Application of Augmented Reality in firefighters training: From Safe to SafAR

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Abstract: The application of Augmented Reality (AR) for training of first responders such as firefighters is novel. It is expected that tailor-made AR use cases provide a value added, concerning the provision of technical and procedural information as well as open an immersive training landscape, which were before not possible or difficult to realize. The paper presents the design of an AR app with three distinct training cases. The training cases selection was based on an international survey among practicing firefighters. The developed AR app includes use cases such as rescuing persons with catastrophic bleeding from traffic accidents, handle accidents with hazardous substances as well as prepare firefighters for responding to road accidents with electric car and truck. The paper argues that AR promises a modern and pedagogical sound way to enrich existing firefighters' training, but further piloting is needed with practitioners in classroom and potentially in live training to verify that hypothesis.

Keywords: Augmented Reality (AR), first responder, firefighter, simulation-based training

1 Introduction

A firefighter is a rescuer, of persons and property, and a team-player.[1] A wrong or slow response can set human lives on risk or damage health of first responders themselves [La21]. To respond and react to emergencies accordingly, in a timely and a professional manner, firefighters need to be well trained. This helps them to catch up with the increased tactical, strategic, and technical demands of modern firefighting. Technological developments seem promising to immerse firefighters in more realistic training environments [Wi21], by using visual aids, such as smart glasses.

AR is understood as the superimposition of the visible reality with digital information in real time and its anchoring in space [Gr13]. The use of interactive and three-dimensional objects allows an enrichment of reality. AR is suitable for imparting technical knowledge as well as for non-routine works. This is important when used in firefighters training to visualize objects that are too expensive or dangerous to use for training purposes. Because of novelty of AR it is not clear yet how these hands-on simulations will help trainees to gain not only technical and procedural skills, but also competencies and professional identity through self-directed learning [Kh14].

The application of AR during first responders training is currently rather new, due to the availability and affordability of applicable hardware and suitable content. The aim of the

[1] https://www.prospects.ac.uk/job-profiles/firefighter (accessed on 13.08.2022)

paper is to presents the AR learning app design for three practical use cases to cope with existing deficiencies during firefighters training. The development and the pending piloting of tailor-made application with firefighters from four EU countries is presented.

2 Theory

Virtual Reality (VR) application for firefighters currently exceed the number of AR applications. As VR is applied for work activities, which are too dangerous or too expensive [Bu20] and to support the acquisition of operating procedures, but when uninstructed could lead to learning on rather trial-and-error basis [Ze20]. In addition, VR found suitable for increasing the preparedness for incident response, decision making, team coordination and task level skills [Wi15]. VR found effective for spatial presence and situational awareness of firefighters like incident commanders due to its higher level of realism [Na20] [Po20].

In contrast, AR mainly focus on supporting the visualisation of spatial information, such as distances and hights and allow verbal and non-verbal communication especially for the preparedness of first aid [Ka18]. AR is the choice for synchronous or asynchronous provision of technical knowledge by involving a remote expert (AR remote assistance) or an interactive digital twin for a self-directed learning. In addition, AR has the potential the enrich with optical markers or by using QR codes a real environment with a versatile use of interactive visualisations. Therefore, triage situations e. g. after a terroristic attack are possible to train in a real environment and with lesser human resources, as actors are not needed.

3 Tailor-made AR-App for firefighters with three different use cases

The selection of suitable training cases was based on online survey results in April 2021 by MS forms among 63 firefighters from Estonia, Lithuania, Czech Republic, and Slovak Republic. Half of them had first experiences with VR, only 7 (11 %) had used AR glasses before.

The following three training cases (see Figure 1) for AR were seen suitable by practicing firefighters and therefore were developed further in tailor-made AR-app presented in this paper.

