P1.7 *INSPECT: A NEW TOOL FOR EMERGENCY AND CONSEQUENCE MANAGEMENT*

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ABSTRACT

This paper presents a new tool researched to assist users in rapidly assessing potential (pre-event) and actual (post event) damages from environmental related circumstances. This investigation led to the formulation of interactive analysis by tying disparate data sources together through a lens and filter paradigm. In the preliminary development, a relational database, a gridded model, and an abstract analysis tool (graphs) were connected through a highly visual interactive interface to minimize text entry and decrease the time to achieve situational analysis. Unique features, like dynamic lenses, were developed to capture the time dependent characteristics of the situation. The investigation results and the application of INSPECT to a notional flood modeling example are discussed. The same approach can be applied to many other environmental situations like plume or hazardous material dispersion.

1. INTRODUCTION

Information visualization is a key component in exploiting large gridded or text-based data sets that contain multiple variables or tables with spatial and temporal properties. The INSPECT tool will demonstrate techniques to overcome some of the traditional problems associated with understanding large modeled and text-based data sets. A key goal of this research was to focus on visual techniques combined with generalized operations to help users grasp difficult concepts and relationships more quickly and efficiently. A flood scenario provides an excellent example of challenges in satisfying this goal. Visualization may accurately show the flood extent when overlaid on ground imagery of the region of interest but what about timing, damage assessment, etc.? Color-coding the surface of the water by depth may help users visually understand both the extent of the flood and derive notions about areas of maximum damage based on flood depth. While impressive, this type visualization alone is not directly useful in quantifying the impacts of the flood. Also, the current tools for manipulating data tend to address only one or two of several key aspects of visualization. INSPECT attempts to leverage many visual cues and functions to help solve the stated goal. Some traditional visual features used by INSPECT are colorization, animation, and a variety of analysis functions to assist in problem quantification such as iso-surfaces, slices, contours or other visually graphic analyses. The dilemma for analysts who must figure out ways to try and comprehend the full complement of information contained within the data is how to extract the knowledge needed for decisions from the data sets and portray it effectively. This is particularly true for large text-based or gridded data sets which change over time, like the dispersion of a plume or a flood's height and extent, for example.

To improve the ability to assess and quantify the impacts of modeled or post analyzed data, INSPECT combined the ability to visually query a relational database and to graph the database tables; thereby providing an avenue for the rapid quantification of the flood event using two disparate data sets (a flood model and a relational database). Since the tool design emphasized visual interaction, the text-based relational data is converted into graphs, icons, and other symbols of the users choosing based on data characteristics. The user's ability to visually query and retrieve information while minimizing text manipulations was accomplished using a lens-filter paradigm. The lenses and filters provide the basic tool set for data discovery and exploration.

INSPECT leverages the *EDGE*™ [1] visualization environment. The *EDGE*™ visualization engine fuses disparate data types to produce the most realistic and contextual view of the information possible. A large number of data types and sources can be brought together to generate a contextual view of the situation in this visual environment. The data include ground imagery, weather imagery, maps, digital elevation models (DEM), gridded data fields, text based data,

[1] Trademark of Boeing Autometric

annotations, etc. By combining the data sets, *EDGE™* can create real world views of the data in a detailed geospatial context. 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 has a universal clock. This allows the user to 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 functions of INSPECT allows users to rapidly perform data reduction, data exploration, and attain high levels of understanding through the visually rich real world context of the display.

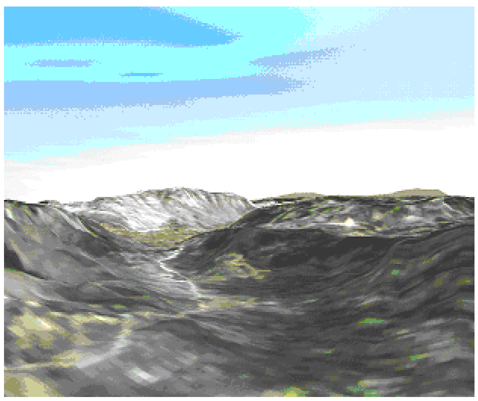

Figure 1. An example of data fusion using the EDGE™ visual environment. All data in this scene is derived from actual data: Ground (Landsat imagery and digital terrain elevation model) and clouds (DMSP imagery)

