The Digital Headquarters

Julian EDER (IL – Ingenieurbüro Laabmayr und Partner ZT GesmbH)*

Thomas HALWAX (Syncpoint GmbH)

Mario VOITHOFER (Realsim)

Abstract:

Urban military operations pose enormous challenges for operators. Complex spatial situations and a flood of data, provide challenges for the planning process of such operations, especially when trying to understand them with traditional planning tools. The project NIKE within the Austrian Armed Forces aims to tackle these challenges with modern digital tools and Rapid Data Integration and Visualization. We describe different techniques for visualizing various types of data and compare them for their possible applications in a decision-making process.

Key Words: urban operations, common operational picture, command & control, Virtual Reality, Mixed Reality

1. Introduction

Urban military operations strongly differ from other types of military operations. Especially the complexity that arises from the combination of the different domains, subsurface - surface - supersurface - cyber, poses challenges to the operators in this environment.

> *"Being considered as a key terrain for future military engagements urban environments present the highest imaginable complexity for action forces as operations must be synchronized within [...] interdependent movement levels." (Hofer et al. 2022b)*

The project NIKE of the Austrian Military Academy aims to improve the capabilities in coping with complex urban operations through training of operators, preparation of available information about infrastructure as well as advancements in the decision support process. This paper aims to provide an overview of the different approaches taken to create a digital headquarter, which will allow decision-makers to communicate plans of action and follow the current events in a modern digital way, improving efficiency and therefore resulting in better mission accomplishment.

> *"The improved spatial apprehension within Extended Reality (XR) applications significantly improves decision-making and supports synchronized mission planning and execution. As close cooperation and information exchange between operators of subsurface service structures and action forces is a prerequisite for success, the integration of all relevant factors and actors will massively increase comprehensive collaboration. The project enhances the common perspective by displaying relevant information within a truly comprehensive Common Operational Picture, thereby enabling more accurate and precise action, reducing own losses and collateral damage." (Hofer et al. 2022b)*

2. Motivation

To achieve the best possible understanding of the situation as a basis for decision making, a truly comprehensive common operational picture (tcCOP) is required. This means that the current knowledge about the operation should be displayed in a way that is common, therefore all the information is shared with all relevant actors, and comprehensive, therefore the information is easy to understand and work with.

Traditionally this planning is done on a print-out map, writing the information onto the map with a pen. This is intuitive to learn and flexible (anything can be drawn) but has the disadvantage that a user has to

*(corresponding author) Preishartlweg 4, 5020 Salzburg, AUSTRIA, julian.eder@laabmayr.at

know all standards (like tactical graphics) by heart to create plans that are understandable to others. Additionally, it is more difficult to share and communicate information efficiently, as there is only one copy of the current drawing. The communication problem is especially hard if a plan has to be communicated between persons not being in the same location. To solve these problems, digital tools can be used. The following section gives an overview of different approaches, with their advantages and disadvantages.

3. Approaches

This section compares the different visualization methods deployed in our digital headquarters. Table 1 gives an overview of the advantages and disadvantages of each method.

Table 1: Overview of advantages and disadvantages of the technologies

Method	Advantages	Disadvantages
Printed 2D Maps	• well established • flexible • little infrastructure • no training in handling	• hard to change • no zooming • hard to replicate
Digital 2D Maps	• faster editing/changing • flexible change of representation through layers and zooming • easy digital replication • collaboration (over distance) • print-out possible	• requires simple digital infrastructure • requires basic training in handling • elevation is not intuitive
Digital 3D Maps	• intuitive understanding of height and terrain features • better understanding of subsurface and supersurface • possible usage of XR-Devices • easy digital replication • collaboration (shared presence)	• requires powerful digital infrastructure • requires data preparation • requires more training in handling • danger of information overload • simulator sickness in rare cases

a. Digital 2D Maps

The digital representation of maps in the 2D bird's eye view combines the enormous know-how of cartographers in this discipline with the advantages of the digital era. In the classic 2D plan view, a great deal of relevant information such as dividing or unifying terrain, supply lines and hubs can be quickly identified. Added to this is the ability to estimate distances and times relevant to the mission until a coordination line is reached. Using grid lines or scale bars, this estimation is intuitive and requires no additional tools.

The digital era brings with it a flood of data that complements the classical map view. Whether it is more static information such as zoning maps or dynamic views such as a weather radar, all of this information is available in large quantities. In addition, there are standardized methods and data formats (e.g., those of the Open Geospatial Consortium) that make integration into the 2D view easy.

Only the representation of the third dimension of the terrain is bound to abstractions such as contour lines or hatching, which require a certain amount of practice and imagination from the user of the maps.

The available standards for the representation of military symbols (whether point symbols, lines and areas, or complex geometry such as attack arrows) have been optimized for representation in the bird's eye view and can be used both digitally and on analog maps down to the hand sketch. These representations will continue to be the basis for rapid assessment and communication of the situation in the future. If necessary, a backup mechanism exists in the form of a simple printout on paper, which can be used intuitively and without further know-how.

