Improving Situational Awareness in Military Operations using Augmented Reality

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Abstract. During military operations, the battlefields become fractured zones where the level of confusion, noise and ambiguity impact on how to achieve tactical objectives. Situational Awareness (SA) becomes a challenge because the perception of the situation is unstable, leading to degraded understanding and the inability of the soldier in projecting the proper results. To meet this challenge various military projects have focused their efforts on designing integrated digital system to support decision-making for military personnel in unknown environments. In particular, this work presents an updated compilation of some digital systems using Augmented Reality (AR) as a means of visual representation of the context information acquired. Additionally, we propose an AR framework which aims to improve the SA of the soldiers in the battlefield using AR.

Keywords: Augmented Reality, Situational Awareness, Devices Mobile, Context Awareness, Network-Centric Warfare

1 Introduction

According to Bryant, D. et al [3] the fratricide remains a very real threat in the current battlefields. To address this, the military have put much effort in the development of combat identification technologies to improve the ability of soldiers to accurately identify the enemy.

Saarelainen, Tapio et al [19] argue that future military operations will be based on tools of Command, Control, Communications, Computers, Information and

Intelligence for optimal performance in their assigned tasks in versatile and hostile environments.

SA is a mental representation and understanding of objects, events, interactions, environmental conditions and any other factors in a specific situation that may affect the development of human tasks. Many military operations take place in unknown environments. The SA solutions allow soldiers to make effective use of diverse information in a context of battle being one of the major goals the reduction of cognitive load in times of stress. New technologies offer innovative methods of getting contextual information and then this information is visually represented in natural and non-invasive way without affecting the cognitive process of the soldier. This is the case of Augmented Reality (AR).

AR, defined by Azuma, R. [1] refers to interactive applications in which 3-D virtual objects are integrated into a 3-D real environment in real time (3-D objects, sounds, text, etc). There are several projects that incorporate the use of AR in military applications, since its use could produce dramatic improvements in the soldier performance and provide a great advantage in combat.

The rest of the article is organized as follows: section 2 introduces definitions such as Situational Awareness, Context Aware, Augmented Cognition, Augmented Reality and Network-Centric Warfare. Section 3 presents a review of various military projects using AR to improve the SA on the battlefield. Section 4 proposes an AR software framework. Finally, Section 5 presents the conclusions and future work.

2 Definitions

2.1 Situational Awareness

Brown, David Wm [2] mentions that SA refers to the perception, understanding and anticipation of the elements within an operational environment required to act effectively within that environment.

Tremblay, Sébastien et al [22] define that SA is a prerequisite to timely and accurate decision-making in the fast and highly stressful context of infantry operational environments. The introduction of electronic support technologies onto the battlefield is expected to improve SA by providing the right information, at the right time and in the right format.

Endsley, M. R [7], [8] mentions that SA is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future.

In Figure 1 is depicted the SA model in the dynamic decision making.

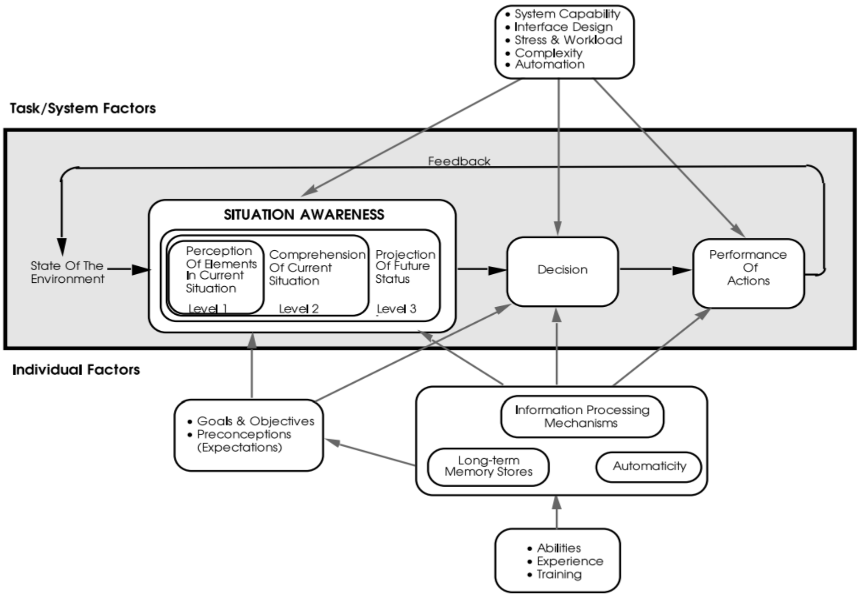

Figure 1 – SA model in the dynamic decision making (Endsley, 1955)

Endsley, M. R. et al [9] determine that one of the most important factors which underlies in the development of a suitable SA is the presence of mental models and prototypical situations schemes. It provides a fundamental mental construction to lead the way to allocate attention and highlight the critical issues.

