The Information Exoskeleton: Augmenting Human Interaction with Information Systems

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Abstract. In the military intelligence cycle the warfighter acts as both a receiver and a producer of information. As a receiver the warfighter must be able to readily assimilate disparate mission-relevant information. As a producer the warfighter must be cognizant of both the current information requirements and the ability to meet them. Both of these tasks are exacerbated by the heat of battle and, in the case of the receiver, the ever-increasing amount of available information. To address these challenges Lockheed Martin Advanced Technology Laboratories (LM ATL) is creating a suite of capabilities to augment warfighter interaction with intelligence services. Much like a powered exoskeleton augments human interaction with the physical environment, our Information Exoskeleton augments the warfighter's interaction with intelligence, providing greater situational awareness with minimal operational overhead. This paper describes our vision for the Information Exoskeleton, the capabilities required to realize it, and related research efforts.

Keywords: Information Exoskeleton, Information Needs Assessment, Context Awareness, Information Alignment, Cognitive Alignment.

1 Introduction

The past two decades have witnessed a dramatic rise in military intelligence collection and dissemination. Advances in electronics, communications, and automated technologies for performing data integration, analysis, and dissemination have made it possible to rapidly push increasing amounts of intelligence to warfighters. The recent proliferation of mobile devices means that dismounted warfighters are increasingly able to a) to receive intelligence in the field, and b) collect and disseminate tactical information essential to the generation of intelligence while supporting ongoing missions.

Actionable intelligence is key to success in tactical operations such as reconnaissance patrols, cordon and search or combat patrols, but its utility is undermined if it is not presented in a fashion that allows it to be easily understood and applied for greater situational awareness. Interacting with a myriad of information from different sources can impose significant cognitive and physical burdens (Claburn, 2009; Shanker &

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Richtel, 2011). Dismounted warfighters are forced to maintain the shifting operating picture, mostly in their heads, while taking into account data from multiple systems and devices such as Blue Force data, enemy position reports, audio communications, video and RF signal detection, requiring extensive context switching (Hsu, 2011). If intelligence is delivered to these warfighters without regard to timing, relevance, or modality it will likely be underutilized, or may overwhelm or distract them when lives are at stake.

Research on attention and multitasking suggests that in demanding situations requiring sustained attention, especially life-threating ones, individuals have difficulty successfully multitasking. This has been demonstrated in classroom learning conditions where students who were allowed to use laptops to browse and use social media during a lecture suffered decrements on tests of memory compared to peers who did not split their attention (Hembrooke & Gay, 2003), as well as a driver's ability to quickly respond to driving-related stimuli is hindered by either handheld or hands-free use of a cell phone (Horrey & Wickens, 2006) However, other research has shown that certain military functions like sentry duty allow a warfighter to successfully manage both the visual scan task as well as responding to auditory signals (McBride, Merullo, Johnson, Banderet, & Robinson, 2007). In fact, the researchers observed that when the work rate was increased, overall performance improved. These results suggest that attention is an important resource that cannot be overly taxed lest it result in delayed or missed reactions, or under-utilized lest it result in an individual tuning out from the task at hand. Technology to support the warfighter must take these extremes into account and carefully estimate the level of attention to help keep the warfighter in an optimal state to respond effectively to incoming intelligence while opportunistically collecting data relevant to known intelligence requirements.

What is needed to better equip dismounted warfighters for current and future operations is a system built upon a solid framework that supports the constantly changing needs of the warfighters and their shifting context. For the past decade, investigators at Lockheed Martin Advanced Technology Laboratories have been conducting research toward our vision of an Information Exoskeleton (IE) for the warfighter. Much like a powered exoskeleton augments human interaction with the physical environment, our Information Exoskeleton augments the warfighter's interaction with intelligence, enhancing the warfighter's ability to benefit as a consumer of mission-relevant information and also act as an intelligence producer with minimal operational overhead. The IE ensures that the intelligence cycle provides the greatest situational awareness (SA) with the least amount of operational disruption. This paper describes our operational vision of the IE, explores the challenges and required capabilities to enable it, and presents our current and planned research efforts.

