Machine Learning for Educational Metaverse: How Far Are We?

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***Abstract*—The concept of metaverse is becoming pervasive and promises to revolutionize the way people will interact among each other in a sustainable manner. The educational context seems to represent an ideal use case, as the metaverse may provide a digital environment empowered by analytical instruments able to monitor social and psychological needs of students, other than lowering the entry barriers of students with disabilities. Machine learning will represent a key component of such a new consumer technology, yet little is known about its adoption within an educational metaverse. This paper overviews the current state of the art and provides a discussion about its suitability, in an effort of highlighting future research avenues and challenges.**

***Index Terms*—Consumer Technology for Metaverse; Education; Machine Learning; Deep Learning.**

I. Introduction

Consumer technology refers to the definition of any kind of novel technology usable by a large variety of users [1]. While several notable advances have been proposed in the last decades, one of the next frontiers is represented by the use of *Metaverse*. In particular, the concept of metaverse builds upon the idea of having a persistent, online 3D universe where people from all around the world can interact, socialize, and work toward common goals. Major companies, e.g., META believe that the metaverse will be the largest technological revolution since the advent of the Internet and, for this reason, they are investing billion dollars on the creation of instruments that can effectively enable the metaverse.

The advances done in research fields like virtual/augmented reality, software engineering, and artificial intelligence, the availability of computational resources, along with the rise of social distancing due to the COVID19 pandemic have further accelerated the technological transition, especially in contexts where people need to develop their own skills and personalities through learning, engagement, and socialization [2].

Education represents a *unique* use case because today's students are digital natives, having new attitudes toward the learning process, different learning styles, and higher expectations for teaching and learning [3]. For this reason, the metaverse would not limit itself to the presentation of an exact digital replication of the surrounding educational world, but would also empower it under multiple perspectives, providing novel learning instruments enabled by the digital environment, social and psychological monitoring systems based on student's activities and, perhaps more importantly, lowering the architectural barriers for students with disabilities. In addition, metaverse may potentially help mitigating logistic issues and reducing didactic costs, hence positively contributing to environmental and economic sustainability.

Despite these promises, little is known on the development of new consumer technologies for education metaverses. Machine learning techniques will represent a key component, as these may enable online participation of students, other than increasing user engagement and experience.

In this paper, we aim at conducting the first step toward the definition of new machine learning techniques for educational metaverses. We first overview the current research on the matter and then discuss about limitations and further research opportunities to build an effective education metaverse.

II. Machine Learning in Educational Metaverse

The metaverse can build secure, scalable and realistic virtual worlds on a reliable and always-on platform by combining AI with other technologies such as AR/VR, blockchain and networking. Several **Machine Learning** (ML) and **Deep Learning** (DL) algorithms have been implemented from two perspectives. The first relates to the metaverse infrastructure, which includes the use of ML techniques in 5G systems and upcoming 6G systems to handle a variety of difficult tasks, including automatic resource allocation, traffic offloading, attack prevention, and network failure detection. The second concerns the human-relational perspective, in which simple human movements and complex actions can be analyzed and recognized using wearable technology based on sensors and other devices. As a result, users' physical movements are translated into actions in virtual worlds, giving them complete control over how their avatars interact with other objects in the metaverse. In addition, these avatars can interact with a variety of real-world modalities, including speech recognition and emotional analysis, which are supported by artificial intelligence in terms of accuracy and processing speed. These modalities include facial expressions, emotions, body movements, and physical interactions. The state of the art related to machine learning and deep learning highlights some methodologies that can be included within the metaverse. In fact, Huynh-The et al. [4] have considered the main technical aspects and algorithms of ML and DL and how they improve user experience in the virtual world, by highlighting two approaches: Machine Vision and Neural Interfaces.

Machine vision is a technology that allows machines to visually understand their surroundings by using one or more vision sensors in combination with application-specific software. While machine vision itself can solve a number of problems in many engineering fields, it is often used in combination with machine learning methods to make manufacturing smarts. In fact, the raw data perceived from visual environments may be captured and processed to infer higher-level information, which can be then displayed to users via head-mounted devices or any other smart devices.

