ORION White Paper

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The U.S. faces a severe national threat to its maritime infrastructure. According to Coast Guard & Maritime Transportation Subcommittee Chairman Frank LoBiondo,

> "Protecting our ports and maritime transportation system is of critical importance to our nation as the maritime industry contributes $742 billion to the gross domestic product each year and the ripple effects from an attack on one or more of our ports would be felt throughout the economy of the nation."

The critical challenge in providing adequate security is to have the right information at the right time, such that it becomes actionable intelligence. Unfortunately, a humanly insurmountable volume of intelligence information becomes available everyday. This information is produced from different sources, and consequently, different formats as well. In addition, the information is periodically updated or removed, which adds to the challenge of evaluating the information and incorporating it into decision-making or analysis processes in real-time. Another challenge is how to quickly analyze and fuse information of interest from thousands of sources. This is an impossible task at present because information is typically catalogued by content or format type and not necessarily by the facts contained in them. In some cases, the information may not even be catalogued, but simply left in its raw form. Finally, there is a dearth of intelligence analysts to search for important clues. According to House Select Intelligence Committee Chairman Porter Goss,

> "There is a persisting shortage of trained intelligence analysts who must sift through the giant haystack of information we collect to find the little needles that are really important."

Actionable intelligence is critical for threat-vulnerability analysis and for assessing potential terrorist threat scenarios. However, the lack of an automated information discovery and analysis system that allows fast and effective retrieval, analysis, and fusion of information severely weakens the effectiveness and efficiency of using all available information for decision-making and threat analysis. Currently, experienced analysts must perform fusion of such information. As a result, much of the staggering collection of information is not utilized or significantly underutilized.

Utilizing ORNL's expertise in information analysis and fusion techniques, these challenges can be met using an agent-based information analysis and fusion system that applies the following technologies:

<u>Software Agent Technology</u>: ORNL has extensive experience in developing and deploying intelligent agent systems. The multimillion-dollar research investments made on a number of projects will be leveraged to provide significant productivity gains in the proposed system. Our most recent project, VIPAR, used intelligent software agents to successfully address challenges facing the intelligence community in quickly gathering and organizing massive amounts of information and then distilling that information into a form directly and explicitly amenable for use by an intelligence analyst. This system automatically and intelligently leverages the analyst's

expertise to process and distill information four to ten times more thoroughly than can be accomplished by traditional methods.

Image Processing and Analysis: The Image Science and Machine Vision (ISMV) group at ORNL has been performing applied computer vision research and development since 1987 and is recognized for its work in biomedical imaging, industrial inspection, and national security. A primary focus of the group has been in the development of technologies and capabilities for image data representation and management in large data system environments. These technologies are representative of the experience we have in image segmentation, description, analysis, indexing, and management and that will be leveraged to address large-scale spatial processing and analysis through this proposal.

Technical Approach

U.S. port security has the problem of finding rogue ships and cargo at a vast number of U.S. and worldwide ports. The overall focus of our proposed research effort is to address this problem by developing an information fusion architecture. The architecture will provide the means to support threat-vulnerability analysis for preventing and mitigating terrorism.
According to the Joint Directors of Laboratories Data Fusion Subpanel [2] [4] data fusion has been defined as

> "a process dealing with the association, correlation, and combination of data and information from single and multiple sources to achieve refined position and identity estimates, and complete and timely assessments of situations and threats as well as their significance".

