Augmented Reality and its Contribution to Enhance the Operational Capabilities of the Armed Forces

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Abstract: This paper aims to highlight the importance of integrating Augmented Reality technology by the Armed Forces as an institution and by Weapon Systems servicing them since it consists of a significant tool in order to achieve the Objective. Therefore, an analysis of the concept of Augmented Reality and its contribution is attempted for the Armed Forces to achieve their Mission and enhance Situation Awareness on the battlefield. The specific technology provides a multiplier of power for achieving a country's territorial defense, national independence, and supremacy against any external threatening or aggressive action.

Keywords: Augmented Reality, Armed Forces, Objective, Situation Awareness.

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1. Introduction

Armed Forces (AFs) across the globe are investing in innovative technologies to achieve their Mission at the three levels of warfare (strategic, operational, and tactical) which includes the defense and territorial protection of Countries. Through the use of cutting-edge military technology, among a variety of tasks, competent military authorities are struggling to provide troops with the expertise required to overcome any trials and compensate for losses/disasters on the battlefield, while at the same time, it contributes decisively to maximizing their capabilities by ensuring timely and rapid access in plenty of essential data and the acquisition of critical information that will act as a catalytic factor on the achievement of the Objective.

Augmented Reality (AR) technology is revolutionizing how the AFs train and prepare for combat and the way in which they operate in the field, ensuring increased survivability, cost compression, casualty reduction, reduction of material resources and means, achieving maximum performance in the AFs Mission.

2. Augmented Reality

Nowadays, AR technology is rapidly developing with numerous applications in various scientific and non-scientific fields. The ever-increasing advancement that is being witnessed is a result of people's quest for digital representation of large amounts of information to facilitate their daily activities. The goal of AR is the integration of digital content (processed and enhanced by computer systems) on data collected from multiple sensors from the real world in real-time in order to achieve a more complete understanding of simplified reality. By utilizing AR, users can interact with virtual information that would not be able to perceive and process through their own natural senses.

2.1 Definitions

The term Augmented Reality was given by Boeing Researchers, Tom Caudell and David Mizell in 1990 [1]. According to the computer scientist Ronald Azuma (1997), Augmented Reality is defined as a system that in general terms [2] combines the real and virtual world, interacts in real-time, and is registered in 3D (three dimensions).

Unlike Virtual Reality (VR) [3] technology which places the user in a fully computer-generated (digitized) Virtual Environment (VE), AR synthesizes 3D virtual objects that are integrated in real-time into the real world [4]. In addition, AR is defined within a more general framework called Mixed Reality (MR) [5] which refers to a range of multi-axis domains covering VR, AR, Telepresence and other related technologies. Finally, the broader framework to which AR, VR and MR belong is called Extended Reality (XR).

2.2 Categories

AR, based on the technological means used and the goals which are predefined, is divided into four categories [6]:

1) **Marker-based AR**: This type of reality is also known as Image Recognition and uses markers such as QR codes, barcodes, images, symbols, objects themselves or other markers, which are simple and discrete patterns, for easy recognition, and low processing power. Applications based on this type detect the markers using a camera through algorithms in order to provide results.
2) **Markerless AR**: This type of reality is also known as Location-based and it does not use markers but utilizes the

physical objects. More specifically, through the sensors of each device, such as the sensors of proximity, compass, location (GPS), light, gyroscope, accelerometer, magnetometer, velocity meter, etc., location data are determined and inserted in the devices. It recognizes things that were not directly provided to the application in advance, unlike Marker Based AR and it uses algorithms only to identify the patterns, the colors, and the other features in order to provide results. These applications are based on SLAM (Simultaneous Localization and Mapping) technology, to directly locate the exact position of the device on the map, as well as to map it and benefits from new technological advancements such as LiDAR (Light Detection and Ranging) and Drones.

