D→K→I: Data-Knowledge-Driven Group Intelligence Framework for Smart Service in Education Metaverse

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***Abstract*—Metaverse is the fusion of cyber–physical–social intelligence, and the fusion becomes the core and fundamental property of the metaverse. As an important part of social operationalization, the education domain leads to the birth of the education metaverse. This article answers three basic questions about smart services in the education metaverse: 1) learning scene; 2) technical framework; and 3) initial expansion. Specifically, four key elements constitute the learning scene in the education metaverse: 1) the learner; 2) its time; 3) space; and 4) learning event. In this learning scene, we propose a novel data-knowledge-driven group intelligence framework, aiming to transform data in the education metaverse into knowledge, and intersect and integrate intelligence with knowledge; based on this framework, we apply it to specific services, i.e., transaction and management services. We hope that our work opens the door to research on smart services in the education metaverse and more scholars will work for these challenges.**

***Index Terms*—Artificial intelligence (AI), data, education metaverse, fusion, knowledge.**

I. Introduction

EDUCATION metaverse is built based on developing cyber–physical–social intelligent technology (CPSI) in cyber–physical–social systems (CPSS) [1], [2], [3], [4], [5], [6], [7], including immersive reality and digital twin [8], [9], [10], [11], [12], [13], and offers a virtual society that is a new space integrating social network, economic transaction, and operational decision making [14], [15], [16], [17], [18], [19], [20], [21].

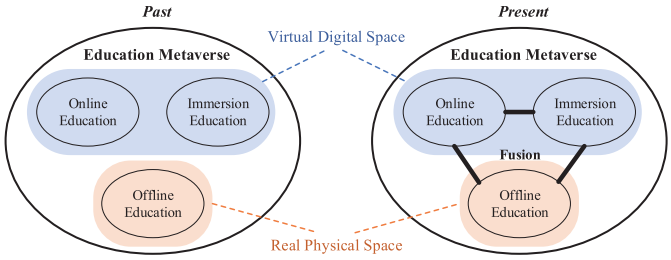

Fig. 1. Past and Present of the education metaverse. Compared with the past status, the education metaverse focuses on the fusion of offline education, online education, and immersion education now.

Education metaverse is broadly divided into three categories as shown in Fig. 1: 1) offline education; 2) online education [22], [23]; and 3) immersion education [24], [25].

1) Offline education (i.e., "face-to-face" education) is an ancient mode of education. It may have originally existed in the teaching practices of tribal priests [26]. Early education could only be enjoyed by the aristocracy [27]. Confucius started the education for the common people in the Spring and Autumn period of China [26]. Johann Pestalozzi pushed for the education of the common people in the 17th century of Europe [28], [29]. Education has been the road to change the lives of common people ever since. Thousands of years of education habits and patterns have made this ancient mode still remain the mainstream of education until now. However, with the advancement of CPSI, offline education highly depends on the physical and economic environment [30], [31].
2) Online education is the fundamental way to access the education metaverse and undertakes to transform traditional offline education. Unlike offline education, there is a contradiction between efficiency and effectiveness: while online education breaks the time and geographical limitations for efficient teaching, it compromises the immersive effect of "face-to-face" between the teacher

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and students in the offline classroom. It has led to many problems with online education, such as the risk of being distracted [32], damage to eyesight [33], and delay in question and answer sessions [34].

3) Immersive education is the primary way to experience the education metaverse. It has landed in many colleges and universities, such as *The Education University of Hong Kong* [35], *Central China Normal University* [36], *Ohio University* [37]. Immersive teaching based on the head-mounted display brings a virtual reality experience to students but also causes some problems, such as poor communication, dizziness, and nausea [38]. It makes students cannot be typically taught.

From the above current status analysis, it is evident that education metaverse should not only combine online education with immersion education and achieve the unity of efficiency and effectiveness but also organically integrate online education with offline education, and the *Key of Education Metaverse is the Fusion* as shown in Fig. 1. To this end, we need a new service framework for the education metaverse. Naturally, we need to tackle the following three questions.

