A Three Pronged Approach for Improved Data Understanding: 3-D Visualization, Use of Gaming Techniques, and Intelligent Advisory Agents

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ABSTRACT

Applications of multi-sensor fusion span a variety of domains from crisis management, military tactical situation and treat assessment, environmental monitoring, and more recently, monitoring of information systems. Rapid advances in data collection and dissemination provide the opportunity for major improvements in the information gathering aspect. However, a fundamental paradox exists in the understanding side. The paradox is that information analysts are drowning in a sea of data but unable to obtain the knowledge that they need to address difficult problems. This has often been referred to as the data overload dilemma or more recently framed "cogmenutia fragmentosa". On one hand, an unprecedented capability exists to collect data via distributed sensors, commercial information providers, human sources, or Internet resources. Smart micro-scale sensors, wireless communications, and global Internet accessible resources enable the entire earth to be a potential information resource. Such information is available literally at the fingertips of the analysts. However, the wealth of data has not produced a commensurate improvement in analyst abilities. Analysts are literally swamped with data. They have a wide variety of choices to make as to what is useful and usable, given the context of what they are trying to understand.

This paper describes a three-pronged approach to improve information understanding including; (1) use of 3-D visualization and interaction techniques, (2) role-playing gaming (RPG) concepts, and (3) use of team-based intelligent advisory agents (cyber-advisors). The environment promotes rapid development and evaluation of hypotheses regarding evolving complex situations in an environment in which enormous amounts of data and information are available, but for which there is no clear mapping between observables and underlying threat conditions or activities. Use of advanced visualization techniques and gaming concepts assist in focusing the analysts' attention and promotes an interactive, creative analysis process in which hypotheses are formulated, evaluated, criticized, modified, and changed. The use of gaming techniques leverages the skills of new analysts, already experienced in gaming technologies.

Comments are made concerning the application of this approach to understanding network information.

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1.0 INTRODUCTION

At the Pennsylvania State University, we are developing techniques to enable analysts to perform their jobs faster and more accurately as both individuals and as members of an analyst team. Our concept, illustrated in Figure 1, involves three major innovations:

(1) A 3-dimension, full-immersion environment with new displays and multi-sensory interaction, using concepts such as *deliberate synesthesia,* will enhance the ability for analysts to understand an evolving situation and to extract patterns in complex, large data sets;

(2) An engaging gaming environment, modeled after role-playing games (RPGs), will allow analysts to alternate between a strategy-based game interface (a macro decision-maker who plays a "god-like" role to assimilate data and develop hypotheses) and an RPG interface (a micro decision-maker who interacts with characters who will tell him/her stories which assist in the quest to determine the accuracy of evolving hypotheses and to create an interpretation of a situation or threat); and

(3) A virtual cyber-advisory team will provide expert advice in specialized domains, seek fallacies in evolving hypotheses or interpretations, bring forward historical case information, and occasionally act as "curmudgeons" who seek to question the arguments developed by an analyst. The advisory team will be modeled using team-based intelligent agents based on the recognition-primed decision (RPD) cognitive model.

These concepts are being developed and tested in a living laboratory environment to determine the effectiveness of the tools and cognitive aids.