2.2 Context Aware

The formal definition of Context Aware most widely accepted is provided by Dey, A. and Abowd, G. D. [6]: "*Context is any information that can be used to characterize the situation of an entity. An entity can be a person, place or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves*".

To Dey, Anind K. et al [5] the context may be considered as a set of information including user activity, location, personal preferences and current status. The mobility creates situations in the user context. The context is dynamic and keeps on changing. The context is best defined as states or environmental settings, such as location, orientation, time, nearby objects or people, ambient light level, noise and temperature.

According to Schilit, B. et al [21], the access to the context increases the wealth of man-machine communication and the effectiveness of the elaboration of the task.

Hull, R. et al [12] define Context Aware as computer systems capable of sensing, interpreting and responding, according to the environment in which the user is located.

2.3 Augmented Cognition

To develop an information display system, it must be examined the information needs and it must be determined the best modality or combination of modalities to present that information in order to make the system be robust, usable and effective. The information processing capabilities of humans has quickly become a limiting factor in human-computer interaction. This problem has motivated the development of a new scientific discipline mentioned in [15] called Augmented Cognition (AC). Methods to detect and mitigate the limitations of human processing of information and design solutions to improve the exchange and use of information on man-machine systems are the specific concerns of AC.

2.4 Augmented Reality

According to Hicks, Jeffrey et al [10], AR provides the user with superimposed information that can be seen in the real world, that is, it complements the real world with virtual information. AR improves the perception of the natural world by adding information to the senses whether visual, sound, smell or tactile sensations. AR refers to the mix of the signals from the tridimensional real environment on the user perception. It denotes the fusion of virtual 3-D images on the users' natural vision of the world around them, using glasses or HMD (head-mounted display). Through the ability to present information superimposed, integrated in the user environment, AR has the potential to provide significant benefits in many application areas. Many of these benefits arise from the fact that the virtual signals shown through AR system may go beyond what is physically visible.

2.5 Network-Centric Warfare

According to DoD [4] network-centric warfare is a military doctrine that aims to turn an informational advantage in a competitive advantage through a strong network of forces, geographically dispersed, but well-connected and informed.

Moffat, J. and Atkinson, S. R. [17] describe that it is moving towards an organizational structure of network-centric warfare which is flat, fast and it is based on information, in contrast to the hierarchical structure of slow movement, based on the model of command and control. In the Network-Centric Warfare, computers integrate information acquired from multiple sources to increase SA in the battle space in three dimensions and create an image that provides critical and relevant information to all levels of command and control, which include the soldier. The networks are formed by nodes with the information transmitted through command positions, vehicles and the soldiers' wearable computer.

3 Review of military projects

3.1 Background

Zieniewicz, Matthew J. et al [24] mention that in 1989, the U.S. Army used a small wearable computer to help soldiers on the battlefield tasks.

James Schoening, research analyst who worked on the CECOM (Communications Electronics Command) of U.S. Army, is who started to use wearable computers. Working with Matt Zieniewicz, Schoening transformed his idea into system architecture with specific technologies, such as wireless data transmission, image capture and integrated Global Positioning System (GPS). In 1990, Schoening and Zieniewicz associated with John Flatt, Sal Barone and Almon Gillette to demonstrate the Soldier's Computer System. Later, based on the Soldier's Computer project it gave rise to project SIPE (Soldier Integrated Protective Ensemble). The SIPE project, directed by Carol Fitzgerald, was the first in which the U.S. Army treated the various components of the combat devices as an integrated system.

3.2 Eyekon Project

Hicks, Jeffrey et al [10], define the EyeKon project as a support system for decision-making based on intelligent agents installed on a wearable computer that the soldier carries. The dismounted soldier visualizes the target information and other information on his weapon. The main idea is developing the smart icons and notations that are superimposed on the video of soldier's weapon. The basic functions are on a wearable computer connected via a secure wireless network to a local and remote database. Incorporates sensors that provide real-time information (e.g. inertial sensor, GPS, IR, etc.). Eyekon is an intelligent agent-based decision support system hosted on a wearable computer with an available database and updates via radio links. On the weapon display, the information is superimposed using AR techniques.

