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Emerging technologies for the Early location of Entrapped victims under Collapsed Structures & Advanced Wearables for risk assessment and First Responders Safety in SAR operations

D4.2 Situational Analysis & Impact Assessment

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Executive Summary

In this deliverable situational analysis and impact assessment are addressed with the development of an application, aiming at improving both and thus facilitating the task of decision making. The 3D Mixed Reality Command Centre application allows the decision maker to enhance their situational awareness by blending the real world (what is happening around them in the command centre) with the virtual world by visualizing all the units and victims state during the search and rescue mission and additionally by live stream video from robots and UAV. The application allows timely decision-making by representing the spatial and chronological information in an easy-to-understand way. The application is developed for the Microsoft HoloLens 2 headset taking advantage of its natural user interface and communication capabilities. The development process of the application is presented with the system architecture and the description of its functionality.

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1 Introduction

1.1 Situational Analysis and Impact Assessment overview

Situational analysis and impact assessments are important tools to prepare crisis management decision-making and plan effective response. Within SnR, such assessments are conducted to identify damages and needs through mobile applications, airborne sensors, via social media and crowd-tasking and by integrating information from different agencies, actors and dimensions.

Situational analysis is the iterative process for the collection and analysis of different pieces of information that allow for the decision maker to understand how this information relates to each other and influence potential decisions. For the decision makers, the result of situational analysis is situation awareness [1]. Impact assessment in crisis management refers to procedures for the determination of the severity of the impact of the disaster in the affected area.

Situational awareness is the perception of environmental elements and events with respect to time or space, the timely comprehension of their meaning, and the projection of their future status. Insufficient situation awareness has been considered as a causal factor for many accidents attributed to human error [2] and consequently for the coordination of search and rescue activities.

1.2 List of Abbreviations

Abbreviation	Explanation
3D MR CC	Three-dimensional Mixed Reality Command Centre
BIM	Building Information Modelling
GIS	Geographic Information System
IP	Internet Protocol
MR	Mixed Reality
SA	Situational Awareness
SnR	Search and Rescue Project
TCP/IP	Transmission Control Protocol/Internet Protocol

Table 1-1: List of Abbreviations

2 State of the art and objectives

2.1 Situational awareness

Situational awareness (SA) is an area strongly related with human factors. The SA theoretical framework that is commonly accepted and used is based on [3]. The framework distinguishes 3 levels in the process of SA.

1. **Perception**: The first level of SA is to identify all the internal and external elements of the system (objects, peoples, events, systems, environment, environmental factors) how they relate and interact with each other and collect information for their state (locations, conditions, modes, actions).
2. **Comprehension**: The second level in the SA process concerns the understanding of how the system elements from the first level influence the operation goals. At this level, pattern recognition, interpretation, and data integration are used having as target the creation of holistic picture of the system.
3. **Projection**: The final level of SA concerns the impact assessment of the future actions to the system. At this level, extrapolation of the information from level 1 and 2 is used to determine the impact of actions to the system and the state of its elements.

Endsley's model also includes external factors that influence SA, including the ability and the goals of each individual as well as tasks, and environmental factors concerning workload and complexity of the system.

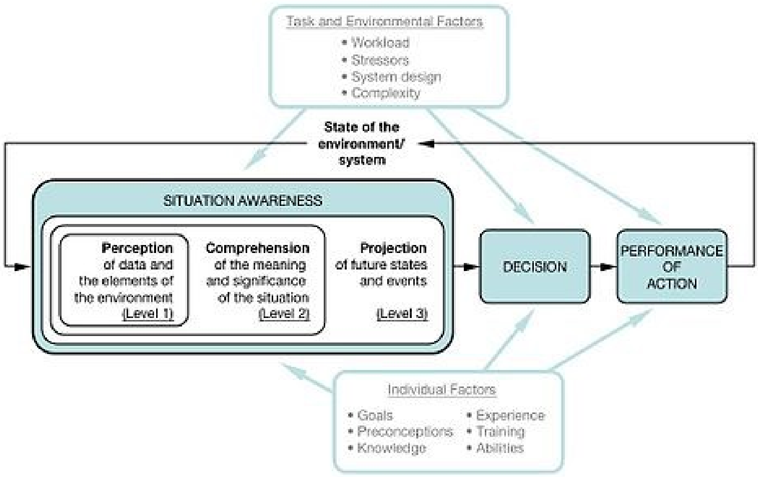

Figure 2-1: Endsley's model of SA

2.2 Mixed reality

According to [4] Mixed Reality (MR) is a particular subset of Virtual Reality related technologies that involves the merging of real and virtual worlds somewhere along the "virtuality continuum", Figure 2, which connects completely real environments to completely virtual ones.

