A Review on Development and Application of Virtual Reality (VR) Training Platform for Testing, Inspection and Certification Industry

S. L. Mak, Fanny W. F. Tang, C. H. Li, Geddy T. W. Lee, and W. H. Chiu

Abstract—The Virtual Reality (VR) training is one of modern simulation tools which has been used to help train up staffs to operate equipment and facilities, as well as handling emergency situations in different industries. This paper discusses the theories supporting the adoption of VR technologies in the laboratories and pros/cons of Virtual Reality Training systems. Virtual reality technologies have been applied to different types of trainings in many industries, such as product design and manufacturing, facilities maintenances and territory teaching purposes. A typical virtual reality system includes four basic elements: 1) Input devices in order to simulate the working behavior; 2) Output devices; such as VR headset to allow the user in the virtual environment; 3) graphical system that produce simulated scenario(s); 4) Database to store the different conditions to simulate the operation environment.

Index Terms—Simulation, technology acceptance model, testing engineers, virtual reality.

I. INTRODUCTION

The Chief Executive of the Hong Kong SAR established the Task Force on Economic Challenges (TFEC) on October 2008. In early 2009, the TFEC has identified six economic areas where Hong Kong enjoys clear advantages [1]. The Six Industries are i) testing, inspection and certification (TIC), ii) medical services, iii) innovation and technology, iv) cultural and creative industries, v) environmental industries, and vi) educational services. Fig. 1 shows the trend of persons engaged in the industry. In 2017, around 280 persons are engaged in the TIC industry and 14 300 persons out of them are employed by private organizations [2], [3].

Due to the continual increase of the practitioners and change of international testing and certification standards, the industry faces the challenges to train up the new staff to become more competent. The traditional training approach was arranging new staff to follow experienced ones to learn and practice in the fields until the supervisors felt satisfactory and arrange the assessment to test the competences of staff in order to the meet the needs of organizations and the ISO/IEC 17025 Requirements of Laboratory Management System [4].

HKCTC had conducted the survey to the TIC industry and found that 47% of employees (around 6750 persons) were professionals and associate professionals in the private organizations of TIC industry. The staffs of testing laboratories and inspection bodies are non-degree holders. And the percentage of university level graduates is increasing to join the industry. They had studied the relevant disciplines in universities, including science, applied science, engineering, fashion and textiles and so on. The industry reflected that about six months on-the-job training is required for new graduates when they join this industry. The certification bodies always recruits the university graduates with working experience in relevant trades. The employee may study the various academic disciplines but have good

Fig. 1. Number of persons engaged in Testing, Inspection and Certification (TIC) Industry from 2012 to 2017.

The research project involved five phases. The first phase, a survey was conducted to understand the need of VR training in the industry by the interview and questionnaire. Based on the survey result, the toy flammability test item was identified. In the next phase, the training kits were developed workers by applying virtual reality (VR) technology. As the project is technically supported by the TIC industry, the selected scenarios will be recorded. The research support assistants used the softwares (e.g. Unity and 3D studio Max) to draft the scene and programme the inter-relationship between each entity in order to simulate the real situation. Afterwards, the developed training kit will be provided to both experienced and new workers to try. The individual assessment will be conducted to evaluate the effectiveness of Virtual Reality-based training.

II. CHALLENGES AND PROPOSED SOLUTION OF TRAINING IN TESTING, INSPECTION AND CERTIFICATION INDUSTRY

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926
communication skills. For new staffs in certification sector, 6 to 9 months on-the-job training is always required [5].

J. Georgious and et.al pointed out that teaching science or engineering either at school or at university is a very challenging task as the trainer/instructor shall provide a specific phenomena and equipped laboratories to conduct the experiments. Otherwise the trainee cannot practice to learn both theories and techniques to become the competent person. However, the number of experiments carried out is limited due to the safety factors, lack of appropriate infrastructure and equipment, time and space. The researchers had studied if simulation could be one of proper solution.

