XR4ED: An Extended Reality Platform for Education

Fotis Liarokapis, *CYENS - Centre of Excellence, Nicosia, 1016, Cyprus*

Václav Milata, *CYENS - Centre of Excellence, Nicosia, 1016, Cyprus*

Jose Luis Ponton, *Universitat Politecnica de Catalunya, Barcelona, E-08034, Spain*

Nuria Pelechano, *Universitat Politecnica de Catalunya, Barcelona, E-08034, Spain*

Haris Zacharatos, *CELLOCK, Nicosia, 2018, Cyprus*

Abstract—Recent developments in extended reality (XR) are already demonstrating the benefits of this technology in the educational sector. Unfortunately, educators may not be familiar with XR technology and may find it difficult to adopt this technology in their classrooms. This paper presents the overall architecture and objectives of an EU-funded project dedicated to XR for education, called Extended Reality for Education (XR4ED). The goal of the project is to provide a platform where educators will be able to build XR teaching experiences without the need to have programming or 3D modeling expertise. The platform will provide the users with a marketplace to obtain for example 3D models, avatars, and scenarios; graphical user interfaces to author new teaching environments; and communication channels to allow for collaborative VR. This paper describes the platform and focuses on a key aspects of collaborative and social XR which is the use of avatars. We show initial results on (a) a marketplace which is used for populating educational content into XR environments, (b) an intelligent AR assistant that communicates between non-player characters and learners and (c) self-avatars providing non-verbal communication in collaborative VR.

Exteded Reality (XR) has the potential to facilitate a richer, effective, and collaborative learning, than is possible with 2D alternatives and provide a high rate of knowledge transfer. XR technology empowers learners with the ability to: a) manipulate visual 3D objects, processes, and procedures and elicit additional information about them, b) access inaccessible views of objects, processes, and procedures, c) combine and compare multiple views, and d) augment their senses. XR learning environments make physical spaces and materials redundant. Learners in XR classrooms have several possibilities that are impossible otherwise (i.e., to learn in different methods they will never be able to before in traditional educational settings).

These affordances help learners to experience phenomena that are not possible in the real world, to visualise complex spatial relations and abstract concepts, and to compare/contrast and interpret multiple/alternative perspectives. In particular, they can save and access teaching material and experiences in the cloud. They also enhance the learning experience by using 3D synthetic objects for learning to interact with which grab and hold the attention of learners, enhance learners' immediacy and immersion, foster effective collaborative, and situated learning, and foster practices and literacies that cannot be enacted in other traditional computing environments.

XR, when properly used, can foster effective learning by leading to increased motivation and active engagement and participation of the students rather than passivity (learning by doing), by allowing learners to proceed through the learning process during a broad time period at their own pace, by encouraging social interaction among users in collaborative settings, by bridging formal and informal learning and by improving the transfer of knowledge and skills to real situations through the contextualization of learning and the mastering of authentic tasks by learners.

The use of XR can expand the range of activities through which students can gain hands-on experience, enabling them to go beyond abstract knowledge and supporting skills-based teaching and learning. Currently, developing XR applications for education require specialised knowledge and strong XR development skills. The process takes a lot of effort, time, and money. To overcome these problems we propose the development of an XR platform called XR4ED, that can be used by non-technical users to create educational XR applications. Including animated avatars in XR is a natural step towards providing a similar learning experience to being in a one-on-one class, since the teacher can notice if students are paying attention through their gaze and non-verbal communication, as well as use natural gestures to better communicate complex concepts or emphasize information just like they would do in a real class.

The XR4ED project's goal is to design, develop, and maintain a sustainable on-demand education platform by providing a central access point to existing solutions. This article outlines the broad structure and goals of the XR4ED project. Then, we concentrate on one of the hottest topics of XR, which is collaborative and social environments for which avatars are needed. This is crucial for providing learners with XR engaging experiences and it is demonstrated through initial results of (a) non-verbal interaction in collaborative VR and (b) an intelligent AR assistant that interacts with learners and non-player characters in real-time performance.

The rest of the paper is structured as follows. First, social XR systems are described including a brief market analysis. Next the motivation of XR4ED project is presented and then an overview. Furthermore, the most significant concepts are illustrated. Moreover initial results in terms of an educational marketplace, an intelligent AR avatar assistant and VR avatars are presented followed by conclusions and future work.

