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Research Article

Augmented Reality in an Enhanced Command and Control Application

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ABSTRACT:

Having timely information about the combat situation is crucial both in conducting military operations of various scales and in training personnel. The level of complexity of existing military command and control systems is limited to visualization, primarily using tactical symbols. The current state of information and computer technologies allows achieving a qualitative leap in the level of perception with the application of "augmented reality." Peer-to-peer information technology enhances cognitive ability by adding additional, meaningful graphical and text information to a real-time image. Saturation with high-performance mobile devices and the powerful entry of wireless digital networks into the military activity makes it possible to use the technology to the level of an individual fighter on the battlefield. In this article, the authors reflect on the peculiarities of applying augmented reality visualization in the performance of tactical tasks, determining appropriate methods for integrating visual and texts information, offering a model of information interaction with an augmented reality application. They propose a software architecture of a specialized mobile application and present the results of its practical implementation.

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Introduction

Scientific and production organizations engaged in projects in the interest of defence have long-standing traditions in creating, adapting, and developing emerging and promising technologies. The ability to layer additional digital in-

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formation on the end users' field of vision is highly appreciated and used in specific military applications.

Applying an advanced visual perception of the environment, combined with digital communication for remote data transmission, is able to improve situational awareness according to modern perceptions of network-centric combat organization, improve understanding of the tasks assigned and serve to build up shared experience. In general, the final effect aims at reducing response time in critical situations, preventively informing users about upcoming situations, shortening the decision command cycle. In the field of command and control systems, combat control systems, and weapon control systems, developments based on such advanced technologies can be mentioned.

Related Works

Although not yet introduced as standard equipment, a system known as the Integrated Visual Augmentation System [1,2] (IVAS) is being developed for implementation in the US Army. IVAS is based on the Microsoft HoloLens product [3] and will have an extended range of capabilities, including night vision, thermal imaging, target identification, access to navigation data, and more. This system revolutionized the way commanders and soldiers share data, delivering mission-critical information directly into a soldier's field of vision. Active-use solutions reflect how combat operations are carried out: For example, through "see what I see" solutions, fire support tools, medical and other teams can receive real-time instructions and other vital data submitted from remote command posts.

Another system,[4] called the "Force XXI Battle Command Brigade-and-Bellow" (FBCB2), is designed in principle as the US Army's Battle Management System (BMS). It offers command and control, situational picture, logistics, and other key functionality for the front armed forces of various kinds - armored, artillery, aviation, infantry, intelligence, combat repair services, air defense, and more. After 2013, this system was adopted in the Marine Corps.

In the initial versions of the system, the computer was mounted at the disposal of the commander of the combat vehicle (Figure 1 a). In more modern versions, the computer is located in the compartment with the combat calculation in the rear compartment of the combat vehicle.

In Figure 1 b a picture is displayed from the screen of the actual working system. The picture is a removable real-time situation display. Despite its relatively small size, the screen allows touch screen control. The sensitive screen area on the right side is relatively large and ensures effective use even in a machine that is moving with major shocks. The earth control of the display is not functional when the operator necessarily has a protection hand - in conditions of chemical or bacteriological danger or at low temperatures. To ensure working capacity in such cases, a special stylus is provided in the kit of the sensitive display.

From what has been exported so far, some conclusions can be drawn on the critical requirements for such systems.

a) b)

Figure 1: Force XXI Battle Command Brigade-and-Bellow.

Connectivity while driving. In view of the fact that modern combat operations are supposed to be highly mobile, the digital data line (picture, formatted messages, voice) must be able to operate in very difficult conditions – radio interruptions, deliberate interference by the enemy, electromagnetic interference.

Reliability and accuracy. These requirements may be called overriding, given the life-threatening nature of combat missions. Where the system is used in the sense of assisting a command-level decision, the data submitted must be precise and timely.

There is no doubt that the critical requirements shown here are sufficiently met in these and similar systems adopted in leading armies of EU countries. The confidentiality of such studies is a reason why the authors do not have data on the latest developments on the issue. Therefore, the material offers solutions borrowed from advanced general-purpose technologies, data of which are found in open sources.