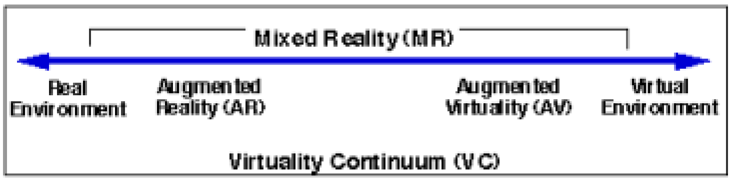

Figure 2-2: Simplified representation of Virtual Continuum adapted from (Milgram, P. and Kishino, F. 1994)

A 3D Mixed Reality Command Centre (3D MR CC) is in development in the SnR with the purpose of visualizing contextually relevant and online spatial information from different data sources to the decision makers. The rescue operations in SnR produce a large amount of heterogenous data with both spatial and chronological information that needs to be timely interpreted by the decision maker in order to achieve the most informed decisions. Virtual reality has already been used for the visualization of big data with geotagged information in the initial geospatial domain [5] with benefits the faster understanding of the underlying structure of the information.

The 3D MR CC allows the user to experience the virtual world without losing connection to the real world. This type of experience allows the user to keep the awareness of the real world (what is happening around them) and at the same time use in their benefit the virtual spatially correct representation of the SnR data.

The development of the application is heavily related to the tools that are available for Mixed Reality and in this case the Microsoft HoloLens 2 headset. The headset apart from its capability to display virtual objects in the real world allows natural interaction with the objects as if they were physical, and supports voice control and communication with voice and video with other users. These capabilities are applied in the 3D MR CC.

Figure 2-3: Microsoft HoloLens 2 headset

3 3D Mixed Reality Command Centre

3.1 Use case application

The 3D MR Command Centre will be used in the use case 2 of the project. Use case 2 concerns a mountain rescue operation for a plane crash in non-urban area. The 3D MR CC will be deployed at the spot using ad-hoc network established for the rescue operation. The 3D MR CC will support the situation analysis from the decision makers and the coordination of the rescue operation.

3.2 Requirements

The requirements for improved situational awareness are based on [6] and [3]. They proposed a set of interface design criteria for enhancing situational awareness and are presented below as they are available in their publications:

1. Reduce the requirement for people to make calculations.
2. Present data in a manner that makes level 2 SA (comprehension) and level 3 SA (projection) easier.
3. Organise information in a manner that is consistent with the decision maker's goals.
4. Indicators of the current mode or status of the system can help cue the appropriate situational awareness.
5. Critical cues should be provided to capture attention during critical events.
6. Global situational awareness is supported by providing an overview of the situation across the goals of the decision maker.
7. System-generated support for projection of future events and states will support level 3 SA.
8. System design should be multi-modal and present data from different sources together rather than sequentially in order to support parallel processing of information.

3.3 Functionality

The functionalities of the 3D MR CC, that tries to meet most of the requirements, are grouped in the following 3 categories:

1. Visualisations:
    - Stereoscopic 3D
    - Image registration for presentation heterogeneous data sources of information (e.g., GIS, Satellite imagery, Live camera and thermal camera feed from drones)
    - Rescue units and rescued people position and condition presentation
    - Visualisation of sensor signals
    - Visualisation of the proposed actions from the DSS, the information these were based on and their impact on the situation

2. Direct communication and commandment of:
    - Drones and/or robots with cameras and sensors
    - Emergency response units
3. Natural user interface

