Work-in-Progress: Construction Safety Using Visual Technological Support

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Abstract. Accidents occur on construction sites that are complex and unique environments, making these difficult to control and monitor. Construction safety intends to prevent people from dying or becoming incapacitated. It is socially relevant and the panorama has not changed substantially. International Labour Organization estimates that losses of GDP due to this type of accidents represent about 4% of GPD. Above all it is not acceptable that in the XXI century anyone dies due to improper working conditions. A European funded project by Erasmus+Programme intends to alleviate this situation. Project arises from the synergy between higher education and construction to foster use of smart digital technologies in proper construction safety training. The idea is that digital tools allow the creation of simulations of construction scenarios allowing the identification and prevention of risks for workers, technicians and engineers. The project develops tools with IR (Immersive Reality) and AR (Augmented Reality) procedures based on BIM modelling capacities to prevent accidents through training. Project also aims at offering training sessions online on an online platform to grant learners and trainees access to interactive material and resources. These tools range from applications to be used on smartphones to virtual reality contexts depending on the needs of training.

Keywords: IR · AR · Construction · Accidents · Prevention · Training · BIM

1 Project CSETIR - Introduction

Most of the accidents that happen on-site are due to human failure either from worker or from safety managers. Manual monitoring and supervision are prone to error due to blind spots, workers loss of focus, awareness, and fatigue. As a result, serious injuries and fatalities are occurring. The human error theories discuss that human error is the factor to be blamed for the accidents, with specific work, and under the environmental circumstances.

M. E. Auer and T. Tsiatsos (Eds.): IMCL 2021, LNNS 411, pp. 788–795, 2022.
https://doi.org/10.1007/978-3-030-96296-8_71

According to the Occupational Safety and Health Administration (EU-OSHA) in 2015, about 21% of workers with a fatal work accident were from the construction industry [1]. In Europe, the construction industry is responsible for a high number of fatalities. This mortality rate will affect the ongoing construction work-flow, other workers moral, lower performance and schedule delay. This decreases also productivity and increases costs like direct costs (equipment damage, workers compensation, insurance, medical expenses, rehabilitation, etc.) and indirect costs (well-being, productivity, morale of workers, etc.). This is a major setback in terms of economic and financial perspectives, the implementation of the project and the image of the construction company.

Although all workers receive training and orientation meetings, they are not receiving on-the-job, hard-knocks-type training that simulates the site conditions. Every construction site is unique with different activities, schedules, execution approaches, diversity of workers attitudes and languages and that makes difficult the standardization of procedures for accident prevention. Therefore, it is crucial the administration of training programs that are effective and can raise the level of preparation of all involved in terms of safety awareness and competences. Yet the traditional methods and approaches do not reach everyone involved to prepare their prevention capacities in accordance with their tasks and responsibilities in the construction site..

This lack of effectiveness in training is probably due to the gap between the industry needs and the education and training organizations. Based on several systematic literature reviews done by researchers, on involvement in several international conferences, in construction safety organizations activities, in construction sector contributions some conclusions and guidelines became clear. First, the research on integrating technologies, such as VR/AR (Virtual Reality/Augmented reality) and machine learning, may bring possibilities to address the needs in terms of training in accident prevention [2].

The situation of gaining knowledge about the existing research and experiences in using new technologies in construction safety created a dilemma. The main issue for the partnership was to choose from theoretical and prospective developments or to try to find concrete applications in this area. The project partnership decided for the latter taking into account the convenience of presenting to construction companies proposals that could be ready to test and to implement. These existing applications will serve as pool for the solutions the project will present to train stakeholders (workers, technicians, engineers) and to educate students in higher education about construction safety. The model and format of training modules will be the same for all while assessment of respective learning outcomes will be adapted to the level of proficiency intended for the personal competences.

After holding several meetings with safety professionals, contractors and consultants from several countries it seemed that construction companies could benefit from possible advancements of technologies and of tools. These might assist in training workers in terms of accident prevention. These facts were an indication to start involving new technologies in the construction industry to train on construction safety. After technologies based on BIM (Building Information Model), VR and AR showed a lot of potential as promising tools for education and training the idea of creating a joint project was adopted. The project CSETIR was proposed to the European Commission for funding and it is being co-funded under the Erasmus+programme of the European Union, KA203 – Strategic Partnerships for higher education with reference 2019–1-SK01-KA203–060778 [3].

CSETIR, abbreviation of Construction Safety in Education and Training using Immersive Reality, intends to offer innovative and effective education and training for prevention of accidents [4]. The concept is based on digital platforms and tools, like BIM and VR/AR simulations, to devise effective procedures to be used by the diverse groups in construction site that should be easy to use, affordable and effective. These tools may also supporting schools and training centers to teach and train future practitioners in accident prevention [5].