Social XR

Social XR systems became very popular in the last years such as VRChat, RecRoom, Spatial, and Mozilla Hub. However, such scenarios are usually limited to only visual and auditory stimuli, without considering the broad range of sensors that we can solicit. The information distributed between a group of people remotely engaged in a complex XR scenario has to be consistent in order to improve the realism of their experience.

Including virtual avatars in XR applications is still a challenge even for expert programmers. Libraries of avatars have been recently made public for research purposes, such as Rocketbox [1]. However, there are still many difficulties when it comes to integrating different tools to complete the pipeline of generating a virtual avatar ready to be animated by a user. When using a head-mounted display (HMD), users cannot see their real bodies, and thus it is important to represent them with self-avatars to induce full-body illusion, which enhances the exploration and interaction capabilities of VR [2]. In collaborative VR, having a simple representation for the users, such as spheres with eyes to indicate the head orientation or an upper body stylized avatar with floating hands (such as those used by Meta in Meta Quest games), can improve non-verbal communication and the Sense of Embodiment (SoE) [3].

Full-body avatars can help users perform cooperative tasks more accurately and quickly [4]. Efforts to animate full-body self-avatars have garnered increasing attention in recent times, driven by the potential benefits they offer. Nonetheless, the field lacks a unified, state-of-the-art methodology. Some HMDs, such as HTC VIVE, can work with 6-degree-of-freedom (6-DoF) trackers, providing positional and rotational information, that can be used to animate a self-avatar using Inverse Kinematics (IK) solutions, and have been integrated by some commercial tools like FinalIK [5] for this purpose.

Previous solutions are not straightforward to include in VR projects and suffer from various problems such as error-prone calibrations or wrong initial premises. Assumptions are made regarding the offsets between trackers and joints that lead to unnatural poses due to the lack of accuracy between the user's body and the avatar dimensions. To improve the results, the user must manually input information or move around trackers through a time-consuming and error-prone tweaking process.

On top of that, the XR4ED project provides a completely new feature that will animate the superimposed information in real-time performance. The platform will provide avatar representations that are ready to be included in an XR environment through an easy-to-use authoring tool, hiding the complexity of the HMD or tracking devices being used.

Motivation

The current start of the art for XR DevOps platform is XR4ALL [6]. The platform aims to provide third-party projects with the required environment and tools to develop new XR components, systems, and applications. XR systems are relatively complex and consist of a multitude of hardware and software components that communicate with each other to deliver a rich XR experience. Currently, creating XR environments and games requires a significant amount of technical know-how, and only developers can work on the game engines that allow this. One challenge in XR4ED is the creation of authoring tools to allow users to dynamically download 3D models to create XR environments. This can help in the development and modification of XR environments. The use of standards such as OpenXR and WebXR can facilitate the creation of XR applications for any platform.

The idea of having an online marketplace for XR in education represents a suitable and beneficial option for online world users who are interested in an offer and demand space that allows posting offers or requests for related services. Within this space, the solutions catalog for XR4ED will be open to users to submit and promote their ready-to-market XR solutions for learning, training, and education. Moreover, there are many companies that are investing large amounts of money in having animated avatars in VR, but they mostly focus on stylized avatars, with floating body parts (heads and hands), for example: Rec Room, VRChat, Altspace, and Meta Horizon Worlds. Over the past years, there has been a lot of effort from the industry to build highly realistic-looking avatars, like Unreal Metahumans, the Codec Avatar Project by Meta, and Unity Technologies recently purchased Ziva (real-time 3D character design).

Another challenge is to animate virtual humans correctly despite the hardware available (HMD model, tracking devices, etc.). Therefore, in this project, we aim to develop an animation solution for avatars that can be universal (i.e., work with any HMD and any device configuration), by providing a unique interface that leverages different animation techniques based on the hardware available.

The most relevant attempt to overcome this barrier is the QuickVR system [7], which provides avatars for embodiment applications. However, it is limited to users who can program and are familiar with the Unity development framework. To democratize the use of avatars for XR applications focused on education, we need solutions that can be easily adopted and used by non-programmers. A good example is the Ubiq [8] framework that attempts to ease the process of creating collaborative VR experiences. Ubiq provides the core functionality of many Social VR systems such as networking capabilities. It also includes stylized avatars consisting of floating upper bodies and hands, which already provide basic non-verbal communication through hand movement.

