Introducing Massive Open Metaverse Course (MOMC) and Its Enabling Technology

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***Abstract*—As metaverse becomes one of the most popular buzzwords in technology, there is still a lack of support to integrate true metaverse learning experiences in Massive Open Online Courses (MOOCs). This paper introduces a new framework of Massive Open Metaverse Courses (MOMCs) and its major enabling technologies, which add immersive and three-dimensional learning experiences lacking in MOOCs. It then describes a detailed case study, the President's First Lecture at the Hong Kong University of Science and Technology (Guangzhou), which we consider the world's first true MOMC environment, enabled by the latest volumetric video and related virtual and augmented reality technologies. We describe in detail how this course is created and discuss the major advantages of MOMC over MOOC as well as its current limitations.**

***Index Terms*—Metaverse, MOOC, MOMC, Virtual and Augmented Reality, Volumetric Video, Immersive Learning.**

I. Introduction

Started in 2011, Massive Open Online Courses (MOOCs) that anyone can sign up for free have taken off, Sebastian Thrun of Stanford University co-founded Udacity, a for-profit online course provider, with David Stevens and Mike Sokolsky. Based on MITx, Harvard and MIT have jointly established the edX platform. Coursera was founded by Daphne Koller and Andrew Ng of Stanford University [1]. So far, the world's three major MOOC platforms have been built, and have begun to be rapidly promoted to all parts of the world.

There is no doubt that the emergence of MOOC is like a huge revolution for the current higher education, and it is known as "the most profound technological revolution in higher education in the past 500 years" [2]. The advantages of MOOC are obvious. MOOC allows the teaching modules to be logically and reasonably divided, instant online testing integrated, and students' learning made easier and more efficient [3]. MOOC resources can be shared without regional restrictions, promoting general and lifelong learning. The collection and analysis of online learning data can promptly help teachers to improve their teaching content, and assist students to adjust their learning plans and methods. In addition, MOOC supports learners' communities on social networking platforms, which can stimulate their learning interests and thus enhance learning qualities [4]. Recently, MOOC course certificates have been recognized by major universities and societies, making participants more willing to learn. Coupled with the development and widespread use of MOOC, particularly during the time of the pandemic [5], online education using the latest technologies becomes a necessity.

MOOC does, however, have obvious limitations in comparison with traditional classroom teaching. First, it lacks a sense of immersion in traditional classrooms. The emotional connection between teachers and students is missing, and the effect of embodied cognition is weakened [6]. Second, less than 10% of MOOC students may persist in completing the course learning, and the learning effect is not productive. Typical MOOC courses are organized into structured knowledge modules, not fully suited to the cultivation of embodied cognition and higher-order thinking [7]. In addition, the usual construction of MOOC environments makes it awkward to support the application of interactive 3D instructional resources. The transmission of instructional information is limited to 2D materials, such as pictures, texts, audios, and videos. Therefore, the current MOOC technology is not suitable for 3D and experiment-oriented training and practice typically seen in traditional, esp. vocational education activities.

Originating from the 1992's science fiction novel Snow Crash by Neal Stephenson, the term metaverse became a "buzzword" after Facebook changes its name to Meta in 2021. Metaverse is a network of 3D virtual worlds that support social connections among its users and allow them to participate in virtual activities like in real life [8]. With the emergence of newer technologies, such as volumetric video, metaverse for education is becoming practically feasible. There have been, however, limited attempts that apply the metaverse technology to MOOC applications [8].

The grand opening of the Hong Kong University of Science and Technology (Guangzhou) on September 1, 2022 marks the beginning of HKUST 2.0. There is an eminent need for a new technology-driven online education platform to be shared by both campuses. Either of the two campuses could be the digital twin of the other such that students on both campuses could participate in courses offered by either campus and enjoy immersive learning experiences.

The above recent changes have motivated us to bring the metaverse technology into MOOC. We propose a new generation of MOOC called MOMC (Massive Open Metaverse Course). MOMC would provide an online education mode in which anyone from anywhere could operate their own

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digital twin to enter the virtual space and participate in a learning environment in a truly immersive, intelligent, and embodied fashion. It should also carry temporal and spatial information in its courseware, fully integrated with lecturing, homework, and assessment facility of existing MOOC. The metaverse capabilities should be able to meet the needs of all types of practical training and practice with an embodied and immersive learning experience. Furthermore, depending on the development platform, MOMC may use different scripting languages to automatically drive all 2D and 3D instructional resources to be delivered on a given instructional mode and logic. It allows all participants, including instructors and learners, to freely interact with these resources.