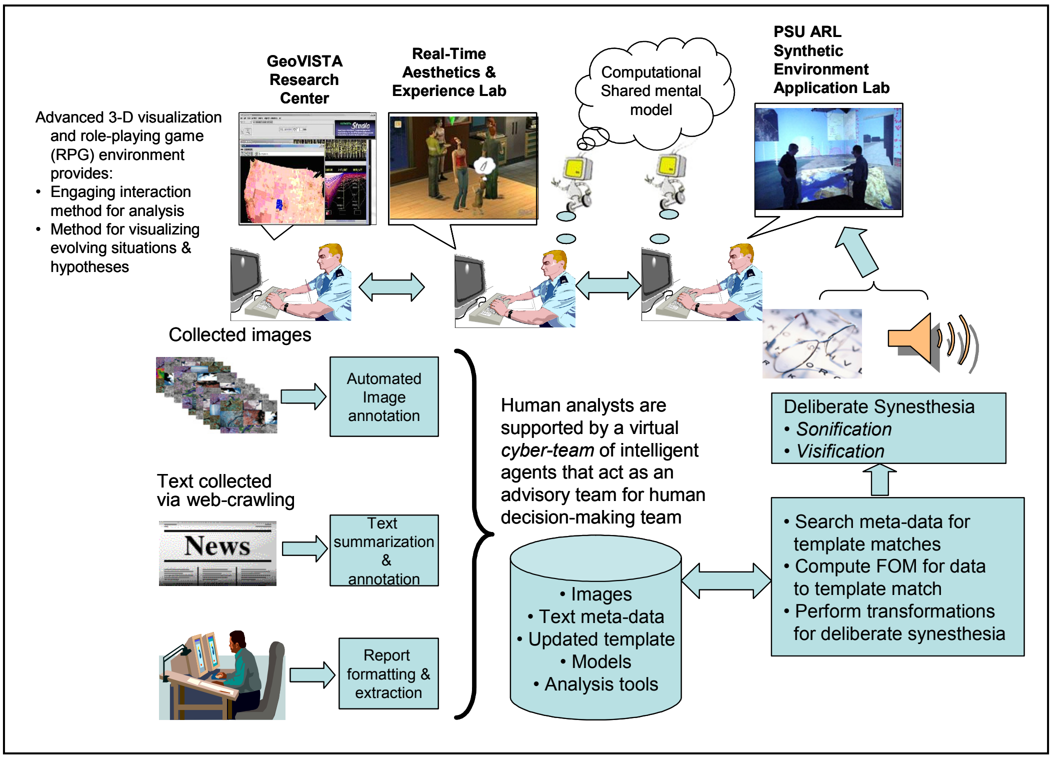

Figure 1: Concept of an analysis environment allowing analysts to use advanced 3-D, RPG gaming environment and a cyber-support team

2.0 MOTIVATION AND PROBLEM FOCUS

The specific problem we are addressing involves how to address the increasing "glut" of data provided to analysts, resulting in analysts "thirsting for knowledge" while "drowning in a sea of data". In particular, we seek visualization techniques, environments, and cognitive aids to cross the longest yard – transforming data from a network centric collection/fusion system (as data rapidly accrues in an evolving situation data base into actionable knowledge inside an analyst's head (Figure 2)).

