Enhancing health and safety monitoring of construction sites with Mixed Reality

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Keywords: Mixed reality, construction sites, health and safety, alerts, reports

Introduction

Mixed Reality (MR) is an innovative technological paradigm that exhibits considerable potential in revolutionizing health and safety monitoring practices and emerges as a pivotal tool for promoting safety within work environments. Within industrial, construction, and manufacturing settings, MR effectively facilitates the visualization and assessment of potential hazards in authentic environments, thereby empowering workers to efficiently discern and mitigate risks. Notably, workers equipped with MR headsets can readily receive visual cues when approaching hazardous areas or encountering unsafe conditions [1]. This technology empowers remote experts to furnish immediate guidance and support to on-site workers, thus fostering improved safety outcomes. Leveraging MR devices, remote experts can observe the worker's perspective, annotate the real-world view, and issue instructions in real-time. This exceptional capability substantially enhances safety measures, empowering experts to identify latent hazards, guide workers through intricate procedures, and ensure compliance with safety protocols [2]. Researchers have recognized the significant potential of MR in elevating diverse facets of construction processes within construction sites. For safety training and visualizing safety information, MR may improve safety awareness and hazard identification on construction sites [3]. At the same time, integration of indoor positioning systems (IPS) and building information modeling (BIM) enhances situational awareness in construction and such visualizations in MR enable efficient visual management, improve planning and productivity [4].

Problem statement

MR enhances worker safety training by creating immersive environments, visualizing real-time safety information, and connecting to IoT sensors and wearables. Integrating MR applications can result in a safer working environment, increased worker awareness, improved training

efficiency and better safety standards compliance. The current study prioritized the design and development of an MR application with specific functionalities: i) enhanced visualizations for better understanding of potential dangers and safety procedures, leading to improved situational awareness; ii) real-time data monitoring for proactive monitoring, early hazard detection, and timely interventions; iii) documentation and reporting for simplifying incident reporting and safety inspections; and iv) collection of safety performance analytics for gaining insights on risk factors and improving overall safety.

IoT ecosystem

The MR application was developed on HoloLens 2 device and was used by the construction site's health and safety officer (HSO). To provide a clearer understanding of the MR application, it is essential to contextualize its role within the construction site. An IoT ecosystem, consisting of various components, called enablers, was constructed inside the construction site, ensuring seamless and secure collection and visualization of all the flowing data that were generated from the construction site. The key to effectively integrating the MR component into this IoT ecosystem lay in harnessing the existing IoT devices and their benefits. This included a comprehensive process of identifying the IoT devices that were relevant to the MR enabler, encompassing an array of sensors, actuators, smart objects, and wearables, all actively gathering or generating data in the ecosystem (See below Figure 3b). Those IoT devices are parts of other enablers, that coexist with the MR inside the ecosystem. Last but not least, a configuration layer was crucial to be designed, in order to ensure that the MR enabler could stay up-to-date and receive real-time data from the rest of the enablers at all times.

MR enabler: Building Information Modeling

The MR enabler significantly transforms construction site management by offering a powerful platform to observe the digital twin of the site, effectively identify its dangerous zones (Figure 1a), and analyze efficient evacuation routes (Figure 1b). Moreover, it empowers a comprehensive graphical representation for individual workers within the construction site. The BIM model of the construction site is designed to accommodate updates and can be uploaded to the corresponding enabler. During runtime, the MR enabler receives the updated BIM model through REST protocols, ensuring real-time access to the latest project information.

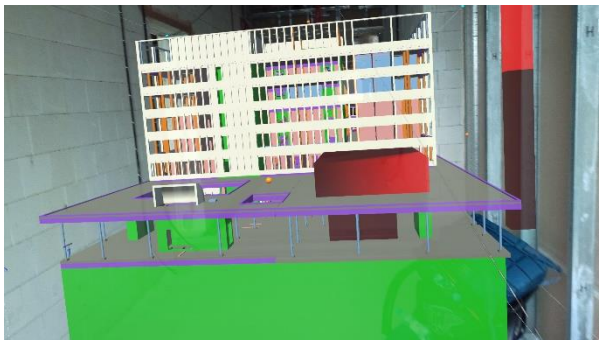

Figure 1a. The dangerous zones of the construction site

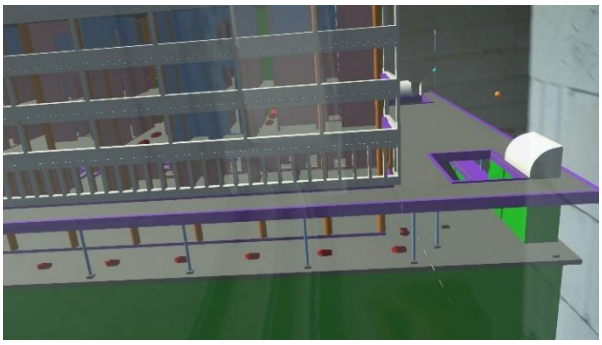

Figure 1b. The evacuation routes of the construction site

MR enabler: Alert system

The application excels at promptly notifying the HSO whenever a worker requires assistance, providing comprehensive and essential information. This data encompasses the worker's precise location and any specific health conditions recorded by the corresponding enablers and sent to the MR through MQTT protocols (Figure 2). To provide the workers' location points and facilitate seamless navigation for the HSO within the site (Figure 3), the application leverages an indoor localization system based on Ultra-Wideband technology (UWB).