XR4ED Overview

The overall objective of the XR4ED project is to design, create and maintain a sustainable on-demand education platform, mobilising the education technology (EdTech) and XR community from the EU, providing a central access point to existing solutions and contributing to a leading position for Europe in cutting-edge while ensuring the European values of privacy, ethics, and inclusiveness. XR4ED's core concept is built around joining XR and EdTech communities to create systems that will assist in education, learning and training. XR4ED is a platform that will encourage and facilitate the implementation of XR systems in the fields. The project also addresses the accessibility issues of such systems, as it presents a one-stop-shop, for all stakeholders in both XR technologies and education. XR4ED will contain an XR solutions catalog along with a Marketspace that will allow the EdTech and XR community to submit and promote their ready-to-market systems. Teachers, students, parents, and school administrators will be able to search for the appropriate educational solution to their specific needs, as well as learn about the products available in the market.

Our ambition is to build on top of the functionalities provided by the XR4ALL platform by providing not just a platform to integrate but also collaborate and use products developed by other parties to be used in a singular project as well as specific tools targeting the education sector. The platform will also provide integration possibilities with pedagogical add-ons to the XR applications. The DevOps platform will be a web-based application that integrates with multiple 3rd party tools to provide DevOps services but also with collaborative tools. The platform will use REST APIs for connection with the back-end. The back-end of the DevOps platform will be built on PHP and will use cloud services for security and scalability. The users will also be able to log in through their Github accounts providing us with easy on-boarding.

In XR4ED, the basic idea is to take the previous studies a step further: A novel XR table-top learning interface will be developed focused on different educational environments (i.e., classroom, distance learning, etc). The focus is on assessing the learning effectiveness via all these diverse settings. The initial user requirements for the XR4ED project were carefully documented through a user-centered design approach. Results highlight the positive outlook among experts regarding the potential of XR as a transformative tool in education as well as the importance of addressing financial, technical, and infrastructural challenges to facilitate successful implementation [9].

The XR interface will integrate the real teaching environment with several different virtual learning scenarios (3D models, spatial sound, animations, and textual annotations) in a student-friendly and engaging manner. The XR4ED XR interface will offer the ability to use sophisticated techniques and achieve better user interaction with teaching material and complex tools. This interactive XR presentation will allow students to gain a high degree of flexibility and understanding of the teaching material. One of the greatest advantages of this research experimentation is that students do not need any previous experience to operate the XR interface. Also, the lecturer/instructor will be able to control the sequence of the XR presentation in the learning environment according to the student's pace.

XR for education is a collaborative experience and thus requires optimal communication between the instructor/teacher and the students. Non-verbal communication plays a particularly important role in giving meaning to messages that require, for example, knowing who and where our interlocutor is and what our interlocutor is pointing at. The between-users interaction needs are not the same if the group of people is looking at a common virtual target or if they are freely exploring a larger virtual environment. XR4ED will tackle user interaction following a multi-modal approach. This will combine IMU sensors, computer vision (gestures), and auditory information. Not all of them will be necessarily used simultaneously, but depending on the circumstances, different configurations will be combined. Collaborative interaction in an XR context is commonly applied to industrial design, education and learning, medicine, gaming, and entertainment.

In XR4ED, we are interested in studying what are the best techniques to facilitate communication and interaction between users of a collaborative VR environment. These techniques will address problems such as awareness about what other users are seeing, and about where the other users are (virtual and real position), including remote collaborators. We will prioritize the scalability of the number of users and the affordance of the devices (i.e., medium-range smartphones with cardboard-like VR adaptors). We will test both single model and complex scene conditions, and gradually move from small groups with one-way communication (e.g., VR anatomy class or industrial tutorials about tools) to larger groups (i.e., VR classes with more students) and multi-way communication (i.e., clinical sessions for inspection/visualization of 3D visualization and medical training).

