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Effective intelligence, surveillance, and reconnaissance (ISR) relies heavily on both technological and human analytical capabilities. Intelligence analysts must be able to detect, interpret, process, and perform other critical tasks to turn data into meaningful information for decision-makers. The ability to aggregate massive data sets into operationally relevant information is challenging due to issues such as information overload, team coordination, time constraints, tunnel vision, and limited or vague guidance. This report describes research and development efforts to enhance training for geospatial intelligence analysts. Initial results from cognitive task analyses with these analysts along with associated technology development are discussed.

Geospatial analysts (GAs) in the United States Air Force (USAF) are responsible for planning, collecting, processing, analyzing, and disseminating (PCPAD) imagery information in order to support air, space, and cyber operations. In order to meet the high demand of the customer base, intelligence analysts must be proficient in detecting, identifying, recognizing, and correlating information to provide information critical for operational planning and execution. These analysts face a number of systemic challenges including information overload, team coordination, time constraints, tunnel vision, and limited or vague guidance (e.g., Heuer, 2005).

The current paper reports training research programs to address some of these challenges by defining characteristics of expert GAs and then developing training to optimize data processing and analysis decisions. Data processing refers to the methods employed by analysts to aggregate, correlate, interpret, and disseminate data to decision makers within the leadership chain. This communication occurs through both face-to-face and computer-supported interactions. Management decision-making refers to the interpretation and conclusions reached by analysts. These decisions can range from the identification of a specific stimulus (e.g., determining a particular building is a hospital) to a conclusion derived from synthesized intelligence information (e.g., based on multiple sources of intelligence, determining a building is clear of males). These aspects of PCPAD are critical to ensuring data is processed and turned into actionable intelligence information meaningful to decision-makers. In order to optimize these processes, we argue that training must provide relevant experiences in which trainees must leverage contextual information to accomplish their mission.

Training Geospatial Intelligence Analysts

At the broadest level, geospatial intelligence analysts (GAs) are responsible for a wide variety of tasks from analyzing the earth's geophysical structure to viewing live video feeds of an area. Largely considered the eyes of the intelligence community, GAs are responsible for interpreting the vast amounts of imagery data collected from various platforms including satellite and remotely piloted aircraft. Analysts view this imagery to accomplish tasks such as the development of patterns of life and supporting ground units. The analyst interprets these activities and creates intelligence products, typically in the form of a presentation with both imagery and textual information. This information is then used by decision-makers from senior command and control officers to ground combat personnel. Indeed, the information from GAs influences the entire air asset tasking process from initial strategy development to real-time mission execution. Thus, expertise for these intelligence analysts is critical for effectiveness.

Training Challenges

GAs face significant training challenges given the diversity in missions and areas of operation supported. This is especially true when the primary method of mission qualification training is shadowing current mission operations. While training during real missions eliminates some of the typical training challenges faced using more scholastic methods (e.g., transfer of training), it also significantly limits the diversity of training experiences to the current operational problem set. In contrast, while more scholastic methods such as classroom and standard computer-based training allow for a variety mission sets to be addressed, transfer of training to real-world missions can be a significant problem. Simulation-based training scenarios might be employed to mitigate both concerns regarding the training diversity in real-world missions and transfer of training with traditional methods. However, current simulation-based training still faces significant technological challenges when applied to the intelligence domain. Application of simulation-based training for pilots was extremely successful largely due to the type of fidelity required for effective training. The focus is often on terrain and structures (e.g., buildings) in a relatively restricted field of view. On the other hand, intelligence analysts are often tasked with viewing imagery to detect, recognize, or identify single entities within very large fields of view. The ability of current simulation technology to accurately render realistic contextual information and cues with high enough fidelity to allow for effective training is still somewhat limited. Additionally, the ability of simulation to represent the sensor data presented to analysts and allow for realistic field of view is also limited. These two issues lead to an overall lack of acceptance of simulation-based training approaches by the intelligence community at large. Future research is likely to mitigate these issues making simulation-based training for GAs more realistic.

Another significant challenge is developing training that leverages contextual information for GA tasks. Contextual information is a critical cue for the detection and recognition of suspicious activities, a tasking which is critical to effective mission support. Development of expertise in this area necessitates learning the culture and typical patterns of behavior for a particular operational area. For example, cues that might allow for insights into differentiating between males and females in certain cultures (e.g., walking next to each other) might not be the same for other cultures. Similarly, actions that might be completely normal in one context, such as a gardener digging a hole to plant tomatoes, might seem like an anomalous activity in another context (e.g., digging a hole to plant an improvised explosive device).

Although humans have a robust capacity to learn patterns, development of expertise in this type of complex pattern recognition generally requires years of extended practice (Ericsson, Krampe & Tesch-Romer, 1993). For example, work in the training literature indicates that expertise in games which rely on pattern recognition, such as chess, require years of training to reach expert levels of performance (Chase & Simon, 1973). This is a significant challenge for intelligence analysts who often work in rapidly fluctuating environments. Analysts report limited day-to-day continuity on tasking making it increasingly difficult to develop expertise in a particular area or to learn an individual's or group's typical patterns of behavior. Furthermore, these positions tend to have a very high turnover rate for multiple reasons including the military's heavy focus on career broadening opportunities, the perception of receiving lower pay than other individuals in similar career fields, and the high stress and long hours often associated with intelligence analysis work. These factors contribute to a very difficult environment to develop expertise.

Developing Training for GAs

Current training research is focused on overcoming these challenges by providing more individualized training for GAs. The approach being used to this end starts with defining expertise using a systematic process to inform adaptive training technology development. Second, the training technologies collect and track trainee experiences and provide optimal content for personalized learning based on their performance. Both of these research activities are highlighted below.