INSPECT was developed on top of the *EDGE*™ visualization and analysis environment. The integration of INSPECT functions with the highly visual display environment will be the centerpiece of the remaining discussion. The *INSPECT* functions were designed to accomplish complex tasks using highly visual user interactions. The desire to attain flexible and analytical capability, while minimizing textual interactions to accomplish the desired functions, were often diametrically opposed. However, a balance between functionality and user interaction was achieved that tends to reduce the number of keyboard and mouse manipulations, yet provide significant and rapid improvements in the analysis of disparate data sets.

2. RELATED WORK

Research has been conducted in visual interfaces, human-machine interfaces, database query and abstraction, knowledge extraction and a number of related topics. However, the connectivity and smooth transition required for using the various applications together is still beyond state-of-the-art analysis tools. A goal of this work was to research the integration of interoperable actions between disparate technologies to produce a prototype operational system. Many government offices have made this type integration a high priority requirement to help solve operational problems.

Graphical interfaces for large databases and modeled output have been developed by other researchers using differing approaches. The University of Wisconsin developed the VIS5D/VISAD tools to analyze gridded data fields ‘in a box’. Environmental Work Bench™[2] is a similar commercial analysis tool. These tools provide sophisticated analyses of gridded data. However, the data fusion capabilities are currently limited. INSPECT attempts to perform more complex and sophisticated analyses while using some of the same capabilities.

Interactive data exploration and direct database manipulation have also been investigated. These projects target particular data types or structures which limit their general application. Other investigations focus on specific implementations resulting in tools for specific applications. This investigation focused on generalizing a tool set to make it interoperable with many user applications for a variety of posed problems. The following discussion touches upon some capabilities inherent in the INSPECT approach to integrate disparate data sets while providing functions for data exploration and knowledge extraction.

3. *INSPECT*

The underlying research objective was to develop analysis techniques to assist in making decisions more rapidly and effectively through the use of disparate data types and application fusion. To support this concept, gridded model output (like weather forecasts, flood extent, etc.) was combined with relational database information (text data), a visual fusion engine (EDGE™), and a method of showing abstract data (graphs). The combination of these features was deemed sufficient to demonstrate our overall integrated strategy and concept while providing sufficient complexity to test the underlying research architecture.

3.1 Lenses and Filters

To provide reduced user interaction and increased visual reference required the adoption of a new

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

paradigm for our research team. A lens and filter paradigm was selected after a literature review of likely candidate approaches. With the EDGE™ visualization environment as the 'viewer', a key visual objective was satisfied: users must see and interpret the data in 'real world' context. On top of this visual display, lenses and filters were created. Lenses basically represent the 'regions of interest' or the geographic boundaries within which the user desires answers. Filters are constraints on the users problems and may be thought of as criteria for database queries. An example might be a user who wants to show all the power plants within a lens (region of interest) or show all the homes of people between the ages of 20 and 35. Typically, any database query that can be accomplished using SQL can be accomplished within this system with reduced user textual interaction and simple visual actions. This is particularly true since the user does not have learn SQL or any other query language to pose and implement the desired constraints. The queries are generated without requiring user knowledge of a query language like SQL.

The filters (constraints) on the user's problem are built, named, and saved in libraries for re-use on other projects. The filters can be combined using logical functions to generate more complex queries. For example, a filter to show all the people's homes whose owners are between the ages of 35 and 45 could be combined with a filter that queries all the people who work in the power industry. Using 'AND' logic, the filters can be combined to arrive at a result that displays homes for the combined query of people between the ages or 35 and 45 who also work in the power industry.

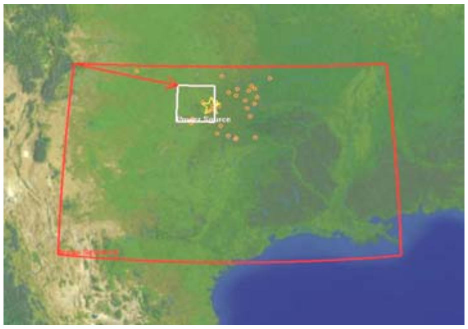

Figure 2. Shows an example of a lens and filter. The pink (smaller) lens shows power plants represented by the stars and the red lens (larger) shows homes lighted by the power plants. The arrow between the lenses shows the relationship dependency between the lenses.