Through future user studies, we will use several techniques to explore the gender dimension, such as neutral avatar representations or models of all genders and body types. The avatars developed in the context of XR4ED will allow the user to select among different appearances and animation types depending on the goals of the lessons to enhance student learning performance. For instance, in some applications, a basic

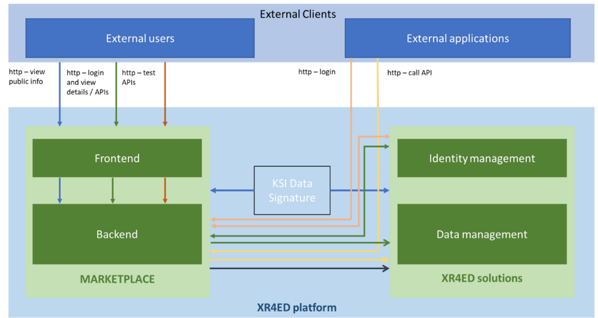

FIGURE 1. XR4ED marketplace

stylized representation may be less distracting for the students (i.e., teaching geography), whereas for other lessons, maybe a fully animated avatar is needed for better gesturing (i.e., to explain complex 3D models in medicine or geometric transformations in computer graphics). Pilot studies will allow us to evaluate how different avatar styles, interaction metaphors, and motion qualities can have an impact on the teaching and learning experience.

Preliminary Results

XR Marketplace

The marketplace utilizes a microservices architecture (Fig. 1). It is designed as a collection of loosely coupled, independently deployable services, each focused on executing a specific business function. This architecture is facilitated by an API Gateway, which serves as the entry point for client requests, directing them to the appropriate microservices such as User Authentication, Data Management, Licenses, File Management and Products. Each service runs in its own isolated environment, allowing for the deployment of updates or new features without impacting other areas of the system. Communication between services is typically handled via RESTful APIs or asynchronous messaging queues to maintain decoupling and enhance fault tolerance. For data management, services often employ their own databases, known as the Database per Service pattern, to prevent data entanglement and ensure scalability. This architecture provides mechanisms for automatic scaling, load balancing, and self-healing, critical for handling the dynamic workloads typical in a marketplace scenario. More specifically the following micro-services have been created and deployed:

- User Auth (Authentication): Responsible for user authentication, ensuring that only authorized users can access the system. Access management is based on roles and permissions in a structured approach to ensuring that teachers, developers and administrators have the appropriate level of access to its resources. In this model, roles are predefined according to job functions, and each role is assigned specific permissions that grant the capabilities necessary to perform that function.

- Data Management: This service handles operations related to data handling and processing. A data management microservice serves as a centralized hub for handling all data-related operations within a distributed system, ensuring efficient and consistent data processing, storage, and retrieval. This microservice is designed to interact seamlessly with various data sources and other microservices, managing transactions, data integrity, and synchronization across the system. It provides APIs for CRUD (Create, Read, Update, Delete) operations, allowing other services to access and manipulate data without directly handling database complexities. Additionally, it implements data governance and security policies, such as access controls and data encryption, to protect sensitive information and comply with regulatory requirements. By isolating data management functions, this microservice enhances the system's modularity, making it easier to scale and update without affecting other components of the architecture.
- Licences: Manages software licensing, which could include issuing, renewing, and validating licenses. This microservice operates independently, interfacing with other services via well-defined APIs to provide licensing capabilities across various applications. When a license is requested, the microservice generates a unique license key based on predefined criteria such as user identity, usage limits, and time restrictions. This key is then issued to the user or system, enabling access to the software or service. The microservice also handles license validation, checking the authenticity and compliance of the license key with each use, thereby ensuring that the software is used according to the terms set out in the license agreement. This approach allows for scalable, flexible, and secure management of software licenses, adapting easily to changes in user needs or software functionality.
- File Management: Takes care of file storage, retrieval, and other file-related operations. A file microservice is a focused component within a microservices architecture, dedicated to managing and facilitating file operations such as uploading, downloading, storing, and retrieving files across various applications. This microservice provides a centralized point for file handling, ensuring that files are stored securely and are accessible to other services through a well-defined API. It supports various file formats and manages metadata associated with each file, such as file type, size, and ownership. The microservice also handles permissions, ensuring that only authorized users can access or manipulate files. By decoupling file management from other application functionalities, this microservice significantly improves scalability and maintenance, enabling efficient management of large volumes of data while supporting high availability and redundancy strategies.
- Products: Deals with product-related functionalities, which might include catalog management, pricing, and inventory. This microservice is responsible for maintaining detailed records of products, including their specifications, features, and categories. It allows for the creation, update, and deletion of product information, facilitating dynamic management of product catalogs. By interacting with other microservices via APIs, such as inventory or pricing services, it ensures that all product-related data is consistent and up-to-date across the entire system. This modular approach enhances the flexibility and scalability of the system, allowing businesses to rapidly adapt to market changes or expand their product offerings without disrupting other system functionalities.