2 Identification of Tools and Strategies

The first steps of the project aimed at identifying existing examples with possible use for further phases of the project like developing training material and validating the effectiveness of procedures. It was created a repository of available and current tools on the market in terms of BIM-based approach to develop AR/VR scenarios for research and for the construction industry.

Case 1: 3M Releases Construction Safety Virtual Reality Programs for Hands-on Learning. 3M has recently released a series of VR construction safety modules. 3M's virtual reality training platforms are available online. The field applications of these safety modules are described on the 3M website for training. This case study can be chosen for use in the execution preparation and in the construction phases. BIM was not an essential tool inside this case study although integrating BIM will help for a training module. The platform may incorporate some VR devices and get an immersive training experience [6].

Case 2: Caterpillar (CAT) safety policy using VR intends to improve jobsite training.

CAT started with safety in road construction and simulating real life scenarios. CAT designed the VR tools as a multiplayer environment so a group of workers could train simultaneously. Application is considered adequate for the construction preparation phase. Training module presents a wrap-up to reinforce the positive lessons learned and stress that no emergency at the jobsite is worth risking the safety of the worker or anyone else. The introduction of communication and mobile modules are possible positive contributions to improve learning outcomes [7].

Case 3: SRI International has developed AR solutions for construction inspection. AR simulates job site operations for construction inspectors and auditors. It may use drones together with the SRI solution that are used for aerial inspection of construction site while comparing with BIM models of the construction. BIM modelling is used to define the planned construction and inspect possible errors or deviations between construction and the respective BIM model. SRI AR captures images from the executed with headset and tags these with notes and sharing with other devices [8].

Case 4: Safety Compass is another example that uses AR to improve workplace safety. It gives access to live information from the construction site that is updated based on the location of the construction worker. It uses AR technology to identify potentially risks at the current location of the worker. It can be applied using mapping on a tablet or smartphone. This application also allows interaction and collaboration of all involved in the construction from different areas and functions. In this application BIM maybe linked to the GPS and the mobile app will give risk alerts and notifications based on the current location. Workers will then be notified of potential risks pin-pointed on an interactive mapping system. This AR application seems effective and easy to apply [9].

Case 5: Examples of use of VR in construction safety presents many applications that pretend that more effective and safer training of construction workers is less expensive and much safer to train heavy-equipment workers, like crane operators. Construction virtual environments allow workers to operate dangerous equipment without any risks whatsoever. It is cheaper than real-life training where you would need a real tower crane to train the operators. Coupled with the training the company CertifyMe.net is specialized on forklifts and has a VR program for practicing in a risk-free environment. Using it, they eliminate any type of injuries and equipment damage, allowing for a trial-and-error approach without adverse consequences. It provides the training and assessment in one hour with awarding the certificate to the trained operators immediately and online [10].

Case 6: New construction safety school uses virtual reality to educate workers and technicians. The school improves worksite safety through a new training centre targeting the construction industry. A key feature of the construction safety school is experiential learning by using AR and VR. Possible scenarios are created in this school with demonstration of equipment connected to the contracting industry. It is possible to certify workers in terms of construction safety. Application may involve workers, engineers, safety professionals, project managers, students, safety managers and safety coordinators. BIM is not used in these training scenarios. AR and VR are used in a wide range of scenarios and with several risks [11].

Case 7: YellowJacket is a software, available also on mobile application, that can monitor and report on quality, health, safety and processes on construction sites. May save time, save money, improve performance and ultimately save lives. Adopting YellowJacket health and safety software and fully integrating it within the organisation′s culture and throughout the supply chain then it is possible to achieve real improvements to health, safety and quality management on construction sites and beyond. It is designed to be as user friendly as possible –giving ‘at a glance’ overview of health, safety and quality across the projects. The YellowJacket mobile application allows employees and contractors on the site to easily input information relating to health, safety and quality. Data is captured ‘as it happens’, rather than staff waiting to get back to a computer [12].

After analysis of the seven cases presented above several strategies can be considered when addressing the use of AR and VR environments to improve education and training for safety in construction sites. Indeed, the targets of training initiatives are a diverse group, including site workers, safety specialists, technicians, engineers, architects and others. The technical skills and education levels for these groups differ considerably, as do their work environments, and functions. This diversity must be considered when defining strategies and solutions, even when the suitable available hardware and software options overlap largely for the different user groups.

Indeed, as described in this document, the same VR and AR hardware and the software components have been adopted in a range of applications. This is considered as an opportunity, as solutions that target one user group might be adapted for different uses. The main current VR and AR development technologies are cross-platform, which largely reduces the importance of the choice of specific equipment within similar types of hardware such as Head Mounted Displays (HMD) or motion controllers.

Naturally, different training environments demand different types of hardware, due to cost, time and other practical considerations. For instance, despite recent developments in CAVE (Computer Assisted Virtual Environment) technology, which allow for lower-cost and quicker deployment, HMDs remain a more practical solution for virtual immersion, while computers and mobile devices are ubiquitous, and provide acceptable VR experiences in many instances [13].