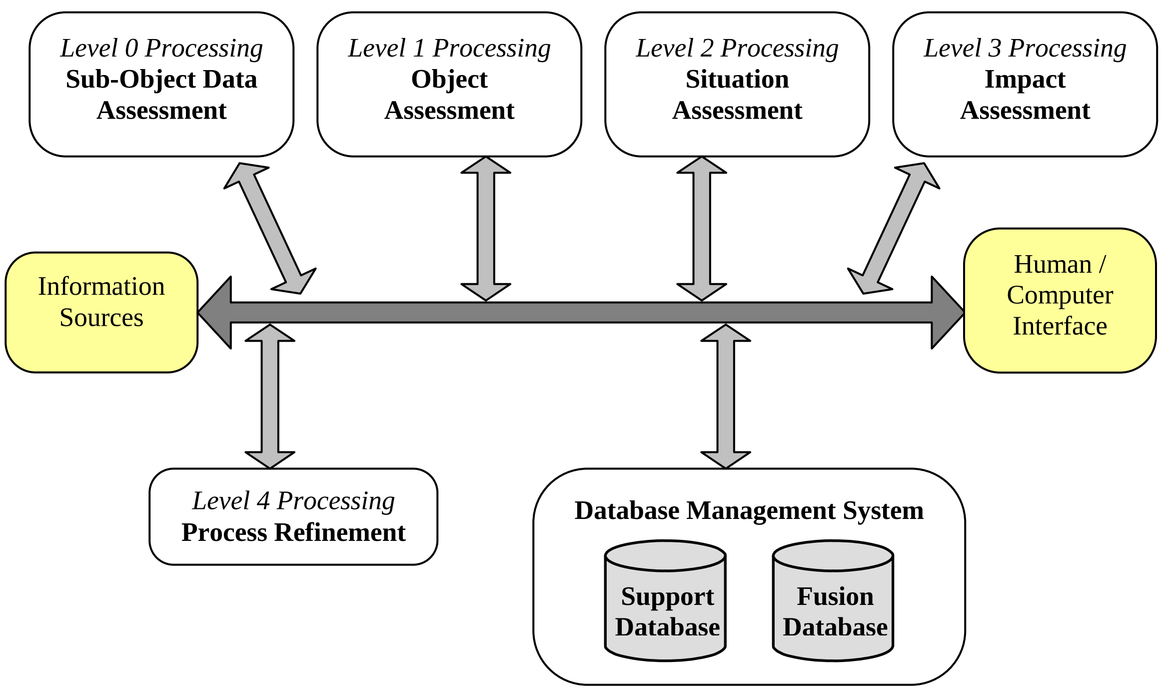

Figure 1. Information Fusion Process Model

This process is shown in Figure 1. As shown on the left, the process begins with some raw data sources. The information from these sources is then refined and assessed at higher and higher levels as the information flows toward the user. Furthermore, as the information flows toward the user, different information sources are also correlated. Ideally, the result is actionable intelligence derived from raw information sources.

This information fusion process model provides the foundation for the system to be developed. The proposed system will consist of intelligent agents that will retrieve, analyze, and fuse maritime information from across the Internet. These agents would gather new information on a regular basis, perhaps hourly or any other period chosen. They would send this information to a collection point where a merging agent would integrate the gathered information about given vessels. This merged information would then be sent to a route agent who would determine the likely route that a ship will take to get to its new location. The route agent would also determine from observation data if the ship were off course, possibly using published routes from the shipping companies. A database will be the underlying storage for information collected by these agents. The agents will record the time and date of any observation made.

This system will integrate various information sources and formats in a scenario-based, analyst-driven computational environment. Upon evaluation, the agents would then work to determine relationships between the various pieces of information, and then determine how the information relates to potential terrorist threat scenarios. The result would be provided to the analyst for evaluation and validation. This system would provide the analyst with a scalable and flexible approach to information management, knowledge discovery, and synthesis and analysis of text, imagery, and other information. Related work can be found in [1] [3] [5].

There are two critical challenges to be addressed during the development of the proposed system:

- Intelligent fusion of information sources.
- Processing of images from video.

<u>Intelligent Fusion of Information Sources</u>

There are several sources of unclassified shipping information available. Examples of these sources include:

- Weather reports from the ships that contain ship call sign, location, date and time.
- Detailed ship information that includes the type of ship, ship name, ship call sign, ship owner, contact information for the ship owner, and ship tonnage.
- Ports or newspapers that publish port traffic information.
- Shipping company Web sites that provide detailed ship information.
- Imagery and video sources

The proposed system will utilize intelligent agents that collect information from specific sources. Weather reports would be recorded by a set of *weather* agents. These agents would extract ship locations from weather reports. Information from these sources includes vessel call sign, latitude, longitude, the date, and time. A set of *port* agents would be used to gather information from a collection of port Internet sites from across the world, such as Houston, London, etc. Port agents monitoring these sites would gather information about ships within a given port. This information may include the vessel name and number, port name, berth, shipping agent, country of origin, cargo, arrival date, and last port of call. Next, a set of *shipping* agents would gather information about shipping lines from individual corporate Internet sites, such as COSCO, K-Line America, etc. This information may include the vessel name and number, the voyage number, and the departure and arrival dates at given ports. Next, a set of *image processing* agents would gather images of ships in port or at sea. Finally, additional agents could be marshaled to incorporate additional information from other sources.

Image Processing

The computer vision task will require the interpretation of imagery supplied from satellite and/or earth-mounted cameras. This task will explore methods for detecting and categorizing vessels in views such as those found in 2. By using knowledge from text data of ship schedules, we can know to look for vessels of a particular size at a particular time. The research will make use of recent advances in machine learning and statistical machine vision to create a trainable system for learning features of sea-going vessels.

Figure 2. (left) Web-cam view of San Diego seaport. (right) Satellite photograph of vessel at sea.