1) What is the learning scene in the education metaverse?
2) What is the service framework for this learning scene?
3) How does this framework fit into specific smart services?

To answer the first question, we analyze the four key elements that constitute the education metaverse: the learner, the time and space in which the learner is located, and the learning event. Further, we dissect the learner's state (i.e., fusion) and its time and space under a particular learning event. The details are presented in Section II.

To answer the second question, we propose a novel data-knowledge-driven group intelligence framework for the learning scene in the education metaverse. It develops new artificial intelligence (AI) technologies to transform data in the education metaverse into knowledge and intersect and integrate intelligence with knowledge. The details are presented in Section III.

To answer the third question, we apply the proposed novel data-knowledge-driven group intelligence framework to specific services, i.e., transaction and management services. The data and information collected by the education metaverse are also far more than other educational services, and we extend the framework to the information security field to protect educational information privacy. The details are presented in Section IV.

Overall, our paper emphasizes the significance of the proposed framework, i.e., data-knowledge-driven group intelligence framework, and suggests this novel methodology for smart services in the education metaverse research. In particular: 1) a structured learning scene containing time, space, learner identity, and learning events is constructed first; 2) Based on the learning scene, a data-knowledge-driven group intelligence framework is designed for the fusion and dynamic interaction of data and knowledge between real and virtual spaces; and 3) based on our novel framework, a dynamic protection mechanism for educational information is presented as one practical application. Our main contribution is that we propose the basic framework of smart services in the education metaverse. To the best of our knowledge, this is the first attempt at the framework based on data-knowledge-driven intelligence to explore smart services in the education metaverse.

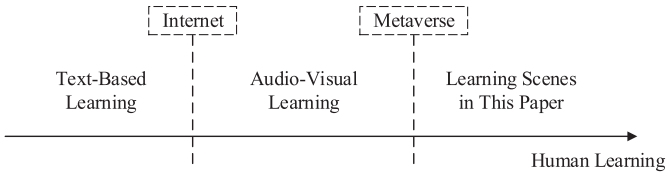

Fig. 2. History of human learning. As information technologies progress, human beings are receiving education in ever-changing manners.

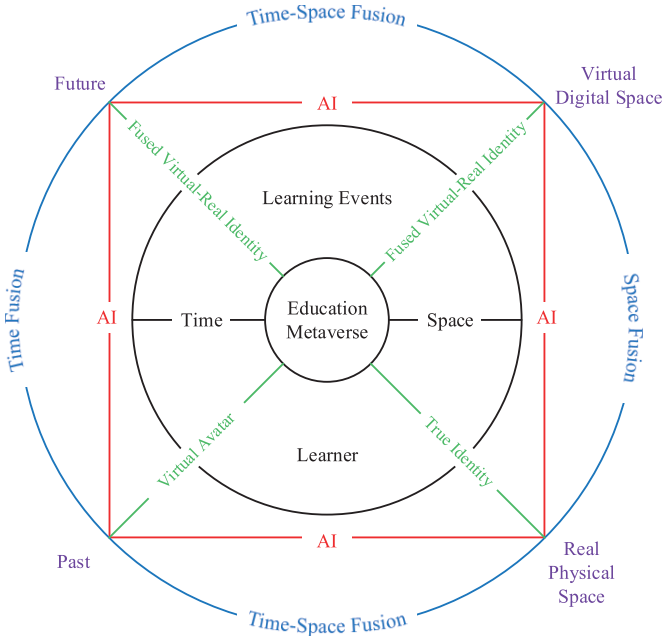

Fig. 3. Fusions in the education metaverse. There are three kinds of fusions: learner identity fusion, learning space fusion, and learning time fusion.

II. Learning Scene in Education Metaverse

The learning scene of education is developing as shown in Fig. 2. Traditional learning content is mainly transmitted by spoken and written language, and human learning relies primarily upon the audio-visual acquisition of their organs [39]. Whether in agricultural societies or the industrial age, the learning process of learners relied on seeing and hearing [40]. Even in the pre-Internet era and the Internet era of the 0th century, the essence of learning still belongs to audio-visual-based learning. However, since the 21st century, when traditional learning evolved into learning in the education metaverse, the multiple feelings of human beings began to be stimulated, mobilized, and engaged comprehensively [41].