3) **Projection-Based AR**: This type of reality uses projection systems. Specifically artificial light is projected onto real-world objects and this allows human interaction by sensing the touch of that projected light. The user's touch is detected by distinguishing between an expected projection and an altered projection. Projection-based AR is used to project a 3D interactive hologram.
4) **Superimposition-Based AR**: This type of reality is based on Superimposition technology. In particular, the original view of an object is either partially or fully replaced with a newly augmented view of that specific object. For its successful completion, it should be mentioned that the object on which the overlay is to be implemented must be correctly identified (during its detection) so that the application can perform the overlay of its view.

2.3 Hardware and Software of an AR System

Hardware [1],[7]**:**

AR allows the integration of synthetic perceptual information with the real-world environment across multiple sensory modalities, including visual, auditory, and haptic. For an AR system to function properly and provide the feeling that virtual objects are part of the real world it should include:

- **an input system** (camera and tracking sensors such as GPS, magnetometer, accelerometer and gyroscope),
- **a processor** [Central Processing Unit (CPU) and Graphics Processing Unit (GPU)],
- **a display device** [Head-Mounted Display (HMD) video / optical see-through or Handheld Display (HHD) or Spatial Augmented Reality (SAR) Display].

Initially, through the camera, an image of the real world is captured. It is then augmented by the addition of virtual objects. Finally, in the course of the processes, the output system presents the result obtained, which is perceived by the user by his senses. It is worth mentioning that in order to achieve computer vision, through the camera, various techniques are used to train a computer to understand what "it sees", such as Deep Learning (DL), Machine Learning (ML), Artificial Intelligence (AI) and Artificial Neural Networks (ANN).

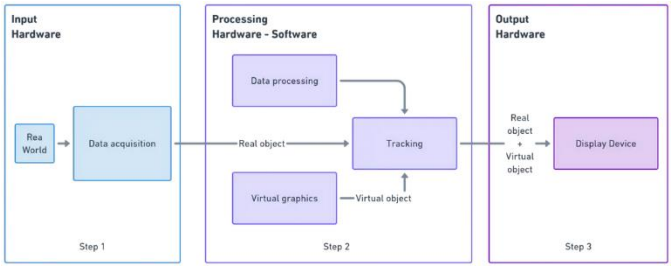

Fig.1. Elements of an AR System

Software [1]**:**

Software is the bridge between the real and the virtual world. The main characteristic of the elements of each software is to interpret the acquired data in order to transform and augment them. To create software for an AR system, the concepts of Platform, Engine, Framework and SDK should be considered.

Platform refers to the Operating System (OS) on which an AR application is developed. The OS is necessary to manage, control and coordinate the operations of a computer system. Examples of platforms that allow the creation of AR applications are Android, iOS, iPadOS and Windows.

The **engine** provides a software development environment or a template with built-in tools for creating AR applications. Examples of these engines are Unity, Unreal Engine AR, Google's Android Studio, and Apple's Xcode.

A **framework** is a structure that provides the basis for the development of software applications. In detail, it includes a collection of ready-made code which is used by developers to accelerate the development of AR applications. Furthermore, it constitutes a template on which programs can be developed for a particular platform and can be modified by developers by adding code in order to give the functionality they want to the application. Examples of frameworks are ARCore and ARKit.

Software Development Kit (SDK) refers to a set of tools for software development. Specifically, this set is used by developers to create AR applications and includes, among other things, utilities such as libraries, ready-made code examples, instructions, etc. Examples of software development kits are the Vuforia SDK and the Wikitude SDK.

3. Augmented Reality in the Armed Forces

Armed Forces of numerous countries have embraced the necessity of using Web 4.0, known as the Symbiotic Web. This specific web environment is an unceasing connected reality that is "always on". It is a Web Operating System – the entire web is a single operating system with information flowing from any point on it to any other interconnected system.

Many countries have adopted AR technology in the field of Defense to achieve clear superiority on the battlefield over their opponents. Some of the globe's leading countries that are utilizing AR technology in their military operations, are the USA (United States of America), Australia, Brazil, France, India, Israel, Canada, China, Great Britain, New Zealand and Norway. AR helps fighters have a better understanding of the battlefield while enhancing the way commanders access

information and conduct operations.