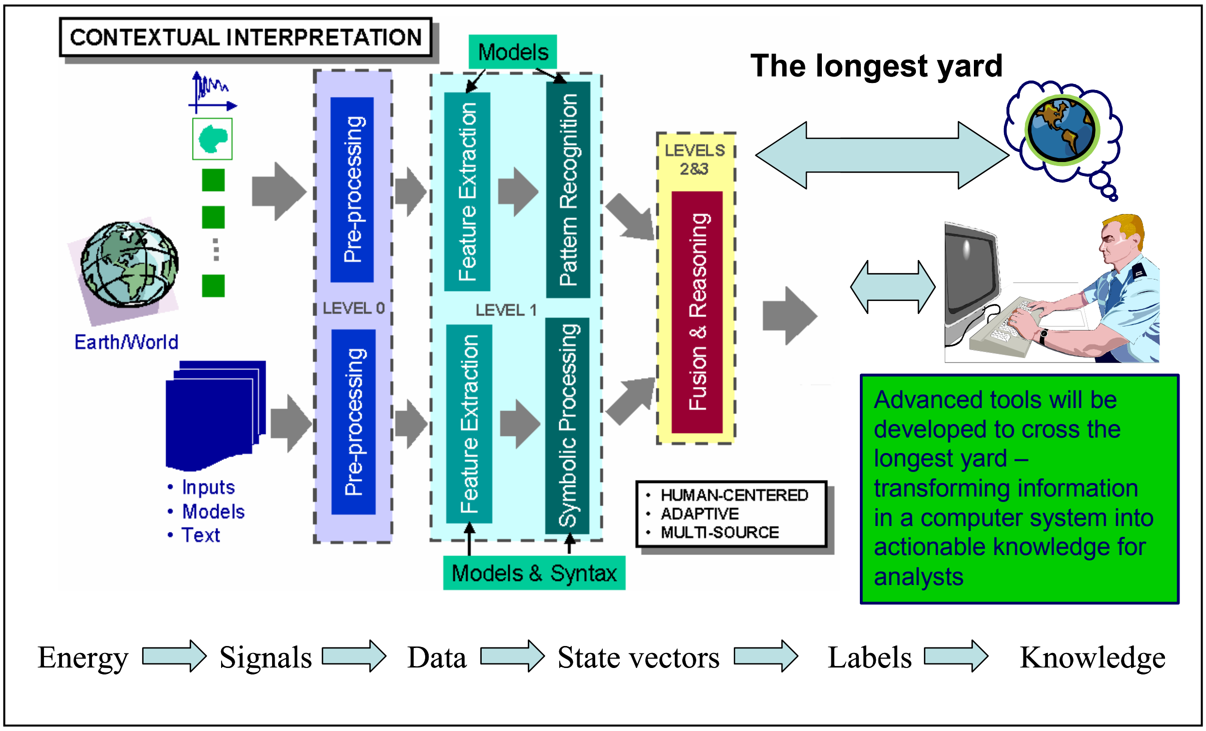

Figure 2: A key challenge is transforming from data inside an evolving situational data base to actionable knowledge for decision-making and understanding

2.1 Barriers to solve the problem

A fundamental paradox exists in information fusion. Information fusion in this context may be used in traditional areas such as national defense, counter-intelligence or situation assessment for tactical military applications (Hall and Llinas, 2001). Alternatively, information fusion may involve emerging applications such as emergency crisis management, environmental monitoring, or monitoring complex systems such as machines or industrial processes. The paradox is that information analysts are drowning in a sea of data but unable to obtain the knowledge that they need to address difficult problems. This has often be referred to as the data overload dilemma (Kuperman, 2001) or more recently framed "cogmenutia fragmentosa" (McNeese & Vidulich, 2002).

On one hand, an unprecedented capability exists to collect data via distributed sensors, commercial information providers (e.g., AccuWeather, Library Services, and commercial search businesses), human sources, or Internet resources. Smart micro-scale sensors, wireless communications, and global Internet accessible resources enable the entire earth to be a potential information resource. Such information is available literally at the fingertips of the analysts. In particular, the Internet has exceeded one billion web pages, with a continuing exponential increase. However, the wealth of data has not produced a commensurate improvement in analyst abilities. Analysts are literally swamped with data. They have a wide variety of choices to make as to what is *useful* and *usable,* given the context of what they are trying to *understand* (Woods, 1998).

On the other hand, the glut of data can be overwhelming and may inadvertently promote poor decision processes (Ferran, 1999). Studies of decision-making under stress have shown that too much information can cause ineffective decision styles. An example is the *hyper-vigilance mode*, in which a decision-maker frantically searches for new information, without taking time for reflection and thoughtful analysis of existing data. The huge glut of rapidly changing data via the Internet may encourage this type of response. Alternatively, a decision-maker may feel overwhelmed with new information and simply ignore new data. Thus, in a rich atmosphere of data, decision-makers are suffocating for knowledge (McNeese and Vidulich, 2002). They may have a large amount of cognitive readiness available to fuse multiple information sources but in fact their meta-cognition (McNeese, 2000) may be very limited. This often makes decisions about "what to do next" daunting.

2.2 Overcoming the barriers

We are addressing these barriers by an approach that; (a) provides new methods for interacting with data and meta-data using multiple human senses, (b) involves a gaming environment to capture the imagination of analysts and make the data analysis process engaging and fun, and (c) provides cognitive aids using team-based intelligent agents to guide the analysis process and critique evolving hypotheses. The intent is to treat analyst attention as a limited and critical resource that must be managed and conserved for improved analysis. We will develop cognitive models (using a knowledge elicitation approach on experienced analysts), implement software prototypes to demonstrate the concepts, and evaluate the effectiveness of the tools and techniques using human subjects in a living laboratory environment.