This paper presents a conceptual framework and key components of MOMC, and our recent work in developing the world's first true MOMC environment and courseware at HKUST(GZ). The paper contributes to the knowledge of education technology in the following aspects by presenting:

- The concept of massive open metaverse course (MOMC) that encompasses metaverse technology in the traditional MOOC settings. Specifically, VR/AR capabilities could potentially facilitate MOOCs to increase their retention power that is currently lacking.
- Our methodology in developing a new MOMC environment and demonstration courseware.
- The latest cutting-edge technology of volumetric video (VV) and its natural application in MOMC and immersive education and learning. All digital humans are realistic captures with natural movements viewable in 6DoF.

The remaining part of the paper is organized as follows. Section II reviews prior work related to MOOC, VR/AR, and metaverse for education. Section III briefly reviews MOOC and metaverse and presents our vision of their integrated educational environment into MOMC. Section IV introduces the volumetric video technology. Section V presents a detailed case study of developing a complete MOMC, followed by our discussion, conclusions, and future work in Sections VI and VII.

II. Related Work

As a new form of online education, Massive Open Online Courses (MOOCs) allow learners from anywhere in the world, at any time, with any level of educational background to enjoy online education experience provided by top universities in the world. Much research on learners' experiences has been conducted ever since its birth in 2012. For example, Nanda et al. [9] surveyed learners of 810 MOOC courses with three questions about their learning experiences and analyzed 150 000 open-ended responses. Their results reveal seven factors that could significantly influence the learning experiences, some of which appear to be obvious, such as the quality of course content and quality of assessment and feedback, and usability of the platform. Ip et al. [10] also designed and evaluated their methodologies for delivering immersive learning experiences to MOOC learners via multiple media. By extracting language and discourse features from learners' discussion posts, Atapattu et al. [11] use machine learning models to learn and analyze and classify students' confusion status during their MOOC studies.

Researchers also attempt to predict learners' behaviors and learning outcomes within MOOC environments, which are comprehensively surveyed by Moreno-Marcos et al. [12] The authors aim to identify the characteristics of the MOOCs that could be used for prediction, classify the prediction features, and identify the metrics for evaluating predictive models, apart from other objectives. Their review reveals a strong interest in predicting dropouts in MOOCs. Pérez-Álvarez et al. [13] developed a Web-based tool that supports learners' self-regulation in MOOCs. They used their tool to perform an evaluation with 263 learners on two MOOC courses to discover how self-regulated learning strategies correlate with course engagement. Their results indicate a positive correlation between learners' final grades with goal setting and organization.

In MOOC environments, discussion forums have been widely used for communication and discussion. Investigating the interactions and participation behavior in such an environment becomes a hot topic recently. Almatrafi and Johri [1] review 84 papers on discussion forums published between 2013–2017 and suggest future directions from two perspectives: descriptive analysis and content analysis. None of the aforementioned approaches and systems, however, use immersive techniques for users to learn detail-oriented skills in a MOOC setting.

Billert et al. [14] develop a 360-degree learning system within a realistic-looking environment to address the problems in microlearning. They claim to have overcome the lack of design knowledge that would support the motivation and performance of employees using such systems. With a workshop-like approach through interviews, concept maps, and video analysis, the authors evaluate the motivation and performance of precision mechanics in an inter-company vocational training center. Using such a 360-degree learning system does indeed produce a positive effect on learning outcomes and motivation, as shown by their experimental results. The authors present guidelines for developing interactive 360-degree learning environments, which could potentially be useful for MOMC development.

Kim et al. [15] has demonstrated a VR installation for a chemistry experiment in a MOOC setting. Researchers find the positive effects of visualizing peer students' appearances as virtual avatars or virtualized online learners in VR learning environments [16], [17]. Liao et al. [18] develop virtual classmates in a VR-supported MOOC environment with the number of participants and their behaviors. They synthesize the participants' messages with time-anchored comments to enable virtual communication. All those VR environments would need each learner to wear a VR head-mounted display (HMD). Although the benefits of using VR technologies for educational purposes have been confirmed [19] and much of the experiences analyzed [20], such an HMD VR system would only be useful for learning skills needed in an immersive setting [21]. HMD causing viewer sickness has been widely reported and thus imposes needs for appropriate motion design tasks [2].

Having reviewed 379 papers on virtual reality used in education, Kavanagh et al. [22] report major problems in adopting VR for education, including software usability as the number one problem, realism as another major issue, and costs in deployment. MacCallum and Parsons [23] find that for both experienced and unexperienced teachers, providing content is more important than helping students to learn in AR environments. Therefore, professional development of content is needed in realizing AR's potential for education.

