Work-in-Progress—Converging Virtual Reality, Robots, and Social Networks to Support Immersive Learning

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Work-in-Progress—Converging Virtual Reality, Robots, and Social Networks to Support Immersive Learning

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***Abstract*—This work-in-progress paper describes the development of a conceptually led Cyber-Physical-Social Eco-System (CPSeS) that seamlessly blends the real with the digital worlds using VR, Robots and Social Networking technologies to support immersive learning. The proposed CPSeS can bring students together by merging the real with virtual social spaces, enabling them to interact with each other, and with real and digital environments through physical and virtual robots. The framework used to design this system provides opportunities for developing innovative interactive systems and educational approaches to support and enhance immersive learning.**

Index Terms—virtual reality, robots, cyber-physical-social eco-systems, immersive learning, digital realities

I. Introduction

Emerging digital technologies have been increasingly adopted to support and enhance education over the past few years. A wide range of techniques are utilized comprising software, hardware and/or their combination, supporting the delivery of effective teaching and learning practices. Numerous tools are available to generate educational content in various formats, helping to foster communication, collaboration, forming learning communities, and offering opportunities for developing digital portfolios and assessments [1]. Many educational institutions are committed in leveraging the use of emerging technologies, for instance Virtual (VR), Augmented (AR) and Mixed Realities (MR), Robots, Internet of Things, Internet of Robotics Things, Digital Twins and others. This paper presents work in progress in the development of a new type of conceptually led Cyber-Physical-Social Eco-System (CPSeS) that seamlessly blends the real with the digital worlds using VR, Robots and Social Networking technologies to support immersive learning. In the following pages a prototype of a system that connects students, robots, real and virtual spaces through a social cyber space making the difference between real and digital realities less distinct is described. The prototype has been developed in VR following a particular CPSeS Framework, where students can connect through the use of the compact and cost-effective option of VR ready smart phones and low-cost Head Mounted Displays (HMD).

II. Background

A. Virtual Reality in Education

The use of immersive learning experiences has been identified to have a positive impact in education for both students and teachers [2], allowing to create virtual spaces for learners to interact with, communicate and collaborate with each other. VR is one of these immersive technologies that offers opportunities to support and engage students in the learning process. For many years, VR was challenged by expensive requirements and technical issues hindering its mainstream adoption. However, with the recent advances in technology, VR has now become a customer-ready solution which is increasingly used in education due to the technology's unique affordances of immersion and presence. Presence is "*the subjective experience of being in one place or environment, even when one is physically situated in another*" [3, p. 255]. Immersion is similar to presence, but distinct [4] and relates to the technology experience of the exchange of sensory input from reality with digitally generated input [5]. Presence is the subsequent reaction to immersion, leading to the user brain reacting to the virtual environment in the same way as it would have reacted in the real environment [6]. The attributes of presence and immersion, and VR's ability to allow developing realistic and/or experiences that deviate from reality are key affordances motivating technology adoption [7], offering immersive, engaging and motivating educational experiences [8]. However, an open issue is the extent to which this astonishing technology can be practically implemented in classrooms and support students in numbers. According to Hussein & Nätterdal [9, p. 1], "*the differences between modern VR compared to the concept of VR presented two decades ago is that the technology is finally at the stage where it can be adapted to any mobile phone*". This demonstrates the significant advancements in VR, and, by utilising the technology that students have in their pockets it can become mainstream in education, especially with the use of low-cost HMDs like Google Cardboard. This will allow each student to use their smartphone to immerse in high fidelity virtual environments and participate in educational activities.

B. Robots in Education

Robots have been used in education since the creation of first programmable robots in the 1950s [10]. With the increasing prevalence of robots in industries the demand for engineers, designers and technicians with corresponding knowledge and skills was also increasing. This resulted in introducing robotics and related disciplines in higher education and in schools. It became obvious that *'Robots offer an excellent tool for teaching engineering concepts that can be employed in teaching and demonstrating a variety of individual subjects, practical exercises, lab*

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classes and project work.' [11]. This educational trend has been well established and robotics nowadays is one of the key disciplines in many universities across the globe. But the role of robots in education has been particularly increased in the last two decades, with technological advances in social robotics. Introduction of social robots has brought the robotics to a new level: they stimulate further collaboration between various disciplines, not only engineering, designers and computer science, but also social sciences and humanities [12]. The social robots also enhance multi-disciplinary projects in schools and universities. This contribute to team-building skills and help raising students' self-esteem in their technological capability [13]. But in addition to 'traditional' applications of robots in education, such as listed previously, the role of robots in education took a new strand, namely, by employing social robots as tutors and /or companions. Initially social robots were mostly used to help young children who have some kind of disabilities, such as learning disabilities, or being on the autism spectrum, to help them learning new skills, in particular to improve their social communication and interaction abilities [14]–[16]. But gradually social robots have begun to take the role of learning collaborators, tutors and even independent tutors. There is a growing number of research articles that analyse and discuss pros and cons of the use of robots as tutors [17], [18]. Among advantages are that robots '*have been shown to be effective at increasing cognitive and affective outcomes and have achieved outcomes to those of human tutoring on restricted tasks*' [19]. However, among disadvantages, one can list the need for developing such skills as emotional intelligence and creativity, which the social robots do not yet possess [20].