All these microservices are interconnected and can communicate with each other through synchronous RESTful calls or asynchronous messaging patterns. They all connect to a PostgreSQL database, which indicates a centralized data storage approach, although each service may interact with its own schema within the database.

Intelligent AR Avatar Communication

In the past, an interactive, low-cost AR educational interface for higher education was proposed [10]. The main focus was on providing learners with a multimedia augmentation of teaching material in a compelling and engaging way. An exemplar of the different features of the AR interface is presented in Fig. 2. Although research suggests that AR technology is a promising and stimulating tool for learning and that it can be effective when used in parallel with traditional methods

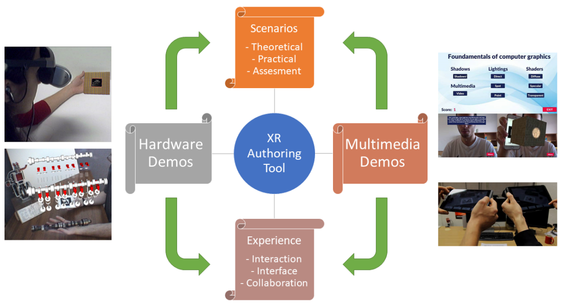

FIGURE 2. Examples of AR educational applications

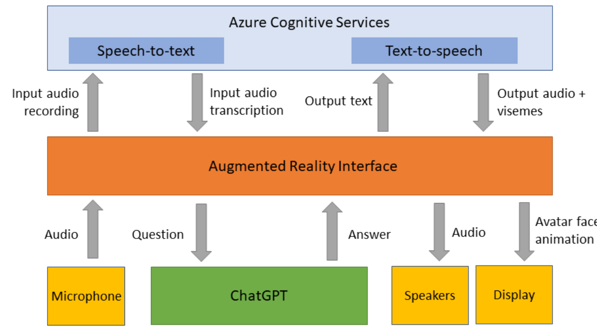

FIGURE 3. AR Avatar Communication Architecture

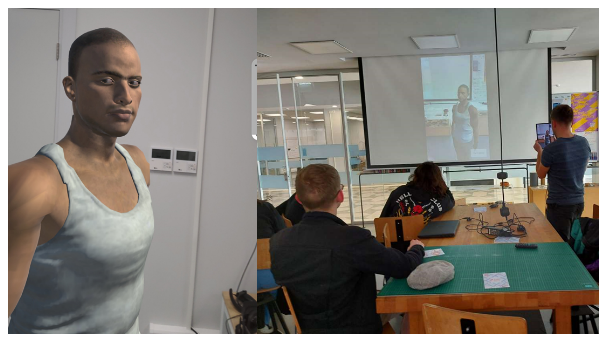

FIGURE 4. AR intelligent assistant. On the left image, it is superimposed on the laboratory and on the right image, it is demonstrated to students via a tablet and a projector

[10], two drawbacks of AR interfaces are that there is no intelligent avatar communication. Creating engaging avatars is crucial for social XR experiences in the education sector. They are not only a vehicle to enter an immersive world, but also a door for a new generation of intelligent characters to step into. XR can provide the necessary level of interactivity for avatars to enable continuous development.

Following this pathway, XR4ED uses AR with intelligent avatars with the aim of helping students and learners explore environments, access information, and complete tasks more effectively. This goal is not only to improve engagement but also to improve the learner experience. Initial results demonstrate an intelligent AR digital twin that can be precisely superimposed into the real environment. This can be done either using quick-response (QR) codes or using simultaneous localization and mapping (SLAM) algorithms. The communication is based on the Azure Cognitive Services. This allows for speech-to-text and text-to-speech features for communication between a user (i.e., learner) and an AR assistant (the non-player character). For the intelligence part, the ChatGPT AI chatbot model was used for generating answers to questions in real-time performance. An overview of the communication architecture is illustrated in Fig. 3.