The use of BIM models as a source of information (including geometry) for the virtual models is regarded as an obvious choice. BIM models are increasingly common in practice, they support different types of information, thus providing great flexibility when deciding on technical solutions, and are compatible with other components such as game engines. Alternative solutions, such as the use of generic 3D modelling tools would require the development of models from scratch, with no relationship with the actual construction process. This means that changes in design or in construction plans would not be quickly or easily reflected in the virtual training environments. These factors greatly reduce the feasibility of a non-BIM solution. Since BIM authoring tools are interoperable, and standard open formats exist for exchanging BIM data, the choice of BIM tools is not considered to be a critical issue when designing a strategy for the development of training solutions.

3 Training Methods

Training in CSETIR project may be provided for levels 1 to 7 of the European Qualification Framework (EQF). In terms of training methodologies it is expected that higher education institutions address levels 5 to 7 and levels 1 to 4 will be developed by vocational education and training (VET) organizations like CEDEFOP, EVBB or EVTA [14]. Training will be based on the outcome based method proposed by Tuning Academy. All modules and training activities will be designed and prepared taking into account the knowledge, skills and attitudes required. The competences required will be defined to face the several risks and preventive measures adequate for the respective level of qualifications. This outcome based training will allow to prepare everyone from basic level (1) to master level (7) [15].

Validation and assessment methods of competences acquired by trainees is necessary to ensure that the competences in terms of construction safety were acquired. The training provided maybe used to qualify some of the trainees to be able to enter the construction site or to perform some risky tasks. Therefore, the assessment has to be suited to type of competences that are supposed to be acquired. Proper assessment of the different competences (knowledge, skills and attitudes) is based on the use to webtool TALOE [16]. This webtool can suggest assessment methods for the different types of competences at various levels from 1 to 7. The assessment methods will be chosen in accordance with the suggestions, the construction site resources, type of training and purpose of the qualification. The assessment of workers, technicians and engineers competences to verify if they are qualified to enter a construction site may be applied to other groups like students or visitors. This evaluation will verify if proper training had the quality that is expected to be provided when using effectively the digital tools involving virtual construction environments.

4 Example of Training Scenario

The example presented is the first scenario developed for training on prevention of accidents. This paper is a work in progress and this example is a prototype of other planned training situations. It addresses the cause of many fatal and serious accidents that is related with inadequate use of ladders. The consequence of mishandling this equipment results in falls.

This risky task of using a ladder present virtual scenarios with fall from height with insufficient designed or laid ladder. Common errors are unsatisfactory length, slope or overlap of ladder. Trainee will identify from each scenario the localization where the risk is present. After the identification learner will have to choose the preventive measure preferred. The possible preventive measures will be shown in images. After identification of preventive measure to use the respective details will be presented. These details include list of costs, necessary training, examples of consequences of applying, implementation process and effectiveness. Simulation of the use of the preventive measure will be provided so learner understands the new scenario. In case learner does not identify the risky situations these will be displayed one by one.

The training strategy is based on visual display of the risky situations, of preventive measures and simulation of the consequences of adopting the preventive measure. The scenarios with risky ladders use a BIM model using Web-based Collaborative Virtual Environments (LIRKIS G-CVE) and preventive measures adequate for each risk using BIM. The trainee´s avatar, who has completed interactive training, stands in front of the reinforced concrete structure on the construction site. Vertical movement of the avatar is allowed by the three ladders, which are individually placed on each floor of the structure [17].

Each of the three ladders will contain a mistake or safety problem. Unless the trainee detects all safety problems, he/she will not be able to climb the ladder. He/she will be able to climb the ladder and move to a higher floor only when he detects and corrects the mistake. The participant's task is to climb the ladders to the upper third floor. After arriving at the trainee will see a recapitulation of new information and knowledge which he/she obtained and will receive a “star - helmet”. For instance an error is that ladder from ground floor to first floor is made of wood and has an unsatisfactory length. Wood and length characteristics are not acceptable. Trainee can adjust the properties of the ladder until there are no evident risks or non-compliances with rule.

5 Conclusions

Paper presents a work in progress of the project CSETIR. It is at the stage of producing the materials that are related with training scenarios for the different risks. Currently 18 construction risks have been chosen as convenient to address to prevent most accidents in construction. The stage of addressing the available useful tools and procedures has been completed but maintains the observation of new developments and innovations that can improve the effectiveness of the scenarios. The project partnership has worked to articulate tools and methods with the set of risky tasks that need effective training to prevent accidents.

Zero vision is a term that implies no accidents on construction accidents. The project intends to contribute actively to that goal through the provision of tools that can be widely used accepted by stakeholders in the construction industry. The partnership is open for contributions from all that may help the performance of training. Partnership is associated with construction safety coordinators association, with groups of civil engineering faculties and with other social partners that may benefit from the project outcomes. All contributions are welcome and society will benefit if accidents in construction stop happening.

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