2 Information Interaction with the Warfighter

2.1 Concept of Operations

To help convey the utility of the IE, we present a Concept of Operations where the IE assists a ground warfighter during his patrol mission.

A dismounted ground warfighter is preparing to go out on patrol in a dynamic urban environment. Prior to a patrol, the warfighter typically receives an intelligence briefing to specify what threats or other activities have occurred recently in the patrol area of operation. With the IE, the warfighter will also be outfitted with body-worn physiological sensors (e.g., monitors for heart rate, blood pressure, galvanic skin response) and tactical sensors (e.g., accelerometer, gunshot detection sensor, blast detection sensor, microphone, camera, gyroscope). The data from these sensors are wirelessly collected by a small handheld or wearable device that provides applications the warfighter can use to file digital intelligence reports, using either texting or spoken language understanding technology, and to receive updates to his understanding of the tactical situation while he is on patrol. The IE system will collect data from the warfighter to understand the warfighter's context of operation, including position, health status, engagement in combat activity, and in turn will use this understanding of individual context to help decide what intelligence to provide the warfighter, as well as the best way to present the information.

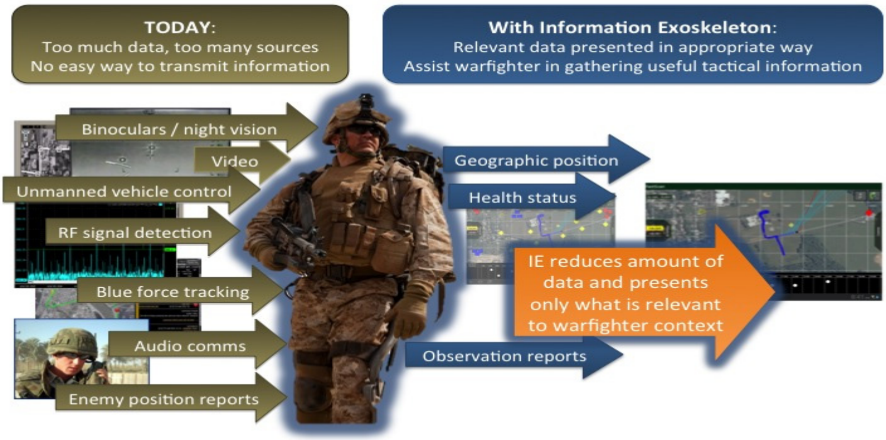

Fig. 1. IE enables the warfighter to efficiently process information

The warfighter provides the IE with a plan for the likely patrol, and the IE checks to see if there is applicable intelligence to the planned mission such as known threats, maps, weather information, and terrain. Once out on patrol, a nearby explosion occurs. As the squad responds with an immediate action drill the IE detects a pattern of inputs from the microphone, accelerometer and gyroscope that matches the signature of an improvised exploding device (IED). The IE initiates actions to aid in near-term tasks. Sound is being recorded on all devices in the squad and the IE requests that other sensors (e.g., GPS, accelerometer) begin logging data to capture movement and changes in posture. The IE creates an observation report template and enters current location and time information so the warfighter can complete and transmit the pre-populated report with information about the IED.

Continuing along the route, the warfighter receives an audio alert that the IE has intelligence that shows a black car blocking the planned route. Suspecting an ambush, the warfighter diverts to an alternate road. The IE prepares information that is relevant to the new route, but recognizes from the speed the warfighter is moving, and the increased stress indicated by physiological sensors, that the warfighter likely cannot attend to the relatively low priority new information. IE begins summarizing and filtering the information based on priority, and stores it for future delivery to the warfighter when cognitive load is lower and assimilating the information is possible. At this point the IE detects that the warfighter is in a good location to collect information to help satisfy a commander's information requirement, and generates an alert that will be sent along with the new route data when the warfighter is ready to receive it.