The approach of combining lenses and filters visually was a key ingredient in achieving high visual interaction. In addition, lenses and filters provide users a method of capturing the domain expertise, tacit knowledge, and novel methodologies that may be developed by creative users since they can be named, saved and re-used on other data sets. Users can also exchange lenses and filters with coworkers to speed task accomplishment.

Lenses are created by the user and may be irregularly shaped. In addition, users can take advantage of vector type data, like Shapefiles, to create regions of interest (lenses). The basic concept of the lens was also extended to include three different types of lenses: static, movable and dynamic. Static lenses are regions of interest that do not move; some examples are state and county boundaries. Movable lenses may be irregularly shaped and can be moved in the viewer to a new location where the lens and filter combination is automatically applied to the data at that geographic location. Dynamic lenses were created to tackle more complex problems that change over time, like the geographical extent of a flood. Dynamic lenses have been coupled directly to gridded model output to demonstrate how lenses, relational databases and gridded models can be used together more effectively. Section 3.5 will describe this capability in more detail.

3.2 Geospatial Object Association

For a visualization to be effective, users need to associate the information displayed with common or familiar visual references that having meaning to them. Consequently, the user is allowed to associate the results of the queried filters with whatever symbols and icons they desire in the colors they choose. This provides an intuitive connection between the display and data associations in the users mind. To enhance the ability to discern relationships in the data, an extension to the lens-filter concept was developed. This extension allowed lenses to work together. For example, one lens could show all the power plants in the region of interest and a second lens would show all the homes lighted by those power plants in the region of the second lens. Since there is a clear relationship between the power plants and the lighted homes, an arrow pointing from the dependent lens (the homes) to the independent lens (the power plants) helps the user understand the relationship and its directionality. Figure 2 shows two lenses with such a dependency.

3.3 Interactive Graphs

Some relationships may not be geographical in nature and the lens dependency would not work for those situations. To support more abstract relationships, graphs were added to the lens-filter paradigm. The lens still functions as the boundary for the region of interest for the graphs. The filters (constraints) on the graphs are determined in a very similar manner to the previously mentioned lens filters. Once the information is graphed, users can see relationships in the data for the lens region. For this work, three types of graphs were allowed: bar charts, pie charts, and scatter diagrams. The graphs are interactive and tied to the query functions and filters. Users may plot the histogram of the number of each type of business in the lens region from a table in the relational database. Once graphed, the user may decide he's only interested in the automotive related businesses. Users can then pick on the bars of the histogram and re-query only the items selected from the bars of the graph. For scatter plots, users would pick individual points or drag a region of points that would narrow the query focus based on the graphed relationship, a cluster of points for example. In this way, tedious and time-consuming text queries are replaced with simple point and click functions allowing users to make rapid assessments of the relationships they discern in the data.

3.4 TIME VARYING VISUALIZATION

Time is a difficult concept to capture when analyzing data. Animation of the modeled field is a standard technique employed to help users capture the time domain. An example would be showing how the weather forecast changes with time. However, this technique is not directly applicable to discerning patterns of telephone calls or credit card transactions. To help identify patterns in these data types, the lens was modified to allow time controlled presentation of relational database information. Lenses can display data over time and help users identify patterns of movement, the types of purchases made, and the value of transactions performed. Due to a unique icon color colorization technique, users can also identify whether particular transactions occurred prior or after some event. This presentation allows users to extract knowledge that could be very difficult to grasp without the additional features.

3.5 NEW APPLICATIONS PROCESSES AND METHODS

A tool like INSPECT may change how future systems are designed and operated. INSPECT can and does operate in a distributed environment. This opens up many possibilities for interagency collaboration and sharing of data sets. The interoperable functions also increase the flexibility in solving problems using disparate data sets and information sources.

