Work in Progress: Towards an Immersive Robotics Training for the Future of Architecture, Engineering, and Construction Workforce

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***Abstract*— Advancements in Artificial Intelligence (AI), Information Technology, Augmented Reality (AR) and Virtual Reality (VR), and Robotic Automation is transforming jobs in the Architecture, Engineering and Construction (AEC) industries. However, it is also expected that these technologies will lead to job displacement, alter skill profiles for existing jobs, and change how people work. Therefore, preparing the workforce for an economy defined by these technologies is imperative. This ongoing research focuses on developing an immersive learning training curriculum to prepare the future workforce of the building industry. In this paper we are demonstrating a prototype of a mobile AR application to deliver lessons for training in robotic automation for construction industry workers. The application allows a user to interact with a virtual robot manipulator to learn its basic operations. The goal is to evaluate the effectiveness of the AR application by gauging participants' performance using pre and post surveys.**

Keywords—Education for AEC (Architecture, Engineering and Construction), Curriculum Design, Robotics and Automation, Immersive Learning, Augmented Reality, Artificial Intelligence in Education

I. INTRODUCTION

Today we are at the brink of the fourth industrial revolution due to advancements in the fields of artificial intelligence, information technology, and robotic automation [1]. The global economy is rapidly being reshaped by the use of sophisticated machines that enhance human dexterity, visual perception, speed, and strength. This intense focus on the creation of new technologies is also bringing rapid change to the building industry and is transforming jobs in design, manufacturing, and professional services at a speed and scale never experienced before. It is projected that by 2030, 60% of jobs in the United States and 40% percent of all jobs worldwide will be affected by automation [2]. Therefore, Preparing the workforce for an economy that is increasingly defined by these technologies is imperative and urgent.

There are several examples of applications where robotics and automation will play a significant role in the AEC industries. For example, when these technologies are applied to construction site layout [3] and planning optimization [4], they can discover inefficiencies and highlight potential safety issues before beginning any construction process. Sensing and wireless communication technologies have been used to detect dangerous conditions and raise alarms to workers in the site [5,6]. Computer Vision approaches have been tested to detect construction workers and machinery for progress monitoring, safety issues detection, and performance assessment [7]. Furthermore, Autonomous Vehicle research and development will help progress towards fully automated construction machinery [8].

In this context, our research focuses on proposing an innovative robotics training curriculum rooted in AI-based immersive learning for the AEC industries. Immersive learning places individuals in an interactive learning environment, either physically or virtually, to replicate possible scenarios or to teach particular skills or techniques. Our on-going research for this grant, builds upon existing research in the field of immersive learning using AR and VR technologies, and proposes an AI-based customization component to offer a unique and practical training experience based on the AEC users' skills and long-term needs.

II. CURRICULUM DEVELOPMENT

The project aims to rethink the future of robotics training which covers all types of robots utilized in current and future applications of the AEC fields. For that purpose, we have studied several robotics learning curriculums in the form of books and web chapters, video tutorial series, interactive web-based programs, hands-on workshops, as well as combinations of the listed method.

We have concluded that our curriculum will be a combination method in a sense that it will not only take advantage of the existing learning formats, but it will also introduce immersive learning tools such as AR and VR, based on the user's learning needs (active or passive) and their long-term professional goals. Thus, we are proposing a curriculum that is centered around an interactive website where new users

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log-in and engage with an AI-based assessment dashboard to determine their training path. In this assessment process, the user chooses their relationship to the AEC fields, software and hardware skills, and future aspirations, and in return, the AI-based suggested curriculum will aim to offer a unique learning experience.

To design this extensive learning matrix, our curriculum research team has determined and researched four main course types: 1) Computational Thinking and Practice, 2) Physical Computing, 3) Mobile Robots, 4) Large Industrial Robots. Each of these categories is not aimed at a specific AEC field, but depending on one's customized training, a training program can offer courses from one or more of these four categories.

The mobile AR application presented in this paper focuses on the process of a new user completing an assessment questionnaire within the AR app and delving into training that could be from any of the above four-course types.