Figure 2a. A new alert was generated for a construction worker

Figure 2b. Worker's heartbeat, tracked by their wearable

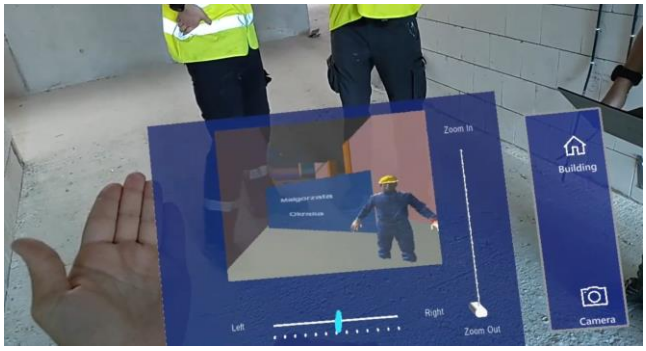

Figure 3a. Worker's precise location inside the building model

Figure 3b. A special wearable is worn by the site's workers that tracks their location and their heartbeat at all times

MR enabler: Documentation and reports

At any given moment, the HSO can readily access real-time information on all the workers that are currently inside the construction site, allowing for thorough examination of their data (Figure 4). Moreover, the application grants the capability to generate new reports in the event of non-compliance incidents (Figure 5). The report may include textual or multimedia information to provide a comprehensive summary of the incident. The MR application establishes communication with the relevant enabler, facilitating the exchange of worker's documents and reports, all accomplished through the utilization of REST protocols.

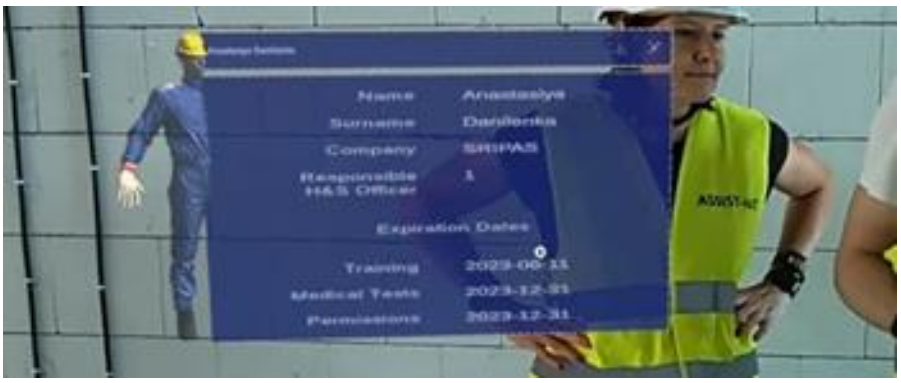

Figure 4. Inspection of the construction site worker's information

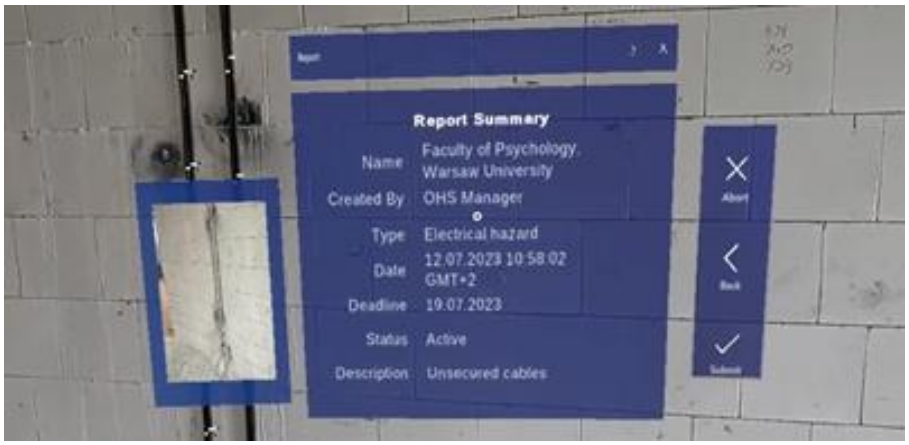

Figure 5. Generate and store a new report through the MR enabler

Acknowledgement

The research of the MR enabler was part of the Assist-IoT project, which has received funding from the European Union's Horizon 2020 Research and Innovation program under the Grant Agreement No. 957258. The opinions expressed herein are those of the authors and the European Commission is not responsible for any use that may be made of the information it contains.

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