3.1 Applications of AR in AFs

For the achievement of the Objective the applications of AR in the Armed Forces [8], [9] mainly affect 5 sectors:

1) Real situations

AR provides realistic information about the actual environment on the field, a feature that makes it superior to other related technologies that refer to the transfer of data to visualize real-world conditions. The conduct of military operations for National Security, requires unceasing contact and interaction with the operational environment in near real-time, while the level of elements/data rendering in virtual reality conditions must be limited to avoid endangering both the operation's Objective and the participants as well as the material resources and means deployed. In addition, with AR, computer digital data (sensor retrieved) converts to a fully realistic display that superimposes natural information and it can be a significant advantage in real-world situations.

The ability of military personnel can be significantly improved in several ways:

- **Perception:** By using 360° camera projection, danger warnings and marking the enemy or other multiple points of interest on the battlefield, they can reduce any errors resulting from fatigue and operational stress as well as the time required to detect and identify situations that may cause failures.
- **Orientation:** Precise navigation (regardless of the environmental conditions in the field) can be provided using instructions (e.g., visual instructions - navigation lines, arrows, compass, distances, etc.) since the AR software uses data from numerous sensors.
- **Keeping focus:** In complex situations with high levels of operational stress on the ground, only the default necessary information is displayed to the fighter.
- **Specific knowledge:** By leveraging AR, fighters can receive specific and accurate information needed at the exact moment, which is either embedded in the AR application itself or obtained from a remote operations center. Via information that is sent interactively at Operations Centre, those with coordination tasks receive realistic information on the data on numerous parameters of the ongoing operation (even data concerning the physical condition and health of the fighters) and retain the ability to update plans and orders with a maximum possibility of success as part of the Situation Awareness (SA) process.

All the above mentioned can be implemented with the hands being in constant contact only with the minimum absolutely necessary armament for example, by controlling the display with voice or facial recognition and at the eyes level. Some examples of such devices are HMDs such as Microsoft HoloLens and Augmented Reality Command, Control, Communicate, Coordinate (ARC4), Head-Up Displays (HUDs), eyeglasses, etc. AR devices can be used in all service branches of the Armed Forces (Air Force, Navy and Army) and enhance their Mission by providing useful information in military operations.

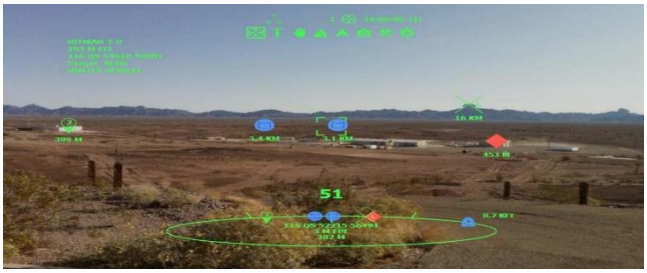

Fig.2. An example of ARC4

2) Training

Training of Units can be long-lasting, cost-intensive and simulation of emergency situations can be poorly performed. All of these adversely affect the level of training and readiness to achieve the National Defense's Objective. The use of AR technology concerning training and military exercises significantly improves the efficiency and quality of the above.

AR contributes to the training of fighters who benefit from its 3D nature as well as its interactivity. Military personnel can be trained in the technologies they will use on the battlefield with their actual equipment. Also, with AR it is simpler for the military personnel to understand the topics explained in user manuals and/or operational plans. For example, military personnel can track in 3D tactics of units on augmented maps.

In addition, facilitating the acquisition of demanding skills, such as Flight Training, significantly reduces the number of hours and costs of using real means, with the point of reference that all instructions are available in front of the pilot's eyes, superimposed on real environment. Furthermore, AR technology improves the practical lessons and learning capabilities in Search and Rescue (SAR) training, which is of utmost importance in real situations as well as in Combat Lifesaver training in order to reduce the loss of life on the battlefield. Finally, AR helps with logistics and supply chain to empower military operations by having everything organized in the field and within the depots while military personnel view augmented instructions.