Virtual Reality is a modern term which refers to the variety of technological, computer-generated experiences. The core of VR is to produce human-machine simulation, specifically simulation of visions, sounds and other perceptual concepts. This field is still new, it is under the study and humans have different opinions about it. Similar terms artificial reality, virtual environments, virtual instrumentations, virtual interfaces, virtual worlds, virtual experiences are often misunderstood and seen other concept. However, one can be said that the more realistic the perception, the more “virtual” the system is. Common to all these concepts is that they aim at providing humans with simulated sensations.

III. THEORETICAL BACKGROUND

Before discussing how VR training programs work, it is important to understand well the psychological factors of technology acceptance and what makes some systems more successful than others.

Technology is changing undoubtedly faster than any other field and its pace of change is unpredictable. But it can be said that the main aspect of technology never changes: it needs to be user-friendly and every minute a number of studies is conducted in order to find the perfect solution for the next technological piece. There are several theoretical models which explain user acceptance of information systems. One of the most spread theories is the technology acceptance model (TAM), which shows how the users adopt new technology, such as Information Technology (IT). According to Davis, individuals’ behavioral intentions in using a system are based on their preconceived ideas on the usefulness and ease of use of that system (Fig. 2). Davis (1989) defined perceived usefulness as “the degree to which a person believes that using a particular system would enhance his or her job performance”. Usefulness for the individuals is measured in the following way: what a person believes how a certain system or technology improves his daily performance and productivity. Perceived ease is defined as the degree to which a person believes that using the system will be effortless. According to TAM, perceived usefulness can be influenced by perceived ease as well, because the easier the system is to use, the more useful it seems to the person [6]. But according to Davis et al. (1989) usefulness was more strongly linked to usage rather than ease of use. As we see the development and the success of any technology is influenced by the user acceptance and if not caring about it would lead to the disaster. As long as the new system, technology or training system proves its perceived usefulness and perceived ease, it can be tried out. To sum it up user acceptance is the key point of the system’s success and future development [7].

Another theory which should be taken into the consideration is Diffusion of Innovation (DOI) model introduced. Diffusion is the process when an innovation is communicated through certain channels among the members of a group. The DOI theory explains how the individuals or groups adopt innovations and the process involve in their decision towards it. DOI model suggests a number of innovation attributes that were perceived to assist the diffusion of technological innovation. Rogers suggests that relative advantage, compatibility, complexity of the innovation plays a key role in an individual’s attitudes towards innovation adaption [7]. The top management of TIC industry shall consider both theories and identified the proper ways to implement the Virtual Reality based training system.

IV. APPLICATIONS OF VIRTUAL REALITY (VR) TRAINING PLATFORM FOR OTHER INDUSTRIES

When talking about Virtual Reality one might think about the games at first, though there are many interesting and useful aspects VR might have. For instance, VR training system can be more productive than traditional training.

Virtual Reality is revolutionary thing in worker safety and compliance training. In use by the military and industries like aviation, mining, VR now allows workers in many industries to learn, practice in a virtual setting the dangerous real-world environments.

IT technologies and VR trainings can be used in several areas. For instance, in the hotels to teach the crew, to train doctors for the operations or to teach fire-safety skills to the children. Also it is getting really popular to use Virtual Reality trainings to stimulate dangerous situations which cannot be practiced in real life, though it is crucial to know how to survive if it happens. Such trainings can be applied to dangerous fields like constructions or mining industries [8].

The construction industry is a complex environment with high accident rates. Despite the fact that a lot of attention is given to construction site injuries, the incidence rate of accidents in construction is double than the industrial average. The main reasons why construction accidents happen so often is that it is to be risky and construction workers and engineers lack the safety knowledge. They lack the experience of hazardous situations which happens once or twice for a person, but one needs to know how to survive it.