- Interactive application
- Multi-user support
- Hand gestures
- Voice commands

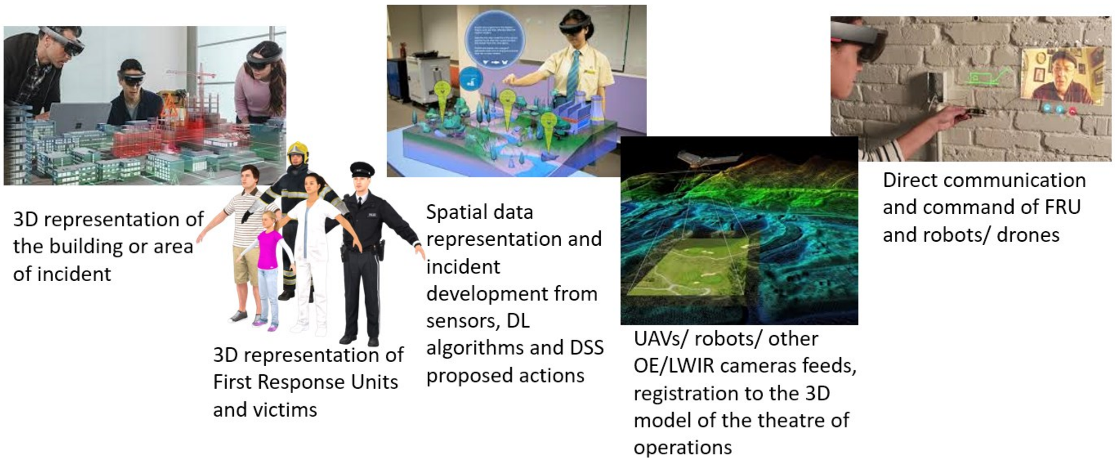

Figure 3-1: Functionality of the 3D MR CC

3.4 Architecture

The Object Process Methodology was used to model the system design. The various components of the system as well as their functions are represented with Objects (squares) and Process (ellipses) respectively. When an object is external to the system, it is represented with a dashed contour line. The objects, the processes and their interaction presented below were implemented for the 3D MR CC application.