The implementation of the intelligent AR interface is based on Vuforia and Unity and it is connected with the marketplace to retrieve multimedia information. It will also be integrated with the XR platform (which offers two options: the VR mode and the AR mode). Currently, the AR assistant can superimpose both types of genders in the form of avatars (male and/or female). Based on [11] head and eye movements during gaze shifts have been implemented into the AR environment. The model consists of two fully independent components: (a) the gaze controller and (b) the face controller. The gaze controller, controls the rotation of the head and the eyeballs whereas the face controller, the eyeball rotation for each eye.

Lip syncing capabilities have been integrated based on an algorithm that redefines visemes as sets of constraints on the facial articulators (i.e., lips, jaw and tongue) [12]. The speech audio is segmented into visemes and a viseme shape is defined. These poses are used as animation keyframes placed at the onset of each viseme, and the final animation is created by interpolating between these keyframes. Furthermore, users can also search on the web and data mine other types of multimedia information. At the moment, this includes only images and metadata, and the search is based on a text prompt. The output of the search is semi-automatically inserted and positioned orthographically into the AR environment.

Moreover, intelligent AR avatar supports videos, panoramic images, PowerPoint presentations and textual information. All of this information can be provided either from the teacher or through the marketplace. Fig. 4 shows a demonstration of the intelligent AR assistant in Erasmus students from the UK. An informal evaluation was performed, and overall, students were impressed with the capabilities of the application, especially the fact that they could ask any questions and they could get answers in real-time performance. They were also asked if they would use this application for learning purposes, and they all agreed that the intelligent AR avatar has the potential to support educational practices outside the classroom environment.

VR Avatars

Immersive VR wearing HMDs requires having avatars that provide us with a self-representation, but also avatars that represent the other users in collaborative VR, and thus, allow us to interact with them in a natural way. Initial results with our *AvatarGo* method [13] show that we can provide non-verbal communication in collaborative VR by having avatars animated with IK and using as few as six 6-DoF trackers. We position those trackers in the head (HMD), the hands (hand-held controllers), and the back and feet (additional trackers), and then follow a calibration process to compute exact offsets between each tracker and the corresponding joint in the skeleton of the virtual avatar.

Our calibration process has two steps: first, the user stands in a T-pose to scale the avatar according to the user's height; second, we show a resized avatar and ask the user to walk inside and position their body correctly aligned with the avatar (with the aid of a mirror, a top view, and a render of all the tracker that are attached to their body). During simulation time, we use IK to animate the avatar and provide accurate positioning of end-effectors for careful manipulation of virtual objects. Our calibration process highly increases the SoE and the quality of both the avatar movements and the positioning of hands and feet. *AvatarGo* is currently limited to the HTC VIVE HMD with three additional HTC trackers. Unfortunately, this is still a pricey solution, thus not affordable for all educational purposes.

To overcome this limitation and further democratize the use of VR, we have been working on extending the animation capabilities to more cost-effective HMDs such as Meta Quest. We aim to provide natural animations without the need for additional trackers. When using only three trackers (HMD and hand-held controllers), the main challenge becomes providing the user with natural locomotion animations. For this purpose, our initial results extend the concept of Motion Matching [14] by inputting a different set of features available in a VR setup (data coming exclusively from the HMD and the hand-held controllers) [15]. In addition, we also included a neural network that learns to predict body orientation from the HMD and the hand-held controllers so that the avatar orientation is not simply defined by the HMD. Thus, our avatar can perform side steps when detecting lateral movement or keeping the correct body orientation while the user looks around by moving the head. Since we have precise tracking coming from the hand-held controllers, the avatar hands are still controlled by IK as in *AvatarGo* to guarantee accurate positioning of the avatar hands. This provides a mixed animation model that combines predicted motion for the legs with IK for the head and hands.

FIGURE 5. AvatarGo provides a framework to easily calibrate and animate avatars for HTC VIVE. It offers collaborative features so several users can be co-located in the same virtual space [13].