Volumetric video is a new technique that captures a three-dimensional space, such as a location or performance. This type of volumegraphy acquires data that can be viewed on flat screens as well as using 3D displays and VR HMD. The viewer generally experiences the result in a real-time engine and has direct input in exploring the generated volume, which is realistic looking. O'dwyer et al. [24] report volumetric video in applications for museological narratives. Zerman et al. [25] present a case study on using volumetric video in augmented reality for cultural heritage. Pietroszek and Eckhardt [26] demonstrate that volumetric video can be used to create immersive stories that sometimes reflect aspects of reality better than realistic 3D models.

Creating immersive stories could potentially enhance the efficiency of learning. Hackett et al. [27] and Regenbrecht et al. [28] elaborate that volumetric videos are relevant in all scenarios where traditional 2D videos are used today, e.g. music and entertaining dramatic performance, gaming, people and celebrities, sports, comedy, film and animation, science and technology, and even pets and animals. None of these works, however, have integrated volumetric video technology into a metaverse environment for online education.

In summary, the current VR/AR, volumetric video, and metaverse provide ideal enabling technologies for effective MOOC education and training. There has been, however, no ready-made MOOC courseware that integrates volumetric video in a true metaverse environment involving immersive educational experiences.

III. MOMC: MOOC WITH METAVERSE

A. From MOOC to MOMC

Early MOOCs could be regarded as integrated platforms of multimedia instructional resources, such as video, audio, picture, text, flash plane animation, etc. These course materials are put together according to specific course themes so that learners are not restricted by time and space, and could learn according to their own needs.

Due to recent changes in teaching needs and the rapid development of technology, MOOC has gradually evolved from a multimedia aggregation platform to a rich media application. The specific manifestation of this change is that multimedia instructional resources are connected with students in a systematic, logical, evaluative, and communicative manner through interactive technologies and functions. Given the concept and technical composition of MOOC, it is difficult to overcome the aforementioned limitations of MOOC.

It is, therefore, time to integrate MOOC with newer digital technology innovations. We propose MOMC as an integral form of Metaverse and MOOC, enabled by the latest VR/AR technologies with the three-layered architecture of virtual world, interaction, and physical world [29]. Illustrated in Fig. 1, the MOMC framework is enhanced from MOOC with new VR/AR/XR Metaverse technological support (gray shadowed parts). The diagram is adapted from the classification of MOOC criteria [30] by adding the Metaverse-related support for an immersive learning experience. A MOMC course would therefore include content created by the latest metaverse technologies, such as volumetric video, and viewed immersively. For example, the entire lecture with student virtual participation and interaction would be recorded as video, as well as the traditional way of content recording. Student homework could include VR/AR/XR demonstrations to be viewed and graded using various devices. Simple homework could be graded automatically by an AI system. A MOMC educational environment moves online education forward in the following three aspects.

B. Enhancing the Dimension of Information

Compared with traditional MOOC, the most significant transformation of MOMC is the change from Online in MOOC to Metaverse. This change represents an enrichment of information dimension, that is, moving from purely two-dimensional information to three-dimensional spatial information with a strong sense of immersion. The current mainstream of MOOC realizes the interaction and communication between learners and between learners and instructors in the form of two-dimensional information flow.

MOMC offers a native environment for creating a three-dimensional space in the form of Metaverse. Apart from the traditional two-dimensional information including user interface, video contents, and social tools, it contains a 3D spatial data model, perceived via multiple interactive modes to gain a truly immersive experience beyond reality. The metaverse technology with various 3D demonstrations of lecture contents supports cultural diversity and overcomes the language barrier. Learners could also use all sorts of desktop and mobile devices to study. This type of multi-model interaction in 3D would further promote learners' knowledge internalization, exploration, and application capacities. These features are not well supported in traditional MOOC environments.

C. Constructing the Embodied Cognition in Learning

Only by participating in classroom learning and experiencing the knowledge, particularly acting with an immersive physical body, can embodied cognition be enabled and students' cognitive sense be enhanced [31]. In a classroom in the real world, teachers can create a learning environment for students under certain physical conditions, such as training bases or laboratories, etc. MOOC platforms are, however, restricted by 2D forms and technologies, and teaching is often disembodied, ignoring the role of sensory experience and environment in learning. Its central task in the training process is to improve mental skills, while the body is placed in the peripheral position, losing the connection between the mental states in the learning process and the body [32]. This teaching