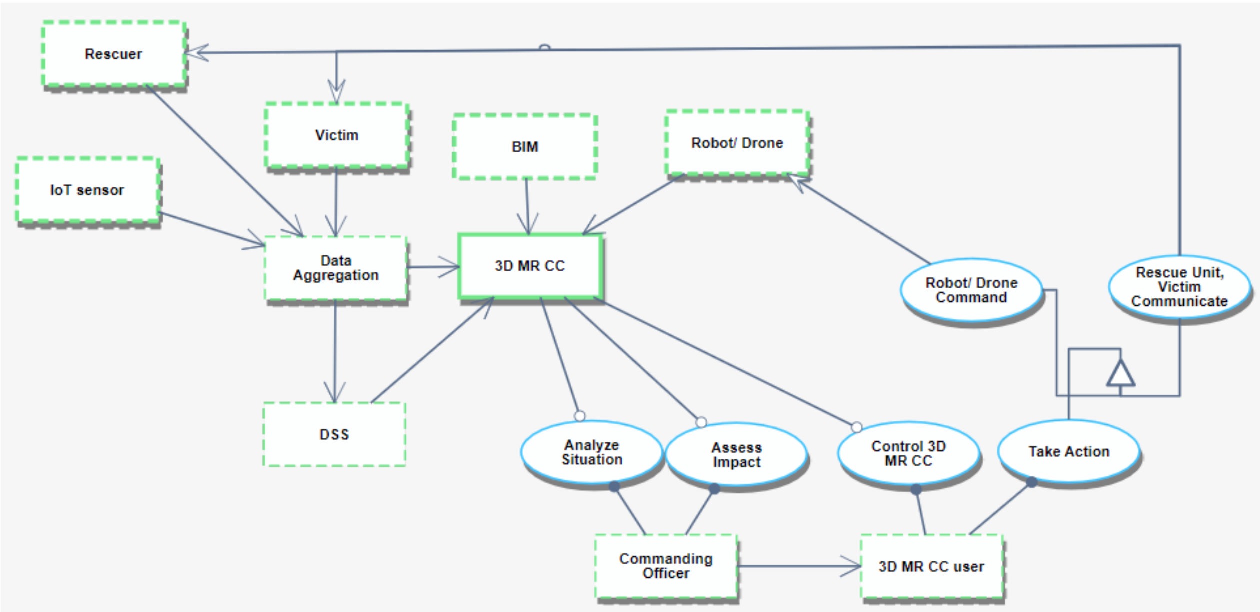

Figure 3-2: Top level system diagram

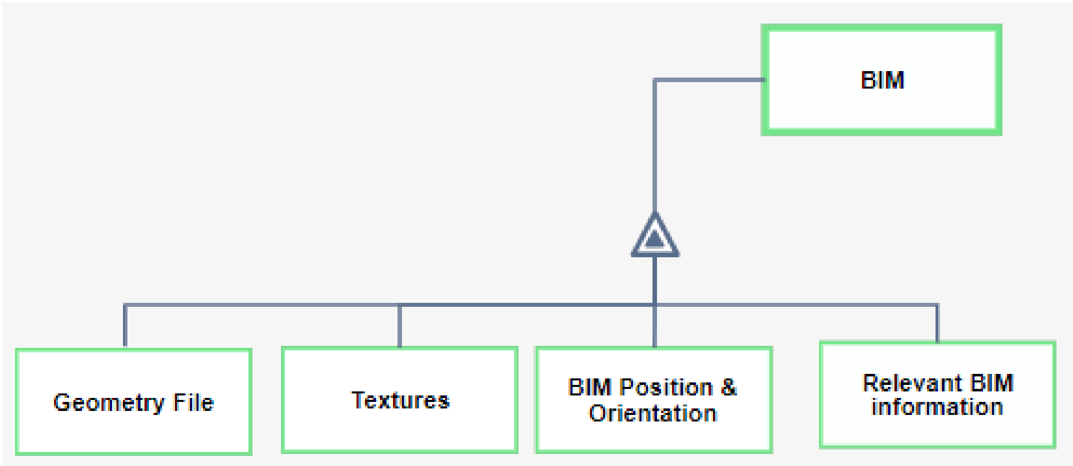

Figure 3-3: Building Information Modelling unfolded

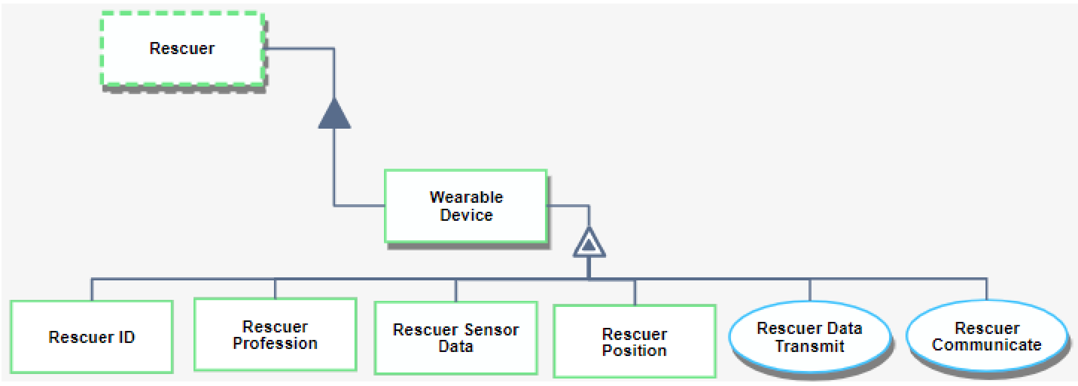

Figure 3-4: Rescuer unfolded

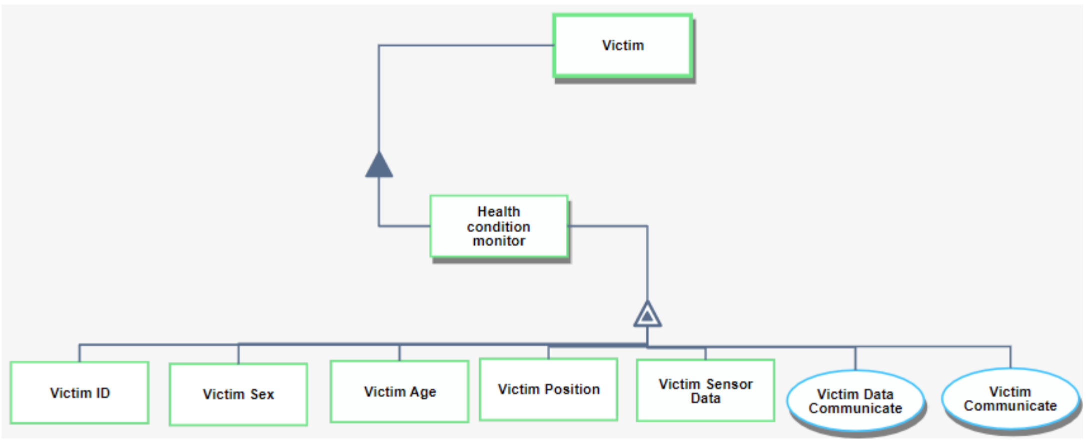

Figure 3-5: Victim unfolded

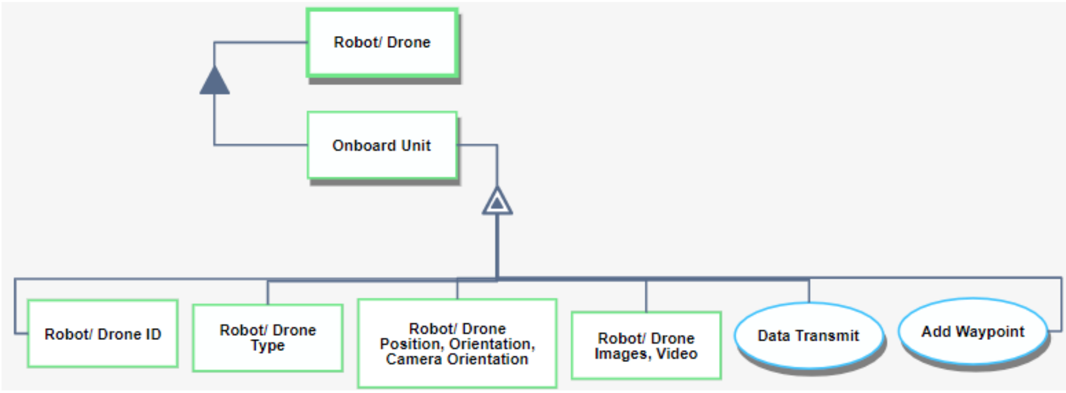

Figure 3-6: Robot/ Drone unfolded

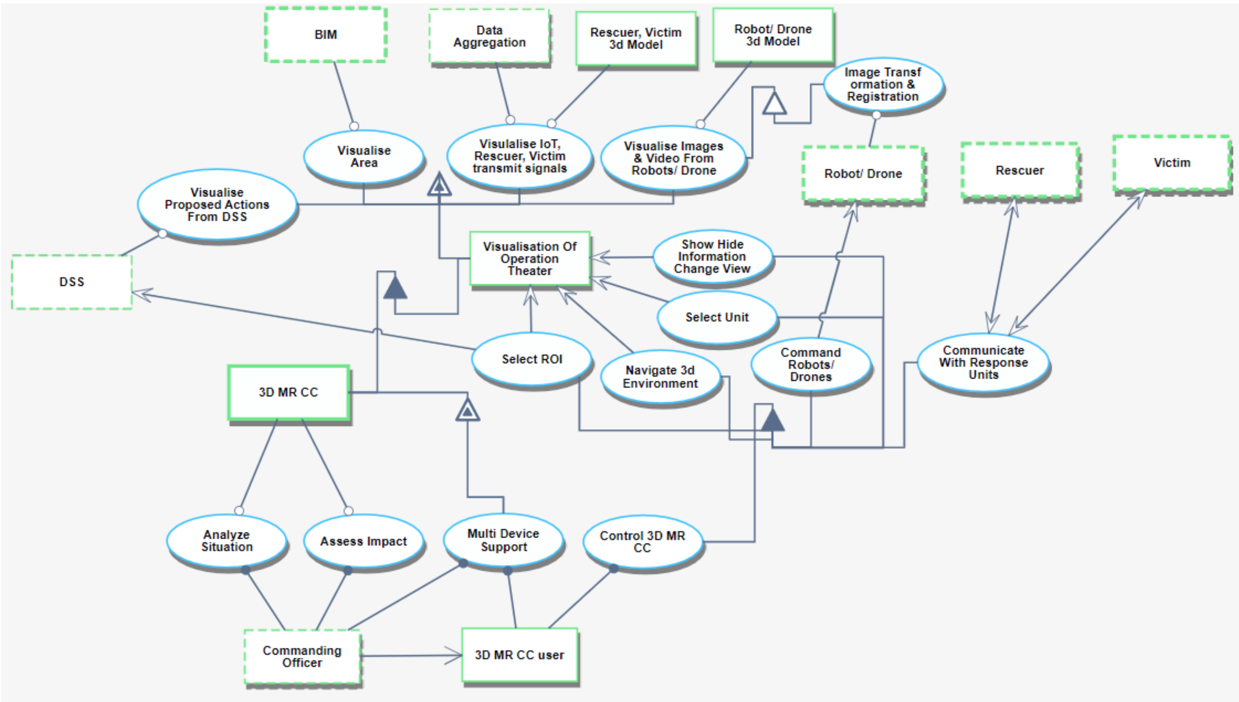

Figure 3-7: Detailed System Diagram

4 Implementation of the 3D MR CC

4.1 Software tools

The 3D MR CC was implemented using the Unity engine. Unity engine allows the cross-platform implementation of 3D games and experiences. The target device for the current development stage is the Oculus Quest 2 (Android) and Microsoft Windows and finally it will be ported to the Microsoft Hololens 2 (Windows Mixed Reality). Unity engine supports the C# programming language and it provides a useful interface for the development of 3D worlds.

The Microsoft Mixed Reality Toolkit (MRTK) was additionally employed for the development of the user interface with the Oculus Quest 2 headset including the hand gesture and voice interactions and it will be used in the future for the Microsoft Hololens 2 headset. MRTK offers tools and components for the development of cross-platform MR applications in Unity and Unreal engines.

4.2 3D Graphic models

The 3D MR CC takes advantage of the 3D capabilities of MR and Unity engine with the aim to present the physical environment of the operation and the information collected from the systems and sensors on the field in a comprehensive way taking benefit from the spatial distribution of the sensors.

The graphic models used for the representation can be grouped in the following categories:

- Map
- Units
- Information

The map concerns the representation of the operation theatre for the search and rescue mission. The 3D graphic model of the map can be a BIM model that additionally includes useful information for the building, a 3D scan of an area using lidar or photogrammetry, an orthophotography map, a digital elevation model (DEM), or a GIS map of the area. In Figure 11, a 3D map that was created from photogrammetry in advance and was used in the application is presented.

The map used in the Unity engine does not have the initial geospatial information but uses a 3D cartesian coordinate system. For this reason, a transformation is performed from the real geospatial coordinates to the cartesian system for the information presentation on the map and vice versa when a coordinate must be communicated from the map to the outside units.

