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NLR-TP-2015-512 | July 2016

Simulation-based concept development and evaluation

Augmented reality concept to improve communication between helicopter crew during firefighting operations

CUSTOMER: Ministry of Defense

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Augmented reality concept to improve communication between helicopter crew during firefighting operations

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Problem area

Fire-fighting using a helicopter requires intense voice communication between the crew members. Each crew member has awareness of a part of the situation, from their own unique point of view. Clear communication is therefore essential for successfully executing the mission. However, ambiguity in the visual scene and not being able to see what the other is referring to in this visual scene, hinders clear communication between crew members.

Description of work

An augmented reality concept is proposed to support the crew in their communication during these missions. This concept focuses on making it possible to see what others are seeing in a way that is conformal to the 3D-world. The views of the different crew members are integrated, while maintaining the right perspective for each crew member. Unexposed (e.g. visually obstructed) areas in someone's view may be visible to others because they are viewing the scene from a different position. Being able to see what the others are seeing, makes walls or other obstructing objects virtually transparent. It allows one to see directly what someone else is referring to, helping to prevent ambiguity. Symbology is designed to further support the crew in communicating more clearly and efficiently. This symbology includes a clock position that resolves ambiguity by supplying distinctive references regarding relative orientation. The concept was developed using Virtual Reality (VR) based simulation and preliminary evaluation was performed using an operational expert.

Results and conclusions

The concept and the simulated demonstrator were well received during the preliminary evaluation. It is expected that it will help to reduce the need for voice communication while improving shared situation awareness between crew members while reducing ambiguity. This demonstrator will now be enhanced and in particular, the additional symbology will be integrated to fully demonstrate the concept and complete the evaluation.

Applicability

The concept is potentially applicable in all task settings that rely heavily on coordination with a team and where individual team members' views are partially obstructed. This can be for example inside aircraft, ships, vehicles and buildings. The concept is thus applicable in multiple domains, not only in aerospace.

GENERAL NOTE

This report is based on a presentation held at the AIAA-SciTech, San Diego, January 3-8, 2015.

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Abbreviations

ACRONYM	DESCRIPTION
AIAA	American Institute of Aeronautics and Astronautics
AR	Augmented Reality
ASI	Application Scripting Interface
CD&E	Concept Development & Experimentation
CLSK/DHC	Royal Netherlands Air-Force Helicopter Command
DHC	Defense Helicopter Command
DLL	Dynamic Link Library
GPS	Global Positioning System
HD	High-Definition
HMD	Head-Mounted Display
JIVC	Joint Information Technology Command
LIDAR	LIght Detection And Ranging of Laser Imaging Detection And Ranging
LPS	Local Positioning System
MoD	Ministry of Defense
NLR	Netherlands Aerospace Centre
SME	Subject Matter Expert
SSA	Shared Situation Awareness
ToF	Time-of-Flight
TRL	Technical Readiness Level
UDP	User Datagram Protocol
VBS	Virtual Battlespace
VD	Viewing Direction
VR	Virtual Reality

Simulation-based concept development and evaluation: Augmented reality to improve communication between helicopter crew during firefighting operations

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Using a helicopter in firefighting requires intense voice communication between crew members. Each crew member has awareness of a part of the situation, from their own unique point of view. Clear communication is therefore essential for successfully executing the mission, but ambiguity and not being able to see what others are referring to, make this difficult. An Augmented Reality (AR) concept is proposed to support the crew in their communication and decision making during these missions. This concept focuses on making it possible to see what others are seeing in a 3D world-conformal way. The view of other crew members is integrated into one's own view while maintaining one's own perspective. Unexposed areas in one's own view may be visible to others because they are viewing the scene from a different position. Being able to see what other see makes walls and other obstructing objects virtually transparent. This allows one to see directly what someone else is referring to, helping to prevent ambiguity. Symbology is being designed to further support the crew in communicating more clearly and efficiently. A concept demonstrator based on simulation using Virtual Reality (VR) is being developed to evaluate the functional concept and. An initial subjective evaluation indicates that the concept is viable in a simulation environment. This is the first step in testing the viability of an actual system. The next iteration of this project will go beyond simulation and will focus on developing a demonstrator with a higher level of technological readiness.

I. Introduction

OPERATING large helicopters during complex operations is a real team effort. Firefighting is an example of such a complex operation and the high amount of voice communication is indicative of the team effort required. The helicopter crew needs to work together to precisely maneuver the helicopter, pick up water in order to release it at the designated location and distinguish the fire or keep it from spreading. The Bambi Bucket that transports water is attached as sling load underneath the helicopter (Figure 1). The pilot cannot see it directly and must rely on the voice instructions of the loadmaster who sits in the back and can see the bucket by leaning out of the side doors. While the loadmaster can see the bucket directly, it is still difficult to estimate distances such as ground clearance. The radio altitude measurement is helpful in this situation, but this measurement is seldom directly available to the loadmaster and can only be obtained through voice communication with the pilot. Clear communication is essential to build up Shared Situation Awareness (SSA) and complete the mission successfully. While this is still difficult under optimal conditions, situations where clear communication is hindered occur regularly. Ambiguity can be a problem in environments with few distinct visual cues such as over a forest or at sea. Hovering over a large lake with few visual cues is a very challenging task for a helicopter pilot. When the pilot relies on the loadmaster's instructions to aim for a specific tree in the forest next to the lake, the difficulty even increases further. Clearly, less ambiguous cues than trees are preferable, but sometimes these are simply not available and much voice communication is needed to exchange information. This evidently affects the efficiency of communication, but may also cause safety incidents through erroneous decision making. To prevent this and improve communication, an augmented reality concept was conceived which allows helicopter crew members to

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directly perceive what other members or sensors can observe. This concept has been developed and evaluated using Virtual Reality (VR) based simulation as part of the L1427 Innovation in Simulation Technology R&D Program funded by Dutch Ministry of Defense conducted by the Netherlands Aerospace Centre (NLR). Stakeholders from the Netherlands' Defense Helicopter Command (DHC) have been actively involved in the project from the specification though the evaluation phase.

Figure 1. Helicopter extinguishing a fire with a Bambi Bucket.

II. The Concept

Being able to see what other crew members or sensors perceive evidently starts with capturing and sharing their views. One may, for example, provide every crew member with a camera system that captures and shares their field of view with others. Any display device can then allow others to see the shared imagery, but for this concept a head worn Augmented Reality (AR) device is chosen to allow crew members to move around. Moreover, the device does not consume any space in the cabin or on the instrument panels in the cockpit. Next, a 3D world conformal presentation of the video imagery is chosen above a 2D inset (Figure 2).

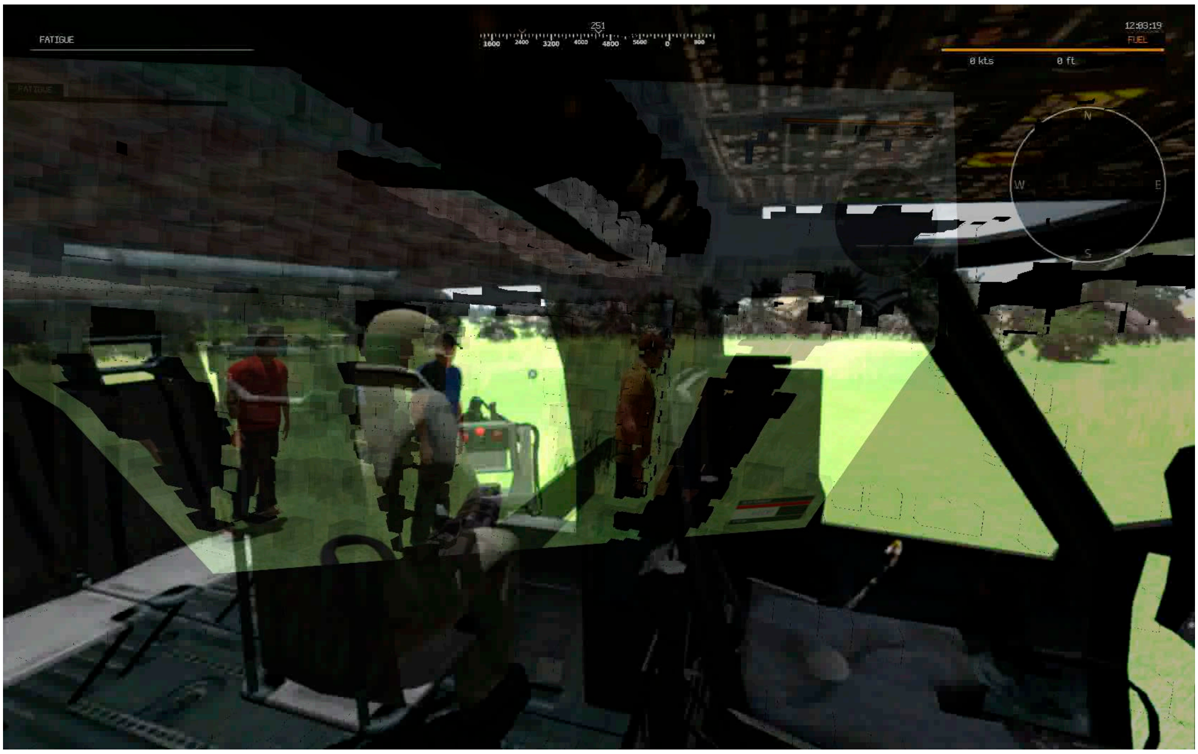


Figure 2. Seeing what someone else sees. This illustrates the view from the helicopter pilot's position while looking in the direction of the gunner. The gunner's view is shown using AR from the pilot's perspective, making the helicopter virtually transparent.