Our interest in robots in education is not the use of them as independent teachers, but as intelligent tools to support and assist education and learning. We are interested in robots in education as a part of a bigger system of 'interwoven' spaces, where robots, their digital twins, students, teachers and their avatars, are all participants, educators and collaborators.

C. Cyber-Physical-Social Systems

The growing connectivity of devices and the hardware, software and communication technology advancements are key enablers for the increasing development of complex interconnected systems. Especially with the introduction of Ubiquitous Computing, Internet of Things, the Cloud and other emerging digital technologies, a significant increase in the interest around complex systems development has been influenced, and a particular domain which has drawn a lot of interest is the area of Cyber-Physical Systems (CPS). CPS are employing integrated computational and physical capabilities (i.e. sensors, computations, actuations) [21], focussing on a tight integration of physical and information systems [22]. CPS are commonly found in the industry to support manufacturing, healthcare, environment, security, automotive, energy, traffic control, smart structures, smart cities and other domains [23]. However, CPS solely focus on the integration of the computational with the physical world, and not incorporating the element of human interaction and social input, and recent research directions focus on the implementation of the human factor in CPS [24]. Such integration is referred to as Cyber-Physical-Social Systems (CPSS). A CPSS is constituted by a physical system, its social system, and the cyber system that connects them [25], extending the CPS, by emphasising on the human factors influencing the system [24].

To support bi-directional integration and interaction between physical and cyber elements and emerge CPSS, a range of technologies have been utilised over the years such as the use of Web services, Internet of Things, Artificial Intelligence, Robots and Mixed Realities among others [26]. Fusing VR and Robotics technologies have been trending in scholar communities recently, with a focus on converging multimodal interactive robotic and immersive technologies. This synergy establishes a new virtual reality paradigm which "*with the help of robots, the changes made in the virtual world are "projected" into the physical world"* [27], and this contribute towards bridging the gap between VR and Robots by adding functionalities in robotics control and operation. However, going beyond the use of Robots and VR for teleoperation and environment visualisation, the opportunities offered when these technologies are combined with Social Networking to establish communication, merge remotely with physical users, and support participation in learning activities are yet to be explored. Emerging a CPSS capable of fusing these emerging technologies can enable to explore novel interactive methods to support immersive learning using a Cyber-Physical Eco-Society framework that applies to a plethora of domains.

III. Conceptual Framework

The system described in this paper is following the conceptual framework developed by [28] depicted in Fig. 1. This framework describes the development of Cyber-Physical-Social Eco-Society (CPSeS) of systems that encompass both physical and virtual environments, including real and artificial agents and elements, capable of interacting dynamically with, reflecting and influencing each other, and with the interactions engendered by humans. The Framework indicates how the three layers of a CPS are linked through dedicated integration layers and merges the real with virtual worlds and with humans. To date, this framework has been used to develop a system that supports Cultural Heritage [28], and remote participation in events as a tool to facilitate access to an event when physical participation is impossible such as during the recent outbreak of the COVID-19 [29], and the authors are aiming to apply it further to a plethora of domains.

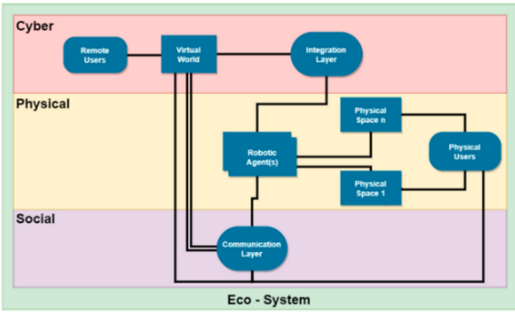

Fig. 1. The Cyber–Physical–Social Eco-System Framework [28].

Using this framework to deploy the system described in the following pages, students are either in the Virtual World or in the Physical Space(s). Virtual Students can navigate in the Virtual World. Real Students exist in the Physical Space(s). The *Integration Layer* is responsible for establishing the connection between the Virtual and Physical world through Robotic Agent(s) placed in the Physical Space(s) (assuming that the Physical Space(s) have robotic infrastructure already installed to support this). The Robotic Agents are responsible for Actuation in the Physical World based on requests issued via the Virtual World and handled through the *Integration Layer*. These Agents also interact with the Physical and Virtual Students and provide Video and Audio feed from the Real to the Virtual World through the *Integration Layer*. The *Communication Layer* establishes communication between the Remote Students and Robotic Agents in the Virtual World, with Students in the Physical Space(s). This layer also supports the capability of Remote-to-Physical student communication in the form of Online Post-it Walls linking the Remote with the Physical Students directly through the use of Tablet devices placed on Robots and through Virtual Walls in the Virtual World.