3) Real-time remote collaboration

Real-time remote collaboration is one of the key advantages of using AR technology as it improves collaboration in:

- **Emergent situations:** It accelerates the decision-making process, enhances SA and reduces time for repair.
- **Regular activities:** It reduces requirements and therefore travel costs, allows for collaboration across multiple collaborative projects and facilitates logistics.

4) Maintenance, Repair, and Overhaul (MRO)

AR technology is proving useful for equipment maintenance and instructions are displayed as layers over the real 3D object which reduces errors and time required for regular maintenance rather than study two dimensional printed manuals. It is also

efficient for emergency equipment repair at remote locations where remote experts can see the same real-time image as people in the field so they can guide them through the repair process safely. A large number of military equipment consists of complex electromechanical systems (e.g., aircraft, tanks) and their maintenance and assembly require extremely high demands on support staff.

5) Security system checks

AR technologies reduce errors and requirements when performing security system checks by:

- Information visualization (information presented visually in 3D space, facilitates understanding, mutual comparison and extraction of the most important data),
- Step-by-step instructions (to simplify procedures).
- Digital security checklist (their use prevents skipping steps).
- Real-time security monitoring (for immediate danger detection in radar systems, monitoring of security systems of objects, etc.).

Some of the AR uses in the Military are the bellow:

- **Flight or Vehicle simulation:** The main advantages of this are the impact on reducing the time and cost required. The fact is that military training is expensive. Especially AF training is very expensive. Therefore, it is more cost-effective to use flight simulators than real aircraft, given the multitude of scenarios that can be added to related training programmes.
- **Battlefield combat simulation:** Combat system simulations are mostly applied to ground vehicles, and tanks or armored vehicles. Particularly AR environment recreates different weather conditions and trains for navigation in unknown locations.
- **Battlefield Medical response simulation:** AR training for combat medics helps to prepare them to provide first aid for bullet wounds, explosive shrapnel wounds and combat injuries on the modern battlefield.
- **Military weapons usage:** Use of any Weapon System, with compression of wear due to use (and therefore maintenance required) and their life cycle costs.
- **Bomb Disposal:** Training programs for bomb disposal squads, which enable them to practice neutralizing explosive substances of various types and configurations without the risks inherent in the use of live ammunition.
- **Remote Maintenance:** Support remote maintenance of military equipment that enables experts to remotely advise maintenance engineers.

3.2 Command and Control

Acquiring real-time information about an ongoing combat situation is crucial both in conducting military operations and in training personnel of AFs. Command and Control (C2) systems [10] mainly concern visualization using tactical symbols. They use AR and peer-to-peer technology to enhance warfighter readiness by adding additional, meaningful graphical and text information to the real environment in real-time. The powerful entry of high-performance mobile devices and wireless digital networks into the military makes it possible to use technology at the level of military personnel on the battlefield.

Applying an advanced visual perception of the environment, combined with digital communication for remote data transmission, can improve SA according to the modern concepts of network-centric combat organization, improve the understanding of the tasks assigned and offer a shared experience to reduce the response time in critical situations (e.g., informing users about upcoming situations, faster decisions). The critical requirements of a C2 System are constant connectivity to the military network as well as reliability and accuracy of the data submitted. These requirements are adopted in leading armies of the EU (European Union) and NATO (North Atlantic Treaty Organization) countries, in Israel, but also competing militaries such as those of China, Russia and Iran.

Information Superiority on the battlefield is a leading issue in modern concepts for conducting military operations. Building a computer network connecting sensors, commanders, fighters, and weapons provides greater combat power with maximum reliability and accuracy, with the ultimate goal of achieving the Objective while combining minimum losses of lives and assets. The command is also about tracking the behavior of a moving target, and with today's data, it involves changes in the position (coordinates) of the target and changes in the spatial orientation (rotation relative to the target's own axes).

