An Augmented Environment for Command and Control Systems

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Abstract: In the information age the ability to develop high-level situational awareness is essential for the success of any military operation. The power of network centric warfare comes from the linking of knowledgeable entities that allows information sharing and collaboration. By increasing the number of commanded platforms, the volume of the data that can be accessed grows exponentially. When this volume is displayed to an operator, there is an high risk to get a state of information overload and great care must be taken to make sure that what is provided is actually information and not noise. In this paper we propose a novel interaction environment that leverages the augmented reality technology to provide a digitally enhanced view of a real command and control table. The operator, equipped with an optical see-through head mounted display, controls the virtual context remaining connected to the real world. Technical details of the system are described together with the evaluation method. Twelve users evaluated the usability of the augmented environment comparing it with a wall-sized stereoscopic human computer interface and with a multi-screen system. Results showed the effectiveness of the proposed system in understanding complex electronic warfare scenarios and in supporting the decision-making process.

1 INTRODUCTION

Gaining a detailed understanding of battlespace is nowadays essential for the success of any military operation. Network Centric Warfare (NCW) is a military doctrine of war developed by the United States Department of Defense in the 1990s (Alberts et al., 1999; Braulinger, 2005). The power of NCW derives from the effective linking of forces that are geographically or hierarchically distributed. The network allows knowledgeable entities to share information and collaborate to build up a shared *situational awareness*.

A Network Centric Operation (NCO) is an operational situation according to the NCW. Figure 1 shows an example of NCO: different platforms have the capability of sensing some limited areas and each one has a personal limited awareness of its proximity. In Figure 1(a) each platform sends collected data to a specific platform, known as Command and Control (C2). The C2 has the special task to fuse data, in a manual or automatic way. In Figure 1(b) the C2 sends the fused data to the different platforms, and

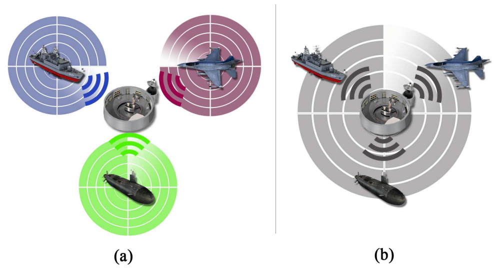

Figure 1: Example of a Network Centric Operation.

in this way they share the same enhanced situational awareness. This process is continuously repeated during any NCO.

As it can be inferred from the Figure 1 example, the C2 holds an important role in these networks: it is the system devoted to the decision-making process of the operational aspects of the warfare. Commanders operate such systems by means of a Human Computer Interface (HCI) in order to get access to the Common Operational Picture (COP) and in order to manifest decisions (e.g., plans, orders).

The COP represents a single identical display of

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relevant information concerning friendly, enemy, and neutral forces. Examples of information that can be integrated in a COP include location (e.g., current positions, rate of movements), environment (e.g. current weather conditions, terrain features), status (e.g., capabilities of offensive and defensive enemy weapon systems).

Being the visualized information the result of several inputs conveyed to the same displayed area, a state of *information overload* is likely to occur when increasing the number of commanded platforms (Shanker and Richtel, 2011). In particular, the information flow rate may be greater than the operator's processing rate, leading to the creation of a wrong mental model of the mission scenario. This results in making wrong decisions that may lead to catastrophic situations.

This paper proposes a novel interaction environment that exploits the Augmented Reality (AR) to increase situational awareness and reduce information overload. The solution proposed is assessed on realistic Electronic Warfare (EW) scenarios.

Next section introduces the related works (Sect. 2). The proposed solution is then presented (Sect. 3) followed by a description of our experiments (Sect. 4). Conclusions are eventually drawn (Sect. 5).

2 RELATED WORKS

Several researches have been performed to design and develop new display paradigms and technologies for advanced information visualization in tactical command and control.

Dragon has been one of the first research projects in formalizing requirements for systems with the need to visualize a huge amount of information on tactical maps for real-time applications (Julier et al., 1999). A virtual environment for battlefield visualization has been realized with an architecture composed of interaction devices, display platforms and information sources.

Pettersson et al. have proposed a visualization environment based on the projection of four independent stereoscopic image pairs at full resolution upon a custom designed optical screen (Pettersson et al., 2004). This system suffers from apparent crosstalk between stereo images pairs.