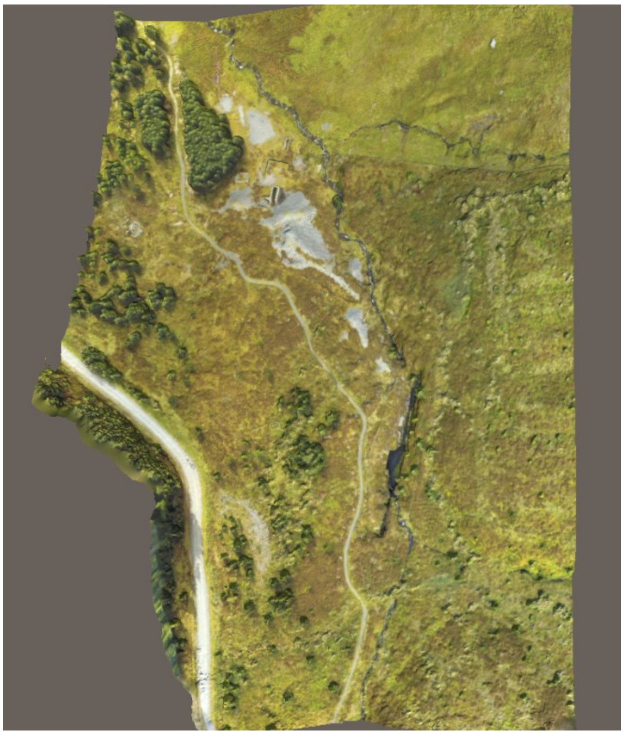

Figure 4-1: 3D map created with photogrammetry using a UAV (adapted for the development of the application from https://sketchfab.com/3d-models/nant-yr-eira-bronze-age-copper-mine-powys-cf6ab27ea29748ac8b5df5f333d61722)

Concerning the units, 3D models available from different sources were used as presented in the figures below.

Figure 4-2: The 3D model of the robot and a quadrotor UAV available from Gazebo Robot simulation library

Figure 4-3: Example of 3D avatar models of a child victim and professionals in uniform available from the Microsoft Rocketbox avatar library

For the presentation of the state of the units, their position and destination canvas text and lines of various colours are used. The vertical lines (stalks) allow the detection of the units on the map when the map overview is required [7]. Selections on the map can be represented with bright circles as in Fig. 12.

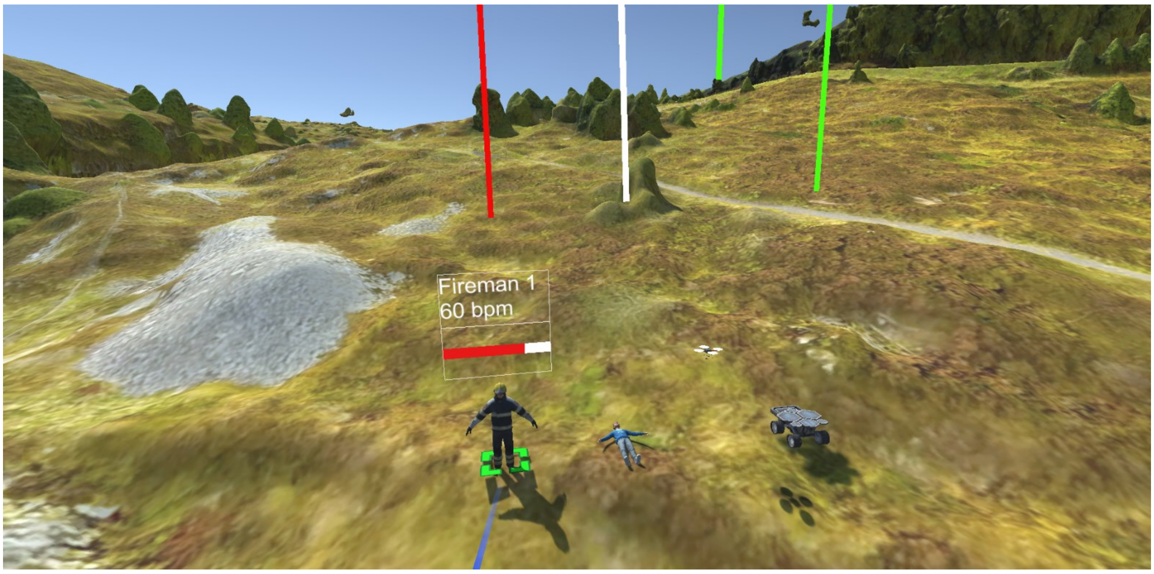

Figure 4-4: Units on the 3D map from left to right a fireman a boy victim a UAV and a robot