To demonstrate how INSPECT technology could be used to solve difficult analyses more efficiently and quickly, a flood impact scenario will be discussed. The flood impact scenario is simulated with fictional data placed in tables of the relational database. The basic problem was to rapidly assess the impact to property values and people given the river was going to flood. For this example, a simulated run of the NOAA Flood Wave (FLDWAV) model provided the assessment of flood height. The flood extent and depth were calculated based on digital terrain elevation model (DTED®) data and flood intersection algorithms developed for previous research applications (Hoffert, et al, 2002).

Figure 3 shows the boundary of the flood extent. The color-coded water surface showing the water depth has been turned off to allow readers to easily see the flood extent relative to the buildings and other structural features shown in the underlying reference imagery of Chattanooga, Tennessee. The first frame in the image is early in the flood simulation. The region of interest is the flood extent zone and is the lens in this example. The filter or query attached to the lens shows flooded properties by icon and name. The graph to the right of the first frame interactively updates as the dynamic lens representing the flood boundary changes over time. In the example shown, the property values are accumulated with time. The graph rescales at each time step since the magnitude of each subsequent lens query is not known in advance when performing this type data exploration. Each subsequent frame shows increasing property damage and increasing dollar values of the damage. The information about the properties, the number of people who live or work at that location and the values of property are contained in the relational database. A single integrated clock with user controlled time step allows users to easily navigate this complex problem.

If a similar flood problem were posed to analysts and someone asked them to figure out the damage for a flood event, it would require the compilation of at least two relational data bases, model output runs completely independent of the ancillary data needed to solve the problem, and tedious estimates of damage based on crude magnitudes for property values and people impacted. It would also likely require several analysts in different agencies working in collaboration to arrive at a conclusion in a rather lengthy period of