In the education metaverse, a virtual-real integration of the learning scene as shown in Fig. 3, consists of four keys: the learner, the time and space in which the learner is located, and the learning event, where the learning event refers to all events in the process of learning, including the operation of the learner's knowledge content acquisition and education metaverse outside the knowledge content, such as various types of sensor debugging and wearing.

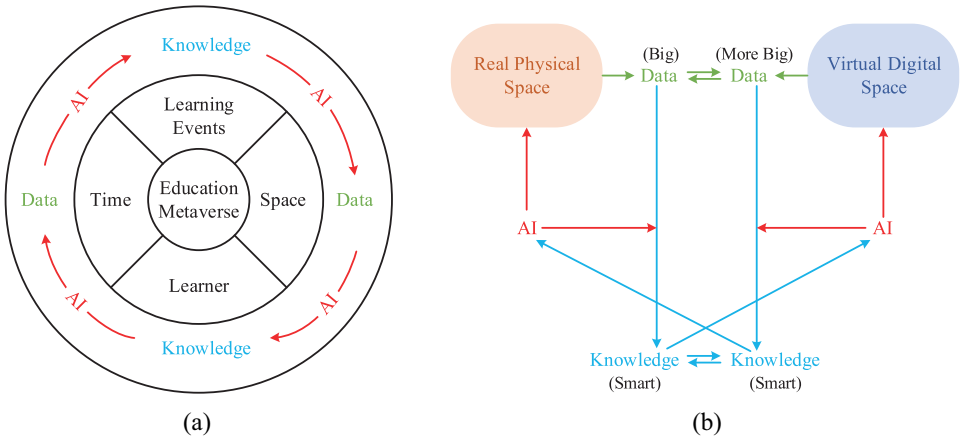

Fig. 4. Data-knowledge driven group intelligence framework. (a) Learning scene this framework addresses. (b) Core of the framework.

In this kind of learning scene, there is a past-future time fusion, a virtual-real space fusion, and a virtual-real learner identity fusion. In other words, learner identity fusion, learning space fusion, and learning time fusion become the unique forms of the learning scene in the education metaverse.

1) *Learner Identity Fusion:* There are two learners' identities in the education metaverse, i.e., true identity and virtual avatar. In this case, the learner "may be me" (the true identity of the learner) or "may not be me" (the virtual avatar of the learner). In other words, the learner must be separated in the education metaverse. These virtual/real identities changes in many ways depending on the scenes between real and virtual spaces. Thus, virtual avatars, true identity, and fused virtual-real identity become the three main manifestations of learner identity in the education metaverse.
2) *Learning Space Fusion:* The education metaverse space constantly changes according to the learner's identities, learning scenes, etc. The education metaverse exists in two forms: a) real physical space and b) virtual digital space. As the learning scene changes, both types of learning space have a variety of variations between reality and digitization.
3) *Learning Time Fusion:* Learning in the education metaverse can seamlessly breakthrough time and connect the past, present, and future. This kind of connection cannot realize in the real world. The basis for this learning time fusion is the logical time integration formed by the virtual avatar of the learner. The present learning time can seamlessly integrate with the logical past and future time. As Albert Einstein once pointed out [42], our understanding of time and all judgments involving time are judgments about simultaneous events. In the real physical world, temporal convergence and coherence are impossible; however, cognitive logic convergence is feasible in virtual conditions.

III. Data-Knowledge Driven Group Intelligence Framework

In the learning scene of the education metaverse, the virtual and real learning activities are composed of the learner, the time, and space where the learner is located, and the learning events. It implies that the education metaverse highlights the fusion, projection, and dynamic interaction between real and virtual learning spaces. In other words, the education metaverse provides a virtual environment beyond the real educational scene based on the reconstruction and self-evolution of real-world data. To achieve this, we propose a novel data-knowledge-driven group intelligence framework.