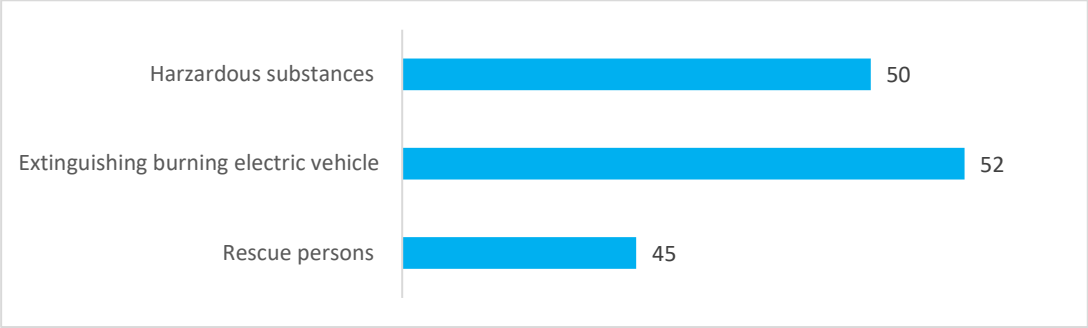

Figure 1: Preferred topics to realize with AR (n = 63)

The AR app for the Microsoft HoloLens 2 includes three separate use cases and is linked with learning modules in a Learning Management System (LMS) outside of the app. Inclusion of full-screen browser page LMS (WordPress is used) into the app has three main aspects. First it allows the provision of upfront knowledge before working within the relevant AR case. Secondly, it is used to give trainees quiz afterwards to check the gained knowledge. Thirdly, trainers can adjust the LMS content that is presented next to 3D models as web browser window and through this give new tasks to trainee to solve without any need to program app.

Figure 2 presents the connection of app to LMS through selected use cases in the middle.

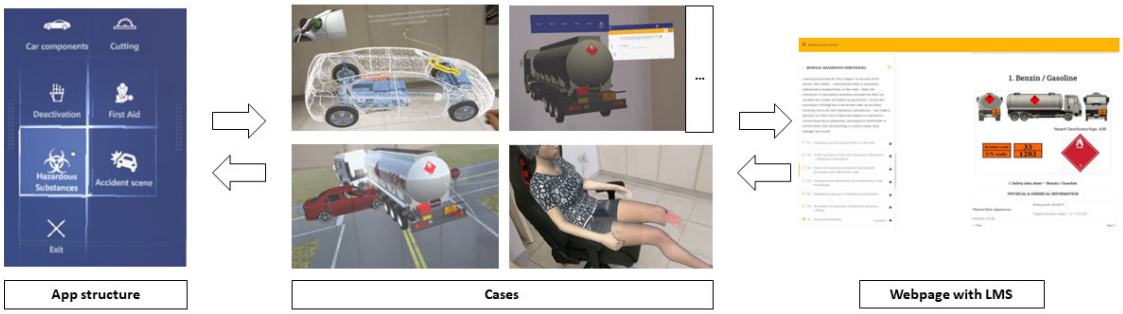

Figure 2: APP structure and LMS

Furthermore, in Table 1 are presented, how these cases are expected to support firefighters training.

No.	**AR app use case**	**Expected benefits**
1	Avatar of person(s) with injuries	Flexible, spatial positioning of avatars which are QR code triggered to create different training scenes with multiple victims
2	Virtual incident landscape: accident passenger car and hazardous substance truck	Spatially fixed virtual landscape for learners to explore it and assess the incident scene by moving physically in the virtually visible space
3	Digital twin of electric car	Self-directed way to learn about expensive car components digitally to disconnect the cars battery

Table 1: Selected AR-app cases – characterisation and expected benefits for improving professional knowledge

The AR glasses and the app were favoured due to their hands-free application when training situational and therefore spatial awareness during firefighters training for selected incidents.

The AR-based interactions seemed to firefighter education experts closer to existing VR based training and live training compared to the use of smartphones and tablets.

Use case I: Person rescue

Almost three third of the firefighters demanded a flexible use case, when dealing with the identification of injuries of persons after traffic accidents. This includes the reaction to catastrophic bleedings, carrying out of ABC (airways management and breathing circulation) and detection of injuries after e. g. car collisions.

In the first step, urgency demands to stop the bleeding first to increase the chances that the victim survives (see figure 3). In the second step, opening airways and assessing breathing and heart rate are necessary to evaluate victims' condition and prioritize help for victims in critical condition. The third step demands the suspection and detection of different types of spinal injuries. The AR App includes to visualize these different injuries by QR code triggered avatars. The QR codes allow a spatially flexible positioning and human role-players can be replaced by avatars.

The AR app is linked to relevant online learning modules to provide relevant, professional knowledge about first aid for traffic accidents. The interaction with the virtual avatars and the planned subsequent cardiac compression on a real dummy supports the transfer into practice (see figure 3, dummy on passenger car driver seat).