Although a 2D inset fulfills the purpose of sharing views, it is not intuitive. Firstly, the viewing direction of these insets is unknown. Secondly, the image source and viewer are at different positions and may have different orientations. Consequently, their view of the world is from a different perspective. Mentally integrating the 2D inset is necessary[1] to actually comprehend it. Furthermore, the integrated image needs to be combined with one's own perspective while monitoring the surroundings simultaneously, which may be difficult[2].

A 3D world conformal presentation[3] is an alternative solution in which the information from the 2D video inset is merged with the 3D environment to facilitate mental integration for the viewer. This means that all objects or information in the 2D video are presented at their true location and orientation. Essentially, the 3D environment captured in the 2D video must be recreated. To achieve this, the video or pixel information in screen/camera coordinates needs to be converted into a coordinate system that is related to the viewer. Figure 3 below illustrates the necessary elements for this transformation. First, the relative position and orientation or Viewing Direction (VD) of the camera with respect to the viewer needs to be obtained (Δx, Δy, VDA, and VDB in Figure 3). Second, the distance to each object in view of the camera, further referred to as depth (see Figure 3), is needed to be able to generate a world conformal presentation of the video imagery. This entails that besides the camera system, each user must be equipped with a device to measure relative position and orientation along with a device to measure depth to objects in view (see section A).

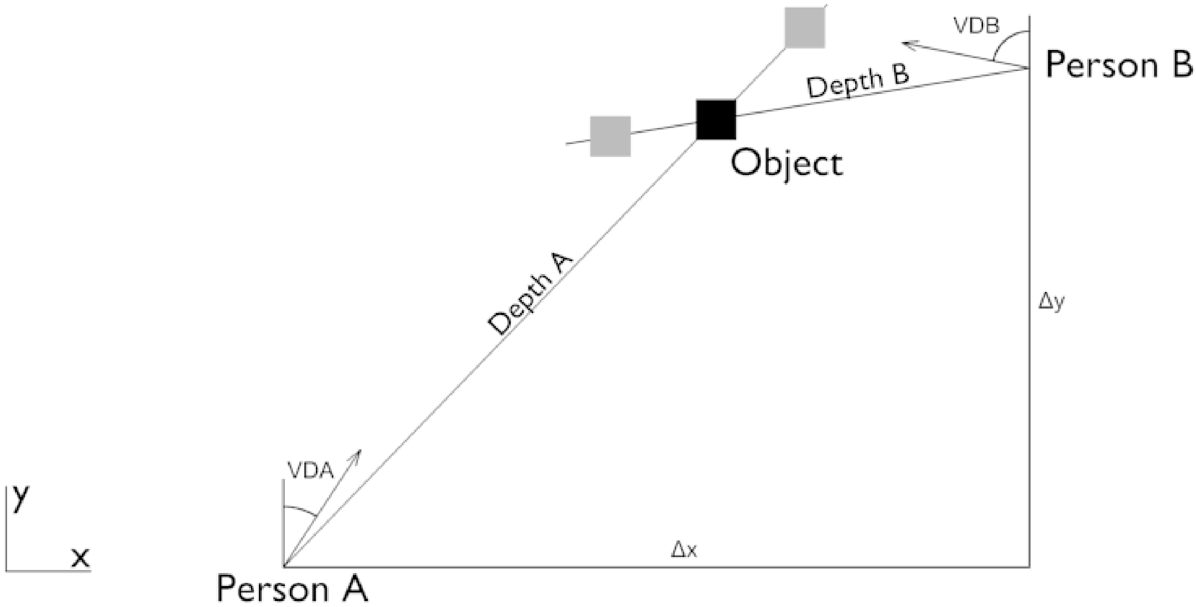
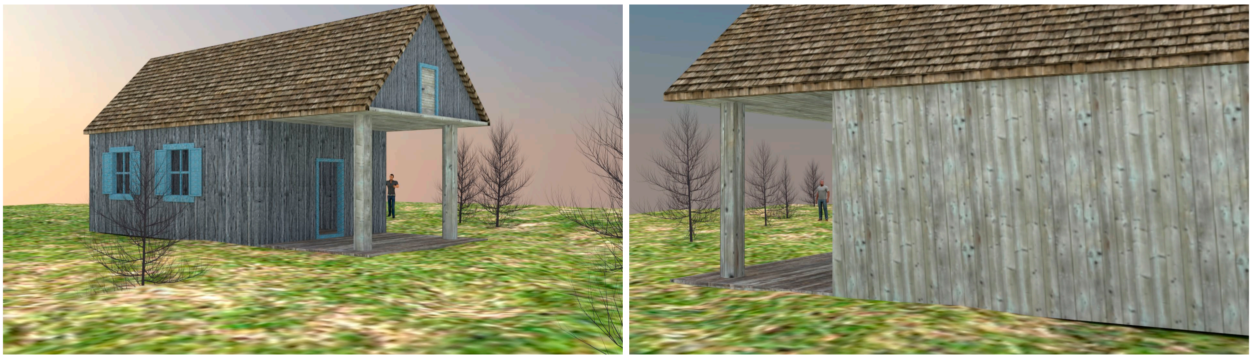


Figure 3. Top view of two persons A and B looking at an Object. The relative position (Δx, Δy) and orientation (VDA, VDB) determine the direction of the object (grey square ghosts). The depth measurement places the object at the true location (black square).

A. Recreating the Environment

Consider the following scene in which two persons are looking at a wooden house from opposite sides (Figure 4). The person on the left will be designated "person A" and the person on the right "person B". Their views are illustrated in Figure 5(a) and (b) respectively. As shown, person B is not able to see the door, the three windows and the left post of the house from his perspective.

Figure 4. Scene in which two persons are looking at a wooden house from opposite sides of it.

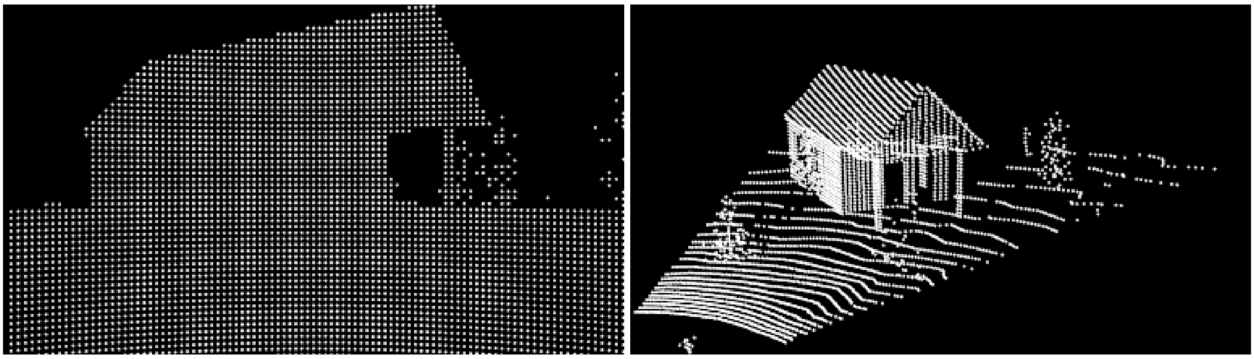


(a) **(b)**

Figure 5. (a) View of person A. (b) View of person B.