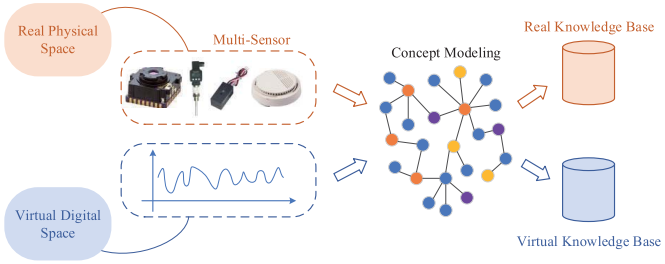

Fig. 5. Data-driven conceptual modeling. The data from the real physical and virtual digital spaces is transformed into knowledge bases by data-driven machine learning.

As shown in Fig. 4, we, first, develop new AI technologies using data arising from the physical and virtual spaces in all past times. In this way, we want to convert big data from the education metaverse into smart knowledge in the education metaverse. Further, we would like to model smart services in the education metaverse and their temporal evolution. Second, we explore methods to combine data, AI models, and knowledge and model the flow between the real physical and virtual digital spaces. Finally, we use AI models to create feedback adjustment of the two spaces and complete the unified interaction between the real physical space and the virtual digital space and complete the unified interaction between two spaces. In general, it is critical to the whole framework to get from data to knowledge, then from knowledge to intelligence, and finally to use intelligence to tune the two spaces. There are three critical steps as follows.

Step 1—From Data to Knowledge (Data-Driven Machine Learning): The education metaverse provides a personalized space for teachers and students. As a result, all is data: from macro to micro, from objective to subjective, from figurative to abstract, and all information is recorded comprehensively.

In this case, we propose the data-driven machine learning process as shown in Fig. 5. In particular, first, we use

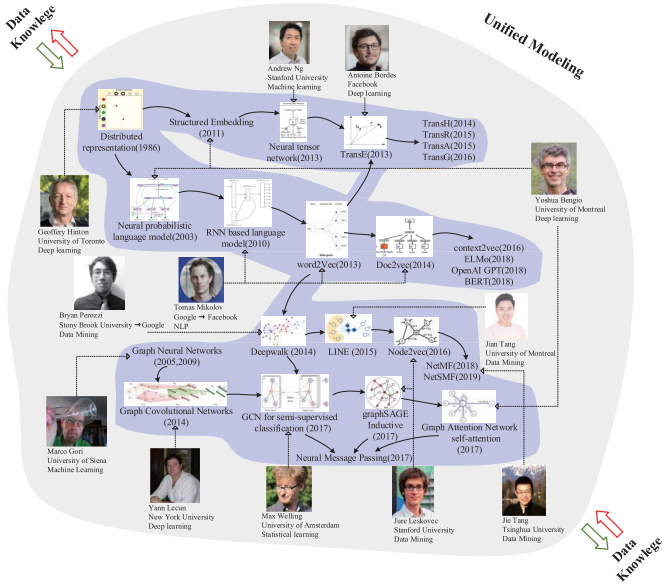

Fig. 6. Knowledge-driven unified modeling. The graph-based models [46] can be a "bridge" among knowledge and data by knowledge-driven machine learning.

multisensor devices to collect information in physical space. At the same time, we use the virtual system from the digital twin to output the corresponding virtual information. The information in both spaces is conceptually modeled for multimodal data to form a multimodal virtual/real knowledge base, respectively. Second, we design the conceptual modeling approach [43] based on a knowledge graph for multimodal data and obtain a high-quality multimodal virtual/real knowledge base. After that, we plan the educational service representation [44] based on the "knowledge triple" from the knowledge graph for implementing the intelligent service analysis technique to capture the characteristics and model dynamics of the two spaces.

Step 2—From Knowledge to Intelligence (Knowledge-Driven Machine Learning): "Knowledge is power." On the one hand, knowledge can guide the training and generalization of AI models so that the performance of AI models can be effectively improved and generalized. On the other hand, the knowledge base can be enhanced when the AI models are trained [45].