Kapler and Wright have developed a novel visualization technique for displaying and tracking events, objects and activities within a combined temporal and geospatial display (Kapler and Wright, 2004). The events are represented within an X, Y, T coordinate space, in which the X and Y plane shows flat geographic space and the T-axis represents time into the future and past. This technique is not adequate for an immersive 3D virtual environment because it uses an axis to describe the time evolution constraining the spatial representation on a flat surface; the altitude information, that is important in avionic scenarios, can't be displayed. However, it is remarkable that the splitting-up of geographical and logical information (e.g., health of a platform) can enhance the usability of the system.

In NextVC2 the main idea is to leverage the Virtual Reality (VR) technology to create a shared collaborative environment with a customized view of the real world objects and events (Carvalho and Ford, 2012).

Hodicky and Frantis have conducted a research program to investigate ways to increase the level and quality of information about the battlefield by means of VR devices (Hodicky and Frantis, 2009). The commander equipped with a HMD can operate the virtual environment by head and body movements.

The use of a system based only on VR has the disadvantage that the virtual world isolates the operator making difficult the connection with the real world. In addition, this technology requires a complex and expensive scene modeling and rendering to faithfully reproduce the represented real world as well as artificial navigation methods.

Adithya has presented a paper-based augmented map for military scope that uses the ARToolKit marker-tracking based approach and a video see-through Head Mounted Display (HMD) to manage interaction and visualization (Adithya, 2010). The dynamic information of the terrain, the placing of virtual objects and the interaction are features of the digital world that are superimposed onto the paper map. The main limitation of this type of system is that the field of action is restricted to a specific area.

3 PROPOSED INVESTIGATION

This paper proposes a novel environment for modern battlespaces visualization, which exploits AR technology to increase the understanding perception and reduce information overload. This is expected to improve operator's performance in terms of both reaction time and number of errors made during the execution of complex tasks.

3.1 High-level Architecture of Loki

The system proposed is part of Loki, an advanced C2 system for EW that coordinates a set of heterogeneous

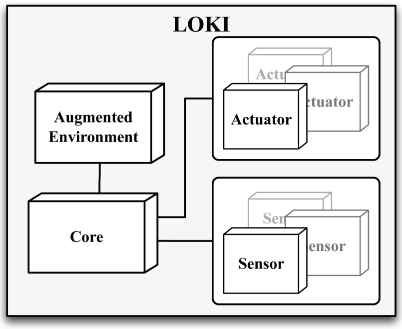

Figure 2: Loki architecture in the large.

platforms (air, surface, subsurface) having on board sensors and actuators in the domain of electronic defence. Figure 2 shows the high-level architectural view of the Loki system.

The Core component continuously executes an advanced multi-sensor data fusion process on the data retrieved from cooperating systems. Once these data are properly fused, the system is capable to infer new important information such as a better localization of emitters and countermeasures strategy. These information are transferred to the presentation layer using a communication middleware based on Data Distribution Service (DDS) paradigm (OMG, 2007).

The Augmented Environment (AE) component provides a digitally enhanced view of a real C2 table configuring the visual appearance of the COP and accepting and validating user input. Moreover, it provides a persistence mechanism to decouple the data-access logic from the core logic.

3.2 Augmented Environment

The mission area is visualized in a new way that allows to increase the situational awareness. The operator, looking through the lens of an optical see-through HMD (NVIS nVisor ST50), sees the virtual world superimposed on the real world (Figure 3). The precise alignment is obtained through the use of an electro-magnetic tracker (Polhemus Patriot) that detects, in real-time, the position and the orientation of the observer's head.

The virtual environment consists of a geo-referenced 3D map of the mission area on which the EW scenario is positioned. The localized platforms (characterized by latitude, longitude and altitude) are placed on the scene faithfully reflecting their geographic coordinates and are represented according to MIL-STD-2525C (Department of Defense, 2008). If the Direction of Arrival (DOA) of a threat is known with a margin of error, the uncertainty volume is shown as a pyramid with vertex in the platform that

Figure 3: Operator equipped with a see-through HMD.