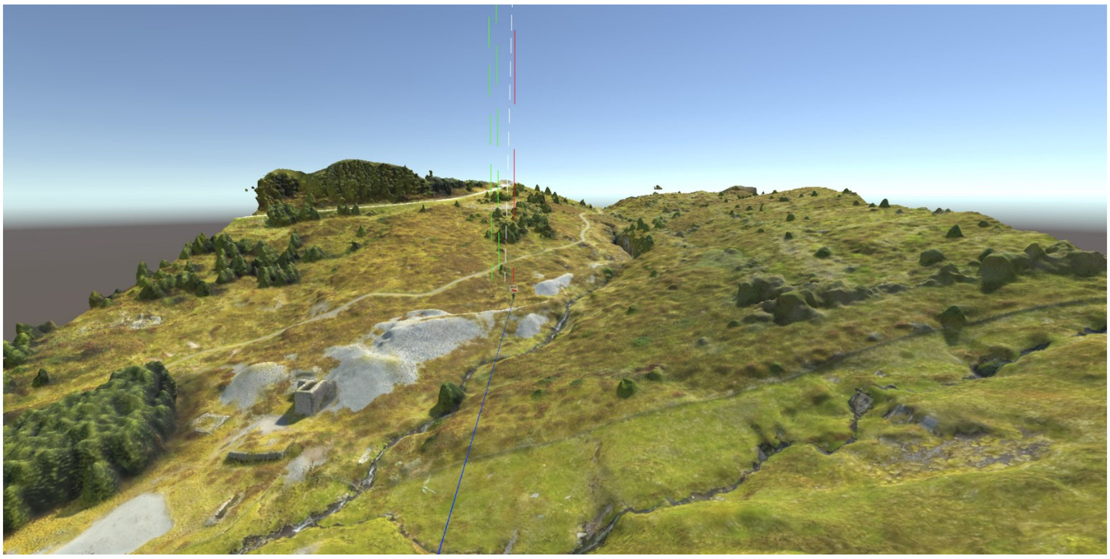

Figure 4-5: Detection from distance of the units using the vertical lines

Figure 4-6: The horizontal blue line demonstrating the destination of the fireman unit

Figure 4-7: A ring demonstrating a selected area on the map

4.3 Data Communication

Data communication with external sources is implemented with the MQTT protocol. MQTT protocol is a publish-subscribe network protocol for IoT devices. MQTT is lightweight and supports lossless communication. The MQTT protocol is functioning over TCP/IP protocol. The MQTT communication consists of a server message broker and clients which subscribe and publish in different topics.

The messages that are used in this application concern the position and state of the rescuers, victims, robots and UAV as messages that can be sent from the application as the selection of an area on the map and new destination to robots and UAV.

A message for a victim is a string that can be formulated as follow: 1623067157; v; 1; 40.56698565; 22.99799482; m; 12; l; 60 with each sub-string separated by a semicolon having the following meaning:

Timestamp: 1623067157

type: (v)ictim

ID: 1

Latitude : 40.56698565

Longitude : 22.99799482

Destination latitude : 40.644145

Destination longitude : 22.936301

sex: male

age: 12

position: (l)ying down

heartrate (bpm): 60

For the implementation of the MQTT communication inside the application the Unity plugin M2MQTT was used. For testing the functionality, a network was used with a Raspberry Pi 4 single-board computer as message broker and a smartphone and the unity application as clients. Messages were successfully exchanged between the smartphone and the application as presented in Fig 14.

Figure 4-8: MQTT test

4.4 Video streaming and registration

The UAV and robot video streams are used in SnR among other applications for live video feedback from the field. The robot is usually operated in areas dangerous to approach by humans while the drone is used for an overview of the operations. The combination of the 3D map with the live video stream provides better situation awareness also to the controller of the vehicle [8].

For video decoding the FFmpeg multimedia framework is used. For the implementation, a Unity plugin developed from Vive that uses the FFmpeg framework is used (Vive Media Decoder). The video can be a stream from IP cameras with a protocol compatible with FFmpeg. In this application, a Xiaoyi action camera was used with RTSP (Real Time Streaming Protocol) streaming capabilities compatible with FFmpeg. The video image was used as material and shader in a quad 3D model. The position, orientation and dimensions of the quad are determined according to the position, orientation and height of the map at the centre position of the camera. The camera extrinsic parameters (position, orientation) can be transmitted using the MQTT protocol.