To achieve this, we present knowledge-driven machine learning as shown in Fig. 6. Specifically, we model a unified representation of the data and the knowledge base, allowing for autonomous updates between the two. We model the knowledge embedding [47] between the knowledge base and the AI model, driving the AI to perform independent knowledge learning. Further, we design a unified data representation and transformation method [48] based on the generative adversarial model to realize the autonomous generation of the data; design a unified knowledge representation method [46] based on the graph model to learn the autonomous complementation and update of the knowledge base and design a knowledge embedding method based on the attention mechanism to promote the independent learning and update of knowledge and AI models.

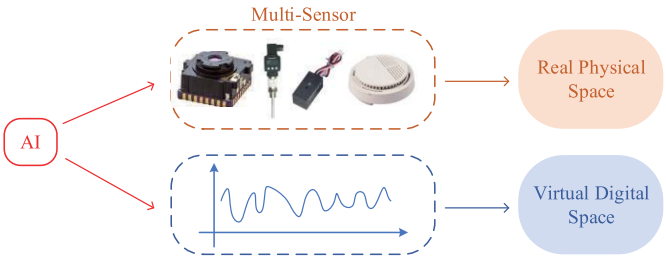

Fig. 7. AI-Driven modulation. The real physical and virtual digital spaces are intelligently improved by multisensors and system parameters, respectively.

Step 3—Intelligent Driven Human–Machine–Scene Modulation: For the intelligence of the education metaverse not to stay at the model level, we need to project the results of the evolution of the AI model into the education metaverse. To this end, as shown in Fig. 7, the AI model is used to adjust the virtual system parameters to feedback to the virtual space and feedback to the physical space through sensing perception modeling of multisensor devices. According to this, we adopt a multiagent perception method [49] based on multisensor devices to realize an autonomous feedback modulation (i.e., human–machine–scene modulation) based on edge computing.

IV. Proposed Framework for Smart Service in Education Metaverse

From the above in Section III, we want to develop a series of smart service architectures as follows: as shown in Fig. 8, first, we use a knowledge graph to conduct precise conceptual modeling of the virtual and real spaces, finely simulate the characteristics and dynamic relationships of the two complex spaces, and fully demonstrate the phenomena emerging from the spatial evolution; second, the real physical space is explored through multiagent-based computational experiments, such as generative adversarial models, graph models, and attention mechanisms, and knowledge and data of complex services are accumulated in the virtual space; finally, the information, such as knowledge and data acquired by computational experiments is projected back to the physical space through sensor-aware perception to guide the evolution and growth of the physical space and feedback to the virtual space in real time. According to the difference between the virtual and the real, the whole process is adapted by AI models, thus realizing the autonomous update and iteration of the education metaverse. Throughout the process, we need to use the appropriate AI model according to the practical situation, so we use the intelligence brought by this class of models, rather than a specific model. (This is why the title is called "group.") We use different AI strategies depending on service types and their characteristics to improve smart services in the education metaverse, e.g., we use federated transfer learning to improve transaction and management services.

Proposed Framework for Transaction and Management Services: In order to protect the privacy of educational information for this specific service requirement, we extend the proposed framework to propose a dynamic protection

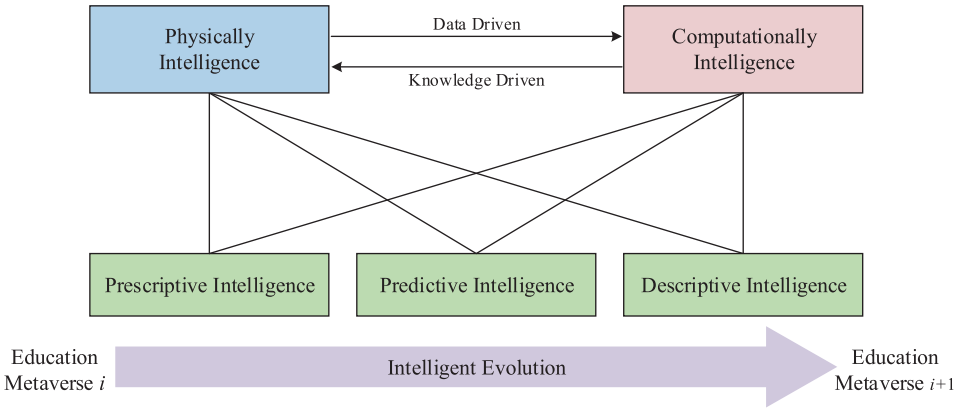

Fig. 8. Smart service architectures in the education metaverse.