Figure 3: Avatar (catastrophic bleeding, left picture) in a classroom and pre-test in life-training with Estonian Firefighters (right picture).

Use case II: Hazardous substances

To prevent harm to people and to the environment the immediate and correct handling of accidents with hazardous substances is important. These substances can be chemical, biological, or radioactive. The focus of the AR app and content in the LMS is to understand what hazardous substances transportation on the road is and what kind of procedure of firefighter's intervention is necessary after a crash involving a car and a hazardous substance

truck. These supports measures like lifesaving, using protective equipment, detection of chemical, decontamination, stopping leakage, first aid and so on.

The spatially fixed virtual landscape (see figure 4) is a 3D model of the whole accident site, which can be place anywhere. The trainee needs to make full 360° recognition of the scene by walking around to collect the relevant information about the accident site (see also figure 3 above). It will need to be tested whether experiencing the correct and real dimensions helps to integrate mental learning with physical sensations. The firefighter sees at first an incident scene of a car crashed into a hazardous substances truck. He or she needs to assess the incident scene by moving physically in space to see where the casualties are, whether there is a leak and the hazardous material labelling of the truck. It is expected to support situational awareness of the firefighter.

Figure 4: Incident scene after crashing of a car into a hazardous substance truck

By the identification of the relevant pictogram on the tank the hazardous substance can be detected. For training purposes up to five chemicals and their pictograms can be shown. These includes Gasoline, Ammonia (NH_3), Chlorine (Cl_2), Sulfuric acid (H_2SO_4) and LPG (Liquified petroleum gas). By clicking the hazardous substance sign, a pop up will be shown from the LMS, which includes the relevant safety data sheet with information on the characteristics and handling of the chemical. After doing that a knowledge quiz must be successfully completed in LMS.

Use case III: Electric car – deactivation of the battery

More than 80% of the firefighters asked in the upfront demands survey for an AR visualisation to support the deactivation of the car's battery after an accident, which could lead in the worst case of a burning car (see figure 1).

The digital twin of the electric car is meant for self-directed way to learn about expensive car components using a 3D movable model (see figure 5). It ensures to have a real electric car to

demonstrate the positions of the important elements like the cars' battery as it is too expensive and unsafe to disassemble it just for training purposes.

By the prior completion of relevant e-learning modules in the LMS the learners transfer their knowledge to the interactive AR visualisation. They should be able to:

a) Shut down the engine, remove the key from the interior and disconnect/cut the 12V battery cables.
b) Disconnect/cut the 12 V battery cables and locate fuses box and remove one special fuse from it.
c) Disconnect/cut 12 V battery cables, locate and disconnect service plug.