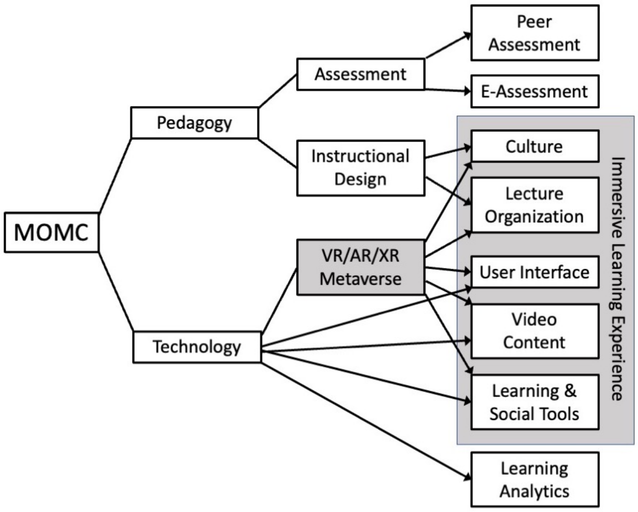

Fig. 1. MOMC framework with enhancements (in gray shadow) from MOOC.

mechanism leads learners to ignore the generative role of body participation in the construction of knowledge structure and its relations with the outside world. As the result, the dualism of teaching concepts (body and spirit) becomes the dilemma countering the traditional cognitive science theory.

Naturally integrated with three-dimensional virtual and real spaces in Metaverse, MOMC offers an embodied learning environment containing ample three-dimension stereoscopic vision according to the subject characteristics. Students could integrate digital twins into the three-dimensional learning environment [33]. Students could thus interact with each other, cultivating their knowledge cognition, construction, and higher-order thinking abilities in an exploratory, task- and experiment-oriented manner.

D. Realizing the Teaching of Humanism

Humanistic learning theory pursues the combination of cognition and emotion, and strives to highlight the role of emotion in teaching activities. It advocates a teaching model that coordinates cognition and emotion and makes emotion as the driving force of all teaching activities [34]. Unlike traditional MOOC, MOMC utilizes the technical composition of Metaverse to create an exclusive 3D digital twin for every teacher and student, highlighting the sociality and participation of teachers and students. It can therefore organically combine emotion and cognition, such that each digital twin participating in the learning becomes an "integrated person".

Humanism encourages collaborative learning, including collaboration between students, and also between teachers and students [35]. It promotes the exchange and sharing of learning information, more importantly, the expression of body language and the communication of ideas, the "collision" of the soul, and the "run-in" of the character. Students' capacity for communication and independent learning is thus cultivated [36]. The digital twins of teachers and students live in the same 3D stereoscopic space and cooperate to complete their learning tasks. The behavior, language, body movements, expressions, and other multi-modal data of teachers and students could be linked to their digital twins, thus enhancing the emotional interaction between the participants. It could make a profound learning impact, improving the learners' agile capability in adapting to any changes in the real scene.

IV. Volumetric Video and MiaoDa

As one of the latest technologies, volumetric video is the key to the realistic rendering of 3D activities in a wide range of metaverse applications, as briefly introduced below.

A. Volumetric Video

Volumetric Video, also known as free-view video [37], is one of the most efficient techniques in producing dynamic 3D human assets. Captured in a studio with up to 100 cameras and reconstructed by multiview photogrammetry (Figs. 2 and 3), the resulting textured mesh sequence can express the fine geometry and texture details of a person. Compared to the traditional avatars constructed using computer graphics, instructors captured by a volumetric video are more vivid in a metaverse course. Serious or moderate, the emotions carried out by facial expressions and gestures play an important role in attracting learners' attention.

B. MiaoDa

We introduce a metaverse education platform, MiaoDa [38], which supports cutting-edge XR, AI and volumetric video technologies and provides an ideal development platform with intelligent and digital twin construction mechanisms for MOMC. It integrates all the MOOC education features, including an online selection of courses, time, virtual classrooms, and seats, as well as course content development, modulation, group study, assessment, and grading, etc. Within MiaoDa, users could control their digital twins freely to participate in teaching, and practical training, not constrained by time and space. All the available portable devices are supported for end users. MiaoDa also enables online multimedia interaction, such as text and voice messages, with all the functionality of social networking for MOMC users.

The above are just a couple of examples. Volumetric video could be widely used in video games, virtual reality, metaverse social platforms, digital twin factories, and digital cities, wherever the virtual world involves realistic-looking actors, such as dancers, singing celebrities, and even pandas and penguins.

V. A Case Study: MOMC Construction of the President's First Lecture

The grand opening of the Hong Kong University of Science and Technology (Guangzhou) on September 1, 2022 attracted nationwide news coverage. HKUST(GZ) is the realization of this ambition to transform education for the future, with its cross-disciplinary academic structure designed to complement the well-established disciplinary foundation at the Hong Kong campus. Many courses are offered to students of both campuses, and thus ideally delivered in a Metaverse environment.