3 Capability Requirements

The dissemination of intelligence to a warfighter can greatly increase SA of the battlespace. However, pushing information without regard to timing and usability can negatively impact warfighters. Three major challenges that must be addressed to effectively disseminate intelligence to dismounted warfighters are 1) determining the relevance of information to the warfighter given the dynamics of the battlespace, 2) ensuring the usability of available intelligence and 3) effectively presenting information to that warfighter. Satisfying these will enable the warfighter to achieve the highest level of SA with the least amount of operational disruption.

Warfighters must be cognizant of the commander's intelligence requirements as they go into battle because at any given time they may observe, or discover, new information that can strengthen the commander's SA or satisfy the existing requirements. There are challenges for the tactical warfighter to overcome in order to collect the right information. The tactical warfighter needs knowledge of the requirements along with help recognizing when to collect information and the facility to capture information essential to the generation of intelligence. The goal for collection of useful tactical information is to maximize SA while minimizing operational overhead.

We believe that the challenges to interaction for both information dissemination and collection can be addressed by three core IE capabilities:

1. Assessing the warfighter's operational context
2. Assembling information based on context
3. Adapting the user interface to the information and user operational context

While engaged in an activity, individuals are in a particular cognitive state and exhibit predictable physical conditions. These cognitive and physical indicators are part of the tactical warfighter's operational context. The context consists of elements such as geographic position, health status and engagement in a combat activity. It can be thought of as a plan or task being executed by a tactical warfighter along with physical and cognitive states. Physical context attributes include physiological response and body position, while cognitive state describes individual awareness, cognitive load, and current interests. Body-worn physiological and tactical sensors assess heart rate, blood pressure, pulse ox, stature, detect and geo-locate signal activity (Regli, Tremoulet & Stibler, 2013). The operational context may also include descriptions and status of his current mission, his role in the mission, and environmental details.

Currently, the volume of information being processed by Companies is large enough to justify a dedicated Company Intelligence Support Team (CoIST) which assists the commander in intelligence analysis and fusion, else the intelligence becomes stale and dangerously obsolete to patrols (Morgan, 2008). While there is a wealth of data being collected and fashioned into intelligence, very little of it is ever used by the tactical warfighter. The reason is two-fold. The tactical warfighter does not have the bandwidth to scrutinize data and correlate it with other information and is not able to constantly monitor a screen while patrolling with a weapon in hand. While just providing tactical warfighters with all possible intelligence seems to be the solution, it would create larger problems by disrupting their primary task and information overload. Tactical warfighters cannot spend time sorting through data. They need correlated sets of information relevant to their current task and environment verses streams of information. They can draw some conclusions in the field, but really need someone to help them “connect the dots” to have a greater situational understanding of the battlefield in which they are operating. Filtering data and correlating information from various sources will ensure that the warfighter receives more manageable amounts of highly relevant data. For example, the warfighter might be interested in historical IED blasts along his mission route, but only those that have occurred within a pre-defined timeframe. Another way to reduce the data would be to determine a pattern in the blasts. Maybe they occur at a particular time in the day. Maybe they are triggered by another event such as the passing of a convoy through an intersection along the route. The capability to provide tactical warfighters with controlled amounts of relevant data will enhance their situational awareness while still allowing them to successfully perform their primary mission.

Timely intelligence is most beneficial to warfighters when it is delivered via a method that enables them to rapidly assimilate the information, thus minimizing disruption from primary tasks. Relevancy is vital since context switching is extremely difficult and potentially dangerous in their operational environment. Presentation of the information is equally important. The most appropriate set of modalities (visual display, auditory or tactile alert) for presenting new intelligence depends upon warfighter context, including the immediate environment (noisy? potentially threatening? light sensitive?) and what tasks are being performed (patrolling an area? looking for a specific vehicle?). For successful information transfer, tactical warfighters need a system that has the capability to adapt its timing and communication modality to the user’s tasks and environmental constraints.