Undoubtedly, the critical requirements presented here are sufficiently covered in these and similar systems adopted in the leading armies of NATO countries. The confidentiality of such research is the reason why the authors do not have data on the latest developments on the subject. That is why the material offers solutions borrowed from advanced general-purpose technologies, data for which are available in freely available sources.

Requirements for highly mobile command and control systems

Information superiority on the battlefield is a leading theme in modern concepts for conducting military operations.[5] Building a computer network connecting sensors, commanders, and weapons provides greater combat power with the maximum possible reliability and accuracy. In the performance of the tasks of a single perception of the environment and a higher efficiency of the fire impact on the adversary, some studies on specific solutions of sensor systems are implemented.

At a certain level of the chain of command is tracking the behaviour of a moving target, and hereby behaviour, we understand changes in the position (coordinates) of the target and changes in spatial orientation (rotation relative to the target's own axes).

Kumar and co-authors provide a valuable introduction to the scientific aspects of the issue. [6]

This quoted material is civilian-directed, presents a mobile application in which data from an inertial sensor is combined with results from a visual recognition system to ensure soundtracking of an object and reporting its orientation. This combination of different methods overcomes the shortcomings associated with applying one method or another individually. The visual recognition part uses an algorithm based on digital filtering, and for accurate localization, mathematical processing of data from an inertia sensor that is mechanically paired with the video camera is applied. The said material states that in order to achieve repetitive good results, individual components need to be independently tested and precisely regulated.

The application of the method described above for military purposes in order to complement the sensory picture of a digital battlefield can potentially lead to satisfactory results. Possible failures are related to the distortion of the sensory data or the accumulation of a computational error in the algorithmic implementation. To better understand the problem, an analogy can be made with the known methods [7] for marker and marker-free identification of a stationary object.

Applicable Protocols for Information Interaction

As a result of their scientific and practical activities in the interest of the armed forces, the authors are acquainted in detail with the command and control system of the Bulgarian Army Field Integrated Command Information System [8] (FICIS), the US Marine Command & Control system. for Personal Computer [9] (C2PC) and the Joint Conflict and Tactical Simulation [10] (JCATS) Armed Forces Modeling and Simulation System. In connection with the work on this material, attention is paid here to the built-in possibilities for information exchange with the above-mentioned systems for simulations, command and, control.

C2PCcommand and control system

Objects are displayed on the map using Allied Procedural Publication (APP6B)/MIL-STD 2525B. Objects can be attached/removed from the screen depending on the threat they pose, their category, level, and time of activity.

The characteristics of each object include position, name, symbol, flag, affiliation, speed, course, and can be edited in different ways. To be able to communicate electronically between nodes on a C2PC Client network, a C2PCGateway software module is applied. One possible way to communicate is to send a typified "Position Report" message, as shown in Figure 2.

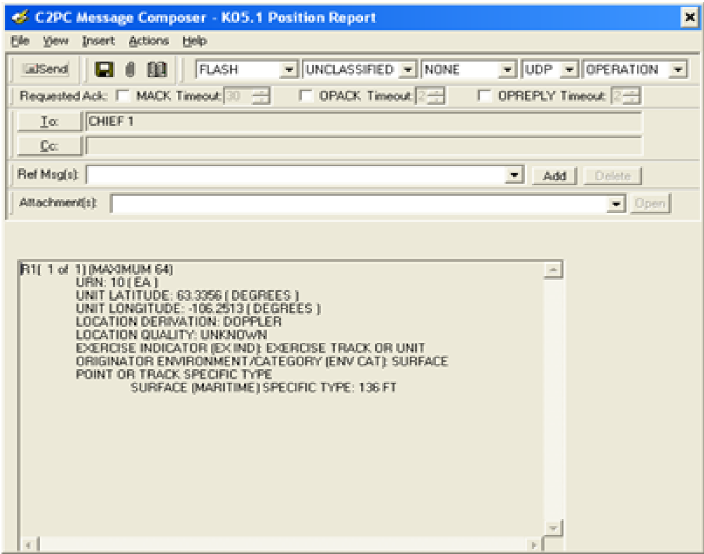

Figure 2: Send a text message Position Report.

