Experimental User Interfaces to 3D Visualization of C2 System

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Abstract. The article describes development of 3D visualization system that works with Czech C2 system. Various projects that contributed on development the 3D visualization of data from the C2 systems are mentioned as well. The main focus of the article is on using motion tracking and augmented reality approaches to simplify the user interface of this visualization system.

Keywords: Command and Control, C2, Visualization, Augmented reality, Motion tracking.

1 Introduction

One of the generally accepted definition of Command and Control (C2) system dates back to 1986. C2 is a system of systems that can be characterized by high degree of complexity, distributed environment focused on distribution of decision making process over the agents, high demand on reliability and inevitable human machine interface implemented to support communication between operator and system [1] C2 system can be seen in many domains such as traffic control, manufacturing system, nuclear system, military system, etc. Military C2 (MC2) system is C2 system that operates in the real time battlefield domain with the main goal to achieve operational and information superiority [2].

MC2 system research activities began in 1970 and from that moment battlefield information was strictly connected to geographical position information. Thus the main MC2 interface was born as a battlefield real time picture with related geo information. Interface was called common operational picture (COP) and its name is still in use. COP is usually composed of visualized military information (SW solution) and physical interface to control this environment (both HW and SW solution).

Visualized military information is divided into:

- Friendly position information (blue forces)
- Enemy position information (red forces)
- Unit tactical data information
- Geo data (raster, vector and satellite imagery)

From the visualization point of view the military information is visualized on the map resources.

Physical interface is composed of:
- Visualization system (LCD, projector)
- Input devices (keyboard, mouse, trackball)

The most important demands on COP are:
- Credibility of visualized information
- Accuracy of visualized information
- Visualization in natural and understandable way
- Easy and user-friendly interface
- Ability to work in field conditions

1.1 Current state of MC2 system

First MC2 system has been implemented in 1995 in the US Army. This system was capable to gather all battlefield data from sensors and to visualize it in 2D map resources. The progress of technology and mainly the growth of computer power enabled to develop application that was capable visualize friendly units in 3D terrain in 2008 [3]. That was the first attempt to visualize COP in 3D (Figure 1).

FBCB2 3D solution has these shortcomings:
- Friendly and enemy units are visualized as a symbol (not 3D objects)
- Not exactly expresses the area covered by unit (only connected to a point, not to the area of operation)
- Unit tactical data is not visualized (combat efficiency, movement velocity, fuel capacity, ammunition capacity, etc.)
- Human machine interface is slow and old fashioned (keyboards, LCDs)

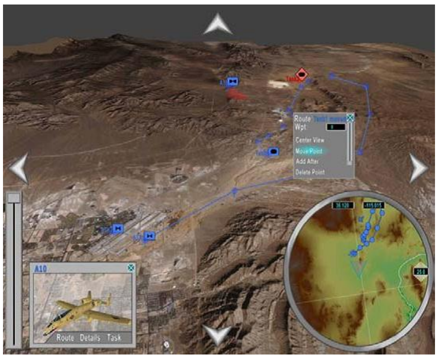

Fig. 1. Blue and red forces mapped on the 3D terrain - COP

In 2007, The Defense department of the Czech Republic accepted a new research project called:" Virtual reality devices in ground forces tactical command and control system (GFTCCS)". The project concentrates on increasing commander situational awareness at a tactical and operational level in three dimensional (3D) terrain visualization. This project is based on integration of virtual reality devices into command and control process.
The main project goal was a demonstration of a new presentation layer of GFTCCS with virtual reality devices. A global architecture of GFTCCS was designed in 1999 and its presentation abilities were obsolete. The commander could get information about battlefield in 2 dimensions (2D) only. The terrain spatial data were available but they were not used to visualize the battlefield in 3D. Communication between the commander and GFTCCS was supported only by a mouse or keyboard. A resolution of visualized battlefield was given by output devices abilities - CRT or LCD monitors. The old presentation layer offers common features of Geographic Information Systems (GIS) such as zoom in, zoom out or movement of actual position over a map.
The main ability of GFTCCS is to show a position of friendly forces as it can be seen on the picture bellow.