Establishing a contextual understanding of the user allows for collection and dissemination of information relevant to that context. A warfighter’s operational context leverages the most current information, correlates it with the known information and incorporates it into an existing perspective. Since the system has been tailored to present only information relevant to a warfighter's mission, including the current location and route, we expect a reduction in review time. Before sending data, the IE verifies that the warfighter is in the right context to be able to process the data. If the physiological and cognitive sensors suggest an overload and the intelligence is not time-sensitive and does not pose an immediate threat to the warfighter, it may wait to notify him. It will also refrain from detailing existing information requirements and identifying opportunities for collection of information that may satisfy those requirements. Pertinent information is presented to warfighters using formats and modalities that make it easy for them to understand how the information is relevant to their missions.

4 Component Structure and Applicable Research

Figure 2 presents a diagram that shows how the main IE components work together to provide information to the user. This section will focus on the function of each component and the areas of investigation we have conducted to lay a foundation for our IE vision. In addition to a reference structure, we have created prototype implementations on Android platforms to enable active engagement with subject matter experts to help evaluate and enhance the capabilities.

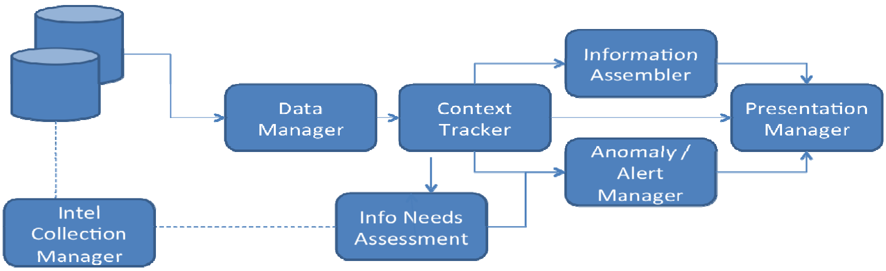

Fig. 2. Information Exoskeleton Component Diagram

The ***Data Manager*** stores all of the information collected by the system in a form that is easily accessible from the rest of the system. Data can come from sources varying from biometric sensors, GPS, accelerometers, to reports, blue force tracking and RF detections.

To collect data about the warfighter's context without having to interrupt the warfighter's activities, we developed a generic data-modeling component to provide automated collection, storage, and dissemination of sensor data generated by body-worn physiological sensors and/or other tactical sensors. When data is requested from another warfighter, messages are constructed with the sensor outputs and sent over the network to that warfighter's device. We have demonstrated collecting sensor data from simulated sensors and from real sensors that transmit their sensor data via Bluetooth wireless communication. This sensor technology has been applied in several domains, including medical triage and casualty reporting.

As information is collected, multiple trackers and components work together to organize the information being received. The ***Context Tracker*** determines what is relevant to the human based on a set of predetermined contexts: biometrical, world, human, and tactical contexts.

We have developed prototype systems that adapted the user interfaces based upon user task and operational contexts. As part of these efforts we developed the abilities 1) to assess individual's cognitive states through physiological data, and 2) to track and manage the tasks that require operator attention (Morizio, Thomas, and Tremoulet, 2005). We developed mitigation strategies to minimize disruption of the user's primary task (Regli, Tremoulet, Hastie, and Stibler, 2006). More recent research has involved tracking and adapting user interaction based on other aspects of warfighter context such as mission status, walking versus stationary, etc.

Our research in Plan Execution Monitoring (Allen, McCormick, 2005) enables the IE to be intelligently informed about the changing nature of the operational context. The plan monitor compares the values returned from environmental sensors with the values in the models to determine which activity is currently being executed, and the status of that activity. For military domains where explicit plans are used (e.g., tactical missions) the IE can leverage this approach to determine plan state allowing the context tracker to know the warfighter's current activity. Armed with this contextual information the **Information Assembler** is better equipped to provide mission-specific information for the warfighter.

The ***Anomaly/Alert Manager*** component monitors the data and produces alerts based on the rules of the context in which it is operating.