2.3 Current Applications

For crisis management and related applications, we have developed cognitive models (using a knowledge elicitation approach on experienced analysts), implemented software prototypes to demonstrate the concepts, and evaluated the effectiveness of the tools and techniques using human subjects in a living laboratory environment. The living laboratory environment links observations of analysts working in real environments, to development of cognitive models using a formal knowledge elicitation approach, and development and evaluation of prototype tools. The tools are tested in a simulation environment using teams of human subjects to quantitatively evaluate the effectiveness of the tools. A special laboratory environment and simulation tool (neoCITIES) is used for the evaluation. The implementation of these tools leverages several special laboratory facilities including: a synthetic environment applications laboratory containing a full immersion, 3-dimensional visualization facility, a laboratory for intelligent agents, and the user science and engineering laboratory. In addition gaming tools and visualization creation tools are used from our real-time aesthetics and experience laboratory.

3.0 THEORIES AND TECHNIQUES GUIDING THIS RESEARCH

3.1 New 3-D Multi-sensory Techniques for Data Interaction

Innovative concepts are being developed and demonstrated for improved information retrieval, data understanding and interpretation (McNeese and Hall (2003). A new concept of intelligent information interpretation, search and retrieval (I^3SR) is being developed by exploring concepts such as multi-sensory interaction, dynamic computer-guided focus of attention, deliberate synesthesia, utilization of negative space concepts, and adversarial game concepts. This effort uses The Pennsylvania State University Synthetic Environment Applications (SEA) laboratory to explore the use of new multi-sensory interactions: e.g., sound, vision, haptic interfaces. Demonstrations are being developed to explore the concepts identified above and also exploring user/information control and feedback mechanisms. Examples of potential demonstrations include novel, multi-sensor interactions for data display and interaction; utilization of deliberate synesthesia effects, use of negative space and blink comparison concepts, deliberate blurring and transparency of displays and novel *fly by electronic-wire* control concepts. Figure 3 shows an example of a situation display in which height above the floor represents time of year, different shapes represent different data types, and sound is used to indicate "goodness of fit" (viz., measure of association) among different data types.

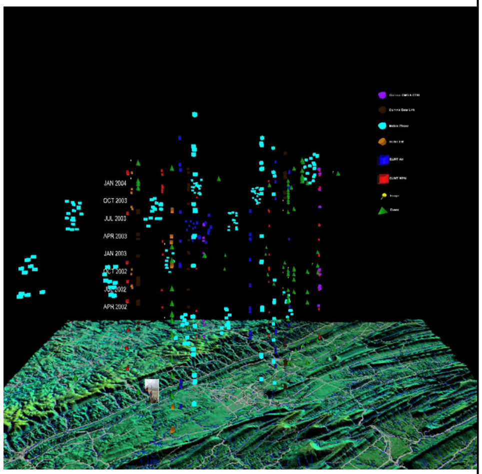

Figure 3: Example of Multi-Sensory Interactive

3.2 Game-based Techniques for Improved Visualization and Analysis

We are exploring several directions, based on video gaming, to create tools that would enable analysts to perform their jobs faster and better. Our goal is to explore the utility of video gaming (a) as visualization methods and (b) as interaction models to:

1. Increase productivity of analysts by a) providing an engaging interaction method based on game design patterns and b) providing a visualization method based on game methods. This is based on the belief that next generation analysts are game players and thus are familiar with the visualization methods used in games. Providing a closer visualization method to what analysts are accustomed to will enable them to assimilate information quicker. Game visualization methods have been successfully used in mainstream games to enable quick decision making in a game type environment, where making decisions quickly is an important element of game play.

2. Increase the speed by which analysts extract information by providing an abstract visualization method based on cinematic/theatric techniques that allow users or audience members to grasp the story quickly through the set design, character composition and music.