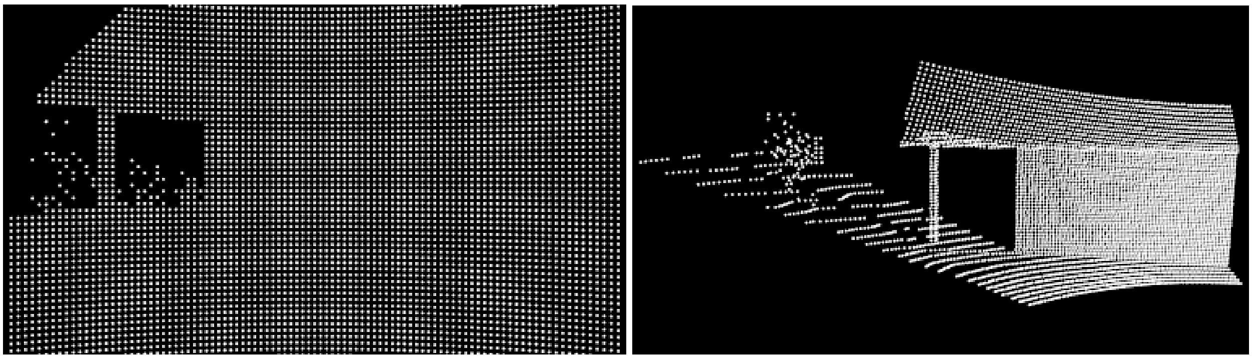
When these views are captured, shared, and shown to the other person using a display device, both persons have the same visual information and can see what the other person sees. The two sides of the house with and without windows are then visible to both of them. Still, the proposed concept describes a 3D world conformal representation of the shared imagery as described in the previous section. As such, a virtual 3D environment of the world in view has to be created.

When assuming that the relative position, orientation and depth measurements are available from various sensor systems (see section E), a 3D-point cloud can be generated. This is shown in Figure 6 for person A and Figure 7 for person B, both illustrated from their perspective (a) and from another (random) perspective (b) to get a clear overview of the cloud.



(a) (b)

Figure 6. Generated point cloud of person A by taking distance measurements. Shown from the actual perspective (a) and from another (random) perspective (b).

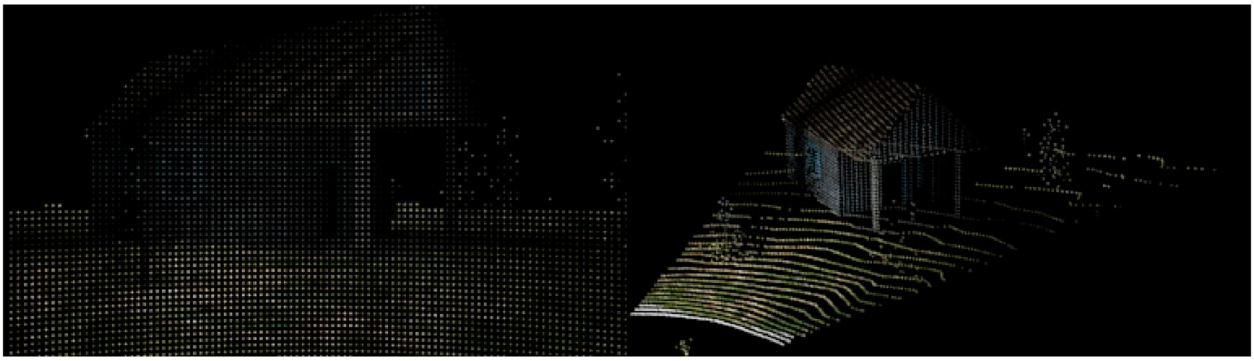


(a) (b)

Figure 7. Generated point cloud of person B by taking distance measurements. Shown from the actual perspective (a) and from another (random) perspective (b).

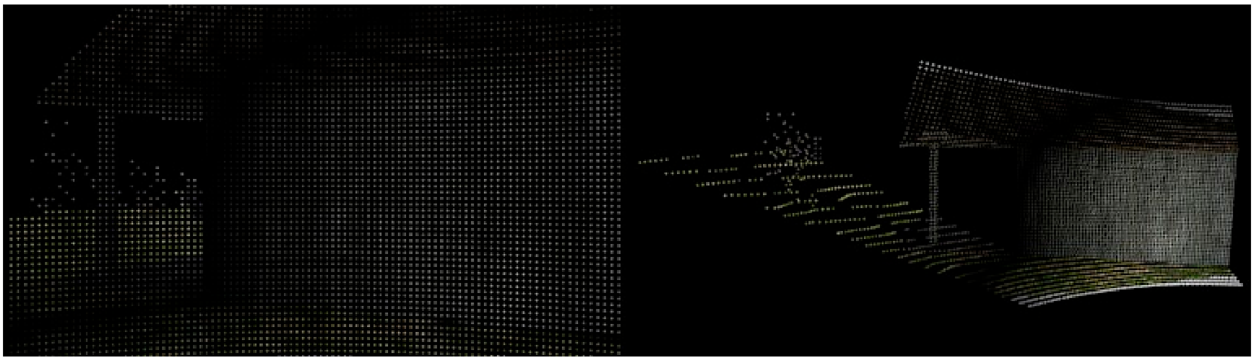
B. Colorizing the recreated environment

As can be seen in Figure 7(b) and Figure 8(b), the point cloud obtained from the relative position, orientation and depth measurements, actually becomes clearer when looking at it from another perspective. Colorizing the point cloud using camera imagery will improve this picture even further. A view that can be compared with a colorized LIght Detection And Ranging of Laser Imaging Detection And Ranging (LIDAR) image is obtained (see section E). The result is shown in Figure 8 for person A and Figure 9 for person B, both illustrated from their perspective (a) and from another (random) perspective (b).



(a) (b)

Figure 8. Colorized point cloud of person A. Shown from his perspective (a) and from another (random) perspective (b).



(a) (b)

Figure 9. Colorized point cloud of person B. Shown from his perspective (a) and from another (random) perspective (b).

C. Sharing the Recreated Environment

The colorized point cloud obtained from each user's wearable sensor system can be shared in a computer network. The individual point clouds can then be combined into a single point cloud as shown in Figure 10. This way, a more complete virtual environment is created. The same combined scene is shown in Figure 11, but from the perspective of both persons A and B. Note that the view of person B clearly shows the left post of the house which that person cannot see in his real-world view. This is just one way of combining and presenting the shared data.

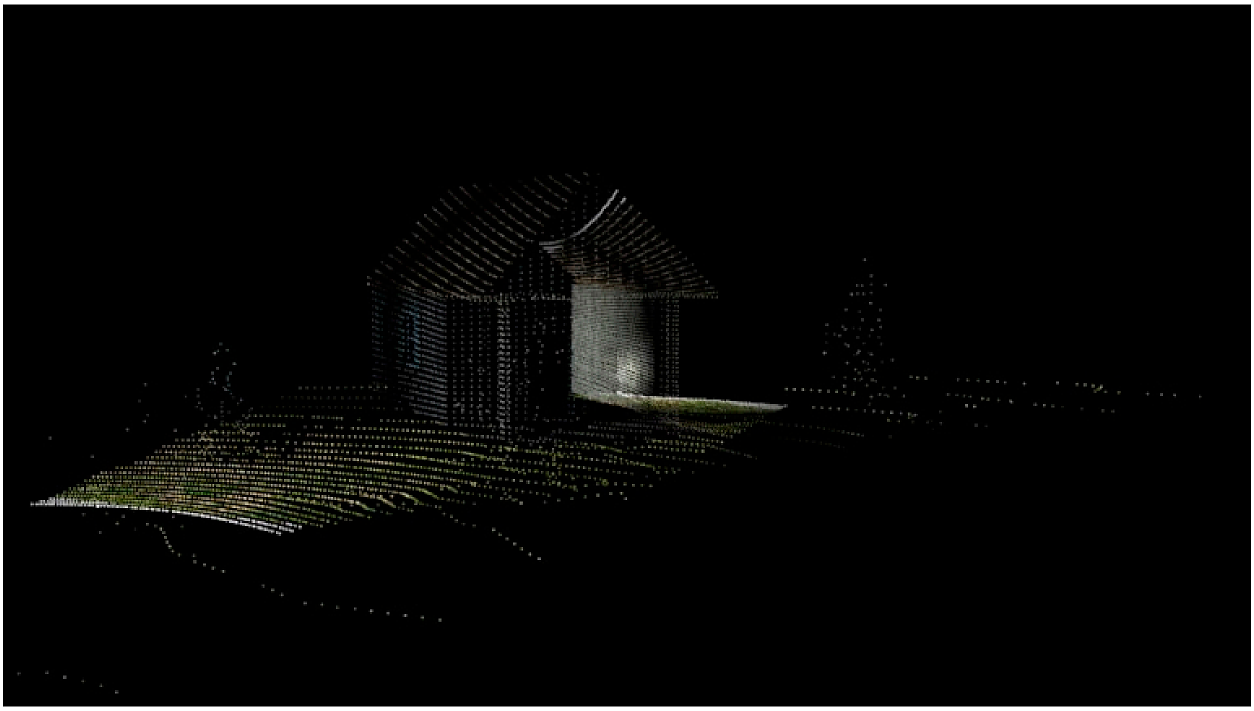
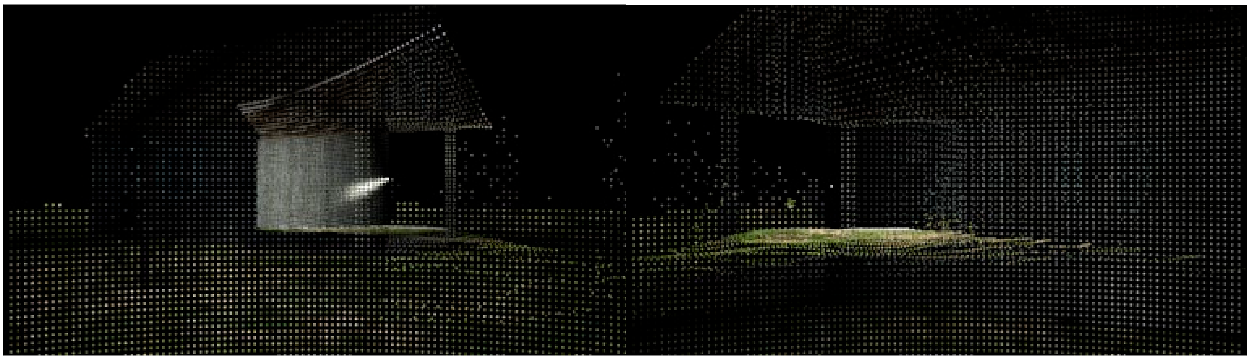


Figure 10. Recreated world by combining the individual point clouds of person A and B.