While this sort of flexible ship detection and characterization is a very challenging task that is not currently handled in state-of-the-art computer vision, we benefit from technology developed at ORNL for the computationally efficient detection of human faces. ORNL has developed methods of constructing decision trees to rapidly sort instances of face imagery into the correct pose category. Recent methods of efficient feature extraction are used to discriminate face pose using standard computer hardware. Figure 3 shows the variety of poses represented in Carnegie Mellon's PIE (Pose, Illumination, and Expression) database. This database contains 40,000 facial images of 68 people.

Figure 3: Pose space of CMU (Carnegie Mellon University) PIE (Pose, Illumination, and Expression) database.

In 4, the results from ORNL machine learning are shown. The figure visualizes the successful pose categorization of a decision tree generated without human intervention. While a human was needed to label poses in examples, the tree generation algorithm automatically chooses features and discriminant functions for splitting tree nodes. The resulting architecture can be used in real-time to test candidate image regions for the presence of any facial view while requiring a minimal number of feature extractions and evaluations. This will make it possible to detect faces from multiple views using standard computing hardware.

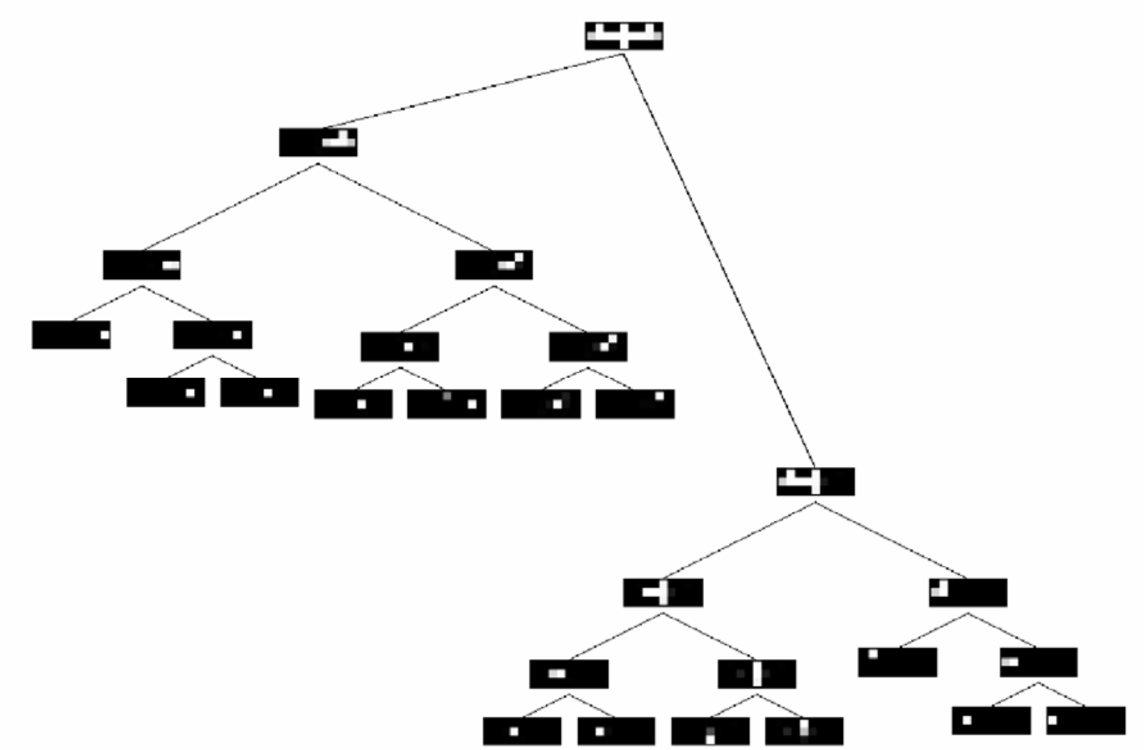

Figure 4: ORNL results from decision tree sorting visualized by histogram images of PIE database. Histogram pixel locations correspond to pose layout in Figure . Each histogram image is normalized such that black indicates no instances, and white indicates the greatest number of instances. Leaf nodes show localization in pose space.

We plan to make use of the above concepts and apply them to the efficient characterization of ships. This will require the development of graphical user interface (GUI) for human-parsing of training video. The human will identify ships in the video and label information such as the bow, stern, and major axis. A decision tree approach for statistical feature and discriminant selection will then be used. Lastly an algorithm for run-time detection and vessel classification must be developed. In this algorithm, we will make use of prior information and situational constraints as much as possible to improve performance. Priori information would come from text data as mentioned above. Situational constraints might include use of ship berth or port characteristics to constrain possible ship scales, locations, or orientations.

References

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