Fig. 2. The volumetric video capture studio with a camera array.

Fig. 3. An infrared image used in multiview photogrammetry.

A. *President's First Lecture*

On the first day of opening the new HKUST(GZ) campus, apart from the opening speech, President Lionel M. Ni delivered the "First Lecture of the Semester" to the very first class of MPhil and PhD students and invited external guests. The president's first lecture is a well-designed and highly interactive course based on the motto of FUSION, CREATION, and ENVISION, well suited to a MOMC realization. This section presents how the First Lecture is developed as the world's first MOMC with various innovative and never-seen-before features.

The first lecture is supposed to introduce the new campus' academic structure emphasizing interdisciplinary schools that are called "Hubs" and departments that are called "Thrusts." The president takes one demonstration example of Dunhuang from the Computational Media and Arts Thrust of the Information Hub and another of aero turbofan from the Smart Manufacturing Thrust of the System Hub. The two demonstration examples serve as the killer applications of metaverse within a MOMC environment.

Fig. 4. The digital twin of a lecture hall in HKUST(GZ).

Fig. 5. The digital twin of a lecturer in a lecture hall at HKUST(GZ).

B. *Modeling of HKUST(GZ) and Lecture Hall*

Taking a lecture hall of HKUST(GZ) as a reference, a digital three-dimension stereoscopic space (6 degrees of freedom) of lecture theatre is established, as shown in Fig. 4. This space allows the digital twins of lecturers and students to enter and freely enjoy interactive activities. A 3-dimensional model of the classroom's digital twin allows all types of 2-dimensional multimedia contents to be displayed or projected on the walls and floor areas.. In the event of social distance required due to the pandemic, we may deploy a method for detecting participants and their distances [39].

C. *Digitizing the Lecturer*

The digital twin of a lecturer is created using volumetric video. The body movements and expressions of the digital twin are correspondingly changed according to the speech contents through voice-driven technology.

We capture the footage of the lecturer of two types, i.e., real speaking footage and casual chatting loops. The first type is the real presentation of the course for the entire duration, including the opening speech and the explanation of key points. This type of footage is directly played back during the course,

Fig. 6. The captured frame (left), detected key points (middle), and fitted SMPLX (right).

Fig. 7. The volumetric video of a Dunhuang apsara dancing in Cave 285 of the Mogao Caves.

making sure the key points of the course are well conveyed to the audience.

The second type is casual motion loops, starting from an idle pose of the lecturer, turning into talking and casual gestures, and ending with the idle pose (Fig. 5). This type of footage can be called by scripts to mimic continuous motions to cover long-duration lectures.

Interaction with computer graphics-generated objects is one of the important extensions for volumetric video footage. We apply 2D pose detections [40] on multiview images and fusion into 3D in the RANSAC manner. The fused 3D skeleton key points can be used to fit a predefined human model, called SMPLX, to provide meaningful human body motions, including fine finger gestures. Fig. 6 demonstrates the 2D, 3D, and SMPLX fit for pose estimation results.

D. Digitizing the Courseware

Apart from the lecturer, volumetric video can also produce assets for teaching materials, particularly effective for human motion demonstration. We could capture a variety of course materials, such as dancing, Kung-fu, or even the Heimlich maneuver to show the details of body motions.

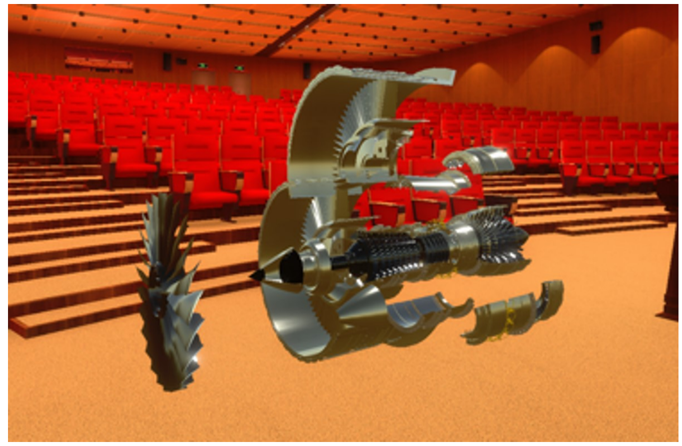

Fig. 8. The digital twin of an aero turbofan.

Fig. 9. A student using a virtual reality headset to pariticpate in MOMC.

As one of the research areas of the Computational Media and Arts Thrust at HKUST(GZ), the cultural heritage of ancient Chinese arts could be vividly demonstrated using the new immersive technologies. We choose the Mogao Caves in Dunhuang as our showcase example.