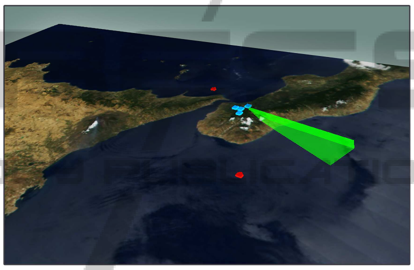

Figure 4: Geo-referenced 3D map.

has performed the detection (Figure 4).

Different kinds of views are provided through the activation of layers normal to the C2 table. In Figure 5 the intersection of the uncertainty areas relating to a specific threat is shown by a top view of the 3D model. A small viewport, placed in the upper left corner of the display, provides critical information (e.g. warning emitters detection) to the operator. This type of visualization permits to visualize in a correct way the different elements of the scene and to delete any form of information overload.

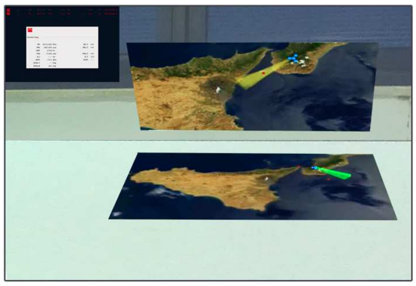

Figure 5: Activation of a layer normal to the C2 table.

The users around the C2 table can collaborate face-to-face maintaining the ability to use real-world objects.

3.3 SW Design and Implementation

The AE has been designed with high modularity applying User Interface Design Patterns (UIDP). These patterns help to ensure that key human factors concepts are quickly and correctly implemented.

The SW has been developed in C++ using OGRE, an open-source 3D engine that abstracts the details of the underlying system libraries (e.g., OpenGL, DirectX) and provides an interface based on high-level classes (Ogre 3D, 2001; Rocha et al., 2010). Qt Core API has been integrated to take advantage of its powerful mechanism for object communication called Signals & Slots and to handle, by means the QtSerialPort add-on module, the serial port to which the electromagnetic tracker is attached (Digia, 2015).

The high-definition map of the mission area has been generated through several steps. First, the 3D model has been generated starting from Digital Terrain Elevation Data (DTED), using Autodesk Infrastructure Design Suite. After that, Autodesk 3DS Max has been used to add textures, details and colors. Finally, the resultant model has been converted in a format supported by OGRE. An important thing that must be considered is that in this process the georeferencing information is lost and a mapping algorithm (Bowditch, 2012) to associate a specific point inside the map to each pair of longitude and latitude value has been implemented.

To avoid a different spatial perception of the virtual context through the HMD in contrast to the real world, the camera view frustum has been calibrated to the display view frustum. The calibration method adopted (Kellner et al., 2012) requires that each user aligns tracked real world markers with virtual target positions and can be completed in approximately one minute for both eyes.

4 USABILITY EVALUATION

4.1 Test Procedure

The purpose of the evaluation was to assess the usability of the proposed AR system. The formal usability study was carried out at the facilities of ELT in Rome and involved 12 members of the armed forces of different countries. The case study required about tree hours per participant to be completed.

The test procedure started with a brief presentation of the system and the aim of the investigation.

Each operator was involved in the understanding of complex NCW scenarios, using the proposal AE, a wall-sized stereoscopic HCI (Zocco et al., 2014a; Zocco et al., 2014b) and a multi-screen system. Three visual detection tasks of increasing complexity were assigned to participants (i.e., identification, correlation and triangulation).

To measure the operational behaviours, the number of failures and the completion time were automatically acquired for each task. In addition the following qualitative data, referring to the users' experience, were collected using questionnaires and interviews:

- depth impression;
- viewing comfort;
- level of immersion;
- sense of isolation;
- understanding perception.

4.2 Results Analysis

The results for quantitative parameters are shown in Figure 6 through line graphs.

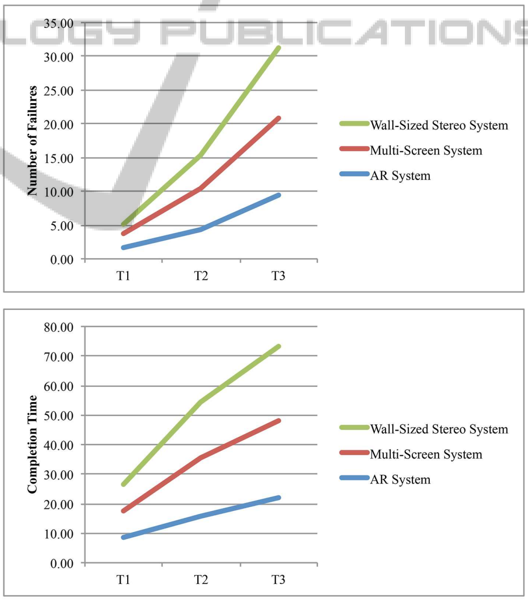

Figure 6: Quantitative data related to users' performance.