Our Human Alerting and Interruption Logistics - Surface Ship (HAIL-SS) system is based on anomaly monitoring and alert management research. HAIL provides alert management to maximize the benefit of timely critical alerts and minimize negative effects of human interruption. It is composed of services that alert human operators appropriately, and help the operators recover work-flow context afterwards. HAIL-SS enables operators to maintain higher levels of situational awareness despite a high volume of alerts that are generated from automation. (McFarlane, 2006)

Alerts generated by the ***Alert Manager*** are delivered to the ***Information Assembler*** for processing. The ***Information Assembler*** collects, organizes and correlates relevant data, producing useful information for the warfighter.

We have been investigating how to most effectively express information that is typically requested and used by intelligence analysts in a manner that is consistent with the tactical language and perspective of a warfighter on patrol. The first part of the challenge is enabling queries to be expressed in tactical language by presenting tactical vocabulary as a front end to queries that contain logic gleaned from intelligence experts (Samoylov et at., 2009). It also requires an understanding of tactical tasks to enable the presentation of different types of data from multiple data sources in a manner that is correlated and filtered to match the task goals that the warfighter is trying to accomplish. This area of information assembly research is ongoing.

The ***Presentation Manager*** component determines how to deliver the data via an appropriate set of modalities to the user's interface based on the user's current needs.

We developed an "environment director" component that selects presentation modalities based on the task's preferred modality, the application's modality capabilities, and user context. More recently, to enable geographic display of relevant information including blue force tracking and reports by location, we have developed a lightweight graphics library that can display geo-rectified objects (e.g. map tiles, icons, grid lines) on a map display. The library supports panning and zooming in and out of the map tiles that are stored at different zoom levels. The current GPS position of each device is collected and shared with all the other devices and shown on the map. We have employed this lightweight mapping and visual location display technology on several efforts, including the observation reporting domain and medic triage and casualty reporting domain.

In the dynamic battlespace information requirements change along with the operational context. Given updated contexts from the context tracker, the ***Information Needs Assessment*** component determines the types of information that best support the current state of the mission. We have conducted extensive research into automatic and semi-automatic approaches to anticipate the information needs of the warfighter. Our fully automated approach is based on direct mapping of mission state and warfighter role to information requirements based on historical/statistical analysis of prior information requests. Our semi-automated approach is a recommender system that leverages information ontologies, historical analysis of prior information requests, and mission state. When the warfighter requests information the system recommends additional information that might be relevant.

Finally, the ***Intel Collection Manager*** supports the warfighter by providing simple, intuitive, multi-modal interfaces for gathering and disseminating tactical intelligence.

Our capability in the area of tactical information collection in support of intelligence generation enables the warfighter to speak the contents of standard tactical reports; the spoken utterances are parsed into structured digital reports that can be shared more easily, sent to a tactical operations center (TOC) when possible, and made available for use by other warfighters or by intelligence analysts for near- or long-term increase in overall situational awareness of the battlefield. A multimodal interface enables report entry by voice when hands are occupied and by text when there is a need to remain quiet. We have applied spoken language understanding technology to several domains including small unit logistics, squad-level observation reporting and casualty reporting.

5 Discussion

Our research is guided by a vision of an intelligent Information Exoskeleton that seamlessly allows the right information to be collected, processed, pre-positioned, requested, and delivered in a manner that amplifies human effectiveness. The IE hosts a suite of capabilities that understands a user's tasks, anticipates needs, assists in gathering knowledge and presents relevant information in a time, format and modality-appropriate way that minimizes disruption. As such, the IE functions as a contextual window between a tactical user and the world.

Our future efforts will focus, primarily, on enhancing this contextual window by expanding and aggregating our views into the warfighter's operational context. While we are currently able to monitor executing missions, some roles in the military aren't represented by such explicit, well-defined plans (e.g., intelligence analyst). Recent research in Task Context Management (Kersten & Murphy, 2006) shows that such tasks can be tracked with minimal, if any, human intervention. Additionally, we would like to develop techniques for aggregating the disparate contexts into a unified warfighter profile that can be leveraged by both the IE and other information systems to provide better intelligence to the warfighter.

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