To best reflect the embodiment of the immersed learning of ancient Dunhuang art, we specifically create the digital twin space (6 degrees of freedom) of Cave 285. To further inspire the students to imagine and appreciate the original scene inside the cave, we use a volumetric video to construct a dynamic dancing performance of a Dunhuang apsara (Fig. 7). This type of virtual and immersive learning resource is one of the key elements of MOMC.

Next, an aero turbofan from the Smart Manufacturing Thrust at HKUST(GZ) is demonstrated with fine details for students to view at a close distance via their digital twins Fig. 8). This type of three-dimensional instructional resource is constructed by computer graphics techniques. The three-dimensional model of an aero turbofan is designed for this course. The lecturer and students could observe and interact with the 3D model from any desired perspective by controlling their own digital twins. For example, they can observe the dynamic working state and even disassemble the main components of the aero turbofan.

Fig. 10. A student using a laptop to pariticpate in MOMC.

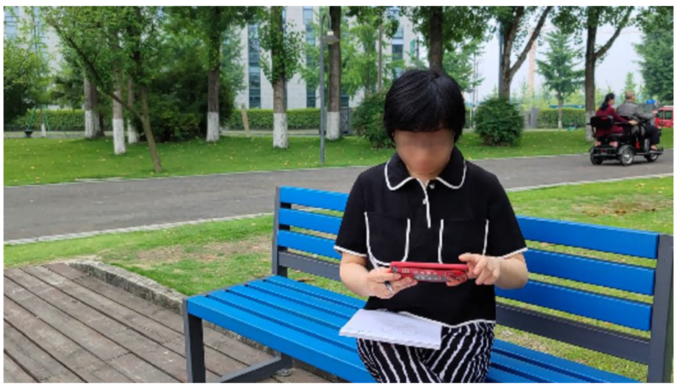

Fig. 11. A student using her smartphone to pariticpate in MOMC.

E. Immersive Experiences in MOMC from Anywhere

Integrating the three-dimensional digital twins of the lecture hall, lecturer, Dunhuang apsara, aero turbofan, etc. with the traditional two-dimensional instructional resources in a systematic instructional flow, we have developed the world's first MOMC.

Similar to the traditional MOOC, once MOMC is deployed, it supports teachers and students around the world to use multiple devices and terminals simultaneously to participate in the immersive learning environment. They could participate from different locations at different times. True immersive experiences could be gained using virtual reality headsets, as shown in Fig. 9. Other devices, such as personal computers (Fig. 10), smartphones (Fig. 11), etc. could be used by the same or different participants. A student could even learn live bodily actions easily via mobile augmented reality [41], as shown in Fig. 12.

In addition, each student participating in MOMC is allowed to control the personal digital twin through their personal device and is then able to observe, recognize, and learn from any free perspective (6 degrees of freedom) as demonstrated in Fig. 13. The digital twins are pre-produced using computer graphics or volumetric video techniques, in a similar fashion as digitizing the lecturer discussed in Subsection C. The digital twins of students could walk into the grotto to watch the apsara dancing, and could easily walk close to the wall to view the beautiful cave drawings of over 1000 years of age (Fig. 14).

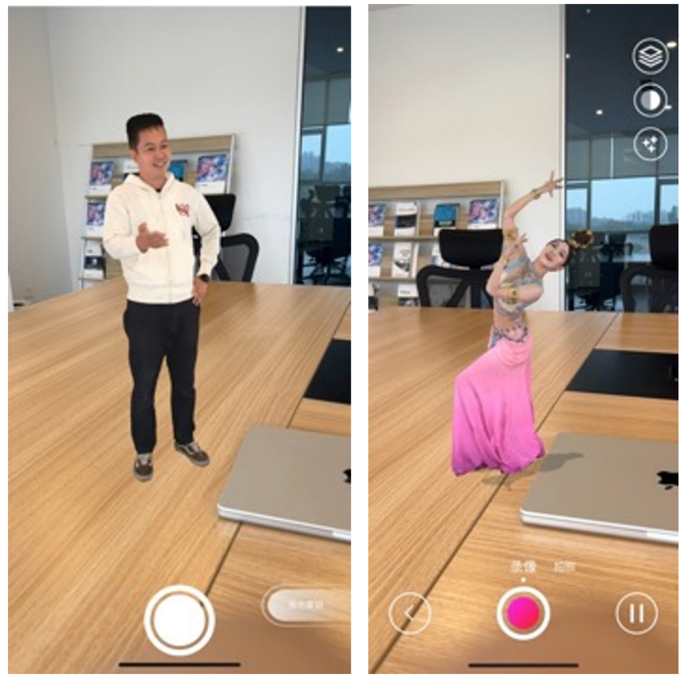

Fig. 12. Bodily actions via mobile augmented reality in MOMC.