Regarding to the simplest task T1, only minor differences have been detected between the considered display systems. The impact of AR becomes evident after increasing the level of task complexity. The reduction in the number of failures and in the completion time under AR conditions is impressive for task T2 and T3.

The above results represent the major outcome for our experiments. Under AR conditions users acquire greater situational awareness and this leads to a reduction of both the reaction time and the number of errors committed.

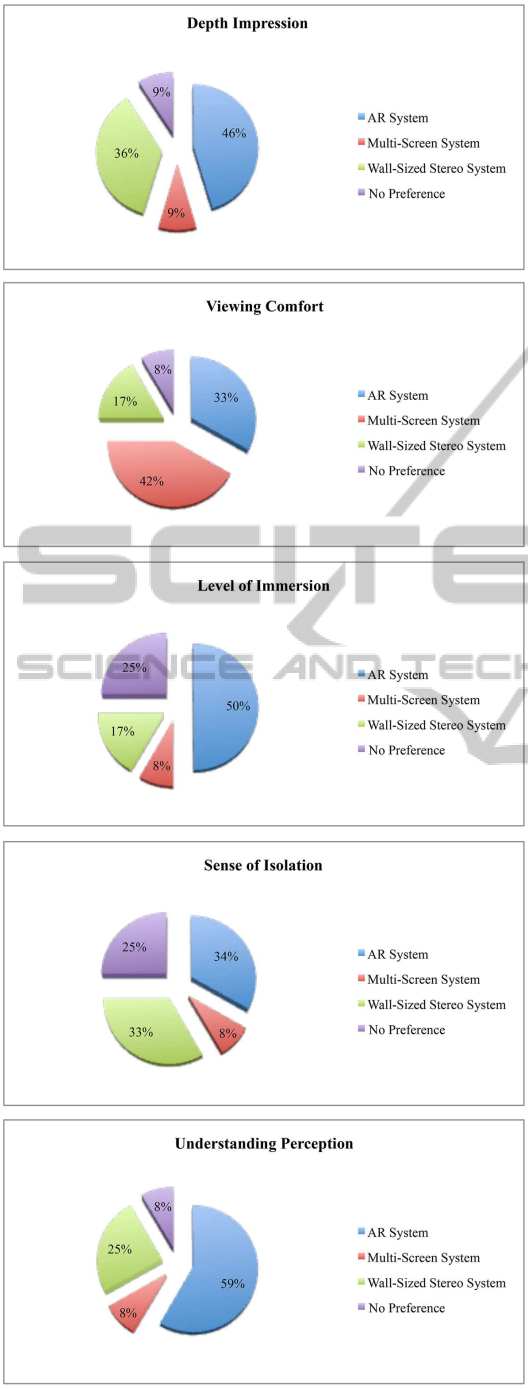

Figure 7: Qualitative data related to users' experience.

The results of the questionnaires and interviews are consistent with quantitative data (Figure 7).

Most of the participants had no doubts that the depth impression and the level of immersion are higher in case of stereo visualization (AE or wall-sized stereo system). With complex EW scenarios, when monocular depth cues are ambiguous, the stereo viewing enhances spatial judgments: it is possible to detect very closely spaced icons (representing platforms or threats).

Positive judgments about viewing comfort were provided on all display approaches. Many operators (42%) preferred the multi-screen system because no wearable device (e.g., shutter glasses, HMD) is needed.

The sense of isolation is approximately equal between AR system and wall-sized stereo system. In the AR system the perception of the virtual world as part of the real world, allows to relieve the seclusion that derives from the use of an HMD.

The majority of participants (59%) perceived a better understanding of the scenarios in the case of AR system. This indicates that the methods of handling the information overload and of reporting warning notifications have a significant impact on the decision-making process.