At the information protocol level, the text message uses the Variable Message Format (VMF) or US Message Text Format (USMTF) methods. These methods are standardized for the US Army, and their technical parameters are according to STANAG 5048, MIL-STD-6017, MIL-STD-6040 standards.

JCATS Simulation System

The effective implementation of the procedures for modeling and simulations of the course of military operations presupposes the existence of an electronic transmission medium. Depending on the scope of the training, the transmission environment in the form of a local computer network (LAN) can cover a limited number of automated workstations (AWP) or be expanded with outsourced jobs using a resource from the digital infrastructure network. In some specific use cases for a network simulation environment, the global computer network (WAN) is also applicable.

The software packages for modelling and simulation have specialized protocols for interaction between the server module and the outsourced client software modules. Some basic protocols have been introduced to allow interaction via software applications provided by different manufacturers. Distributed Interactive Simulation (DIS)—working according to IEEE-1278 [11] and similar to C2PC—are used as some of the most common standardized simulation protocols.

FICIS field integrated command information system

The Bulgarian Army's field integrated communication and information system uses the Army Tactical Command and Control Interoperability Specifications

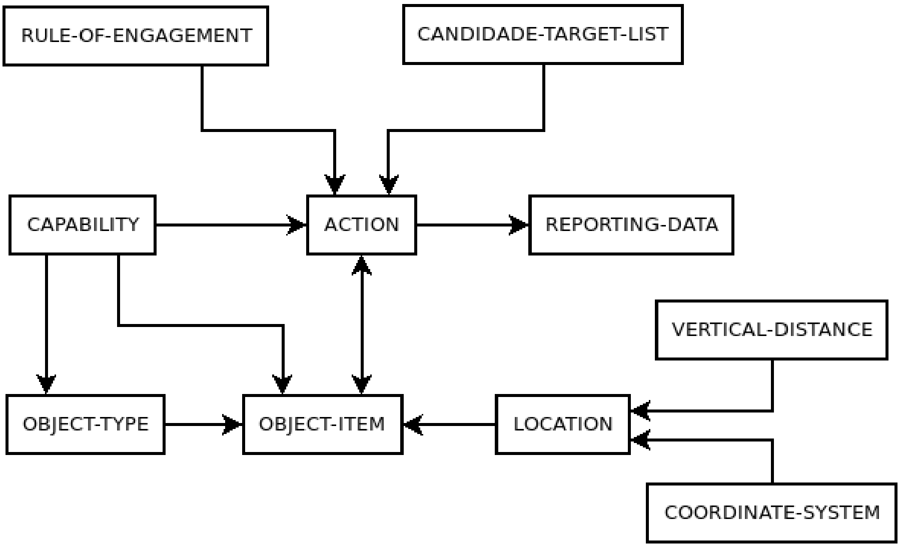

Figure 3: Logical structure of C2IEDM.

(ATCCIS) model,[12] further developed as the Land Command & Control Information Exchange Data Model (LC2IEDM), published in the allied publication ADatP-32.[13]

Detailed analysis of the reduced logical structure of the data in the LC2IEDM model brings to the fore the main functional connection ITEM-ACTION-LOCATION, shown in Figure 3.

Referring to the development of army command and control systems allowing to expand the possibilities through the application of augmented reality, these three information-related domains are interesting for further consideration.

Proposal of a Model for Information Interaction

The scope of the scientific study is to clarify the flow of data and define the need to create additional links and new information structures to expand command and control systems with augmented reality elements.

In further consideration, we accept that the beginning of the information flow is an existing command and control system. Figure 4, as C4I Workstation, a workstation is marked by a system that is networked and configured with software modules to exchange formatted messages or database replication.

Operational data entered automatically or by an operator using a man-machine interface (GUI) is available through a centralized data store, hereafter C4I Server.

The augmented reality subsystem is built as additional modules that use data from C4I Server without in any way affecting the basic operation of the command and control system. The new elements of information support related to augmented reality technology solutions are data structures for 3D visualization of elements of the battle order – 3D Models Geometry, related military conditional signs, and APP-6A image. A subsystem is provided for filtering the level of representation of augmented reality elements – AR Interest Filtering for different types of tactical tasks, augmented reality will react to individual sub-classes ITEMS.