The ability to collaborate in creating a plan on a digital map from multiple devices simultaneously and replicate it digitally at the click of a button is well aligned with the goal of creating a common operational picture efficiently.

b. Digital 3D Maps

In the space of immersive three-dimensional (3D) representations, two major technologies have emerged: Virtual Reality (VR) and Mixed Reality (MR)[1]. Often these terms are combined under the overarching term Extended Reality (XR).

A 3D digital representation of an environment can add additional intuitive comprehension of a mission environment. Especially in urban operations, where multiple lines of movement can be stacked on top of each other (e.g., subways, road tunnels, streets, buildings, and supersurface elements), or in mountainous regions this can provide an immense advantage in intuitively understanding the mission environment. Here it is possible to combine terrain data (heights) with satellite images or map material as well as with building data, to get the best possible understanding of the environment. While already being useful when perceived through a computer screen, the intuitive human understanding of 3D-spaces can only be completely utilized when perceived through a stereoscopic display (VR or MR goggles).

In a VR environment, the user is visually completely isolated from reality (everything seen is computer generated). Therefore, this type of display is useful for detailed planning of operations. Users can select any angle of view, from a bird's eye perspective, down to a 1:1 representation, giving the same view as if being on site. This allows for planning what can be seen from any point in the mission environment and understanding what cannot be seen because it is behind a mountain or inside a tunnel (Figure 1).

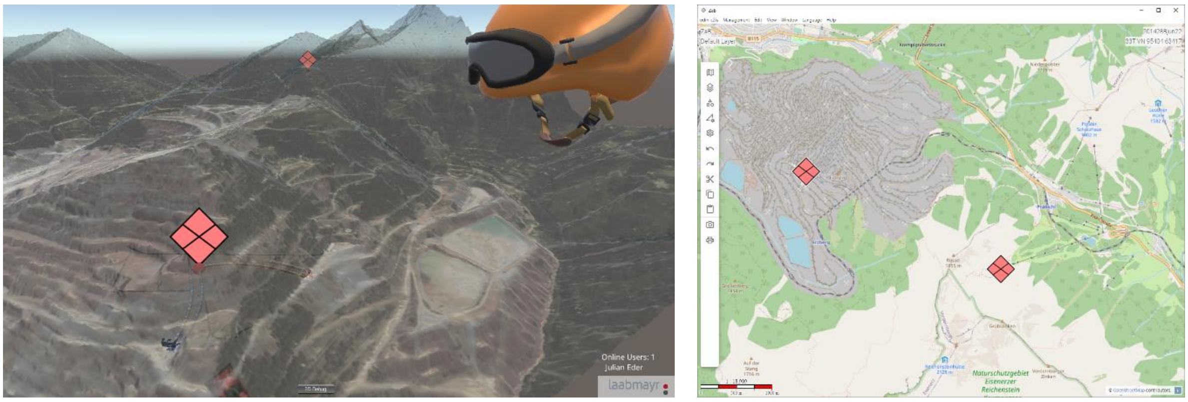

Figure 1: A VR-Environment with transparent terrain allows the user to understand that positions, annotated with tactical graphics are in a tunnel or behind a mountain from a specific viewing angle (left). An Overview of the same situation on a 2D map (right). Pictures: Laabmayr, Syncpoint

MR devices, on the other hand, allow overlaying the real world with a scaled-down digital model of the mission environment (Figure 2). While this only allows for more basic interactions, it works well for briefings where multiple users analyze and discuss the situation in a shared, real space. Each viewer sees the representation from his or her viewing angle. For example, the model can be viewed at the center of a briefing room from multiple MR devices and users can discuss by simply pointing at different aspects of the model, while they can still see their surroundings and each other's faces. The advantage of MR is, therefore, that the reference to the real environment is not lost. A disadvantage of MR headsets is that the technology is highly complex and currently still in an early development phase. As a result, the necessary hardware is

[1] We use MR synonymously with AR – Augmented Reality.

still more expensive, compared to VR devices and complex holograms cannot yet be displayed in comparable visual quality.

While digital 3D representations have the same advantages in replication and collaboration as their 2D counterparts, they also make a shared virtual "presence" possible. This is realized in the form of digital Avatars, where users can see each other's head and hands in VR or share a model inside the same room in MR. Digital 3D Maps also have some disadvantages that need to be considered when deploying them. Firstly, they require additional technical equipment that is not as commonly available. This also leads to users not being as familiar with these types of interaction and display, which therefore requires more training in handling the equipment, before it can be used efficiently. Secondly, they require a larger amount of data preparation to be useful. While the terrain heights can easily be provided through standardized interfaces, every displayed 3D model needs to be acquired separately. This can be done through laser-scans, importing CAD or BIM[2] models from civil engineering, or in case none of those are available in advance, with the Fast Tunnel Modeling Tool (Hofer et al. 2021).

Figure 2: Planning of a mission in VR using tactical symbols (left) MR Visualization of a mission environment and on a 2D map (right). Pictures: Laabmayr, RealSim

c. <u>Dissemination and Distribution of Plans</u>

As mentioned before, MR headsets can be used to visually present and discuss the scenarios planned on 2D or 3D maps in larger groups. With MR technology it is also possible to display the planned scenarios in real size at the planned location and to overlay the reality with holograms of e.g., military vehicles, soldiers or tactical symbols (for training purposes).