3. Enhance the quality of hypotheses generated by a) providing a method for visualizing hypotheses to assist in revealing contradictions or visualizing probable hypotheses and b) providing a gaming technique for finding contradictions and holes in hypotheses or stories

We are building a 3-D environment where analysts alternate between a strategy-based game interface (macro decision-maker) and a Role Playing Game interface (micro decision-maker). We believe visualization and interaction methods provided through RPG (Role Playing Games) and Strategy-based games can provide an environment that achieves the goals set above.

An example screenshot from a strategy-based game is shown in Figure 4. In a typical strategy-based game (e.g., *Warcraft*, *Civilization*), the player is omniscient. He/she looks at the world from above. Interaction methods mainly involve strategic actions concerning resources, such as allocation of soldiers and directing action of specific units or groups of units. Several visualization techniques are used in these types of games. For example, the play often observes the world as a 2-D or 3-D map. Players can zoom in and out of the map or can maneuver in the world space to different parts of the map. There are several symbols that are used on the map to indicate specific information, such as names of region or resources. In Figure 4, boundaries of specific countries or civilizations are shown in the map. Also, there are context-based icons or menus that are usually displayed based on the user cursor or upon execution of specific events.

Figure 4: Screen shot from Civilization IV

We are also exploring several directions in mapping a strategy-based game interface within the analyst domain and measure its utility in enhancing analyst productivity, speed, and quality of hypotheses generated. Several explored visualization techniques for analysts have assumed a removed point of view with a GIS (Geographic Information System) (Risch, Rex et al. 1997; Rex 2002; Chen, Atabakhsh et al. 2005; Corporation 2005). These works are similar to the visualization methods used in strategy-based game. Strategy-based game interfaces have evolved over many years. The interfaces have evolved adopting a very minimal context-sensitive interface to visualize dynamic and static information and events. We develop several mappings between analyst's data and the current types of displays or visualizations used by strategy based games. We envision using graphics elements, such as maps, bars, sprites representing people, to represent different elements such as events, people, and their relationships, etc. Our goal is to use gaming techniques as well as cinematic techniques to visually depict analyst related data in a way that allows analysts to quickly grasp the situation and the event.

Since the strategy-based game interface provides a removed interface, analysts may decide to dig deeper into a particular accumulated data abstracted in the strategy-based interface. In such cases, analysts will need another type of interface. We will evaluate the utility of an RPG-based game interaction model and visualization method.

Figure 5: Screenshot from Neverwinter Nights

Screenshots from the RPG game, *Neverwinter Nights* are shown in Figure 5. In RPG games, a player assumes the role of a character within the game. He/she normally experiences the narrative from a third or first person interface as opposed to the God view as in strategy-based games. In these games the interaction model involves talking to different characters, solving quests, or fighting enemies. In role-playing games the player often confronts many characters who will all tell him/her their stories. Some of these stories are relevant to the game mission and others serve as side missions or quests that players take on if they desire.

We are also developing a 3D representation of the current reports that analysts analyze. In this 3D representation, the analysts will be immersed in a 3D world similar to the ones used in RPG games. The analyst will be able to talk with characters who give him/her specific information, e.g. CNN reporter exposing a specific story that was on the CNN website, etc. As the characters talk, we envision using 3D abstract graphics to show the story, using similar visual metaphors as used in the movie *Mirror Mask* (http://www.sonypictures.com/homevideo/mirromask/). To compose such visual representations of stories, we will develop an artificial intelligence (AI) system that maps a story instance to an abstract story segment based on a composition of story patterns that we will develop based on example stories that analysts monitor. These story patterns will be developed following the same methods used by Propp (Propp, Wagner et al. 1968). Using these story patterns and the instance story, the AI system will compose a 3-D abstract representation.

Finally, we are exploring the utility of gaming in hypothesis visualization and evaluation. We will also explore the potential of using games as a storyboarding technique to visualize a hypothesis and evaluate its validity. The specific goal of this task is to increase analyst engagement and the quality of the hypothesis he/she generates.