The neural interface aims to further reduce the gap between physical and digital worlds. In fact, virtual reality employs some physical devices (e.g., keyboards, mouse, headsets, visor controllers) as devices to control the virtual world. Through the use of neural interfaces and machine learning algorithms, it is possible to increasingly reduce the adoption of physical devices and have direct contact through neural impulses *a.k.a. Brain Machine Interfaces* (BMI). Many BMIs use external electrodes or optical sensors that are attached to the skull and other parts of the human body to detect neural signals. BMIs can manipulate thoughts with transcranial electromagnetic pulses, exploiting these noninvasive devices which can only read and control minds on a rudimentary level.

III. Limitations and Research Opportunities

ML and Metaverse: The Technical Side. Current machine and deep learning approaches are not tailored on the dynamics of the metaverse. This aspect makes their employment within an educational metaverse a critical challenge to address. While machine vision offers a great potential, researchers should further analyze the way it can be as effective as possible in the context of a metaverse. Indeed, the specific environmental conditions characterizing the educational context, e.g., the continuous interaction between teachers and students and among students, represent novel perspectives that should be taken into account when defining novel machine vision instruments that may support those new conditions. In this sense, we envision new empirical investigations into the needs that should be fulfilled by machine vision approaches applied to the metaverse, other than the definition of new techniques tailored on those needs. Furthermore, the access to the metaverse is typically allowed through neural interfaces, which are known to produce negative physical effects in certain circumstances. For instance, VR/MR headsets can cause headaches and eye strain is worn for an extended period of time. Previous literature has already attempted to mitigate these effects: as a matter of fact, various machine learning algorithms have been employed to optimize images so that the sense of visual fatigue is reduced. Nonetheless, the educational context would require the durable use of neural interfaces, e.g., high-school students may need to wear VR/MR headsets for an extended time period on a daily basis. This leads to major challenges for researchers working in the context of neural interfaces, who are called to investigate further this matter and possibly propose alternative interfaces that limits the negative effects that these may have on health.

ML and Metaverse: The Psychological Side. Further challenges relate to psychological concerns. An educational metaverse intrinsically implements the concept of social distancing, possibly enforcing students and teachers to be isolated. This aspect may lead to psychological issues, including depression, as we witnessed too often in the news during the pandemic. On the one hand, this perspective cannot be ignored by machine learning experts: novel neural interface and machine vision techniques should be devised and assessed to take their impact on psychological properties into account: for instance, we envision notable advances in the field of emotion recognition, where techniques able to identify psychological stress and depression could be used to alert the teacher or even inform machine vision techniques and allow to adapt themselves to recommend when to take a break. On the other hand, further empirical research is needed to understand the natural limitations of the metaverse, possibly leading to an improved knowledge on when and how to use metaverse for education and when, instead, a physical interaction would be preferred.

ML and Metaverse: The Social Side. Last but not least, it is important to remark that the currently available neural interfaces may be expensive and out of reach for most users. While this mainly pertains to hardware engineers, some considerations can be drawn on the software side as well. First, little is known on which are the best mechanisms to enter the metaverse. Neural interfaces can indeed provide an immersive experience, yet the amount of empirical studies targeting human-computer interaction aspects within the metaverse is still limited. As such, we envision a number of additional work along this line of research in order to define the best instruments and ways to engage with the metaverse. Perhaps more importantly, several factors (e.g., learners' knowledge levels, cognitive styles, preferences, motivations, self-efficacy and regulation, and learning attitudes) could affect the acceptance and performance of a new technology from learners and teachers. In this sense, the metaverse is a brand new concept in education and, for this reason, it requires further empirical research to understand how different learners interact and progress in metaverse-based educational experiences, how they can be continuously advised with immediate personalized feedback, and whether they benefit from metaverse-based experiences.

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