That’s why it is important to teach employees safety skills and promote healthy working environment. However, current training methods and tools are not able to provide students with real practical experiences. The technological
development: progress of digital media and Virtual Reality started to play a huge role in creating new training methods for the construction safety and health education process. Virtual Reality game provides a comprehensive training environment, which bring new pedagogical opportunities and tools to teach safety. Game technology based visualizing safety assessment helps students to feel the reality and visualize specific situations they might fall in. Hazards which might arise on construction sites are either predictable, as part of planned activities, or emergent (resulting in unpredictable situations). Cognitive and psychomotor processes including decision-making skills, attention, reaction time, contrast sensitivity, and visual pursuit are the main skills one have while working on the construction [9]. Accordingly, hazard situation perception is a cognitive skill with many aspects and it can be improved with experience. Training can improve a person’s ability to diagnose the potential hazard situation and risk correctly and experience can have a positive impact on risk-taking perception and behaviors particularly in the perception of the risk of injury. [10]

V. PROS AND CONS OF VR VIRTUAL TRAINING COMPARING WITH TRADITIONAL TRAINING

VR trainings help to deal with the emergency situations. It also helps with the cost of the product as all risks are avoided, leads to the improvement of product quality and it saves the production time. For instance, the automotive industry has been actively using VR across a number of applications, including design, manufacturing, and training.

A. Design

Car design is a long process which requires number of modifications and reviews, with the necessity to go back to previous decisions several times before the car finally reaches production. This phase of production has been seen as one of the most expensive and time consuming aspects of the whole process. According to Gomes de Sá and Zachmann (1999), the early design phases can impact on up to 70% of the total cost of a product [11]. In this scenario, VR can reduce cost and time by replacing real changes and rebuilding phases with virtual ones. Virtual Reality can be used for designing the early phase models without even building anything. Another advantage is that VR can be used simultaneously by multidisciplinary teams all over the world and can work together on the same prototype at the same time.

B. Manufacturing

The application of VR to manufacturing is called Virtual Manufacturing (VM). VM has led to the improvement from the decision making process to cost reduction (Mujer et al., 2004), to the enhancement of risk measures and control of manufacturing processes (Lee et al., 2001).

C. Training

Borsci et al. (2015) demonstrated that mixed training with Virtual Reality is preferred by trainees over traditional observation-based approaches. The retention of information after 2 and 4 weeks is higher for participants trained with VR than with other systems. [6]

Today’s training consists of exercises with simulations, such as in nuclear power plant drills, product engineering, fire-fighter training, operations, hazardous crashes and others. Although the objects like trucks, roads, are real, it is difficult to create the sensation of a real emergency situation. Virtual Training would not focus on handling devices, shutting down engines, or applying first-aid techniques to people. It would focus on finding ways of getting through a building, locating sensitive devices, creating new design devices and finding ways through smoky rooms [7]. Different scenarios focus on different types of emergency situations. While the trainees act under difficult conditions such as restricted visibility and breathing problems due to smoke, the trainers could stand next to them in a “clear” cyberspace and control the trainees’ actions and advise them. At any time during the simulation, the trainers can change the environment of the cyberspace; for instance, create more smoke, increase the temperature, make a building fall apart, or switch instantaneously from summer to winter conditions. [7]

Training is currently one of the most popular areas of research in the VR field. A safe virtual environment can be used to simulate a real or planned one that is too dangerous, complex, or expensive to train in. There is potential for increasing safety standards, improving efficiency, and reducing overall training costs. VR-based training is particularly well suited to situations where cognitive and spatial skills are important. In general, current VR technology is much less effective than training in a real environment where touch and feel is a significant factor for learning. A particular advantage over traditional training technologies, such as books and video, is that the trainee is active and can improve skills and understanding through practice. Informal assessment suggests that the level of concentration and involvement required of the trainee results in greater retention of skills acquired when compared with other forms of off-the-job training. VR technology is often used to build training simulators. The knowledge encoded in such systems is typically only oriented towards enabling the simulation environment to behave realistically. While these systems usually lack integrated support for computer-guided training, they can be run in parallel with systems such as computerized procedure systems, to enhance training. These systems are usually operated with an experienced human instructor present.

VR training systems can go a step further by integrating intelligent computer-based training functionality with a simulator. In addition to behavioral knowledge, the simulator can have knowledge of correct, or appropriate, responses to situations, so that the system is able to guide the trainee, either to teach a correct procedure or to assist the user in making appropriate corrective action. Such systems can be used with instructors in a classroom situation but can also be used by trainees to practice effectively without a human instructor present.