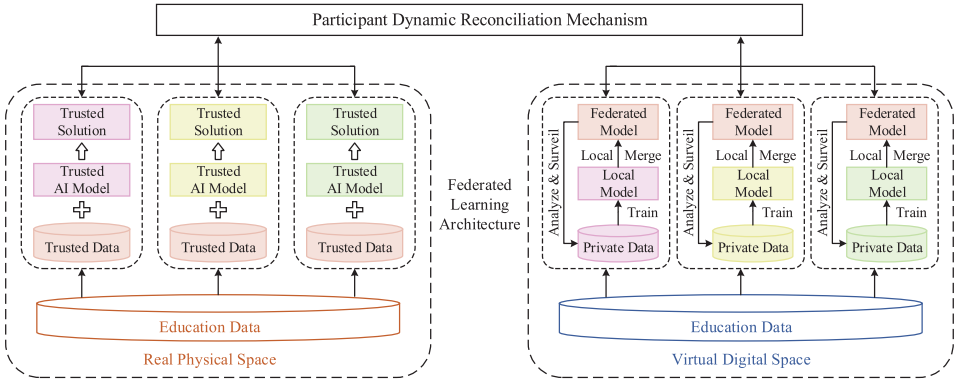

Fig. 9. Framework for transaction and management services.

mechanism for educational information, taking into account the characteristics of the education metaverse.

As shown in Fig. 9, we leverage a next-generation AI federation learning architecture [50], [51] to ensure that educational data is stored locally by the data owner. We use the blockchain technology to connect all participants, and the participants perform all service model updates and calculations locally. At the same time, parameters are cryptographically peer-to-peer exchanged using the blockchain technology. New participants are determined to register for the service by the established participant dynamic reconciliation mechanism. As shown in Fig. 10, the participant dynamic reconciliation mechanism established is implemented according to the proposed framework. We finally determine whether the participant matches the smart contract in the blockchain by using knowledge reasoning techniques and feeding it to the corresponding blockchain system. The entire iterative process is tuned using federated transfer learning, which enables fast updates and evolutions.

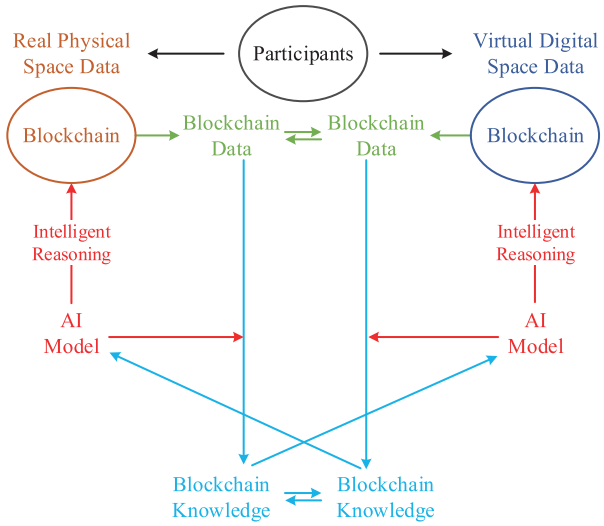

Fig. 10. Framework of participant dynamic reconciliation mechanism.

V. Conclusion: Opening the Door

This article explores the learning scene based on the education metaverse and proposes the technical architecture of the education metaverse. In the education metaverse, there is the learner, its time and space, and the learning event. Further, we propose a novel data-knowledge-driven group intelligence framework for the learning scene in the education metaverse. Indeed, the research on smart services in the education metaverse is still initial in this article. We hope that this is a door (i.e., a beginning) and many questions remain to be explored more deeply by the academic community in the future.

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