

Agent Based Intelligent Decluttering Enhancements

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Abstract

Model-driven visualization (MDV) is a novel framework that supports more effective, intelligent user interfaces to improve decision making in complex environments by coupling cognitive and perceptual theories of information processing with advanced artificial intelligence methods. It embeds empirical and theory driven approaches for identifying and prioritizing data based on the information requirements and needs of the human decision maker within intelligent agents. The agents automatically deliver and present information based on its likely value using visualizations that best convey that information to the user(s) of the system. Agents also reason about the context and constraints of the user, environment, and display to enable a higher degree of personalization within an interactive user interface (e.g., by drawing a user's attention to interesting aspects of the data such as trends, anomalies, and patterns). We apply cognitive systems engineering processes to help identify the information available to individuals and/or teams, where it resides, where it is needed, and ultimately how to create the mappings required in connecting critical information to those who need it with innovative visualizations that most effectively support the end user. This paper describes the application of MDV to intelligently deliver timely, mission-critical information by adapting a Common Tactical Picture (CTP) display used for maritime situation awareness, threat assessment, and decision support.

Introduction

The USS Vincennes incident provides a clear example of the need for decision support tools that convey information to decision makers in a way that enables them to obtain situation awareness rapidly and accurately (Fogarty, 1988). While several improvements have been made over the past 20 years to help operators make good decisions, there

remains an abundance of design challenges to enhance human performance. For example, as the United States and our allies continue to develop and deploy sensors at an increasing rate, the vast amount of data available continues to grow exponentially. This glut of data has led to a phenomena commonly understood as data overload (e.g., Shanker & Richtel. "In New Military, Data Overload Can Be Deadly". *New York Times*. 17 Jan 2011). The sheer amount of data far exceeds the capacity for operators to interpret that data.

To address these challenges, Aptima and our partners, CAPT Ronald Steed (UpScope Consulting) and Dr. Paul Scerri (Carnegie Mellon University), developed the Agent Based Intelligent Decluttering Enhancements (ABIDE) system for providing decision support with real-time, intelligent decluttering. ABIDE couples intelligent agents, validated models and metrics of display clutter, and visualization methods designed to support the commander's decision processes (e.g., how they find, process, and interpret visual information).

The remainder of this paper describes the early research and development of the ABIDE system.

ABIDE Design Process

The Aptima team first conducted a thorough examination of the domain and held several knowledge elicitation sessions with Subject Matter Experts (SMEs) to learn about the high level information available in the domain such as descriptions of the missions, tasks, workflow, and what types of information are important to executing these tasks successfully. Our analysis focused on the points at which the display may suffer from information overload and therefore may benefit from a decluttering strategy. This information was then used to develop the policies, behaviors, and rules for the ABIDE agents. One interesting extension of this research includes using machine learning algorithms to derive this information from observations of expert operator behaviors.

Next, the team developed a scenario to help operationally ground the ABIDE approach and to facilitate the development and testing of the agents and visualizations. A simple use case that describes how the system intends to operate was developed, which focused on formally capturing the users, tasks, and operational context for improving situation awareness through intelligent, adaptive displays.

The next step involved reviewing and categorizing the range of methods available for decluttering displays. We focused primarily on two areas – methods for measuring clutter and methods for reducing clutter. Clutter is a difficult concept to measure because it involves both bottom-up and top-down components. Therefore, multiple subjective and objective measures should be used in conjunction to accurately measure clutter. Kaber, Alexander, Stelzer, Kim, Kaufmann, and Hsiang (2008) developed a subjective measure of clutter by presenting operators with rating scales that cover several underlying dimensions of clutter, including redundancy, colorfulness, feature salience, feature dynamics, feature variability, and global density. An overall measure was computed using a rank-weighted sum of ratings across the dimensions. Clutter is recognized as multidimensional and this approach compensates for the lack of objective measures for some identified dimensions.