5 CONCLUSION

Inadequate situational awareness in NCW may lead an operator to make wrong choices with potential disastrous outcomes. Situational awareness is challenged by information overload. This makes the HCI a key element is the design and development of the C2 system for NCO.

This paper proposed the use of a novel interaction environment that leverages the AR technology to provide a digitally enhanced view of a real C2 table.

The formal usability study showed very clear trends with our users performing significantly better under AR conditions in terms of understanding perception, depth impression and level of immersion. A significant reduction of both the number of failures and of the completion time has been obtained.

The results presented represent the initial experimentation phase of continuing research into user interaction for military purposes. The lack of comparative evaluation with respect to other works specifically addressing NCW is due to the actual complexity of this domain.

In the next future, a comparison between optical and video see-through approaches will be conducted and the gesture and motion control by means of low-cost devices (e.g., Leap Motion, Myo) will be explored.

REFERENCES

Adithya, C. (2010). Augmented Reality Approach for Paper Map Visualization. In *INCOCCI 2010, International Conference on Communication and Computational Intelligence*, Erode, India.

Alberts, D. S., Garstka, J. J., and Stein, F. P. (1999). *Network Centric Warfare: Developing and Leveraging Information Superiority*. CCRP Publication Series.

Bowditch, N. (2012). *The American Practical Navigator*. National Imagery and Mapping Agency.

Braulinger, T. K. (2005). Network Centric Warfare Implementation and Assessment. Master's thesis, U.S. Army Command and General Staff College.

Carvalho, M. M. and Ford, R. (2012). NextVC2 - A next generation virtual world command and control. In *MILCOM 2012, IEEE Military Communications Conference*, Orlando, Florida, USA.

Department of Defense (2008). MIL-STD-2525C: Common Warfighing Symbology. http://www.mapsymbs.com/ms2525c.pdf. [Accessed on 03 January 2015].

Digia (2015). Qt Project. http://qt-project.org. [Accessed on 03 January 2015].

Hodicky, J. and Frantis, P. (2009). Decision Support System for a Commander at the Operational Level. In *KEOD 2009, 1st International Conference on Knowledge Engineering and Ontology Development*, Madeira, Portugal.

Julier, S., King, R., Colbert, B., Durbin, J., and Rosenblum, L. (1999). The Software Architecture of a Real-Time Battlefield Visualization Virtual Environment. In *IEEE VR'99, IEEE Virtual Reality Conference*, Houston, Texas, USA.

Kapler, T. and Wright, W. (2004). Geotime Information Visualization. In *INFO VIS, IEEE Symposium on Information Visualization*, Austin, Texas, USA.

Kellner, F., Bolte, B., Bruder, G., Rautenberg, U., Steinicke, F., Lappe, M., and Koch, R. (2012). Geometric Calibration of Head-Mounted Displays and its Effects on Distance Estimation. *IEEE Transactions on Visualization and Computer Graphics*.

Ogre 3D (2001). http://www.ogre3d.org. [Accessed on 03 January 2015].

OMG (2007). Data Distribution Service Portal. http://portals.omg.org/dds/. [Accessed on 03 January 2015].

Pettersson, L. W., Spak, U., and Seipel, S. (2004). Collaborative 3D Visualizations of Geo-Spatial Information for Command and Control. In *SIGRAD 2004, Conference of the Swedish Eurographics Chapter*, Gävle, Sweden.

Rocha, R. V., Rocha, R. V., and Araújo, R. B. (2010). Selecting the Best Open Source 3D Games Engines. In *SBGAMES 2010, Brazilian Symposium on Games and Digital Entertainment*, Florianópolis, Santa Catarina, Brazil.

Shanker, T. and Richtel, M. (2011). In New Military, Data Overload Can Be Deadly. http://www.nytimes.com/. [Accessed on 03 January 2015].

Zocco, A., Cannone, D., and De Paolis, L. T. (2014a). Effects of Stereoscopy on a Human-Computer Interface for Network Centric Operations. In *VISAPP 2014, 9th International Conference on Computer Vision Theory and Applications*, Lisbon, Portugal.

Zocco, A., Livatino, S., and De Paolis, L. T. (2014b). Stereoscopic-3D Vision to Improve Situational Awareness in Military Operations. In *AVR 2014, 1st International Conference on Augmented and Virtual Reality*, volume 8853 of *Lecture Notes in Computer Science*, Lecce, Italy.