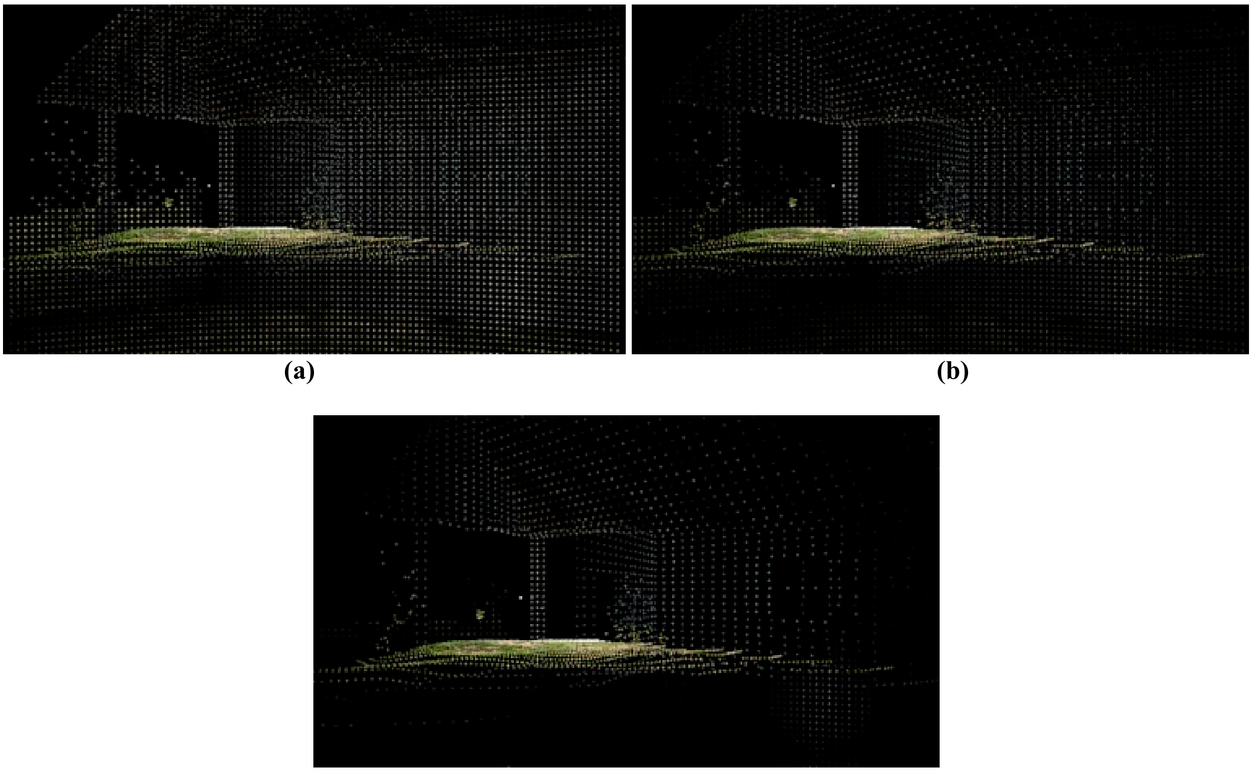


(a) (b)

Figure 11. Virtual view of person A (a) and B (b).

D. Displaying the Virtual View over the Real-World View

The view in Figure 9 could be placed directly over the real-world view of person B using an AR display. He would then also see what person A sees. However, displaying the point cloud generated from his own perspective is less relevant as he already sees this directly. Still this information is needed to distinguish which item would normally be visible or obscured by another item for determining how it should be processed and visualized. In Figure 12 the point cloud generated from the perspective of person B is shown in three variants: opaque, semi-transparent, and completely transparent (removed from his view).



(a) (b)

(c)

Figure 12: Virtual view of person B where the generated point cloud from his own perspective is shown opaque (a), semi-transparent (b) and fully transparent (c).

This view can now be placed directly over the real-world view using an AR display. The result is illustrated in Figure 13. Person B now clearly sees the left post of the house while it is completely invisible to him in the real-world view. Although still recognizable in this example, the door and windows of the house will become more apparent when the resolution of the distance measurement sensor will be increased. This way, people can see what other people are seeing from their perspective. The system becomes a see-through system as well. It is extensible to any amount of users. More colorized point clouds will then be added to the virtual scene and more data needs to be processed, increasing the hardware requirements. Specifically designed additional symbology for helicopter firefighting operations can also be overlaid on top of the see-through display.

E. Required Sensor Systems to Recreate the Environment

The concept relies on various sensors to recreate the environment. Although complex, the concept is assumed to be feasible using the considerations mentioned in this section. Further research into these sensors is beyond scope during this phase of the project.

The system relies on sharing views and as such the base of the system will consist of camera's that can visually capture the environment. During this phase of the project only day operation is considered and as such a camera system that can capture light in the visual spectrum in High-Definition (HD) is required.

As mentioned before, recreating the environment starts with obtaining relative position and orientation measurements of both capturing devices (cameras). There are various instruments and methods available that can be used for this purpose. The Global Positioning System (GPS), Local Positioning System (LPS) and other systems that measure Time-of-Flight (ToF), are typically used to obtain a (relative) position. Compasses can sense the Earth's magnetic field and can obtain a rough estimation of the horizontal orientation. Other systems use similar field sensing techniques, in which the field may be synthetically generated. Typically these systems have a high accuracy on a small range and are used in order to measure orientation and improve the position measurement. Inertial systems, such as gyroscopes, are generally used in combination with other position and orientation measurement and have a high frequency and accuracy when compensated for drifting effects. Each device, method or combination of methods has its own characteristics concerning accuracy and update frequency. For this paper it is assumed that such positioning systems are placed inside the helicopter. Position and orientation measurements relative to the helicopter will therefore be assumed accurate when inside or near the vehicle. However, the helicopter's position and orientation relative to the terrain is assumed to be less accurate.

Now that the positions and orientations are determined, the distances from the camera to everything in view are needed. This depth measurement can be obtained using different instruments and methods such as LIght Detection And Ranging of Laser Imaging Detection And Ranging (LIDAR), structured light, stereoscopic sensors or using offline data of the surrounding environment. Again, all methods and instruments have their own characteristics regarding, accuracy, minimum and maximum distance, resolution, and update frequency. For this research it is assumed that a combination is chosen that allows high accuracy, high resolution and high update frequency for small distances. For larger distances, offline data is used to get a rough estimate.