Defining GA Expertise

The first step in the construction of training methodology to facilitate and expedite the development of expertise in a domain is defining expertise within that domain. The process of defining expertise starts with understanding the characteristics that comprise the competencies, knowledge, and skills that GAs must possess in order to perform their duties and help achieve mission success. One of the challenges of understanding these characteristics is that the context of the missions may influence them—that is, the set of competencies, knowledge, and skills may vary across mission. Fortunately, a variety of analytic methods (e.g., Work Domain Analysis, Mission Essential Competency) exist to elicit these characteristics and distill them across mission areas in order to find the commonalities and differences between them. As a result, the ways in which these characteristics change with changes in context—environment, culture, equipment available, etc.—across mission areas can be known and accounted for in developing training to increase the expertise levels of GAs.

In order to understand the competencies, knowledge, and skills required to conduct geospatial intelligence analysis across a variety of mission areas, we conducted a job analysis technique called Mission Essential Competencies (Colegrove, Alliger, Beard, Bennett & Garrity, 2009; Alliger, Beard, Bennett, Colegrove & Garrity, 2007). This method involves conducting a number of workshops and administering surveys to collect data on the competencies, knowledge, and skills required for the job roles involved in the work environment, as well as information on the training environments and the types of experiences in which incumbents participate to gain expertise. In the job environment we analyzed, one of the roles was a GA. While we cannot report all of them in this paper, several key results pertain to using expertise and experience in understanding the role of context to conduct effective geospatial intelligence analysis activities. For example, understanding the operational environment—what, where, when, why—is important in clarifying tasking to ensure the appropriate data is collected. In addition, having knowledge of appropriate sociocultural factors—such as style of dress, layout of structures, and nominal behaviors—is critical to correctly process and interpret data collected. Our analysis also revealed that experts are more adept at combining knowledge across contextual factors to reveal more accurate and complete information in response to intelligence requirements; for example, combining information about observed behaviors, cultural norms, and time of day can reveal the sex of observed people.

Using Technology to Provide GA Training

As previously discussed, in order for today's GAs to gain and retain expertise in collecting, processing, and exploiting imagery data, they must be adept at utilizing contextual cues—such as terrain features, adversary activity, and typical warning signatures—in their analytical process. However, GAs face challenges that complicate their ability to gain this contextual awareness, particularly when exploiting across sensor types and facing adaptable environments and adversaries. Because each analyst will have expertise in some contexts but not others, training technology should sense and adapt to analyst competencies, knowledge and skill levels with respect to different contexts by constructing individualized training programs.

Training technology that is adaptive to the individual learner can prepare GAs to learn several contexts at once—such as target area identification, terrain analysis, and sociocultural pattern detection—by building contextual knowledge through individualized scaffolding. Adaptive training systems are computer-based training applications that utilize algorithms to determine the next learning content (e.g., event, module, course) to present and to predict the future performance "state" of the learner based on the current performance "state" of the learner. In order for these types of adaptive systems to function, the performance "state" of the learner must be measured and assessed, the learning content must be meta-tagged for what competencies, knowledge, and skills it provides for training, and algorithms must be able to reason over the meta-tagged content and the learner's performance.

One method for reasoning over these factors to provide adaptive training content is to use a statistical Bayesian approach. One such Bayesian method is called Partially Observable

Markov Decision Process (POMDP) for decision planning under uncertainty (Smallwood & Sondik, 1973). POMDP extends the classic Markov Decision Process (Puterman, 1994) and is used in diverse domains such as assisted living (Hoey, Poupart, von Bertoldi, Craig, Boutilier & Mihailidis, 2010), patient management (Hauskrecht & Fraser, 1998), and spoken dialog systems (Williams, 2010), as well intelligent training systems (Andrews, Freeman, Andre, Feeney, Carlin, Fidopiastis, & Fitzgerald, in press; Freeman, Stacy, MacMillan, Carlin & Levchuk, 2009). In fact, adaptive training systems utilizing POMDPs have been shown to reliably accelerate learning relative to a traditional strategy (hierarchical part-task training) when used to train students on a dynamic target selection task (Levchuk, Shebilske, & Freeman, 2012).

Using POMDP as part of a system to train GAs on contextual cues and information ensures that the resultant training is both adaptive and personalized since POMDP solutions continuously adjust their assessment of the student, and select the next component of the curriculum based on the student results as they are obtained. In addition, POMDP solutions or policies are really a training *plan*, which includes next and future steps of the curriculum by identifying training scenarios within the problem space through which students will gain the greatest contextual expertise given their prior performance. Finally, in order for training to most effectively transfer to the analyst's work domain, the training curricula should be designed to accommodate the analyst's typical workflow, which also would allow the system to be used for both "offline" training and mission preparation and rehearsal.

Conclusion

The goal of these efforts is to provide personalized training based on elicited knowledge from expert GAs. The key aspects to developing an adaptive training environment to support the development of expertise include: defining expert performance in terms of the competencies (knowledge, skills and experiences) critical for developing expertise, ensuring the training environment has the appropriate level of fidelity for the operational community, and integrating experiences which take into account contextual factors regarding an operational area. Personalized training will help analysts to develop the expertise to overcome challenges including information overload, team coordination, time constraints, tunnel vision, and limited or vague guidance. Future training capabilities that are being developed will leverage the above work to support and optimize data processing and management decisions across intelligence, surveillance, and reconnaissance (ISR) domains.

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