Fig. 13. Three students using different terminal devices to control their own digital twins in MOMC.

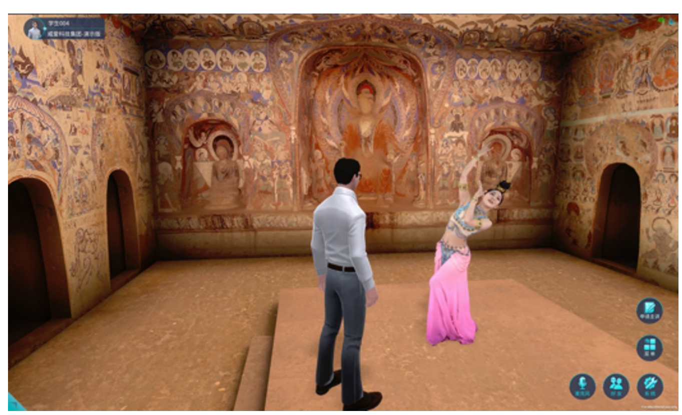

Fig. 14. The digital twin of a student walking into Cave 285.

VI. User Study and Discussion

A. A Preliminary User Study

We have conducted a preliminary user study to evaluate whether our prototypical MOMC system does improve over the traditional MOOC.

We invited a total of 14 MPhil and PhD students, aged between 23 and 34, to participate in our user study. The students have diverse educational backgrounds, including social science, art and design, computer science, vehicle engineering, and architecture, etc., most of whom have used the traditional MOOC. We gave them a live demo while inviting some of them to use different devices, i.e., a VR headset, a smartphone, and a laptop computer, as shown in Figure 15. After 20 minutes of participation, the students were asked to answer the following questionnaire and give feedback comments if they wish.

Q1 Have you used a traditional MOOC before?
Q2 Do you think MOMC (Metaverse MOOC) has advantages over traditional MOOC?
Q3 Will you be interested in learning inside a MOMC environment?

For Q1, 11 answered YES and 3 NO. For both Q2 and Q3, all 14 students answered YES. Apart from these results, we received valuable feedback comments, including "*The improved sense of immersion and embodiment is beneficial for learning. For example, when learning a foreign language and culture, the environment is very helpful.*" "*Preset scripts may be added for the demo models.*" "*I like very much the all-angle viewing capability and easy switch between different scenes, which significantly improved the immersive experience.*" Several commented, "*It would be nice to support interaction with the virtual objects.*" "*Participating avatars could be made more realistic.*" "*I feel it is highly usable, and some knowledge could be made in a 3D demo, enhancing the understanding. The teacher's control of the pace is a good feature. Long-time participation may cause discomfort and texture could be finer and more real.*"

In addition, during guests' visits to our new campus, we gave MOMC demos to some of the visitors and received very positive feedback. Of course, we will need to conduct a full and more systematic user study to evaluate the complete MOMC system in the near future, incorporating the improvements suggested above.

B. MOOC and 3D Virtual Learning Platforms

We then analyze the inherent problems of MOOC and existing 3D virtual learning platforms, such as Second Life, Eduverse, and Horizon Worlds, and the advantages as well as limitations of MOMC. Other issues, such as privacy and data analytics, are also discussed in the context of 3D metaverse environments and platforms. As mentioned earlier, MOOC has the following inherent problems:

- Infrastructure costs: The application of MOOC needs much infrastructure, including hardware and software construction, and thus the construction costs [42].
- Students' learning autonomy and self-discipline: As the form and content of courses become more convenient, students have so much freedom that they could get lost on where to start learning, what to learn, how to get help from online resources, teachers and classmates, resulting on mass dropouts [43]. The lack of interpersonal interaction apparently has negative impacts on learning.

Fig. 15. A scene of the preliminary user study.

Several 3D virtual platforms for education have been available recently [44]. Such environments have a strong sense of presence, promoting effective learning. Online interaction helps shorten the distance between teachers and students, students and their peers, and stimulate the students' motivation [45]. The underlying technical logic of MOMC is similar to other metaverse platforms, such as Second Life [46], Eduverse, Active Worlds, and Horizon Worlds, which are all 3D virtual platforms [47], but have the following limitations [48]:

- Unrealistic and inflexible characters and avatars lead to a weak sense of presence and immersion in teaching;
- Weak interaction between teachers and students in the learning community and environment, resulting in the low completion of students' online learning and the phenomenon of mass dropouts;
- Most 3D virtual learning environments create merely a 3D space, rather than fully supporting a realistic demonstration. It is also hard for them to manage and record the learning process and track and aggregate course contents.
- Research on user privacy in MOOC reveals that as more and more universities participate in and build their own MOOC, there are no specific measures and implementable plans to protect the privacy of online learning users [49].