Other training methods can be:

• Reading the words, charts, or figures on paper;
• Listening to safety training lectures;
• Watching videotapes
• Taking online classes, such as the online OSHA...
applications, which include, design, prototyping, machining, and quantitative perspectives. The following section discusses the use of virtual reality in manufacturing thereby preventing costly mistakes. Virtual manufacturing is defined as a computer system which is capable of generating information about the structure, status, and behavior of a manufacturing environment. One such technology which helps the manufacturers’ and designers is Virtual Reality. Virtual reality allows a user to step through the computer screen into a three-dimensional (3D) world. The user can look at, move around, and interact with these worlds as if they were real. Virtual manufacturing (VM) is one of the applications of applying VR technology in manufacturing applications. Virtual manufacturing is defined as a computer system which is capable of generating information about the structure, status, and behavior of a manufacturing system as can be observed in a real manufacturing environment.

Although it is difficult to categorize all VR systems, most configurations fall into three main categories and each category can be ranked by the sense of immersion, or degree of presence it provides. These categories include non-immersive systems, semi-immersive projection systems and fully immersive systems. Vast amount of VR software packages are available on the market, which can be used to develop virtual environments for different applications. Moreover, software packages have been developed for virtual applications in manufacturing: process planning, cost estimation, factory layout, ergonomics, robotics, machining, inspection, factory simulation, and production management.

VI. MEASUREMENT OF EFFECTIVENESS FOR VR TRAINING SYSTEM

VR holds great potential in manufacturing applications to solve problems before being employed in practical manufacturing thereby preventing costly mistakes. Virtual reality not only provides an environment for visualization in the three-dimensional environment but also to interact with the objects to improve decision making from both qualitative and quantitative perspectives. The following section discusses the use of virtual reality in manufacturing applications, which include, design, prototyping, machining, assembly, inspection, planning, training and simulation.

Product design Virtual design is the use of VR technology to provide the designer with a virtual environment to evaluate the design, evaluate alternate designs, effectively interact with the product model and conduct ergonomic studies using full human body tracking [12].

Prototyping Virtual prototyping means the process of using virtual prototypes instead of or in combination with physical prototypes, for innovating, testing and evaluating of specific characteristics of a candidate design. In the product development process, prototyping is an essential step. Prototypes represent important features of a product, which are to be investigated, evaluated, and improved. Virtual prototyping could be used before building the physical prototype to prove design alternatives, to do engineering analysis, manufacturing planning, support management decisions, and to get feedback on a new product from prospective customers. The virtual environment for prototyping should include:

- Functionality: the virtual prototype should be clearly defined and realistically simulated to address product functionality and dynamic behavior.
- Human interaction: the human functions involved must be realistically simulated, or the human must be included in the simulation.
- Environment: an offline computer simulation of the functions can be carried out, or a combination of computer offline and real time simulation can be carried out. [9]

VR technology has been applied to solve clients’ real-world problems, and has increased profitability, decreased time to market, and increased worker safety. Manufacturing processes and design can be defined, modelled and verified before they can be actually implemented. Virtual reality offers the engineer’s new ways to not only visualize their problems but also to interact with the environment to solve the problems effectively and efficiently. These visualizations, combined with interaction can improve the decision-making capabilities of engineers thereby improving quality and reducing the development time for new products. If these VR technologies are effectively implemented, it can result in improved product design, with superior quality leading to better customer satisfaction.

VII. CONCLUSION

The virtual reality based training technology is developing rapidly and applied in different industries. Due to limited equipment and facilities, VR technology is one of possible solution to replace the traditional training process. This paper introduces the characteristics of testing, inspection and certification (TIC) industry. The theoretical background was discussed and suggested the laboratories to consider before they decided to implement the VR training system [13]-[15]. Some examples were discussed to explain pros and cons of VR training platform. In conclusion, the VR-based toy flammability test system was developed and allow the industry to try. The industry provided the positive feedback. VR laboratory training system will be further developed to suit the needs [16].
CONFICT OF INTEREST
The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS
Dr. Shu-lun, MAK is the project leader, initiated the concept of study, applied the research funding and wrote this paper. Dr. Fanny TANG carried out the data curation and Dr. Jimmy LI developed the methodology of research study. Dr. Winnie CHIU is the project administrator. Mr. Geddy LI supervised the research assistant to develop the VR training platform.

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