III. Immersive Technologies

Traditionally the AEC industries have been using two-dimensional representation methods for producing schematic and construction drawings that communicate spatial and three-dimensional ideas. The AEC industries have heavily relied on standardized construction documents for design communication. Updating interlinked information within a construction document has been one of the challenges of the AEC discipline, which has resulted in the creation of programs such as, Revit and ArchiCAD. This interconnected document structure has carried through into AEC education, placing design communication at the core of the learning objectives. Based on these findings, we have identified that one of the main advantages that immersive technologies offer is in its ability to update the project at any time, saving time and resources. The other significant advantage is in the ability of the technology to display projects in full-scale or proportional scales, allowing an AEC expert to shift between points of view. Thus, in recent years, immersive technologies such as VR and AR have begun to capture the imagination of a small portion of the AEC practices, seeking the ultimate experience for design and creation. However, these technologies have not been tested for AEC-related skills training. The mobile AR app presented in the following section demonstrates the beginning of the robotics training research for AEC fields.

In recent years, there has been a significant overlap between immersive technologies and robotics and automation. First, techniques that are commonly used in robotics and motion planning [9], such as kinematic modeling, filtering, mapping, and localization, are applied in designing AR systems as well [10]. Mixed Reality (MR) is also a useful tool for developing mobile robot systems. In [11], it was shown that combining virtual and physical assets (i.e., robots, sensors, and humans) can lead to smoother transitions between robot simulations and real physical deployments. The ideas were tried in a testbed involving a group of micro-aerial vehicles. A new interesting link between VR and robotics was proposed in [12] where instead of using VR for living organisms it is used for a robot to fool the robot's sensors and make him believe that he is interacting in the real world. This can enable experiences that are more realistic than a simulation and may find applications in reverse engineering and security domains in robotics. Telepresence [13,14] is another area of potential impact where AR and VR can play a significant role by allowing a remote operator to interact with the world through a communication link. As wireless technologies and bandwidth improve, new telepresence robotics applications will open in environments that are inaccessible for humans (e.g., construction, mining, oceanic monitoring) or where experts can are not readily available where needed.

IV. Mobile Ar App Prototype

For our initial prototype, we have specifically focused on developing a lesson sequence in mobile AR. The lesson sequence begins when launching the mobile application where the user sees a logo of the *Robotics Academy* followed by a prompt to determine whether the user is a new or returning applicant. If the 'new user' option is selected, the app presents the user with a series of multiple-choice questions to determine their relationship to the AEC fields, and assess their technical skills, as well as their short and long term learning objectives. If the 'returning user' is selected, the app demonstrates the progress and highlights areas that might require reviewing before continuing with any new content. Based on these selections, the user is presented with a series of AR or Video lessons that need to be completed in a sequence. Each lesson ends with a closing exercise to determine the user's understanding of the subject and overall progress.

A. Immersive Media Selection

Since the dawn of AR technologies during the World War II-era, the AR technology has been mainly associated with Head-Mounted-Displays (HMD) [15]. It was not until 2017 and the release of iPhone6S and Apple's ARkit package and later Android's AR Core package that mobile-based AR was introduced to the general public. In 2018 Unity game engine released its AR Foundation option which provided a platform-agnostic scripting API for making ARKit and ARCore apps that use core functionality shared between both platforms. These recent advancements have been significant steps in rethinking the relationship of AR to the public. Additionally, the release of location-based games such as Ingress and Pokemon Go, have also solidified the public's relationship to AR and has proven that task-specific and entertaining AR has the power to engage people from different age groups and backgrounds.

In this context, we decided to begin building our initial training application in mobile AR and utilizing the AR Foundation package for the Unity game engine. The AR Foundation package allows developing in the Unity game engine environment with the capability to deploy standalone applications for both Android and iOS platforms.