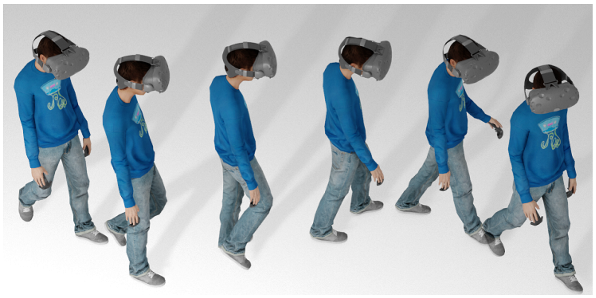

FIGURE 6. Motion matching for self-avatar animation in VR with three trackers [15].

CONCLUSION

XR technologies have enormous potential to enhance learning experiences that are not possible with traditional teaching methods. XR4ED aims to create stimulating and engaging learning experiences for students and learners based on collaborative learning in conjunction with virtual representations of humans and intelligent agents (non-player characters). We have demonstrated initial results of three different components of the XR4ED platform that can allow learners to share their ideas and evaluate different approaches in an intelligent way. The first one presented an intelligent AR non-player character assistant that interacts with learners answering any type of question. The second one deals with non-verbal interaction in collaborative VR through the use of animated self-avatars. In the future, we seek to enhance the functionality of avatar communication by incorporating intelligent conversations between several non-player characters as well as avatars controlled by learners. Additionally, body animation will be synchronized with speech to increase the level of realism of the non-player characters. Avatars will be incorporated into the XR4ED platform so that educators can choose the desired avatar representation and use them within their XR projects without having to worry about specifying the technology being used.

ACKNOWLEDGMENT

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101093159. It has also been partially supported by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 739578 and the Government of the Republic of Cyprus through the Deputy Ministry of Research, Innovation and Digital Policy under grant agreement No 101061303. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

REFERENCES

1. M. Gonzalez-Franco, E. Ofek, Y. Pan, A. Antley, A. Steed, B. Spanlang, A. Maselli, D. Banakou, N. Pelechano, S. Orts-Escolano *et al.*, "The rocketbox library and the utility of freely available rigged avatars," *Frontiers in virtual reality*, vol. 1, p. 561558, 2020. [Online]. Available: https://doi.org/10.3389/frvir.2020.561558
2. M. Gonzalez-Franco and J. Lanier, "Model of illusions and virtual reality," *Frontiers in psychology*, vol. 8, p. 1125, 2017. [Online]. Available: https://doi.org/10.3389/fpsyg.2017.01125
3. K. Kilteni, R. Groten, and M. Slater, "The sense of embodiment in virtual reality," *Presence: Teleoperators and Virtual Environments*, vol. 21, no. 4, pp. 373–387, 2012. [Online]. Available: https://doi.org/10.1162/PRES_a_00124
4. Y. Pan and A. Steed, "The impact of self-avatars on trust and collaboration in shared virtual environments," *PloS one*, vol. 12, no. 12, p. e0189078, 2017. [Online]. Available: https://doi.org/10.1371/journal.pone.0189078
5. RootMotion, "Finalik: The final inverse kinematics solution for unity," 2020. [Online]. Available: https://assetstore.unity.com/packages/tools/animation/final-ik-14290
6. "Xr4ed," 2023, accessed on March 26, 2023. [Online]. Available: https://xr4ed.eu/
7. R. Oliva, A. Beacco, X. Navarro, and M. Slater, "Quickvr: A standard library for virtual embodiment in unity," *Frontiers in Virtual Reality*, p. 128, 2022. [Online]. Available: https://doi.org/10.3389/frvir.2022.937191
8. S. J. Friston, B. J. Congdon, D. Swapp, L. Izzouzi, K. Brandstätter, D. Archer, O. Olkkonen, F. J. Thiel, and A. Steed, "Ubiq: A system to build flexible social virtual reality experiences," in *Proceedings of the 27th ACM Symposium on Virtual Reality Software and Technology*, 2021, pp. 1–11. [Online]. Available: https://doi.org/10.1145/3489849.3489871
9. F. Škola, A. Karanasiou, M. Triantafillou, H. Zacharatos, and F. Liarokapis, "Perceptions and challenges of implementing xr technologies in education: A survey-based study," in *Smart Mobile Communication & Artificial Intelligence*, M. E. Auer and T. Tsiatsos, Eds. Cham: Springer Nature Switzerland, 2024, pp. 297–306.
10. F. Liarokapis and E. F. Anderson, "Using augmented reality as a medium to assist teaching in higher education," in *31st Annual Conference of the European Association for Computer Graphics, Eurographics 2010 - Education Papers, Norrköping, Sweden, May 3-7, 2010*, L. Kjelldahl and G. V. G. Baranoski, Eds. Eurographics Association, 2010, pp. 9–16. [Online]. Available: https://doi.org/10.2312/eged.20101010
11. J. Krejsa, B. Kerous, and F. Liarokapis, "A model for eye and head motion for virtual agents," in *10th International Conference on Virtual Worlds and Games for Serious Applications, VS-Games 2018, Würzburg, Germany, September 5-7, 2018*, S. von Mammen, Ed. IEEE Computer Society, 2018, pp. 1–4. [Online]. Available: https://doi.org/10.1109/VS-Games.2018.8493406
12. J. Krejsa and F. Liarokapis, "A novel lip synchronization approach for games and virtual environments," in *2021 IEEE Conference on Games (CoG)*, 2021, pp. 1–9. [Online]. Available:

https://doi.org/10.1109/CoG52621.2021.9619128

13. J. L. Ponton, E. Monclús, and N. Pelechano, "Avatargo: plug and play self-avatars for vr," in *Eurographics. Reims, France, April 25-29, short papers*. European Association for Computer Graphics, 2022, pp. 77–80. [Online]. Available: https://doi.org/10.2312/egs.20221037
14. M. Büttner and S. Clavet, "Motion matching-the road to next gen animation," *Proc. of Nucl. ai*, vol. 2015, no. 1, p. 2, 2015. [Online]. Available: https://www.youtube.com/watch?v=z_wpgHFSWss
15. J. L. Ponton, H. Yun, C. Andujar, and N. Pelechano, "Combining motion matching and orientation prediction to animate avatars for consumer-grade vr devices," *Computer Graphics Forum*, vol. 41, no. 8, pp. 107–118, 2022. [Online]. Available: https://doi.org/10.1111/cgf.14628

Fotis Liarokapis (IEEE member) is currently an Associate Professor of Extended Experiences (EX) at CYENS - Centre of Excellence, Nicosia, Cyprus. He holds a BEng in 'Computer Systems Engineering' from the University of Sussex, an MSc in 'Computer Graphics and Virtual Environments' from the University of Hull, and a DPhil from the University of Sussex. His research interests include extended reality, serious games, computer graphics and brain computer interfaces. He is the coordinator of XR4ED project. Contact him at: f.liarokapis@cyens.org.cy.

Václav Milata is a research assistant at CYENS - Centre of Excellence, Nicosia, Cyprus. He has received his BSc degree in Information Technology from Faculty of Information Technology, Brno University of Technology in Czechia. Then he spent several years working in the industry as a software developer, building mainly mobile apps for Android and iOS, while also being a creative code hobbyist and games and virtual reality enthusiast. His main research interests are computer graphics, virtual and augmented reality, applications of machine learning algorithms and building innovative user interfaces. He is developing the intelligent AR avatar communication. Contact him at: v.milata@cyens.org.cy.

Jose Luis Ponton is a PhD student at the Universitat Politècnica de Catalunya. He holds a BSc and MSc in Computer Science from the Universitat Politècnica de Catalunya. His research interest includes character animation, virtual and augmented reality, and deep learning. Contact him at: jose.luis.ponton@upc.edu.

Nuria Pelechano is an Associate Professor at the Universitat Politècnica de Catalunya, member of the ViRVIG (Visualization, Virtual Reality and Graphics Interaction Research Group), and president of the Eurographics Spanish Chapter. Dr. Pelechano holds a BSc in Computer Science from the Universitat de Valencia, an MSc from the University College London, and a PhD in Computer and Information Systems from the University of Pennsylvania. Her research interest includes animation, human-avatar interaction, computer graphics and virtual reality. Contact her at: npelechano@cs.upc.edu.

Haris Zacharatos is the CEO of Cellock Ltd and the technical manager of XR4ED. His research interests include affective computing and machine emotional intelligence, next-generation network architectures and mobile networks, wearable computing, unmanned aerial vehicles, and robotics. Dr. Zacharatos received an MSc in computer science from the University of Cyprus, with a specialization in emotion recognition. He's a member of the Association for the Advancement of Affective Computing. Contact him at: haris@cellock.com.