIT* has enhanced the *EDGE™* visualization environment by allowing the direct analysis of gridded data fields generated from models or simulations. In addition, the *DIT* foundation can be used to support a wide range of applications. The *DIT* features include:

a) *Data reachback interface*: This interface allows users to assign the mode of data extraction and pass that information to other applications.

b) *Multiple interactive graphs*: The graphs allow data discover and exploration of the information contained within the gridded data fields. Text output of the graph content allow users to view precise values.

c) *Association with geospatial objects*: Users can associate the *DIT* with objects within the visualization. These objects may represent aircraft, trucks, satellites, ships, or stationary locations. This is important because users can associate displayed objects with the impacts derived from the gridded fields. For example, an aircraft may use more fuel because it encountered stronger head winds.

d) *Time varying visualization*: Applications that rely on changes over time require the ability to view and understand the data or its impacts over time. The *DIT* provides for temporal information display to help improve user understanding.

e) *Combining data exploration with applications*: The *DIT* architecture can be used as the foundation to build other applications. The imagery collection application was the first such application built using the DIT foundation and has proven the basic architecture is sound for the intended purpose.

6. FUTURE WORK

The *Data Inspection Tool (DIT)* will be improved to support many new applications. Some of the new applications include its use for air traffic management,

emergency management, transportation planning, agricultural planning, and energy management.

Improvements in some of the GUIs will significantly reduce the set-up time and the number of 'mouse clicks' to use the *DIT*. However, the first generation *DIT* tool has successfully demonstrated that it can be used for information mining and application assessment while viewing the data in 3D contextual scenes.

ACKNOWLEDGEMENTS

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