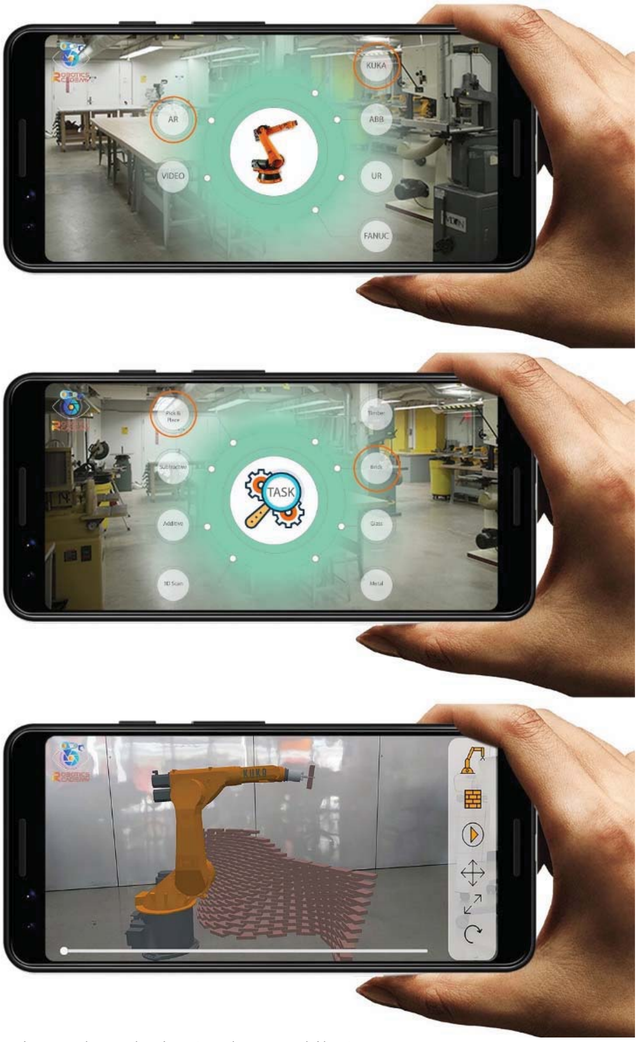

Fig. 1. The Robotics Academy mobile AR sequence.

B. User Interafce Design

A successful AR experience integrates the digital and physical worlds seamlessly to bridge the gap between the constraints of the digital overlays and the surrounding environment. With this in mind, traditional navigation design does not always translate well into the AR experience, thus, requiring a rethinking of interface design. Additionally, each AR medium, such as the AR-enabled mobile devices, have their technical specificities and screen ratios.

Our prototype is using two main types of UI components: 1) Clickable icons which are used as multiple-choice assessment options, as well as icons for navigating the training process within each lesson. 2) Clickable geometry which allows the user to find out more information about specific robot types and parts throughout each lesson. By combining these options, we can create an interactive learning environment where the user can explore each lesson based on their learning styles and preferences.

V. Conclusion and Future Steps

Due to the impending changes in the AEC industries involving robotics, automation, and AI, it is necessary to provide learning resources that enable current practitioners to be an active part of the future workforce. In this work in progress paper, we have outlined a curriculum targeted to AEC participants that involved the use of AR, VR, and AI tutors. We have shown an initial prototype of an app that uses AR to explain fundamental concepts in robot manipulators. Our current working prototype uses AR to convey robotic manipulation concepts. We are in the process of play-testing this work-in-progress application with our students as well as industry partners to assess the lesson flow as well as the UI integration.

We are also currently exploring the use of VR to add to our lesson resources. We believe that VR presents several advantages in safety training in robotics and automation. First, it will allow the trainees to see full-scale details of any robots that may not be easily available. Second, exposure to VR may help the AEC workforce to get familiar with the technology and consider novel integration techniques with BIM [16] and architectural design processes [17]. Another thread of current work is the incorporation of AI with AR and VR, where AI-enabled tasks will offer a personalized experience to AEC trainees. We are interested in extending current work where AI techniques such as Deep Reinforcement Learning [18], Partially Observable Markov Decision Processes POMPD [19], and Multi-Armed Bandits [20] are utilized to personalized the learning experience of the AEC automation workforce. In our system, we will encounter richer sensing and action modalities that will differ from the current work in the area. The goal is to leverage the existing workflows of immersive learning and robotics training with the use of AI in order to rethink the future of automation for the AEC fields.

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