Therefore, some of the aforementioned platforms have been losing users. In addition, other general issues need to be addressed for all existing platforms, including:

- High autonomy of courseware creation in virtual environments causes the loss of control by teachers and students [50]. As a result, original teaching objectives are compromised.
- The privacy issues and leakage of user data during the learning process have not been properly addressed by the aforementioned platforms.

- The misalignment of technical support and education entities could result in issues, such as unclear rights and responsibilities between universities and platform builders.

C. Advantages and Limitations of MOMC

Inheriting the diversity and flexibility of the traditional MOOC, MOMC based on the MiaoDa metaverse education platform combines virtual reality, volumetric video, AIGC, and other cutting-edge technologies. It integrates the teaching needs with an embodied mixed-reality learning environment. Compared with the aforementioned 3D metaverse platforms, MOMC offers significant advantages in supporting teaching in the following aspects:

1) Strong sense of presence to promote both physical and virtual interactions: 3D virtual environments and digital twins of teachers and students (by volumetric video technology) provide a realistic sense of immersion for teaching content and participants. Through a personal computer, mobile phone, virtual reality headset, or other devices, students enter MOMC either physically or virtually by their avatars, allowing intimate interaction between teachers and students. MOMC offers each participant individuality and tailors the teaching objectives and contents accordingly. Students become masters of learning, and teachers update their own knowledge through the teaching process. Meanwhile, students form a learning community with other learners on MiaoDa-enabled social networking to accomplish collaborative learning.

2) Organic combination of high-quality educational resources and cutting-edge technologies: Customized creation of virtual environments could be oriented to different teaching objectives. Teaching and learning entities (e.g., universities) and corporate entities could jointly build and optimize MOMC platforms. The former is responsible for providing courses, while the latter is for providing technical support. They jointly develop professional teaching content, thereby overcoming the problem raised by MacCallum and Parsons [23]. The deployment of proprietary servers for universities can facilitate big data analytics for student learning behavior, and provide personalized adaptive learning advice accordingly.

3) Privacy protection for online users: Users' search and browsing habits, learning characteristics, educational background, and location information allow big data analytics to provide personalized services for users as well as for marketing, the key to privacy protection and prevention of third-party information theft [51]. The deployment of proprietary servers could also effectively prevent the leaking of privacy data, loss of online records, theft of intellectual property, and other platform issues. MOMC embraces both the characteristics of metaverse education and online user privacy protection during the three stages of data analytics (i.e., data collection, data analysis, and data interpretation).

4) Major Limitations: The MOMC approach is our first attempt in extending MOOC with metaverse capabilities, in particular, by the latest technology, such as volumetric video and AI. As a key enabler of MOMC, volumetric video's advantage is its photorealism with smooth actions, but it is currently unable to support interaction and modification of the shot video. High-quality and realistic course contents have to be created within the volumetric video shooting studio and processed professionally, which is costly and involves a steep learning curve.

Although improved from the traditional MOOC interaction mode, students interact with teachers and their peers via their avatars in the virtual space, lacking true intimacy and eye contact. Emotional expression and interaction still need major improvements.

VII. Conclusions and Future Work

This paper has presented our vision and conceptual framework of MOMC, which integrates the latest metaverse technology into a MOOC environment. In particular, volumetric videos become a major enabler for the realistic and immersive educational metaverse. This paper contributes to the relevant literature by demonstrating how such new technology could be used to empower MOMC educational environments and thus enhance learning experiences. We envisage that MOMC would replace MOOC to become a new concept for the forthcoming wave of metaverse-driven online education.

As a case study, we present our recent effort of developing the President's First Lecture at HKUST(GZ) and its major functional components using MiaoDa. Some of the components are digitized using the most up-to-date volumetric video technology. We believe that it is the first full-fledged true metaverse-driven type of MOOC, which is extendable for any new content. The MOMC environment itself would serve as a general and fully extendable platform for developing any type of course content.

Future work includes more integrated approaches to creating the development of MOMC courseware easier and perhaps in a streamlined fashion. The fast-evolving AI technology and the emergence of new platforms enabling 3D reconstruction and modeling technologies would empower MOMC even further. Meanwhile, new approaches to developing more learner-friendly and realistic immersive learning environments become a necessity.

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