3.3 BARS Project

The Naval Research Laboratory (NRL) developed a prototype augmented reality system known as BARS (Battlefield Augmented Reality System) [16]. BARS focused on developing a digital system to help address the increasing emphasis on Military Operations in Urban Terrain (MOUT). The BARS user interface includes a sophisticated but disjoint set of functions that assist the warfighter in understanding the surrounding environment, including information filter to annotate the most important or nearby objects, a set of representations of occluded objects, etc. BARS tracked the position and orientation of the user’s head and superimposed graphics and annotations that aligned with real objects in the user’s field of view. Multiple units shared a common database, where individuals could choose to join a given channel to access its graphic data.

3.4 iARM Project

Tanagram Partners was awarded a contract from the Defense Advanced Research Projects Agency (DARPA) to develop the Intelligent Augmented Reality Model project (iARM) [14]. The objective of iARM is to develop an integrated digital system that could significantly improve decision making of military personnel in complex contested environments via an integrated operating system, a data services model, and a digitally enhanced head-mounted display. The aim is that all these components work together in a seamless fashion which allows soldiers to perceive, comprehend and what is most important, project the best course of action for increased performance to achieve tactical objectives. iARM project covers many of the attributes of artificial intelligence. In Figure 2 is depicted the conceptual design of the HMD and the soldier's vision through glasses.

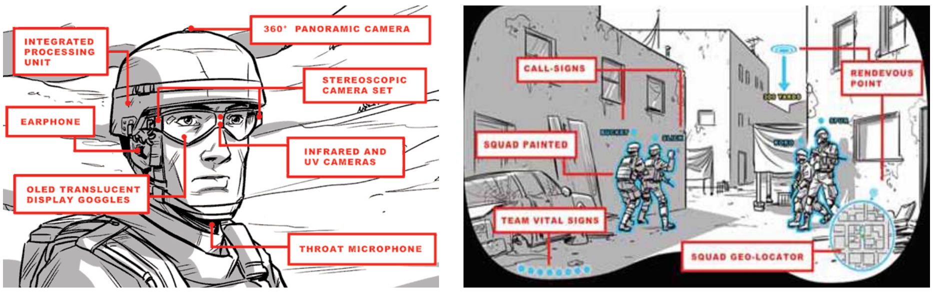

Figure 2 – Conceptual design of iARM

3.5 ULTRA-Vis Project

In [23] is detailed the Urban Leader Tactical Response, Awareness and Visualization (ULTRA-Vis) project, supported by the DARPA, has developed an AR prototype system for soldiers on the battlefield. The ULTRA-Vis system overlays full-color graphical iconography onto the local scene observed by the soldier. To enable this capability, the program developed and integrated a light-weight, low-power holographic see-through display with a vision-enabled position and orientation tracking system. Using the ULTRA-Vis system, a soldier can visualize the location of other forces, vehicles, hazards and aircraft in the local environment even when these are not visible to the soldier. The prototype will be equipped for the gesture recognition using a glove. Allow superimposed symbols in the 3-D battlefield, to locate enemy targets and locate the allied forces. ULTRA-Vis provides to squads a clear tactical advantage enabling collaboration among members of the squadron. ULTRA-Vis enables high SA and the ability to make decisions while on the move in the field of operations. In addition, the system can be used to communicate to the soldier a variety of tactically significant information including imagery, navigation routes and alerts. In Figure 3 is depicted the conceptual design of ULTRA-Vis.

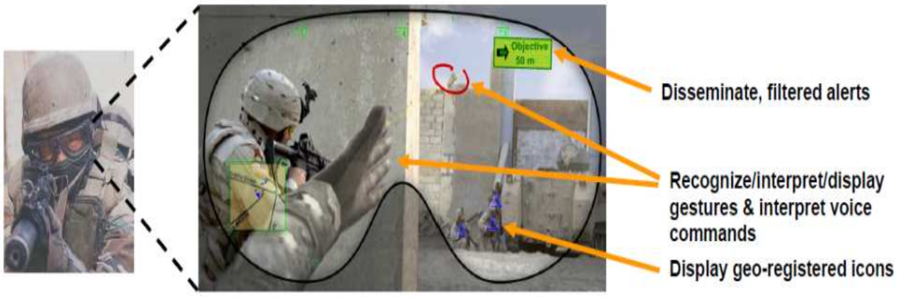

Figure 3 – Conceptual design of ULTRA-Vis

4 Proposed AR framework

This section details the RAIOM framework (in spanish, Realidad Aumentada para la Identificación de Objetivos Militares). Subsection 4.1 details the Information Model (IM). Subsection 4.2 explains the importance of filtering and the representation of information acquired from the context of the environment. Considering the above and after analyzing military projects detailed in the previous section, subsection 4.3 describes the RAIOM framework, which uses AR as visualization technology in order to improve the SA of the soldiers in military operations.