An example of C2 is Integrated Visual Augmentation System (IVAS) [AR/MR system] which has been developed for implementation in the US Army. IVAS is based on the Microsoft HoloLens product and has 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 military personnel share data, delivering mission-critical information directly into an individual's field of vision. Active-use solutions reflect how combat operations are carried out e.g., through "see what I see" solutions, fire support tools, medical assistance and other teams can receive real-time instructions and other vital data submitted from remote command posts.

3.3 Situation Awareness

Situation Awareness (SA) [11], [12] is the perception of the elements in the environment within a specific time and space, the understanding of their importance and the projection of their situation in the near future. It can provide excellent services to both fighters in the field and commanders of the Operations Centre, through unceasing and rapid access to data and processed information concerning a multitude of parameters. The tactics of realistic remote coordination of operations in real-time become feasible given the provided Common Operating Picture (COP) applications which integrate existing technological capabilities (e.g., GPS, data encryption, etc.) under AR conditions.

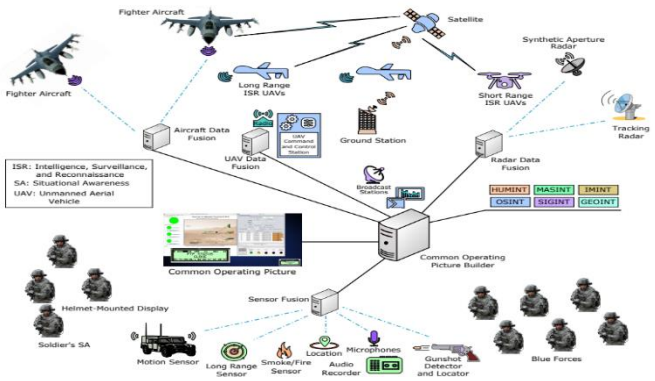

Fig. 3. Situation Awareness

SA includes the loss or incomplete perception or changes to elements present in the operational environment of the fighter. This factor may be related to an individual's limited knowledge of the operational environment. The lack of SA is an operative event in many military accidents. Some of these difficulties can be overcome by using a technology that can organize and display information to the user automatically. In recent years, many military applications based on AR technology have been designed to improve SA as support to decision-making in unknown environments. Set of elements that help to have an adequate SA on the battlefield are.

- **Terrain recognition:** Accurate reference of the place of operations to increase the perception of the environment.
- **Infrastructure recognition:** Identify buildings and infrastructure in the enemy's terrain either to be used as a spatial reference or to execute a specific mission.
- **Geographical environment recognition:** Obtain additional information about the operational environment such as geographic references, artillery pieces, etc.
- **Threat alert using descriptive symbols:** Understanding the symbols of threats by the military personnel to determine the necessary related actions (e.g., avoidance or confrontation).
- **Allied location:** All the fighters must know the position of the Allied forces on the battlefield.
- **Path tracking:** Checking on a digital map the path done by the operational groups.
- **Communication:** Communication between the Operations Center and the Chief of the Combat Team. The communication between the distinct links in the chain of command is part of C2 tasks.
- **Information filtering:** Filtering the information of the contextual environment that is absolutely necessary at any given time.

3.4 Challenges

The integration of AR into the implementation of real operations in the field involves numerous challenges [13] that need to be addressed:

- **Overdependence on Technology:** The main tenet in military personnel training is "train as you fight". The usage of an AR system must be balanced to ensure that basic combat skills do not atrophy (e.g., conducting occasionally analog land navigation with a map, compass, and protractor). An increased reliance on a digitized display of the environment and mission can lead to a loss of operation without the support of AR.
- **Unit and Military Personnel Experience Level:** The information presented in these systems need to be accurate, sufficiently up-to-date, relevant, and timely, without creating a distraction or interrupting the information flow in the tactical setting, to Operational Groups as a whole, and to individual Fighters who have different experience levels.
- **Sensor Data Integrity:** At all times the Fighter in the field must be convinced that his equipment functions according to the strictly defined standards/specifications so that the Fighter's sensors are saturated by falsified/false data (e.g., GPS spoofing).
- **Electromagnetic Signatures:** In the last few years there has been an escalating effort to achieve superiority in the field of Electronic Warfare (EW), where all major military forces seek to develop technology with which they will be able to degrade and disrupt the utilization of the Electro Magnetic Spectrum (EMS). There is a need to share relevant and timely data between the Operational Group and the Operations Center, making every effort to prevent the Groups from detection and alteration of information they receive from their sensors.
- **Extreme Weather, Energy Consumption, and Battery Life:** Extreme environmental conditions will affect electronic equipment, increasing the likelihood of malfunctions and exacerbating the challenge to maintain sufficient power and relevant unceasing system functionality.
- **Network Reliance and Scalability:** Successful utilization of AR systems is contingent upon the Operational Group's ability to provide and receive data to and from the field. AR systems have as their basic operating architecture the utilization of high-quality data with maintained data integrity through limited delivery channels.

3.5 Perspectives

Recent studies show an 18% increase in sales of AR systems for the global defense market between 2017 and 2025. The use of AR systems differentiated the way military operations are planned and implemented, as it has managed to bring about vital changes in the field of operations itself. For example, it is possible to track enemy's movements by Unmanned Aerial Vehicles (UAVs) in incredible detail and redistribute this information for use in real-time, reducing the number of personnel who can operate in specific high-risk missions, while increasing the chances of success and survivability, achieve faster and cheaper rates of production, training, logistical support and maintenance of weapon systems.

There are several reasons why the AFs are adopting Augmented Reality technology. AR, in combination with VR

and MR systems, is changing the perspective of a Country's defense capabilities. To remain formidable and, more importantly, to stay ahead of other competing / enemy forces, they are adopting AR systems from training to strategy development.

4. Conclusion

The Mission of the Armed Forces is the preservation of territorial integrity, national independence and supremacy of a country against any external threatening or aggressive action, while their operational task includes the support of national interests. In the present era, there is a rapid development of Augmented Reality technology. Following the relative development, the AFs of several countries have introduced AR technology in their various applications to meet their operational needs at strategic, operational and tactical levels aiming to achieve the Mission of all branches of the AFs.

Studying the way how modern warfare is evolving, the combination of AR with the technology of Geographic Information Systems (GIS) could be definitely a force multiplier for the relative AFs. For example, the traditional paper orientation grid, of any Hellenic AF base could be replaced by an "Electronic Orientation Grid", which in real-time will be able to provide the same picture on a tactical level both to the competent Units for coordination and to the Force Protection Units of the Base. It will be pre-installed as indicative and non-limiting of all available means that contribute to the survivability of the Base. The entire critical infrastructure of the Unit, as well as specific landmarks outside the Unit, will be mapped in advance using geospatial coordinates to coordinate the assistance of state authorities in order to eliminate threats outside the boundaries of the Base, which affect its survivability. An example of an AR mobile app is "AuGeo" by ESRI labs that we have customized with ArcGIS point data as it is shown in Fig. 4.

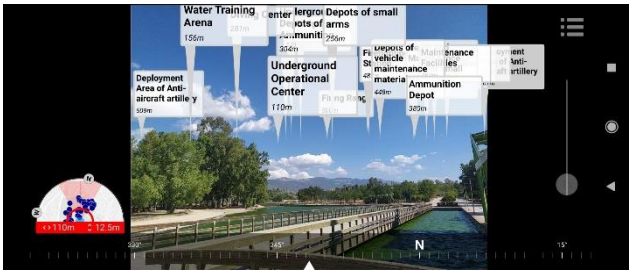

Fig. 4. AR app for a fictitious Hellenic Military Unit.

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Contribution of individual authors to the creation of a scientific article (ghostwriting policy)

Charikleia Papathanasiou carried out the investigation, the resources, the software, the simulation, the optimization, the writing of original draft and editing.

Nikolaos V. Karadimas carried out the conceptualization, project administration, resources, supervision, writing, review and editing.

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