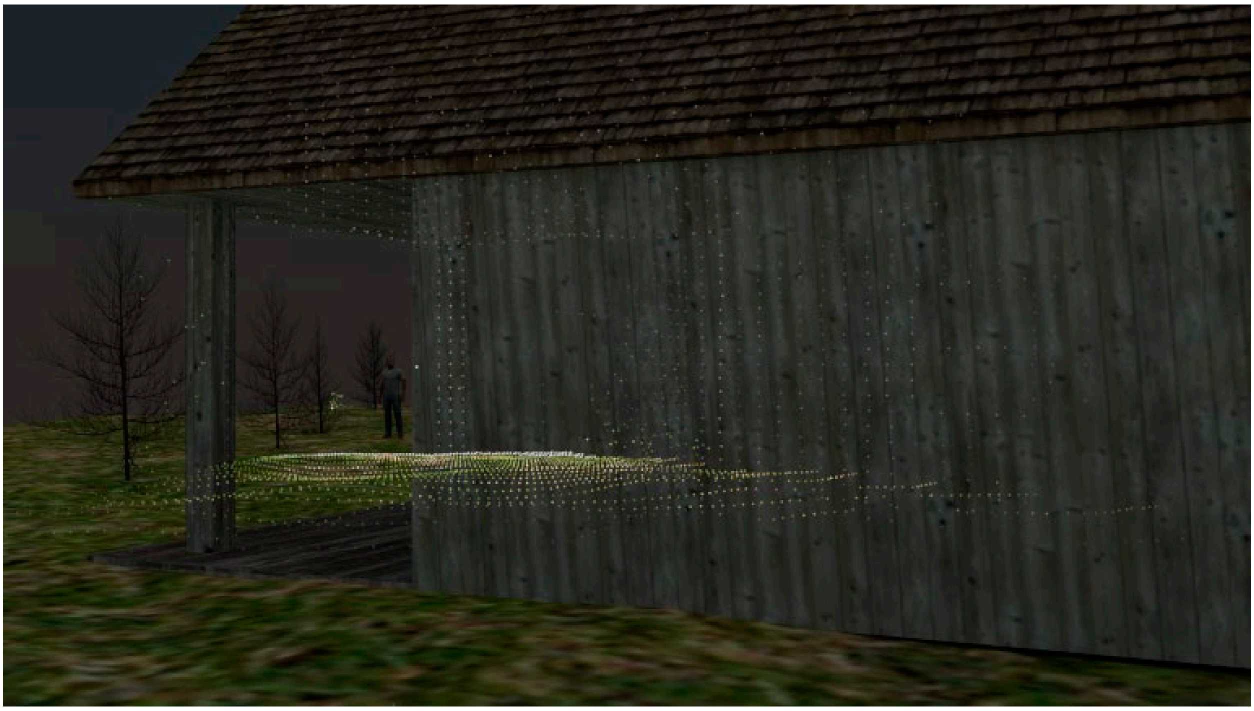


Figure 13. See-through display of person B.

III. Rapid Prototyping Using Simulation

The concept is developed and implemented according to the Concept Development and Experimentation (CD&E) technique. Sub-concepts are rapidly prototyped and implemented in the form of a computer network simulation or concept demonstrator to experimentally assess the possibilities and capabilities, provide insight and determine the possible success of this concept. To obtain unbiased results of this assessment, the concept demonstrator and its components are kept close to system that could be operationally functioning. This approach also allows connecting the concept demonstrator to operational systems after successful evaluation in the simulation phase.

A. Virtual Battlespace (VBS)

Bohemia Interactive Simulations' Virtual Battlespace 3 (VBS3) is a flexible simulation training solution for e.g. scenario training and mission rehearsal (Figure 14). The Dutch Ministry of Defense has supplied the NLR with several VBS licenses to support them with many of their innovative projects. It is used as a virtual world for the concept demonstrator in which virtual players and sensors can be simulated. VBS3 was selected by the U.S. Army as its flagship product for its Games for Training program and has become an industry standard in game-based military simulation.

To demonstrate the concept, a two-player networked VBS session with two physical computers is used.

Figure 14. Virtual Battlespace.

B. Video Capturing and Sharing

Capturing and sharing video is evidently the base of the concept. FFmpeg, a solution to record, convert and stream audio and video, is used to simulate a streaming camera system that can capture and share a person's view. The view of a virtual player in the VBS environment is captured and streamed directly to associated clients as a point to point stream. The MPEG-2 video codec, MJPEG container and UDP protocol are used to maintain low latencies.

C. Simulating (Relative) Position, Orientation, and Distance Measurements

LIDAR was chosen as the main method for distance measurement to recreate the environment. Offline height data of the terrain was used as a secondary method to supplement this measurement. Combined with relative and absolute position measurements, this enables recreating the environment in view. While there are methods available to simulate absolute and relative position measurements, there is no LIDAR simulation present in VBS. Therefore a LIDAR system has been implemented in VBS.

The LIDAR sensor is simulated using straight-line collision detection via the VBS Application Scripting Interface (ASI) as a plugin. ASI enables external applications to communicate with VBS using their scripting language as a Dynamic Link Library (DLL) which is loaded when VBS is started. Straight-line collision detection is performed between a starting and end position and returns the distances to all objects it comes across along the way. The starting position is located at the camera position near the player's eye. The concept envisions a depth measuring device as part of a multi-sensor system that includes a camera system. The end position is determined by the maximum range of the LIDAR sensor, but for ease the maximum viewing distance in the virtual world is used for simulation. Straight-line collision detection can return multiple hits along the line in VBS, but to simulate an actual LIDAR sensor, only the first hit is taken in to account. Preferably, the LIDAR sensor should scan the camera's field of view with a high resolution. Therefore, a linear scan pattern is implemented that scans the camera's field of view left to right and from top to bottom sequentially. Unfortunately, the resolution that was allowed by the simulation is far below the resolution of an actual LIDAR system because of computer performance limitations in VBS. To counteract, a randomness factor deviation to the scan pattern was introduced to obtain a higher resolution after buffering sequential scans.

D. Sharing the Measured Data

The LIDAR data and (relative) position and orientation needs to be shared in the computer network to allow clients to access it and present it to their users. Optimally, this data is included in the video stream to assure synchronization. Unfortunately, this could not be achieved within the time frame of creating this concept demonstrator and a separate User Datagram Protocol (UDP) stream is applied using the Netherlands Aerospace Centre (NLR) proprietary high performance and easy to use network communication protocol. Although this approach may introduce some synchronization problems, these are expected to remain small because of the low latencies achieved in the stream implementation..

E. The Client: A Viewer to See what Others See

The objective is being able to see what other crew members or sensors see in a 3D world conformal way using a Head-Mounted Display (HMD). To demonstrate the concept, a Virtual Reality (VR) device is used. This is mainly because low-cost HMD devices were unavailable at the time. The Oculus Rift DK2 was chosen as VR device during the simulation. The main disadvantage of using a VR device is that one's own view needs to be simulated as well, while this would be directly visible in a see-through HMD. Still, this has benefits. The need to simulate one's own view in a VR device also means that the entire scene will be virtual and independent of its actual surroundings and no real helicopter is needed to demonstrate the concept. Besides this, the simulated system closely mimics an actual system. The client is developed as standalone application that only receives data from sensors and other sources from the computer network.

The client is created using the open-source 3D graphics toolkit OpenSceneGraph. As mentioned before, to be able to share views, the view itself needs to be shared by using a video stream. OpenSceneGraph's FFmpeg plugin is used to play to the video streams within the client. The plugin is customized to minimize latency between the video capturing and playback by disabling playback buffering. To be able to create a 3D world conformal presentation, first, the (relative) position and orientation need to be obtained from the UDP stream mentioned in section D. This allows placing the virtual players in a 3D scene and when loading offline terrain data, the first step in recreating the environment is made. When the video is played back on the virtual terrain using the projective texturing technique[4], one's own view will be partially recreated (see Figure 15).

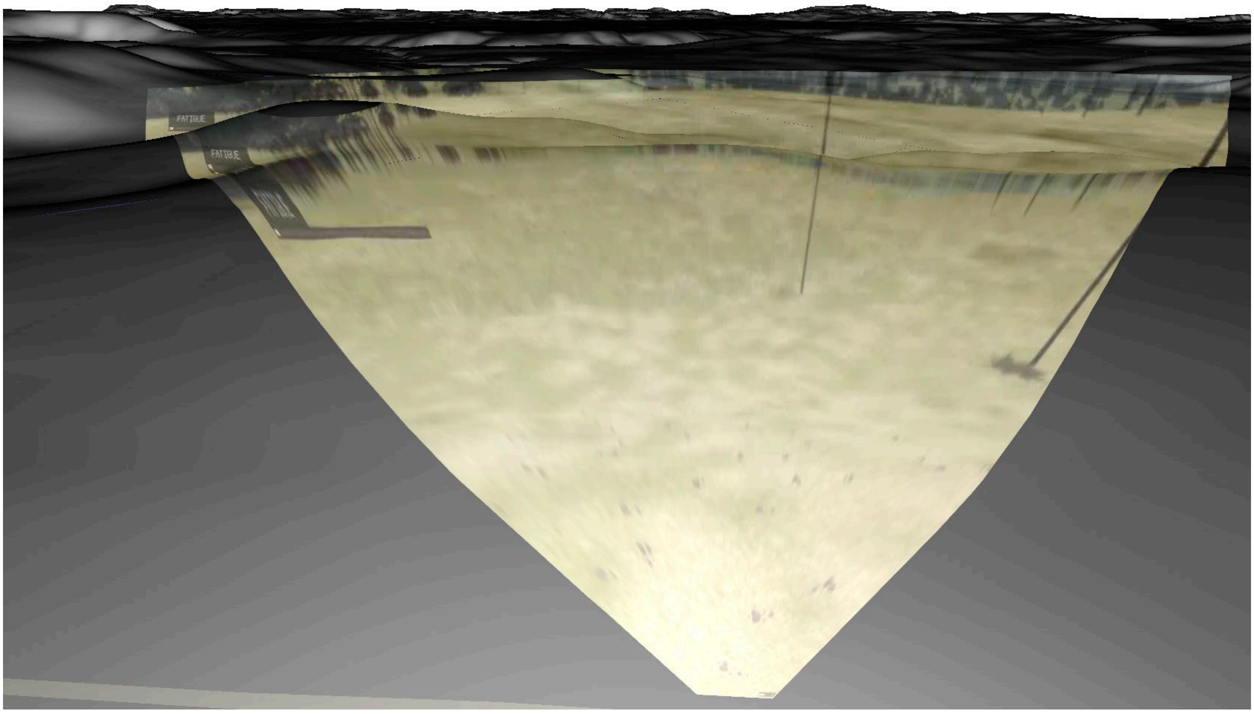


Figure 15. Projective texturing using offline data and global positioning and orientation.