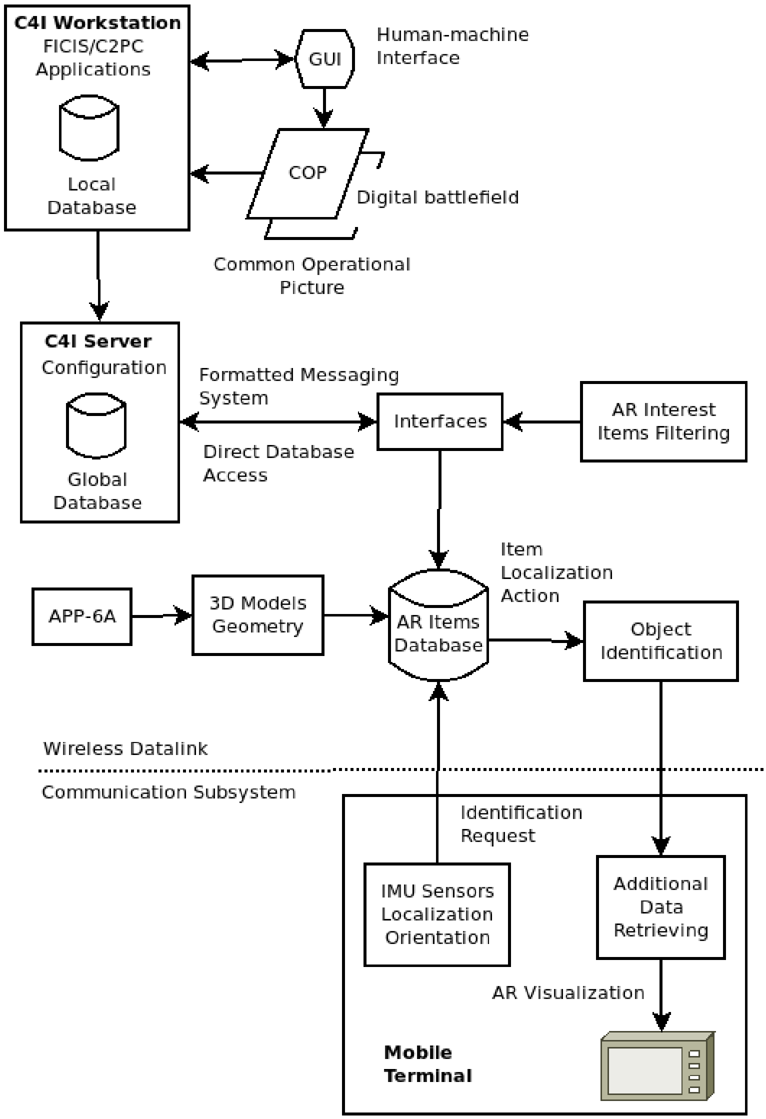

Figure 4: Model of information interaction.

The end element when using augmented reality is a mobile device with the end-user, here designated as Mobile Terminal. By applying Mobile Terminal in a field setting, looking through the built-in camera, the information subsystem complements the image with additional ACTION data for a specific ITEM that is set by the LOCATION system.

Software Architecture of a Mobile Application for Augmented Reality

Figure 5 features a mobile app software architecture designed to present augmented reality elements.

The main component in the software architecture proposed by the author is the freely distributed Android Studio product.[14] By applying the described architecture, a computer configuration is prepared for testing algorithms developed by the author in a virtual environment, as well as on a real smartphone device under the control of Android OS.

Software project:

- Manifest – basic configuration file. It describes the main properties of the application and states the possibility of using hardware and software modules available on the device.
- Camera – built into the test smartphone, video stream source for subsequent analysis, frame modification, and presentation.
- Orientation Sensors – built-in smartphone accelerometer, gyroscope, compass, GPS, magnetometer, which provide digital data to determine the current orientation in space and the current position of the mobile device.
- Resources – a packaged set of string constants, icons, and icons, defined views of the individual screens of the application.
- OpenGL ES 2.0 – a software library for defining and manipulating 3D scenes. It is included in ASIDE by default. It is necessary to apply for the use of the specific application.
- Java code—the main software code of the application—defines the program methods for activity management and the methods for the interaction of all software components.
- C++ code—additional software code, mainly for supporting OpenCV operations—provides efficient frame-by-frame processing and manipulation of the video stream in real-time.
- jniLibs – interface software libraries for the connection between the additional C ++ and the main Java modules of the application.
- apk – application installation package, obtained in the process of compiling valid software code.
- Graddle settings – text files with a description of the rules and the exact options for the proper process of compiling the application.
- Virtual Device Manager – a subsystem in ASIDE, used to select and configure a virtual device (emulator) for testing the mobile application.