Many analysts engage in a process of hypothesis generation, composition, and rating. Currently this process all happens in the analyst's head. As a result, analysts can only generate simple hypotheses that are formulated based on only a small amount of information that can reside in one person's head at any moment in time. These hypotheses may then be invalid or less complicated than what they should be. We will enhance this process by exploring a storyboarding game-based technique. We aim to give the analyst a way to sketch out their stories or hypotheses using a SIMs like environment.

Figure 6: Scenarios Created using *The Sims 2*

The Sims 2 (the second version of *The Sims* game) is a game that is similar to a doll house in 3-D (Figure 6). Players can make their own custom character using a base set of characters. They can then customize their personalities and construct houses for them and put them in these houses. They can then direct the characters and initiate scenarios to tell a story, e.g. make two characters fall in love or kill another character. *The Sims* was a major hit and many people worked for hours putting together their own scenarios and characters. Will Wright (the creator of *the Sims*) reported receiving over 75,000 customized characters for *The Sims* game.

We believe using the same motif for a doll house would provide an engaging method for analysts to storyboard hypotheses. In addition, this method would also allow them to visualize the hypothesis and may lead to composition of complex scenarios and early discovery of conflicts and different scenarios or hypotheses.

The Sims as is, however, will not suffice; it would be too low-level for an analyst-type hypothesis and may take a long time to construct a relevant scenario. We believe the analyst needs a tool that will allow him/her to quickly put together a scenario and play with it. For this purpose, we will build a Sims-like environment with add-on tools that allow analysts to drag and drop story patterns from a set of defined story patterns that we will compose based on Propp's morphology (Propp, Wagner et al. 1968). We will also build several character models that represent several stereotypes that analysts can use to depict their scenario. The use of stereotypes and story patterns will enable analysts to quickly visualize the hypotheses and identify problems with them. The system will include several rules that enable some low-level AI, allowing characters to react to events represented in the story patterns, and thus creating a world dynamics based on the patterns dropped in the world, similar to *The Sims*.

Once hypotheses are collected through this tool, the game will begin. Analysts can invoke a debate where other analyst teams (composed of virtual and real analysts) try to find contradictions to the hypotheses presented. Analysts would use the tool to drag and drop patterns and maneuver characters, thus showing the contradictions or other possible hypotheses.

3.3 Cyber Advisory Team

A framework is currently being developed to use intelligent software agents to assist in data understanding and situation assessment. The framework is based on a team-based agent environment developed by Yen (Yen et al (2004). In this model, intelligent agents act similar to the way a good human team operates; namely cooperating in a dynamic and positive way, sharing a team mental model of the decision and analysis process, and proactively sharing information among team members to improve their analysis and decision-making performance. The framework developed by Yen includes an architecture, knowledge representation and reasoning methods and internal information exchange language to emulate human teams. In addition, the architecture is based on the recognition primed decision (RPD) model of human teams in complex, dynamic environments.

The intelligent agent concept will allow creation of a virtual advisory team to support the analysis process (Figure 6). The concept is analogous to a defense or prosecution team that uses a team of special experts, specialists to search for related case studies, analysts to watch jury reactions and others to assist in dynamically preparing and modifying a defense or prosecution. By analogy, analysts are developing an understanding of an evolving situation and creating and assessing hypotheses regarding the case – modifying their approach as more data are uncovered or new interpretations are brought forth. One or more intelligent agents could act as "curmudgeon" agents, designed to guard against known cognitive biases such as the confirmation bias (in which a human seeks information that only confirms his or her hypothesis rather than looking for refuting evidence).