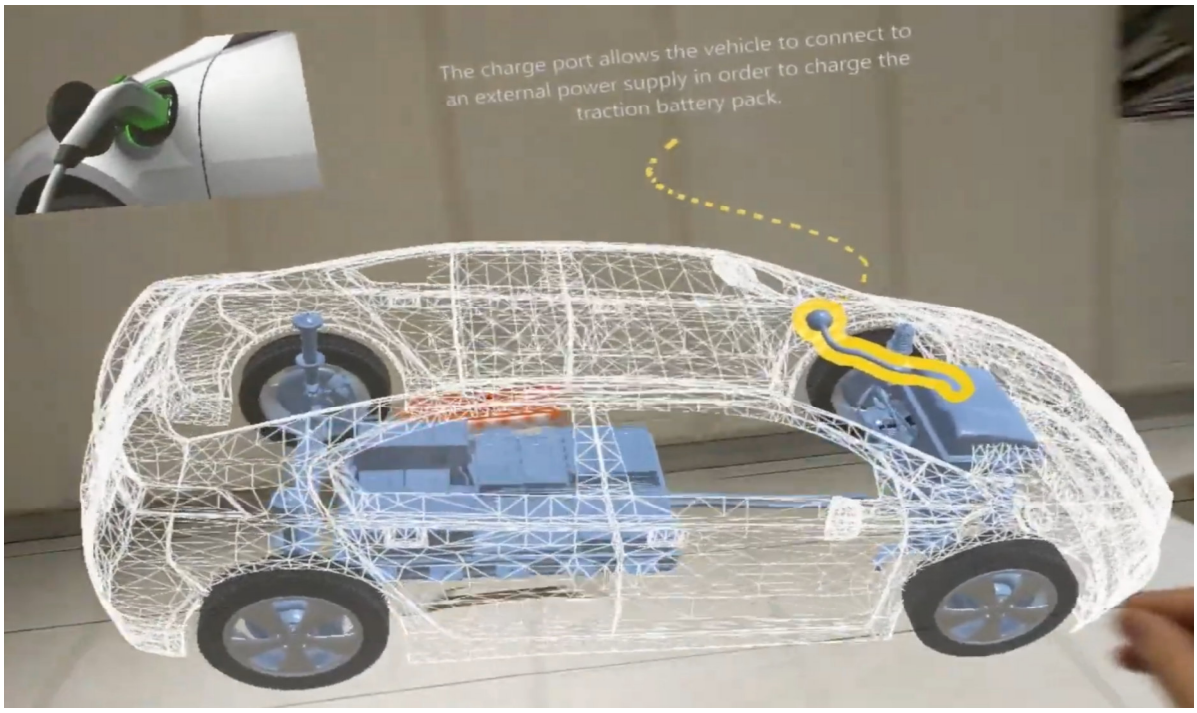

Figure 5: Electric car - battery deactivation training

The AR use case is intended to provide all necessary information for locating relevant car components and deactivate them. They app use shall be followed by a brief knowledge quiz in the LMS to support the further transfer into firefighters' practice.

4 Discussion and summary

The AR app design is a novel and tailor-made way, which aims to support firefighters training in areas that are too expensive or hazardous to train during live training. The close involvement of practicing firefighters in the development of the AR app ensures the integration and a versatile use and integration into existing training environments according to virtual simulation case design [Du15]. The chosen and to be tested training cases also allow to design dangerous cases for AR, which are normally a domain of VR. As using VR for long

time have shown negative effects, it remains to be research does use of smart glasses reduce simulator sickness [Bi22]. SWOT analyses in the field of emergency named one of the weaknesses of VR the uncertain skill transfer [En19], because AR connects virtual elements to real world this VR weakness becomes AR possibility.

Nevertheless, the use of AR in firefighters training is still a new due to the only recent availability of suitable AR glasses. To tap into relevant AR applications, it is still necessary to draw partly analogies to VR in terms of scenario building and expected outcomes, where a longer history of application exist. It is expected that the focus on the provision technical knowledge and the training of scenario specific rescue procedures provide a pedagogical added value. This will be tested, and formative evaluated during the upcoming piloting sessions with practicing firefighters from the four EU countries until the end of FightAR project.

We expect that the piloting results in training will show, that the three selected use cases and their realisation (LMS + AR app + Quiz in LMS) support the firefighters training by allowing them immersive and realistic training scenarios. Part of the project usability tests and user experience tests as well expert evaluation is planned. We hope e. g. that the simulation of and the reaction to catastrophic bleeding of a car crash victim can be better trained with the use of AR compared to VR or live training. The detection of the right use cases where AR can provide a pedagogical added value is key for further research and development.

5 Outlook

The use of AR is novel in first responders training and therefore needs to be further researched. Selected training organisation have previous experiences with VR. It is expected that with the availability of more affordable AR glasses and relevant training content AR will be the choice for the provision of technical and procedural knowledge and skills in hazardous situations.

Experiments could be carried out to answer for example following questions, does AR help to improve the situational awareness of firefighters by a novel way to provide technical skills in a self-directed learning fashion by using digital twin of persons and objects? Or does AR use in classroom-training reduce errors in the subsequent transfer in live-training? We propose that AR supports better firefighters skills training compared to VR, because AR allows repeatable scenarios combination with traditional live training using expensive or hard to find 3D objects like hazardous material trucks or electrical cars.

Further fields of application are experts support during live training using e. g. remote assistance or support. The application of AR can be carried out by using interactive holograms for visualizing visible or non-visible parts of e. g. a machine or by providing online support via audio-visual guidance by an external expert (AR remote support). The use of AR seems to have advantages when it comes to teaching professional skills. In combination with suitable forms of communication and collaboration, new communication spaces (single vs. group, synchronous vs. asynchronous) are created.

The AR use at the incident scene is from the current point view thinkable, but still years ahead in the future, due to the current price tag of suitable AR hardware as well as easy to build interactive AR visualisations. By time AR will prove its practicability and integrative potential in accordance with existing regulations (e. g. for health and safety). The transition from a training tool to an incident scene management tool is right in front of us.

6 Literature

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