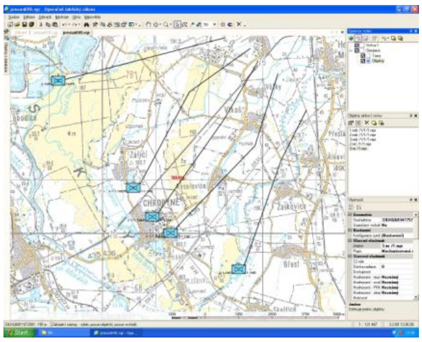

Fig. 2. Old presentation layer of GFTCCS

The new presentation layer comes out from experience with virtual reality devices in the modeling and simulation world. It was based on project with code name "Virtual" (2008-2009) that implemented a new presentation layer for Czech GFTCCS system that is capable to visualize friendly units as a 3D object in virtual terrain. The virtual terrain is fully automatically generated from geo data resources without any operator involvement and visualized unit covers by its volume the unit controlled area.
This new presentation layer was tested by commanders and the visualization part was positively accepted.
The new 3D visualization system could display 3D terrain based on digital geographic data and 3D units in forms of tactical symbols in App6a format but it was not able to display any other tactical graphic – the tactical overlays from GFTCCS system.

Fig. 3. GFTCCS 3D Visualization system

Project with code name "Visual", started in 2010 and ending in 2012, enhances the 3D visualization capability mainly in the field of tactical data visualization in 3D. The 3D visualization methodology of tactical overlays (tactical lines, areas, directions and points) has been designed and implemented. It uses a non-official standard for tactical overlays exchange in C2 system – the NVG (NATO Vector Graphics). The NVG standard is composed from two parts:

- NVG data format
- NVG service

The NVG service is based on web-service standard and is implemented in the GFTCCS system and provides tactical overlays graphical data in NVG data format. The overlay in NVG format is converted using a special service on the side of 3D visualization system into 3D representation.

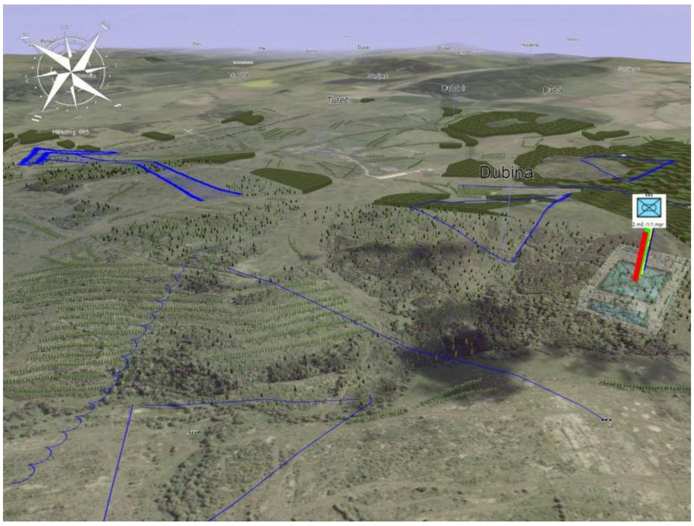

Fig. 4. Shows the tactical overlays visualized in 3D

2 Experimental user interface

The traditional user interface consists of computer mouse and keyboard. This type of user interface is satisfactory in the desktop configuration – monitor or multi-monitor systems, but for the projection systems it does not give the commander a freedom of move. The commander must voice command the operator of the system to move the view in the 3D environment. So an idea of using the body movement and hand gestures was introduced. As a body motion sensor was tested the Microsoft Kinect sensor.

2.1 Using the Kinect sensor

Microsoft Kinect sensor was chosen to control COP as a low cost device. Originally it was developed only for Xbox game console, but currently Kinect can be used on the PC platform. This devices is composed of two infra cameras and one standard camera that enables the drivers to measure distance between important points in the tracked area. The exact position of appropriate joints of user (or two users) standing in front of it can be solved by Kinect API and customized SW application.