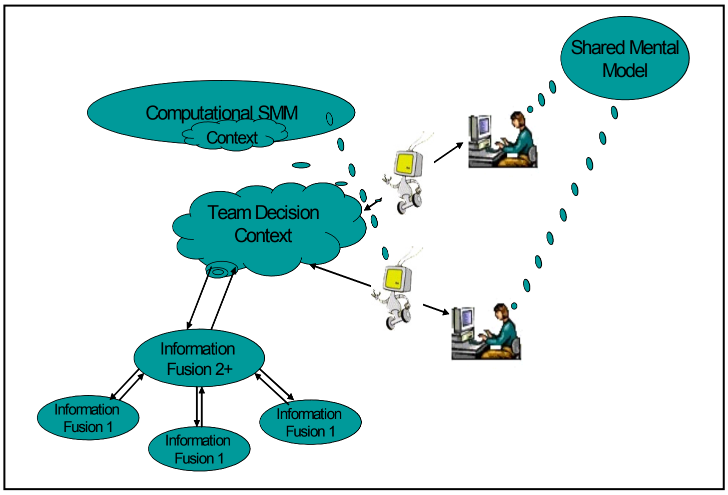

Figure 6: Intelligent Agents as a Virtual Advisory Team

4.0 METRICS AND MEANS OF EVALUATION

Numerous tools and techniques are being developed or adapted to assist the data analysis process. While proponents argue that their proposed method or tool will "significantly improve" the analysis process, such claims are difficult to validate without implementing the proposed tool in an operational environment. This is problematic for many reasons including disruption of already overloaded operational centers and analysts need to train analysts on the utilization of the new tool or technique, and difficulty in making quantitative comparisons of the analysis process "with" and "without" the introduced tool. Moreover, even if the proposed tool or technique is implemented it becomes a "point solution" and does not allow experiments to determine how variations of the tool or technique would affect the analysis performance. Our research uses the concept of a "living laboratory" (Figure 7). The concept involves a simulation environment (NeoCITIES) that allows introduction of tools such as collaboration aids or cognitive tools into a team decision environment using human test subjects. The subjects act in a team decision environment and are given the task of analyzing an evolving situation and making decisions. The simulation environment (via NeoCITIES) provides test subjects with reports and information related to an evolving scenario. The subjects work in teams (with separate roles for each team member) to assess the situation. The simulator drives the analysis process and collects data on the efficacy and accuracy of the student teams. In this way statistical information can be collected for quantitative evaluation of introduced tools.