While planning missions on a higher level in the command structure with digital tools seems to be an advantage, it might sometimes not be possible to deploy this technology everywhere in the field. In this case printouts, or digital documents (PDFs, pictures) can easily be produced and deployed as paper maps or on mobile devices. This includes a 2D map, as well as pictures (screenshots) created with the 3D application.

4. Interfaces and Interoperability

Aligned with the different approaches described in the previous section, three different software products are evaluated for their usage in planning military operations during this study. ODIN[3] for 2D visualizations, SOMT[4] for 3D-VR visualizations, and Holopackage[5] for 3D-MR visualizations. We conclude that there are different areas in the planning process of a military operation where they can be applied best: (1) 2D-Maps for the large-scale planning in wider areas, (2) VR for the fine-grain planning in smaller areas and (3) MR for dissemination and discussion in briefings. This leads to the requirement of interfaces for data exchange

[2] CAD – Computer Aided Design, BIM – Building Information Modeling (both processes for planning in civil engineering)

[3] https://odin.syncpoint.io/

[4] https://www.laabmayr.at/tunnel-plus/rd/somt-subsurface-operation-mission-tool/

[5] https://www.realsim.info/commandsystem

between these systems in an open way. Core information needs to be shared between all applications. Even though it is sometimes useful to simplify the display of some information in a specific system, or enhance it with additional data in another, everybody should have access to the core information, providing a consistent COP in each visualization method.

While other Command and Control Information Systems (C2IS) with enormous standards are used for large-scale operations, we focus on a small and flexible system, based on the latest available technologies, that provides easy to use and flexible support for small to medium sized missions. Therefore, we use a REST-API based system with a single-point-of truth for the data and identified the following core features that all systems have in common:

a. Projects

Projects are used as a framework for a single operation. Typically, a user would create a new project at the very beginning of planning an operation or a training exercise. Additionally, projects can be prepared in advance for specific locations with 3D models of buildings or tunnel systems, to have a planning environment ready in advance.

b. Layers

Layers are used to group information together during mission planning. Most software products allow hiding or displaying information on a per-layer basis. In a typical mission, one user could draw the estimated current situation into one layer, while another user could plan the mission of the friendly forces in another layer. Data from a specific sensor-system would also be organized into one specific layer. To enable replication in itself, layers represent the smallest entity. Based on the layers, e.g., permissions are assigned per user of the system.

c. Geo-spatial Data

We have agreed upon the usage of GeoJSON (RFC 7946) for the military features. Thus, we follow the definition for the assigned geometries like points, linestrings and polygons. If a property of a feature is changed in one of the systems, the feature is replicated in its entirety (geometry and descriptive properties).

d. Military Features

The standardization of the representation of military symbols dates back to the early 1990s. In 1994, the US Department of Defense introduced the "Common Warfighting Symbology" (Department of Defense 2008) under the designation MIL-STD-2525. In 1999, NATO adopted an almost identical catalog of symbols under the designation APP-6A "Military Symbols for Land Based Systems". Since then, both symbol standards have evolved in parallel, with the most recent editions "D" again being nearly identical in scope after a period of divergence.

Currently, edition "C" is the most widely used, since edition "D" introduced a completely new concept for the "Symbol Identification Code" (SIDC), which is not compatible with the already existing system.

In addition to the identification of the symbol itself (frame, icon, echelon, etc.), there are a number of text modifiers. They are - depending on the symbol - placed around or on top of the symbol. These include, for example, the Date-Time-Group, Unique Designation, Higher Formation, etc. Each text modifier is assigned an identifier. In our work, we extend the properties of the underlying GeoJSON structure by the SIDC as well as by all necessary text modifiers to describe the symbol entirely.

5. Automated Data Collection

Based on this relatively simple interface, a variety of automated data collection methods (cyber-physical systems) can be developed and integrated into the COP with relatively little effort. This concept is currently under evaluation within the projects NIKE BLUETRACK[6], NIKE SUBMOVECON[7] and NIKE DHQ-RADIV[8], which test techniques like tracking for friendly forces through navigation in GNSS denied environments and tracking for civilian/hostile forces through cameras and microphone-arrays among others. Because information needs to be available for the decision maker as fast as possible, we call the overall process spanning from the generation of the information until it is displayed: Rapid Data Integration and Visualization - RADIV (Hofer et al. 2022a). Our system allows easy integration of new data collection methods in the future, which could include Artificial Intelligence (AI) based methods.

6. Conclusion

During this study, three different software products are evaluated for their usage in planning military operations. They were compared in their capabilities and various advantages and disadvantages were identified. Therefore, we concluded that there are different areas in the planning process of a military operation where they can be applied. Additionally, we identified basic Features that should be exchanged between the systems to make them interoperable and provide a truly comprehensive common operational picture at all times. Preliminary testing and demonstration showed that this digital headquarter provides improvements in efficiency and quality of the planning and decision-making process, compared to the previous analog methods in complex military operations.

7. Acknowledgment

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