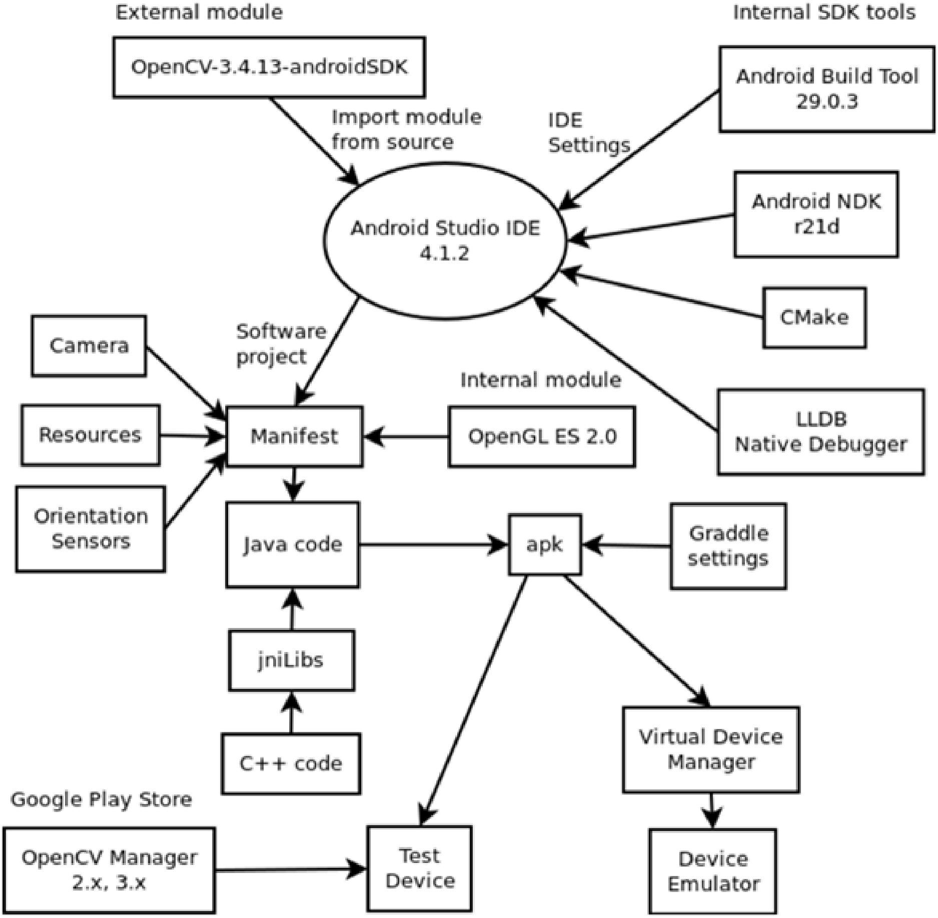

Figure 5: Software architecture of a mobile application with capabilities for reflecting augmented reality.

- Device Emulator – allows testing of the mobile application on the screen of the computer configuration of the developer.
- Test Device – a physical device, in this case, a smartphone, on which the apk created at compilation is installed and launched.

Degree of Practical Realization

A working environment has been configured to create mobile applications for devices running the Android operating system. A minimum version 4.0 is set in the basic settings. The specific versions of the accompanying software tools are listed as follows:

- Android Studio IDE (ASIDE) 4.1.2 - the main product for developing mobile applications for Android devices.
- OpenCV-3.4.13-androidSDK – a development tool and software library for frame-by-frame analysis and video stream modification. It is provided by a standalone internet source and is built into ASIDE as an external module.
- Android Build Tool 29.0.3, Android NDK r21d, Cmake, LLDB Native Debugger - additional software tools internal to ASIDE. They are used in the process of compiling and debugging the application.