The Kinect device was implemented into GFTCCS solution. The commander can stand in front of sensor and his movements are tracked by the Kinect device. The tracked body movements and gestures are used to control the COP visualization process. The Kinect is a wireless device so the commander does not need any other attached motion tracking sensors.

Not only was the Kinect device employed into overall architecture. The figure 5 shows the complete COP visualization architecture solution. Commander and his staff (usually 5 persons) wear glasses that are synchronized with 3D stereoscopic projector projecting the visualized imagine on a standard projection screen (active stereoscopic projection is used). The Kinect device is placed under the projection screen. The projector can placed either on the floor or mounted on the ceiling. The ceiling projection mounting allows more room for the commander but floor projector placement is easier for fast deployment. This configuration was designed and tested for easy deployment in standard military field tents. The active stereoscopic projection enables better depth sensing of the visualized terrain and is very appreciated by the commanders and staff.

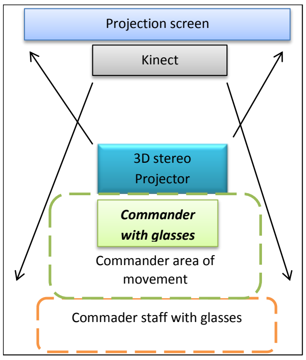

Fig. 5. Basic scheme of Commander post equipped with the Kinect sensor

Fig. 5. Motion tracked commander post demonstration

2.2 Utilization of augmented reality

The visualization using stereoscopic projection allows better depth sensing for the user that controls the camera position in the virtual environment. But works in the way that user controls the virtual camera in the virtual environment and “fly with it”. On the contrary a lot of commanders is used to work with the traditional sand tables and want to walk around this virtual terrain as they can around the sand table. This experience is able to give them the augmented reality solution only.
The augmented reality solution can work in two ways:

- Using the motion tracker
- Using the pattern recognition

Both solutions require wearing see-through glasses that are connected with a personal visualization computer. As a personal visualization computer can be used any tablet or embedded computer such as Fit-PC2 or similar.

2.2.1 Augmented reality with motion tracking

The most important thing in the virtual sand table solution is the tracking of user's head. The head position and orientation information determines position and orientation of virtual camera in the virtual environment. To obtain such data a motion tracking platforms should be used. The motion tracking can be either optical – using several calibrated cameras and reflexive points on the user's glasses or hybrid using optical and inertial sensors. These motion tracking platforms guarantee precision values and stability of position and information data but as a drawback they are expensive and require precise installation and calibration so they are not designed for the field conditions.

2.2.2 Augmented reality using pattern recognition

The position and orientation information about the user's head can be also obtained by using pattern recognition algorithms. The augmented reality glasses must be equipped with a camera that records user's point of view. A special library for pattern recognition analyses frames capture from the camera and looks for the defined pattern. From the recognized pattern the parameters such as user's relative position and orientation can be obtained and these data are used to render the virtual sand map accordingly. Unlike the solution with motion tracking platform in pattern recognition the camera must see the whole pattern so the freedom of movement is limited and it is not possible for example to come closer to the part of virtual sand table that is too distant from the pattern position because the pattern recognition library would lost the position and orientation information. The advantage is that this solution does not require any complicated hardware just the piece of paper with printed pattern that is placed on the virtual sand table place.

3 Conclusion

We have already done couple of experiments with low cost visualization solutions. We have tested the Kinect sensor and its usability to control the visualization system of MC2 in simulated field condition. We revealed that:

- Kinect solution works perfectly in dark environment (battlefield tents).
- Commander staff must be located in the specified areas (usually on the sides) to not cross the line of sight from the Kinect device to the tracked commander.
- Commanders were able to better understand the vital information from the battlefield.
- Control of visualization was more intuitive and thus faster.
- The overall solution was easy to deploy and ready to use in very short interval – less than 10 minutes.

The augmented reality based virtual sand table was tested in the laboratory conditions only. The tests revealed that the idea is correct but they are many technical difficulties that degrade the quality of the solution. As the crucial factor based on our tests is the precision of position and orientation sensing during fast movements of the user.

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