IV. The CPSeS Prototype

To investigate the capabilities of a CPSeS to support immersive learning, a VR prototype has been developed. This is a multi-user environment in which students connect and co-exist in the same shared space, interact with each other and with the virtual environment and with the Digital Twin of the robot Fetch54, a real robot which is placed at one of the host University's exhibition spaces (Fig. 2a). Fetch54 is a mobile manipulator industrial robot featuring a mechanical arm to reach and grab items, multiple sensors capable of perceiving, navigating and manipulating objects, high-resolution camera, and laser scanning [30]. The environment is designed using Unity 3D. The prototype is currently targeting Android smart phones, and users are experiencing it using a specific low-cost HMD device which features a thumb hole underneath allowing users to touch the screen and perform swipe and other gestures to interact with the environment.

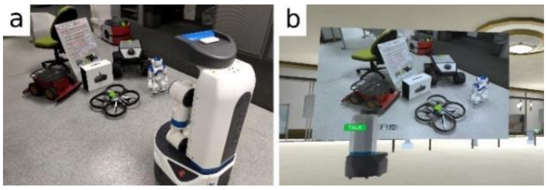

Fig. 2. Robot Fetch in the real (a) and virtual world (b)

To develop the functionalities of Fetch robot, the Robot Operating System (ROS) framework has been used. ROS is a middleware framework system that provides tools and libraries to allow controlling and manipulating robots [31]. Specific programs have been developed and are also under development to enable the Robot to navigate in, reach and grab objects. To establish connectivity between Unity and ROS, and by extend, to the robot, the RosBridge framework [32] and ROS# [33] Unity plugin has been used. Using these tools, data can be transmitted from the virtual environment to and from the robot, enabling to engage and use the robot in the real world through the virtual world (Fig. 2b).

A. *Initial Functionalities of the CPSeS*

When users connect to the environment, they choose between single or multiplayer experience. Users land into an orientation area to learn the basic functionalities of the system, how to interact with the environment, and communicate with others. Users then select the scene they want to load. The system features the RoboSHU museum of Robotics [29], [34] (Fig. 3), allowing students to learn about the history of robotics, information about particular robots, and participate in an educational game. Once the user is connected to the scene, the digital twin of Fetch robot is generated, providing live video feed and projecting a view of the real world in a panel attached to it, allowing users to see the real world through the eyes of the robot. The users navigate in the environment and learn about the history of robots, interact with the exhibits, and find out more about them. The user can interact with the Fetch digital twin through a User Interface (UI) panel attached to it, allowing to choose actions to be executed by the robot in the real and virtual world. When the user decides on the action, the system submits a request to the real robot, which in turn is executed and the Robot's movement is synchronously replicated by its digital twin in the virtual world.


Fig. 3. The Virtual Museum of Robotics Prototype

Users can interact with Robotics exhibits in the environment, learn about them, and choose to see them in action through a demonstration of how the robot operates in real world conditions. The environment also features an inquiry-based scavenger hunt/jigsaw type educational game. The game rules require users to find objects dispersed in the virtual environment and complete a robot jigsaw. Once the user locates the object, a question needs to be answered correctly through a UI panel. Once the question has been successfully answered, the robot part is added to the jigsaw. The game ends upon completion of the jigsaw.

V. Discussion

This paper presents the current work in progress in the development of an educational Cyber-Physical-Social Eco-System using VR, Robots and Social Networking technologies. The CPSeS described allow students to participate in immersive learning activities, offering opportunities to experience immersive situations where the real and digital worlds are blended in interactive ways, and with the utilisation of robots as guides, learning agents, and actuators in the real world. In the proposed educational CPSeS, robots have a clear implementation mission to form a network of mobile and static robotic agents and avatars, that will support students while participating in learning activities occurring in digital and real spaces.

Robots will interact with students in both realities, access large databases and provide instant respond to information requests. Robots can provide remote access to areas which are difficult to access, can be programmed to perform and react to actions, perform autonomously or through teleoperation, and used for social communication and interaction. When robots are then fused with VR to develop environments, situations, activities and complex concepts, students can participate in interactive activities to support their learning experience. For instance, students can practice their coding and engineering skills to program the robots to perform actions and reviewing them through the VR system. And by considering the recent advancements in hardware, VR can now be generated using smartphones and be experienced using affordable HMDs. When adding the power of Social Networks to support the social component of this CPSeS, the development of social networks to facilitate communication between students located anywhere in the world can be established. This can help to build important social dynamics and relationships that promote the feeling of belonging to a community. Future work is on its way to further improve the system and develop additional functionalities. The VR development team is working on a voice over IP component, a registration system, to implement additional capabilities and build further educational activities. The robotics team is working on developing communication, information retrieval, navigation and manipulation functionalities to the robot. Additional robots are also planned to be implemented in the environment and in the real world.

The continuous advancement of technology and the need to deliver high quality education, are interdependent areas. The utilisation of the technologies discussed in this paper as a fusion can result in emerging multifaceted system that will represent a new multi-genre networking system with capabilities and potentials to support and enhance participation in immersive learning experiences.

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