4.1 Information Model

We have named IM to the information transformation process. The process starts when the information is acquired from the context of the environment and the process ends when the information is visually displayed (Fig. 4). The IM defines as information passes through different stages. These stages are focused on *Acquire*, *Send*, *Process* and *Represent* the information obtained from the context of the environment. The *Acquire* stage denotes when the information is obtained from the context of the environment mainly through sensors geographically dispersed. The *Send* stage corresponds to sending information acquired in the previous stage through communication devices. The *Process* stage is responsible for computing the information obtained from the context of the environment. Then the information is treated through pre-processing techniques, detection, extraction, classification, recognition, identification, etc. The last stage of the IM relates to *Represent* the information that was processed in the previous step. The representation of the information is visual and it uses AR techniques to enrich the user's perception of the real world.

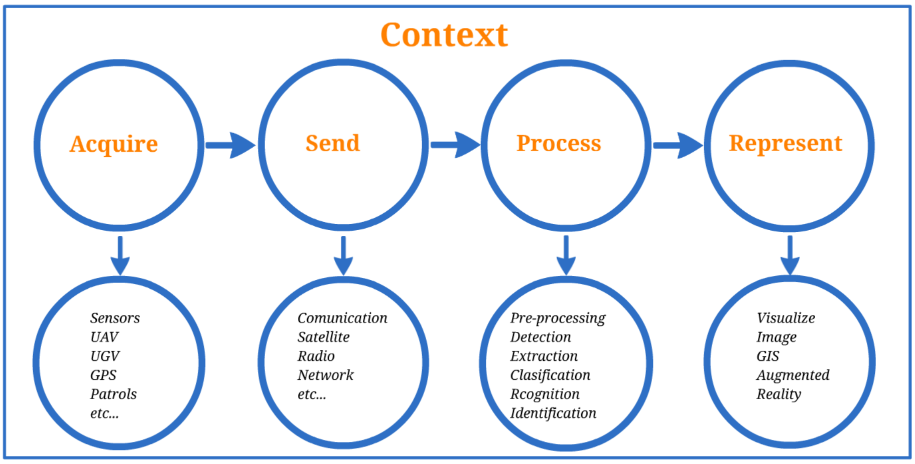

Figure 4 – IM stages. The information transformation process

4.2 Information filtering and representation

Julier, S. et al [13] have presented the idea of using a real-world context as a search cue in information retrieval and implemented a system which filters information based on physical location, for selecting what is displayed to the user by means of AR. The main purpose of information filtering is to prioritize and reduce the amount of information presented in order to show only what is relevant to the user.

Sestito, S. et al [20] mention that because of the soldier's mobility through the environment, the context can change dramatically depending on their position. The amount of information that can be displayed to a user in a virtual world can be overwhelming. To fix this problem, the system must sort and prioritize the information so that it should show the features that are relevant to the soldier, such as threats.

4.3 RAIOM Project

Having analyzed the military projects that use AR to improve the SA of soldiers in the battlefield, we propose the design of a software framework that takes the best features of the above projects and it meets the specific needs of military infantry. The goal of RAIOM project is improving the SA of the soldiers by obtaining information from the context of the environment and then to represent it visually by using the AR in order to help the soldier to make decisions under stress. The RAIOM project is based on an understanding of the current state of digital technology in warfare, the changing nature of combat, the changing role of the soldier and the growing importance of SA.
Operational Capabilities:

- Interactions with gesture and voice recognition for data collection
- Multiple tracking (GPS, sensors, vision, etc.)
- Detection and recognition of 3-D objects
- Face recognition
- Identification of allies and enemies

- Information filter system
- Implementation and integration of the prototype on mobile devices

Features:

- Stand-alone (just a few dependence on external network access)
- Omnidirectional (communication among members of the patrol and command and control center)
- Light-weight (gesture & voice recognition) and Low-power devices
- Security (data & communication channel encryption –C-RAIOM project-)
- Open source (Framework & OS)
- Mobile (Smartphone, tablets and goggles -see-through display-)

5 Conclusion and Future Work

This article has described how to improve the SA by using the AR as an advanced technique of information representation in a military context. For a right understanding was defined the meaning of terms such as Situational Awareness, Context Awareness, Augmented Reality, Augmented Cognition and Network Centric Warfare. The article provided the historical review of military digital systems using AR to improve SA. The study described the IM to explain how the information goes through different stages from the information acquisition from the context of the environment to the information representation by using AR techniques. The article detailed the importance of filtering information because it dictates what kind of information should be displayed to the soldier and when. Furthermore, the research serves to collect and analyze the state of the art of military projects in order to design the software framework called RAIOM. This framework is designed to support decision-making for military infantry in unknown environments using AR.

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