The view is only partially recreated since only terrain data is available. 3D object such as trees, vehicle, and people, are not available and the projective texture drapes everything in view over the terrain including these 3D objects. This is where the LIDAR depth measurement is used to detect all objects that are not part of the terrain. The LIDAR measurements can displayed by placing cubes as particles in the 3D scene that will be created when new data is received (see Figure 16). They are removed after a certain variable period of several seconds. The 3D cubes have a constant screen-dimension such that the entire field of view can be filled with cubes while the LIDAR resolution is limited. Optionally, these particle cubes can automatically be transformed such that their orientation is constant towards the VR screen. These particle cubes can also be exposed to the projective texturing technique mentioned before which recreates the 3D environment even further (see Figure 17).

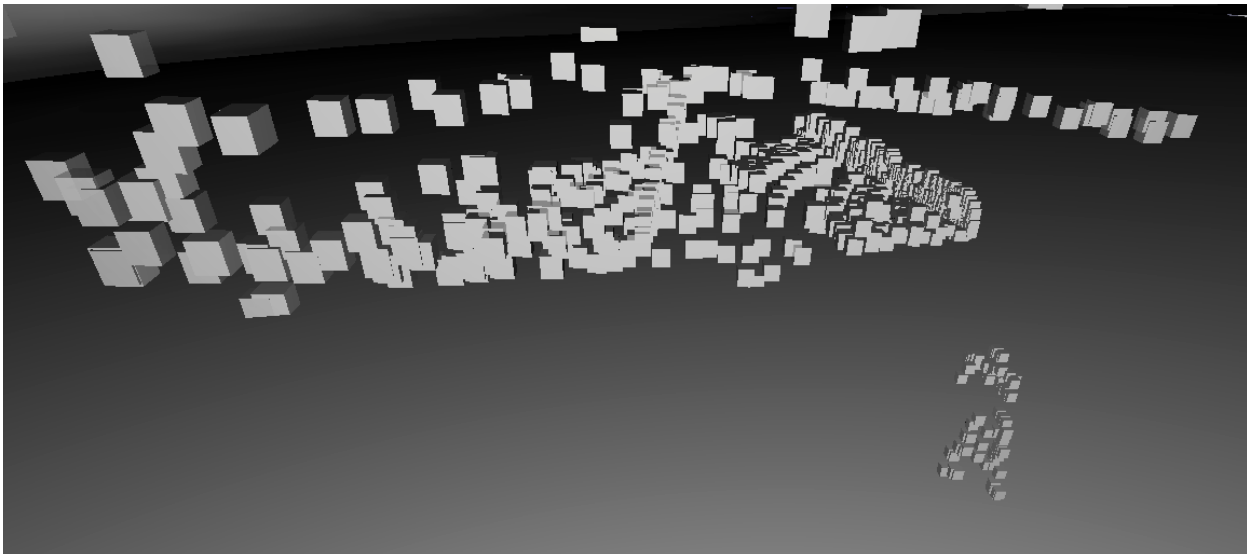


Figure 16. Displaying LIDAR measurements using particle cubes. A person and a helicopter a detected by the LIDAR scan.

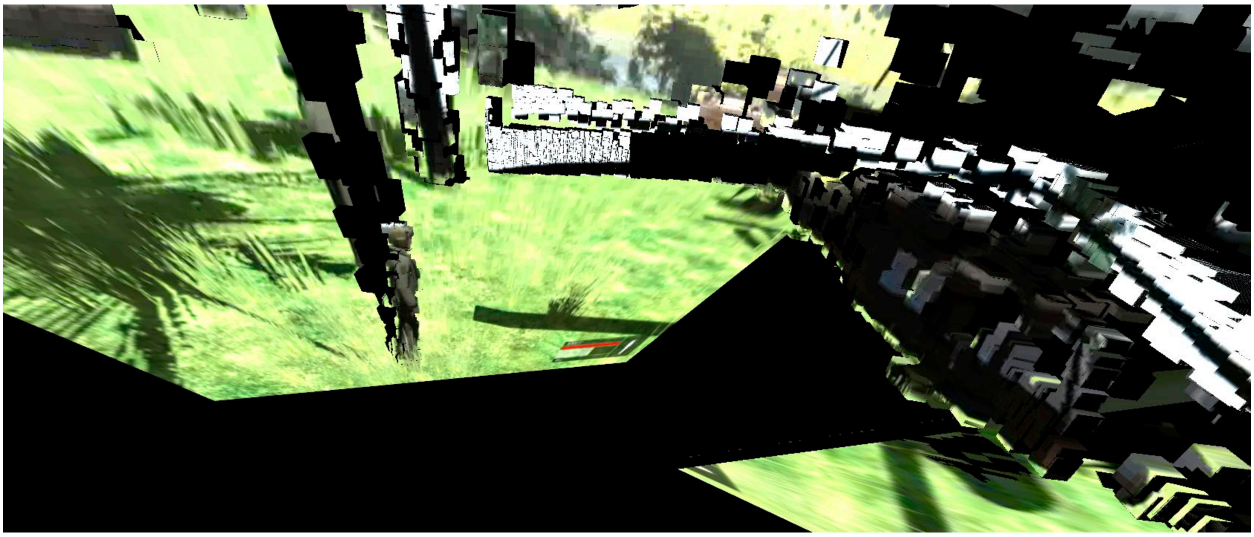


Figure 17. Projective texturing the LIDAR measurement and offline terrain data. Shown from a random position and orientation in the virtual environment.

When virtually looking through the eyes of a player, the projective texture matches up with the screen and the view resembles the players view again (see Figure 18). Note that his view is similar to what one would observe when looking though a see-through HMD, but with all depth information and projection of the other player included. When turning off one's own video image source such that views from other players are visible Figure 19 can be obtained. A combined view can be obtained when varying the transparency of the video images (see Figure 20).

Figure 18. Projective texturing the LIDAR measurement and offline terrain data. Shown from a player's perspective.

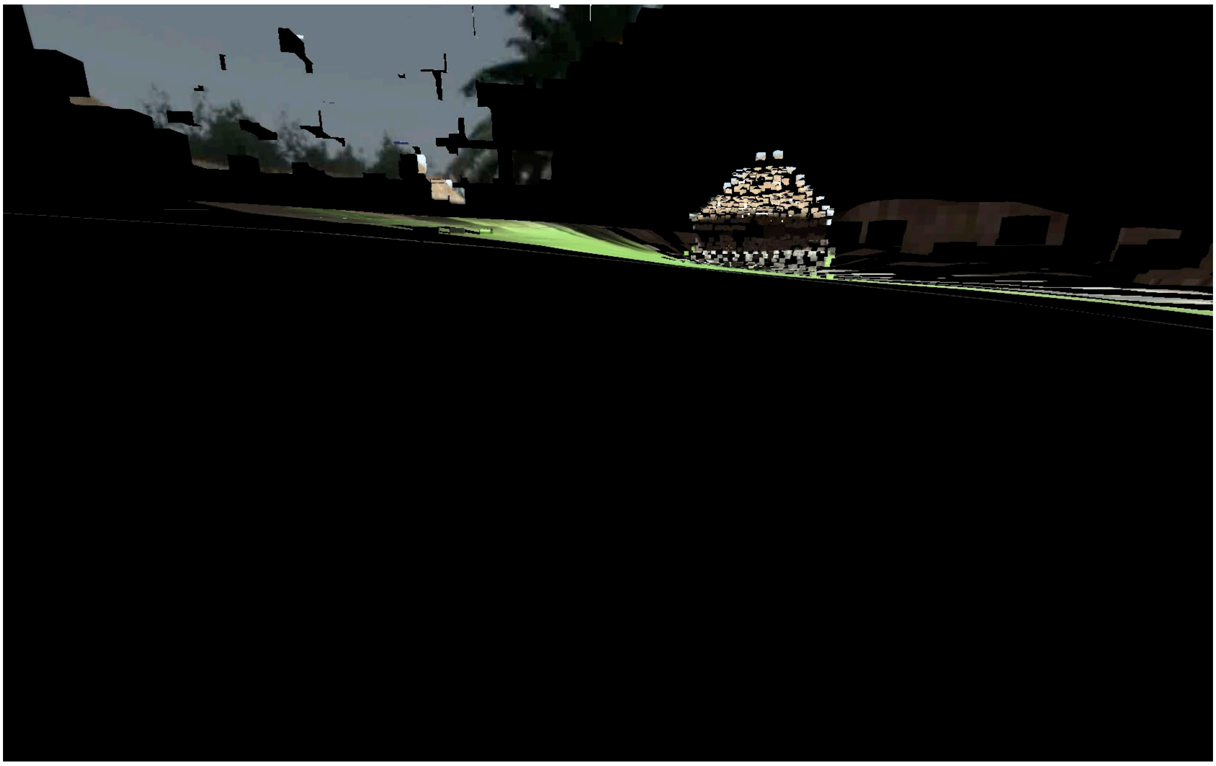


Figure 19. Projective texturing the LIDAR measurement and offline terrain data. Showing the other player's view from one's own perspective.