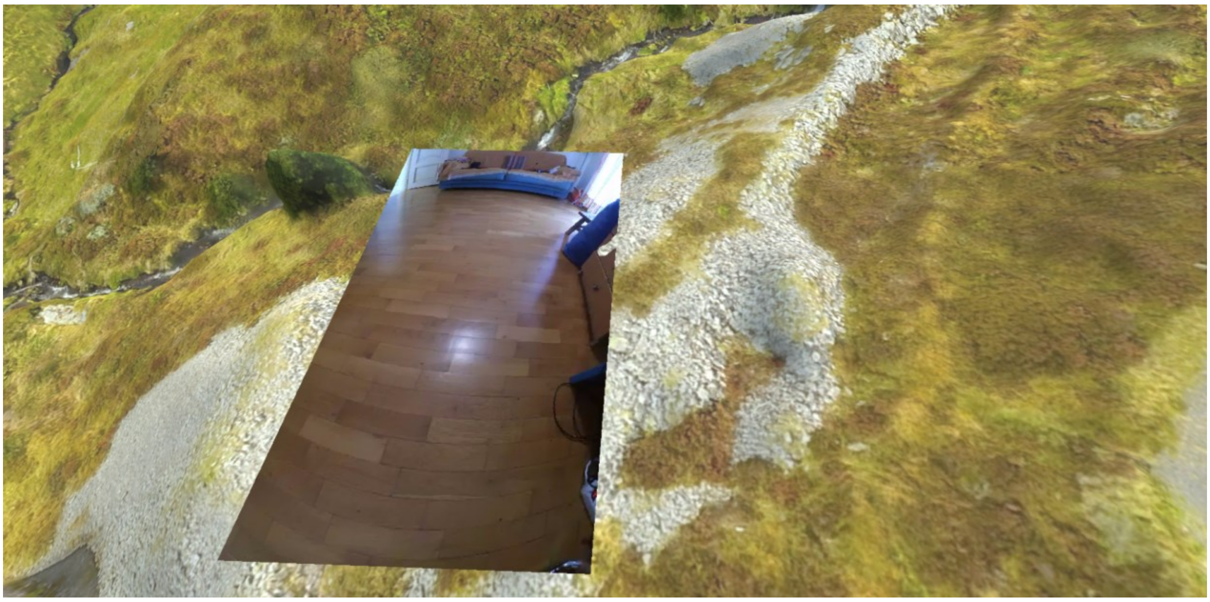

Figure 4-9: Video stream overlayed on the 3D map

4.5 Voice and video communication

Microsoft Hololens 2 supports voice and video communication and collaboration through the Microsoft Dynamics 365 Remote Assist. Dynamics 365 Remote Assist can connect with Microsoft Teams application on smartphones and allow the direct communication of the 3D MR CC with the units on the field. The activation of the communication can be performed with voice commands or with gestures on an MR interface.

The service has not been tested yet because the development system, Oculus Quest 2, does not support the specific application. When the Microsoft Hololens 2 system is available to CERTH the functionality will be further explored.

5 Conclusions

Situational analysis and impact assessment are complex cognitive tasks important for crisis management that are affected by the complexity of the operation, the information available to the user and their abilities. The task of this deliverable was the development of the 3D Mixed Reality Command Centre application with the target to enhance the situation awareness of the user in order to help avoid mistakes in their decisions. The application is trying to achieve this target by using advanced visualization methods that represent the data in a comprehensive way and at the same time do not obstruct the user from their environment. The application further employs a natural user interface and communication capabilities. The application will be further adapted and tested with the Microsoft HoloLens 2 device. The application will be finally integrated with the SnR subsystems as they are completed. The final integration and testing with SnR will be available in D 4.13 DSS Validation, V2.

Annex I: References

[1] Niklasson, L., Riveiro, M., Johansson, F., Dahlbom, A., Falkman, G., Ziemke, T. & Gustavsson, P. M. (2008, June). Extending the scope of situation analysis. In 2008 11th international conference on information fusion (pp. 1-8). IEEE.

[2] Endsley, M. R., & Garland, D. J. (2000, July). Pilot situation awareness training in general aviation. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 44, No. 11, pp. 357-360). Sage CA: Los Angeles, CA: SAGE Publications.

[3] Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. In Situational awareness. Human Factors Vol. 37 (1) pp. 32-64

[4] Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. IEICE TRANSACTIONS on Information and Systems, 77(12), 1321-1329.

[5] Moran, A., Gadepally, V., Hubbell, M., & Kepner, J. (2015, September). Improving big data visual analytics with interactive virtual reality. In 2015 IEEE high performance extreme computing conference (HPEC) (pp. 1-6). IEEE.

[6] Stanton, N. A., Chambers, P. R., & Piggott, J. (2001). Situational awareness and safety. Safety science, 39(3), 189-204.

[7] Feibush, E., Gagvani, N., & Williams, D. (2000). Visualization for situational awareness. IEEE Computer Graphics and Applications, 20(5), 38-45.

[8] Chellali, R., & Baizid, K. (2011, July). What maps and what displays for remote situation awareness and ROV localization? In Symposium on Human Interface (pp. 364-372). Springer, Berlin, Heidelberg.