Many objective measures have been developed that define clutter based on physical display characteristics. Examples include the size of the display region (Ewing, Woodruff, and Vickers, 2006), target size (Muthard and Wickens, 2005), local and global density (Ewing et al., 2006; Muthard and Wickens, 2005; Rotman et al., 1994; Van Olffen, Wickens, & Muthard, 2005), feature occlusion (Wang, Griebel, Brandstein & Hsu, 2001), number of objects (Horrey & Wickens, 2004), target background contrast (Aviram & Rotman, 2000), and the number of active pixels (Tullis, 1997; Rotman, Tidhar & Kowalczyk, 1994). Additional attempts have been made to objectively evaluate display complexity (Xing, 2004) and the similarity of visual objects (Wang, et al., 2001), but these measures still have a subjective component.

Kaber et al. (2008) identified several dimensions of clutter that are not addressed through available objective measures. Subjective measures can assess these factors, but require operator evaluation, which is not available to our intelligent agents at this point. Therefore, we initially identified a group of objective measures that provide a reliable approximation of clutter under various contexts such as the number of tracks, display density, and feature occlusion.

Lastly, the team developed metrics of the feasibility and utility of ABIDE. These metrics are intended to formally define what the technology supports and to what degree. “Feasibility” in this context is primarily an issue of the modeling and software capabilities fulfilling their envisioned function (e.g., how well can our agent-based approach scale?) and “utility” is primarily an issue of human performance (e.g., to what extent does ABIDE reduce workload and improve situation awareness?).

ABIDE Agents

Using the results of the analysis, we designed several “Analysis” and “Visualization” agents that identify and prioritize contacts in the environment, taking into account the inherent uncertainty in the domain, and then determine what actions to take in the display to reduce clutter and draw attention to high value targets.

The Analysis (or Prioritization) agents use a central point for managing agents for individual contacts. Incoming data is examined and sent to agents already assigned to a contact or a new agent is created to monitor a contact. Agents interact to discover elements that need to be prioritized. When interesting interactions are found, a new agent can be created to monitor that interaction and consider how that might influence the priority of underlying contacts. There are currently agents for building up historical track information, fusing or aggregating multiple contacts (e.g., a single contact is producing multiple sensor returns), calculating proximity, and determining if contacts are in operationally relevant regions, such as search areas or areas with interesting environmental features. The RANdom Sample Consensus (RANSAC) algorithm – an iterative method for estimating parameters of a mathematical model from a set of observed data which contains outliers – can be used to estimate the parameters of a model that optimally explains or fits this data given a small set of inliers. With RANSAC, agents within ABIDE can test data against known observations of threatening behaviors. Currently, prioritization agents use this information to generate scores that serve as input to the Visualization agents. Several additional dimensions, such as classification, certainty, and membership are considered in the prioritization rules.

Visualization agents use several types of information to dynamically adapt the display. First, the agents use the prioritization scores output by Analysis agents. Second, the agents take into account metrics of display clutter. Third, the agents contain heuristics based on cognitive/perceptual theories of information processing. This enables the agents to understand the most effective visual representations within the constraints of the human and the display (e.g., high visual contrast or salience conveys higher value information, and objects can maintain high contrast even when they overlap different objects or background layers). This enables the Common Tactical Picture to limit the amount of information portrayed without inhibiting access to data that may be necessary for a novel or unanticipated task, and to guide the operator’s attention to critical targets that are relevant to the current state of a dynamic mission.

Currently, display actions include adjusting icon features such as background shape, background color, transparency, frame type, frame color, icon type, icon color, size, whether to show the icon as a dot, whether to show the label (including color, transparency), and whether to show a “highlight” to convey urgent information.

The ABIDE Common Tactical Picture

The ABIDE proof-of-concept CTP prototype was developed in the Java programming language using the OpenMap programmer's toolkit. OpenMap provides capabilities for displaying geo-referenced shape and image data within a set of static and dynamic layers on a two dimensional canvas. The ABIDE CTP uses the raw contact data in conjunction with the display action data generated by the agents to dynamically generate "intelligent symbols" for each contact being visualized. An icon's features can all be controlled by the agents to draw attention to a particular contact or minimize attention to a contact that is irrelevant to the mission at hand. The example in Figure 1 shows a dynamic change based on uncertainty. Higher certainty corresponds to a greater visual salience (and less transparency levels).