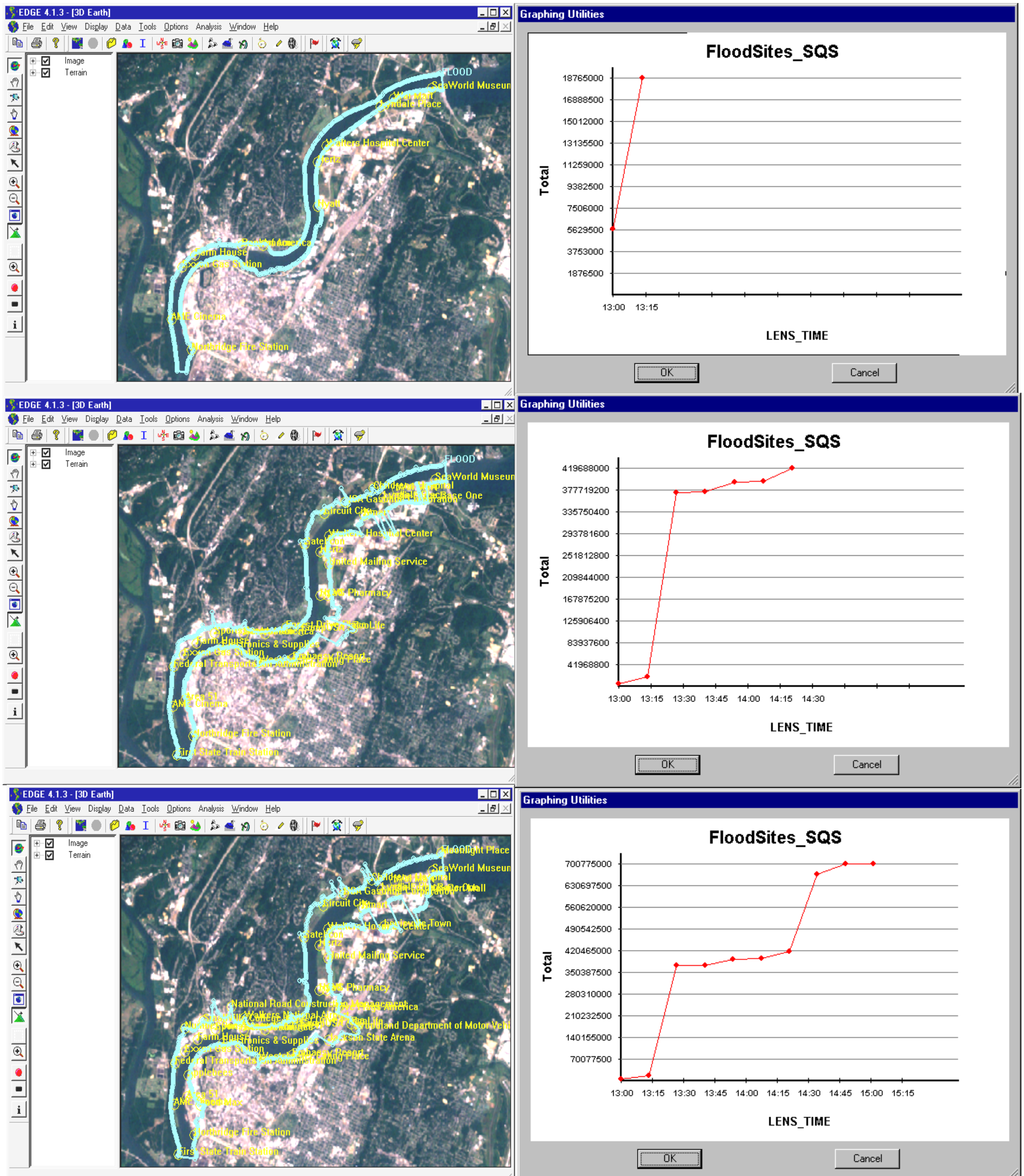

Figure 3. Shows three frames out of eleven generated to represent the flood scenario. The top scene and graph is early in the flood and the next two scenes and graphs are later times during the flood event. The blue region in the images is the dynamic lens boundary shown over the Chattanooga region. The graphs on the right show accumulated property value damages. Icons and labels in yellow show flooded property locations and names.

time. With an integrated and interoperable tool like INSPECT that can work in a distributed environment, this same problem could be solved by a single analyst accessing data from several sources in a significantly reduced period of time. At the same time, visual products can be generated for distribution to emergency crews and warning the general public.

An integrated tool like INSPECT appears to be a step in the right direction for solving difficult problems that require the coupling of disparate resources in a distributed environment. However, the coupling of disparate data sources is not sufficient by itself to achieve major analytical improvements. It also requires interactivity between the disparate information sources using generalized functions and tools. The interactive operation of the various generalized functions is essential to complete the analysis of this scenario in a more efficient and timely fashion. The use of the lens and filterparadigm also adds benefits in terms of capturing analyst tacit knowledge, domain expertise, and user insights that can be applied to future problems through the ability to save and re-use the lenses and filters for other related problems.

4. CONCLUSION

INSPECT enhanced the *EDGE™* visualization environment by allowing the direct analysis of gridded data fields generated from models or simulations, relational databases, and relationship assessment functions like the interactive graphs. In addition, the INSPECT foundation can support a wide range of applications due to the nature of the functions and operations that have been generalized to work across disparate data sets. The *INSPECT* features include:

a) ***Lenses and filters***: This interface allows users to assign the mode of data extraction and visually portray the appropriate relationships in a real world context or an abstract framework.

b) ***Interactive graphs***: The graphs provide a level of abstraction for data discovery and exploration. The graphs can operate alone or interactively with the database query/filter functions and the modeled data.

c) ***Geospatial object associations***: Users can establish their own icons and visual representations of the information to help them rapidly assimilate and understand the information portrayed in the visual displays.

d) ***Time varying visualization***: Time is a difficult concept to capture and use to quantify impacts assessments. While this research demonstrated the value of the tried and true animation technique, it was extended to include abstract representations for problems like credit card transactions and other dynamic relationships.

e) ***New applications processes:*** The flood example was a first step in demonstrating how disparate data sets, interoperable generalized functions, relational databases, simulation and modeling, and a highly visual real world display paradigm can significantly improve the efficiency of analyzing complex problem sets. Using the INSPECT tool to perform the analysis dramatically changes the user focus from how to get the information required to how to approach and solve the posed problem.

5. FUTURE WORK

INSPECT will be improved with additional features to support a broad array or new applications that might include its use for air traffic management, emergency management, transportation planning, agricultural planning, and energy management.

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

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