Figure 20. Projective texturing the LIDAR measurement and offline terrain data. Showing combined views by changing transparency.

The same technique can be applied from inside the helicopter. The raw camera images from the pilot and loadmaster/gunner are shown in Figure 21 (a) and (b). The projective textured images are shown in (c), (d), and (e).


(a)


(b)


(c)


(d)


(e)

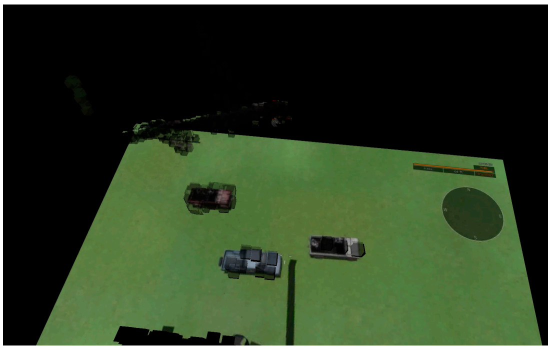
Figure 21. Camera image from the pilot (a) and loadmaster/gunner (b). Projective texturing the LIDAR measurement and offline terrain data. Showing own (c), other (d) and combined views from the pilot's perspective (e).

The raw camera images from the pilot and loadmaster/gunner are shown in Figure 22 (a) and (b). The client's projective textured images are shown in (c), (d), and (e).

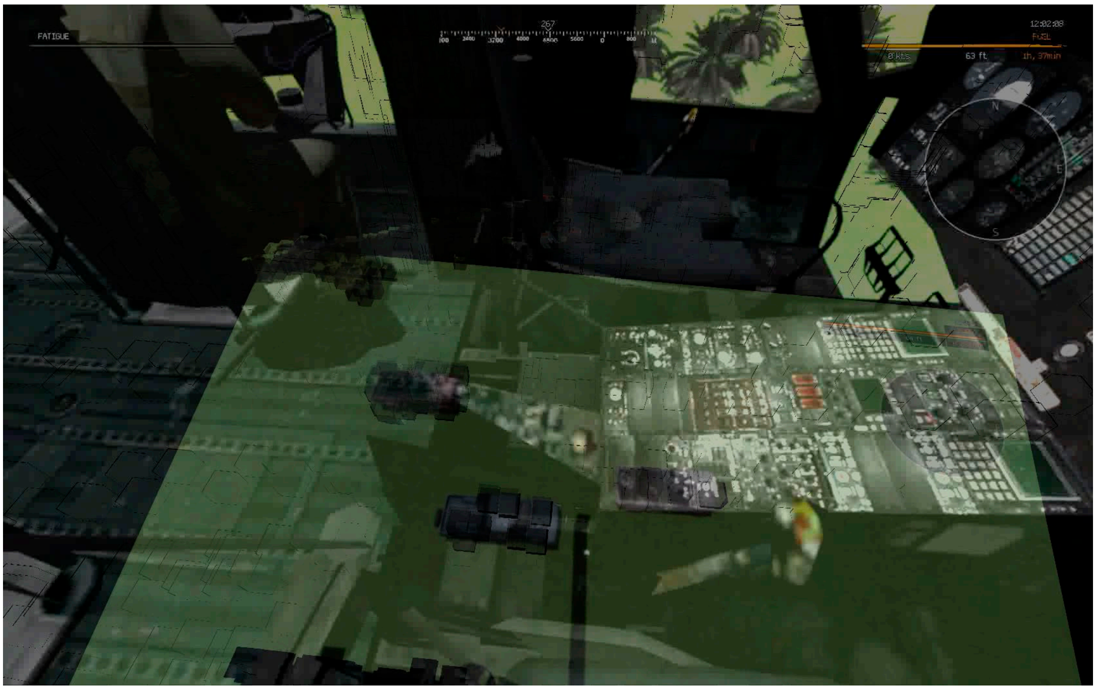
(a)

(b)

(c)



(d)



(e)

Figure 22. Camera image from the pilot (a) and loadmaster/gunner (b). Projective texturing the LIDAR and offline terrain data. Showing own (c), other (d), and combined views from the pilot's perspective (e).

The raw camera images from the pilot and loadmaster/gunner are shown in Figure 23 (a) and (b). The client's projective textured images are shown in(c), (d), and (e).

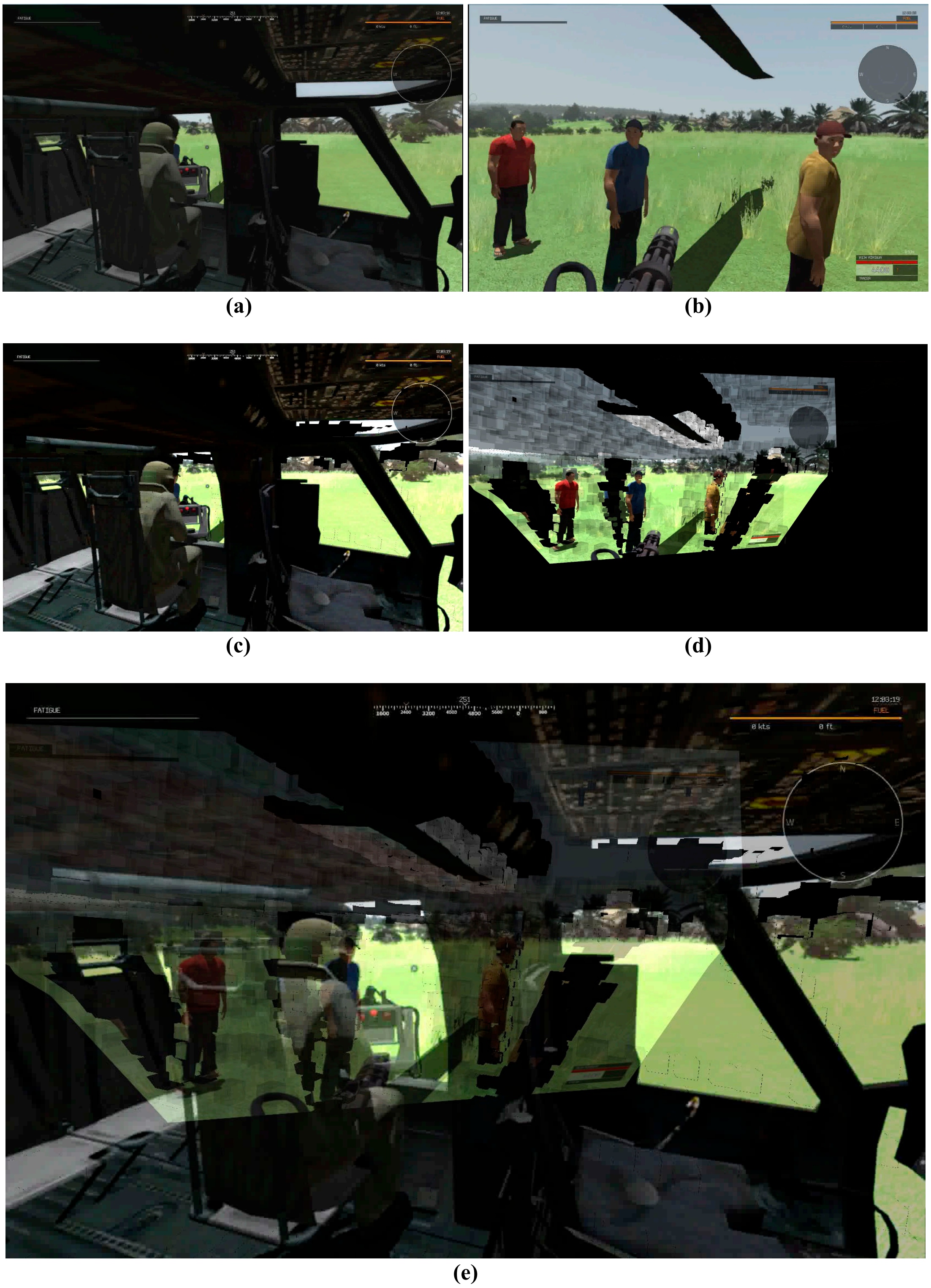


Figure 23. Camera image from the pilot (a) and loadmaster/gunner (b). Projective texturing the LIDAR and offline terrain data. Showing own (c), other (d), and combined views from the pilot's perspective (e).