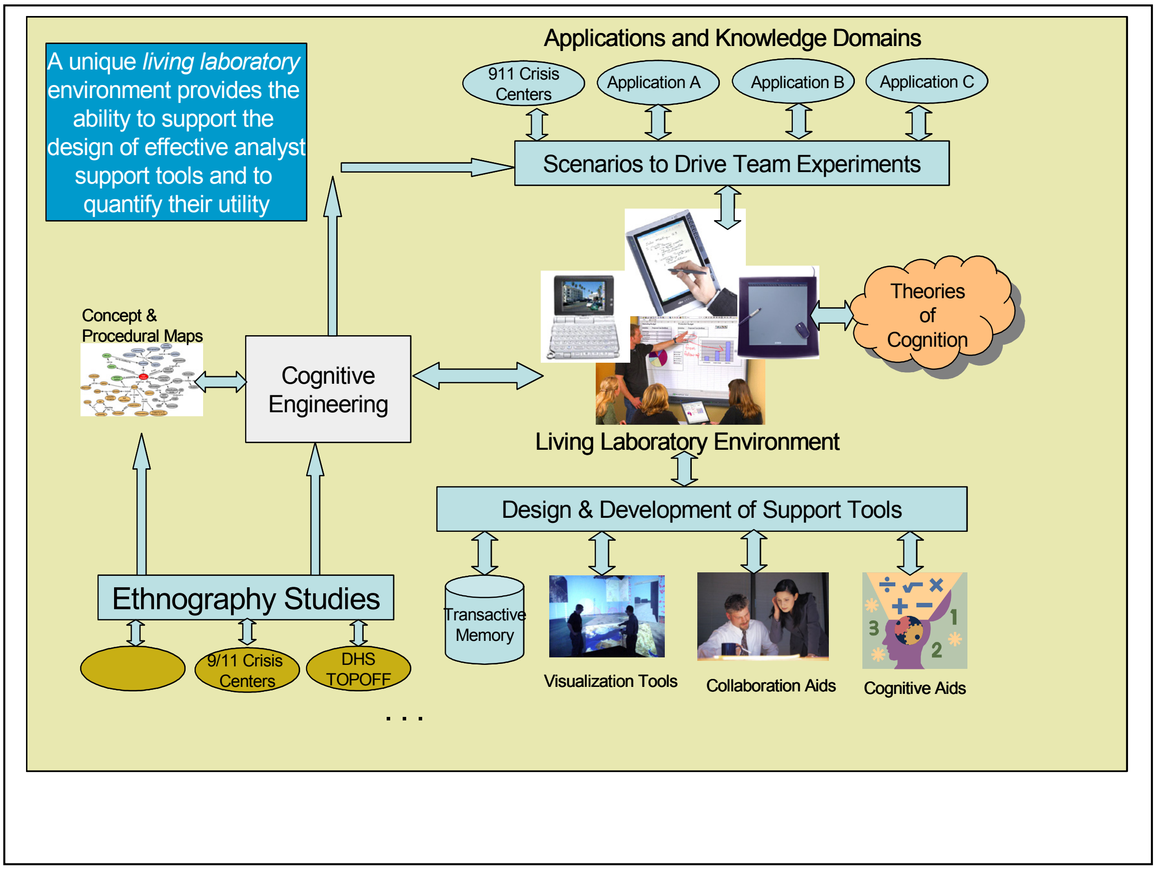

Figure 7: Concept of a Living Laboratory for Quantitative Evaluation of Tools

5.0 APPLICATION TO NETWORK VISUALIZATION AND ANALYSIS

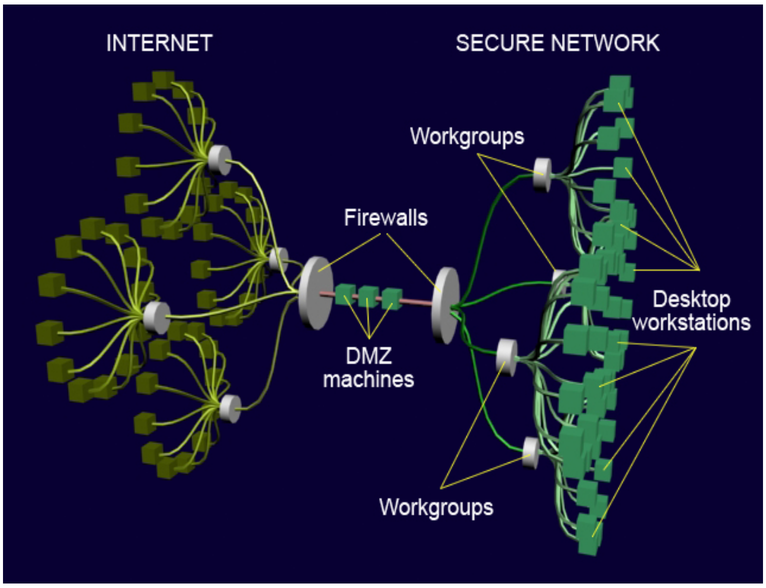

Figure 8: Example of Visualizing a Network

The on-going research described in this paper can also be applied to the visualization and analysis of network systems. For example, figure 8 shows a concept for visualizing a computer network in which local clusters of computers interact with each other and interact with a wider set of computers and "networks of networks" via the internet. Visualization tools, intelligent agents, and gaming techniques can be used for monitoring the health of the network (e.g., utilization of communications, overload of communications channels, undue use by specific individuals, etc). An common example of such overload occurs at Pennsylvania State University at the start of each fall semester, when numerous new students arrive on campus and begin downloading extensive amounts of audio and video files.

We believe these general research thrusts will assist in understanding and managing the huge amounts of data to be collected and fused for both traditional and emerging applications.

6.0 ACKNOWLEDGEMENTS

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