Figure 1. Track Uncertainty

The prototype is currently configured to show a display for each of two different missions –the operational display to support wide area search mission and the tactical domain display to support tracking a particular threat. The Operational/Search mission display (Figure 2a) shows a zoomed-out view of the search space for the purpose of providing overall situational awareness. The Prioritization agents have created the following context specific prioritizations:

- Neutral tracks have low priority
- Hostile tracks have the highest priority, ordered by certainty
- Friendly tracks that are supporting the mission have higher priority

The Tactical/Track mission display (Figure 2b) shows a zoomed in tight display to support tactical level decisions. Any entities that might impact the tracking mission are

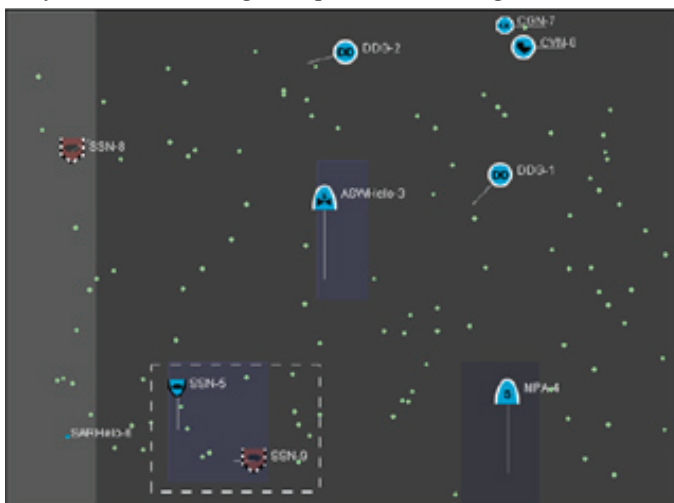


Figure 2a. Filtered "Operational/Search" Display

prioritized (contacts in close proximity to hostile entities, contacts within domain relevant areas). Figure 3 shows an unfiltered view.

An initial scalability assessment of the ABIDE CTP demonstrated that our prototype can scale to about 22,277 agents in a "worst-case scenario" (sensor readings are received and updated for every contact at every second – in operational environments contacts may not be picked up by sensors very frequently, or contacts may be picked up by multiple sensors simultaneously). The ABIDE algorithms are still in prototype form and are not yet optimized (e.g., for integration). ABIDE executes in quadratic time, which we can easily reduce to linear time with a few improvements. In this case, ABIDE would be able to handle over 335,000 agents if updates were received for every contact, every second and over 25 million agents if updates were received for every contact, every minute.

Summary

ABIDE attempts to address the various sources of uncertainty in the domain in order to provide the operator with the most reliable and actionable picture of the ground-truth situation. By decluttering the CTP based on the context of the human-automation system, and then providing methods for modeling and reasoning about uncertain or ambiguous data, the CTP can effectively support an operator's understanding of the situation and empower the user so they can make better decisions.

Cognitive systems engineering processes can help inform the design of complex socio-technical systems that address the requirements of both the user and the automation or intelligence within the system. We have described using a model-driven visualization approach for developing intelligent agents that can help drive adaptive displays, context-sensitive user interfaces, visualizations, or just highlight pertinent information to users. Next steps for ABIDE include a heuristic evaluation to determine the effectiveness of the prioritization scores, display actions, and the resulting dynamic interface.



Figure 2b. Filtered "Tactical/Track" Display

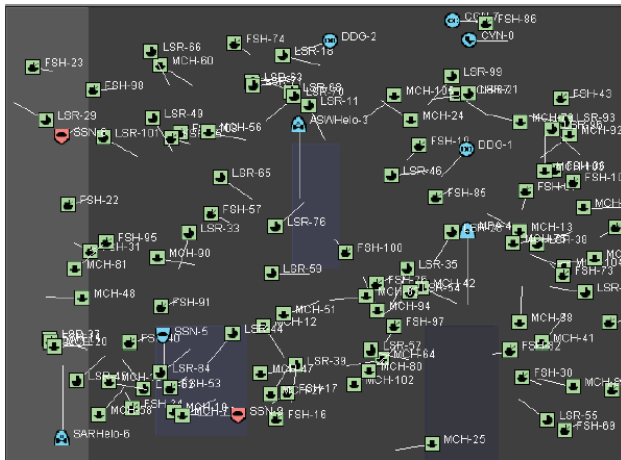


Figure 3. Unfiltered View

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