IV. Supporting Symbology

Using operational input from the stakeholders at the Netherlands' Defense Helicopter Command (DHC) Specific symbology has been designed to support the helicopter crew during firefighting operations (Figure 24). The main purpose of this symbology is to improve communication during such operations by reducing possible ambiguity. Besides this, it contains elements that strive to increase situational awareness and improve the efficiency of the operation as a whole. The symbology elements are described per element in the following sections.

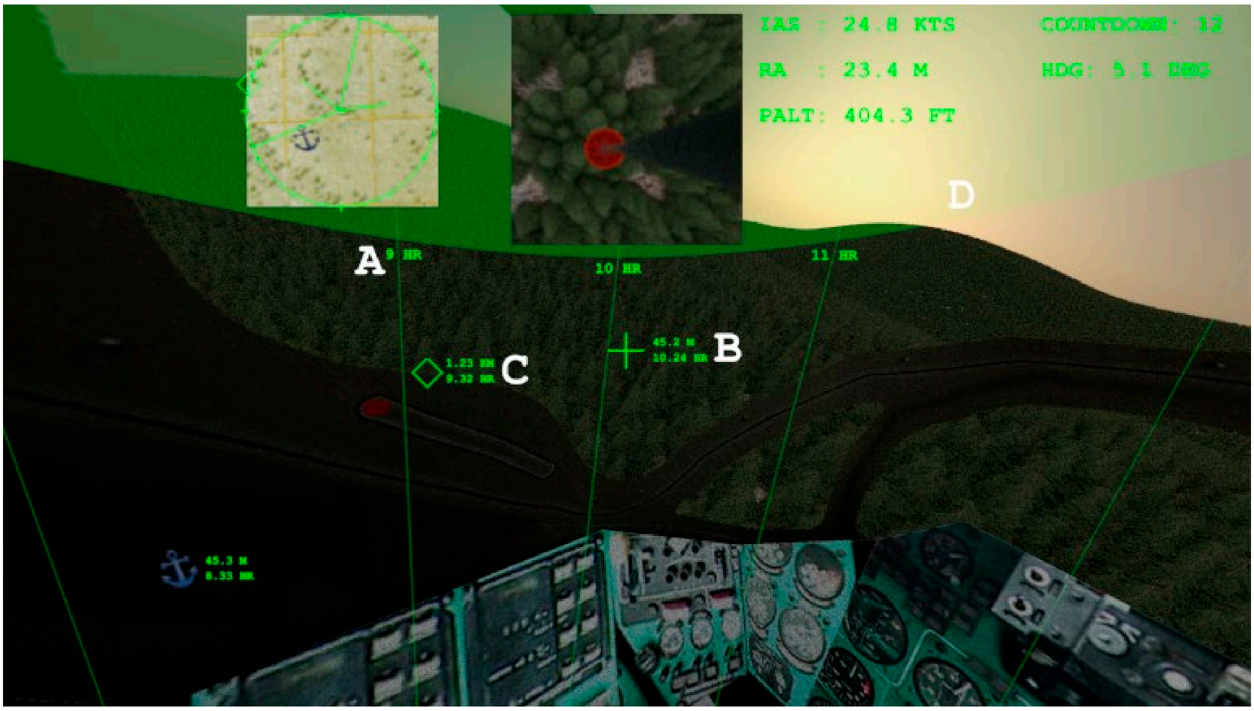


Figure 24. Supporting HMD symbology. The wearer of the HMD is seated left in a helicopter slightly turning left.

A. Clock Position Indicator

The clock position indicator specifies the relative horizontal direction of objects in view related to the helicopter's nose using the analogy of a 12-hour clock. The helicopter crew uses this analogy to communicate directions to one another. Objects straight in front of the helicopter are in the direction of 12 o'clock and objects behind it are at 6. This method generally works well for the helicopter crew, but may also be ambiguous. Generally, the direction is estimated by the crew members themselves and such estimations tend to vary between persons. Also the direction estimation may vary with the position of the person inside the helicopter, especially for objects that are not in the exact 12, 3, 6, or 9 o'clock position. Some persons may try to take the helicopter's center of gravity as a reference, while others may (unconsciously) use their position inside the helicopter. The clock position indicator is introduced to resolve this ambiguity.

A helicopter-centered, helicopter-fixed virtual sphere with large radius is placed with its center at the helicopter's center of gravity. A meridian line for each possible hour interval is shown on this vertical sphere on the HMD. The hour position with 12 at the nose and 6 to the aft of the helicopter is indicated next to the lines. This allows crew members to read out the hour position directly. There will be no variation due to crew members' positions inside the helicopter because the same reference is used, and estimations in hour positions are no longer necessary.

B. Crosshair

The crosshair is centered in the middle of the HMD and points in the head direction of the crew member wearing it. Additionally, the clock position in decimal hours is shown to allow a more precise readout. Also the straight-line distance in the direction of the crosshair is shown. This value is obtained from the same depth measurement devices and/or offline data specified by the concept in chapter II. Again this may solve possible ambiguity caused by estimating distances.

It is also foreseen that the crosshair can be used to interactively mark positions in the environment, by for example pressing on a button, while pointing to the point of interest. Sharing this marked position with other crew members and displaying it on their HMD's may support their shared situation awareness.

C. 2D Video Inset, Map, and Flight Information

Even though the concept describes seeing what others can see in a 3D world conformal way, there may be situations in which a 2D video inset is more practical. Looking 180 degrees behind you, like in a rearview mirror, may be an example. For this reason, the option to show a 2D video inset on the HMD is foreseen.

Besides the 2D video inset an optional map display is foreseen easily show the aircraft's position orientation and markers to indicate places of interest. The pilot normally has displays that are used to display map symbology, but the loadmaster/gunner sitting in the back typically has this information readily available. This is also the case for other flight information such as speed and (radio) altitude. The loadmaster/gunner generally has to request a readout of this information from the pilot using voice communication when needed. Having direct access to the altitude, for example, may help the loadmaster to estimate ground clearance and may help to reserve the voice communication channel for other tasks.

V. Subjective Concept Evaluation

A simulation environment was developed to demonstrate and evaluate the concept as described in chapter III. A Subject Matter Expert (SME) in the field of helicopter firefighting, with the loadmaster position, was invited for the preliminary subjective evaluation. The concept was explained and demonstrated on a computer display and using the VR device. As part of the subjective evaluation the SME was given almost all options to adjust the displayed scene and view its outcome. Taking into account some rough edges in the demonstrator during this preliminary evaluation, the concept as a whole was well received.

Initially, there were some concerns regarding the accuracy of the location of objects originating from other views, but after working with it for a longer period and placing more objects (e.g. different vehicles) in the scene, the SME became convinced of the principle of combining camera imagery with relative positions and orientation and depth measurement. Seeing what someone else sees in a 3D world conformal way and the resulting option to have a transparent cockpit were considered a real added value when operating a helicopter, particularly during firefighting missions. Allowing the pilot and loadmaster to see each other's view directly is expected to enhance the communication efficiency in real firefighting operations. When the loadmaster is instructing the pilot to maneuver slightly to the left to account for the Bambi Bucket clearance and a high tree of terrain, for example, the option to directly see which obstacle the loadmaster is referring to is expected to significantly reduce the communication needed to obtain shared situation awareness. Other examples were mentioned that also resulted in possible ambiguity. Referring to a particular tree or smoke plume may be ambiguous and the concept allows for this to be resolved. Especially when combined with the additional symbology, which was seen as potentially very helpful during actual missions. Pointing options and the displayed clock position were thought to be helpful in preventing ambiguity when communicating about particular orientation. Also the indication of the distance to the crosshair was regarded as helpful to offer clarity by negating interpersonal inconsistencies in the distance estimation.

VI. Conclusion and Future Work

The concept and the simulated demonstrator were received well by the SME during the preliminary evaluation. It is expected that it will help reducing the needed voice communication while building up Shared Situation Awareness and while reducing ambiguity. This demonstrator will now be enhanced and in particular, the additional symbology will be integrated to fully demonstrate the concept and complete the evaluation. After successful evaluation, the foreseen next iteration of the project will involve taking on a higher Technical Readiness Level (TRL) by going beyond the VR simulation and implementing it on actual HMD devices. Incorporating other hardware to measure depth and relative position and orientation, is necessary and choosing appropriate hardware that is representable for an operationally functional system will be the first step in the next iteration.

Acknowledgments

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