A test application has been created in which the authors reproduce the basic functions of the augmented reality system, namely: output of real-time video stream, creation of a 3D scene with additional graphics and text, synchronization of the real image with the computer-generated 3D scene in perspective projection. Objects from the 3D scene are visualized in a point cloud, wireframe, solid systems.

To visually check the displayed results, the relief of the terrain in the vicinity close to the observer is modeled in the 3D scene and 3D models of military equipment are placed. A Touch Screen GUI has been created, with which the observer can adjust the numerical values for the viewing angle of the video camera of the mobile device, as well as to make adjustments for the value of the magnetic declination in the observation position.

The terrain relief model used for tests is available online from the mobile application in geojson format from a freely available source.[15] The visualization models of military equipment are borrowed from the source,[16] available under the Creative Common Non-Commercial License.

Figure 6: Augmented reality with 3DScene terrain model near Sofia.

Figure 6 shows a screen from the application of an actual device – a smartphone, with a computer-generated visualization of the terrain in the vicinity of Sofia.

Shown in Figure 7 is a screenshot of the operation of the application in software device emulator mode. A scene of actual terrain around a selected observer position is shown, and a three-dimensional model of M270 MLRS (Multiple Launch Rocket System) type combat equipment is also visualized in wireframe display mode. When creating the scene, the following initial data were applied: coordinates of the observer 42.66890, 23.37720, azimuth at the place of the observed object relative to the observer 204.50 at a distance to the observer 200m. The actual exchanges of the observed object are approximately 7m x 3m x 2.5m.

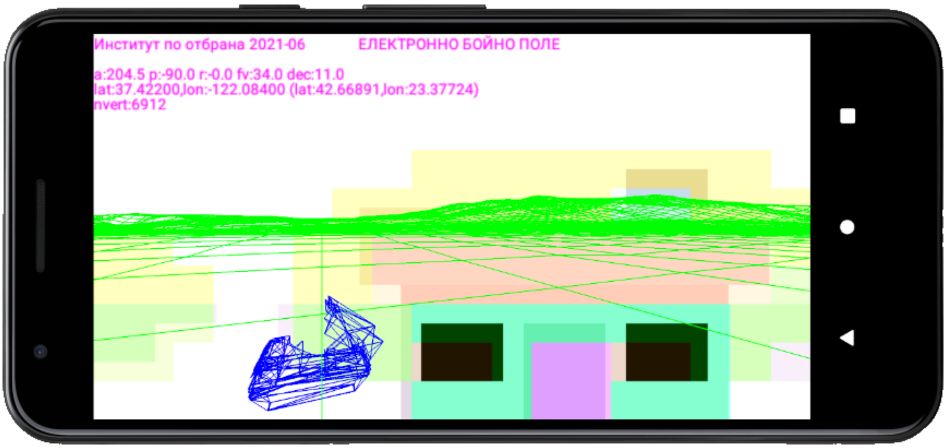

Figure 7: Android Device Emulator Screenshot.

Conclusion and Future Work

In the presented article, the authors explore the possibilities for expanded presentation of elements of the electronic battlefield with the application of information technology “augmented reality.” Examples of existing similar applications in the military field are considered. An essential part of the authors’ professional experience in terms of army command and control systems in terms of their built-in means of information interaction is presented.

The authors propose a model for information interaction between an existing command and control system and a newly developed application for the visualization of elements of an electronic battlefield with the means of augmented reality. A basic mobile application has been created, on which key moments of the technological sequence have been tested. The results obtained at this stage of the study were subjectively assessed as good.

In the process of research and realization of the shown test examples as a problem area is a procedure for synchronization of the real video image of the surroundings at the observer with the computer-generated 3D scene. Problems are concentrated as inconsistencies in scaling or as instability of the generated image. To study the behaviour of the second type of problem, the authors tested different methods for processing navigation data from the inertial sensors of the mobile device. The methods of raw data, low-pass filter, and complementary filter were applied sequentially. Subjective most stable image, while with minimal time delay is obtained when applying a complementary filter. As a direction for future research, the authors envisage the creation of a methodology and algorithmisation of a method for objective assessment of the quality of a synchronous image.

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