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A conceptual framework for cloud-based integration of Virtual laboratories as a multi-agent system approach

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ABSTRACT

With the rapid development in information technologies, numerous Virtual laboratory (VL) studies are being conducted in various fields such as material science, computer science, chemistry and education. While the number of VL studies are rising, possible interactions between these VLs have not been studied yet. The aim of this study is to create a framework in order to gather all VLs in a common base by building interactions between VLs via a multi-agent system (MAS) approach. Cloud-Based Integrated Virtual Laboratories (CIVIL) model has been proposed as a conceptual framework of collaborative networks of a cloud system with the help of MAS. The boundaries of the integrated problem are determined and schematized within the scope of conceptual modeling. Thereafter probable entities that may interact in the framework are included in the MAS model. Communications and interactions between these entities, aims and performance indicators of defined agents are also listed.

1. Introduction

Virtual laboratories (VLs) are online learning media, providing test capabilities in any desired time and place, via integrated information systems by terminating disadvantages and deficiencies of traditional laboratories. There are several disadvantages of traditional laboratories such as machine and material costs, requirement for experienced laboratory personnel, calibration, maintenance and lack of resources. Virtual laboratories alternate traditional laboratories with the help of low costs of computers, flexibility, and multi functionality.

VL experiments are imitations of real world experiments. As a natural cause of physics, all real world experiments have physical limits and boundaries. Hence, all VL experiments are conducted in specific domains with specific boundaries. For instance, Dobrzański, Jagiełło, and Honysz (2008) developed a VL for tensile test in Material Science. They used alloys (16MnCr5, Cu-ETP, etc.) for both tensile and compression. Their VL study was limited with the alloys they have used. Similarly Kiraz, Kubat, Ozbek, Uygun, and Eski (2014) developed a web based VL for the same purpose, a VL for tensile test in Material Science. They used different alloys (AISI4140) from the previous studies. As similar to Dobrzański et al. (2008) study, Kiraz et al. (2014) also have limitations such as allow type. We believe these valuable studies are the tiles of a bigger picture – a mosaic. The boundaries of each study gives us an opinion about the size of the tile.

As stated above, there are several VL studies focusing on similar experiments in the literature. Each study has its own methodology and boundaries. VLs which are isolated, are not communicating and updating themselves have less chance to represent real world experiments. To overcome this problem, this study aims to present a conceptual framework for integrating VLs in a common base by building interactions between VLs via a multi-agent system (MAS) approach. By doing so, we are also aiming for enhancing VLs inference mechanisms and their ability to represent real world with communicating and benchmarking them between each other.

Multi-agent systems (MAS) are necessary for providing integrity of the conceptual model. Conceptual modeling helps to separate functional parts of a complex system. This separation allows understanding the complex systems. Cloud computing technology offers synchronization, online access, platform free access, low cost in hardware and processing manner, and (theoretical) unlimited low-cost storage. The MAS approach enables entities to make autonomous decisions and to interact with others.

Even there are several studies on VLs in the related literature there is no strong evidence about a leading complex self-learning VL model. VLs combined with MAS and cloud-based approaches have not been came across in the reviewed literature. Therefore

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this study also contributes to the related literature in terms of using these two integrated approaches.

2. Related studies

In the early ages of VL idea, first applications were based on remote access of physical laboratories and devices via web technologies. One of the samples of remote VLs was developed by Chen, Chen, Ramakrishnan, Hu, and Zhuang (1999) for mainly in distance education purposes in 1999. In the VL system created by Chen et al., users are able to make various measurements on the physical equipment. Users can also watch curves observed by a web-based oscilloscope.

Few years later, in 2003 a similar study aimed to develop a remote VL for distance education and measurement in electrical and electronical engineering was conducted in Milano by Ferrero, Salicone, Bonora, and Parmigiani (2003). Their claim was cost reduction with VLs in an increasing student and increasing cost environment. They have developed and implemented a Java-based client–server architecture which can be seen in Ferrero et al. (2003). The internet-based laboratory system created by Ferrero et al. is used in laboratory experiments in Politecnico Di Milano.

Another remote VL based on client–server architecture was developed by Gustavsson. The remote VL work carried out by Gustavsson (2002) was used by the students of Blekinge Institute of Technology. His work was mainly focused on electrical experiments for undergraduate students. Students were able to obtain the measurement results by sending all parameters to the laboratory server.

In the study carried out by Kubat and Kiraz (2012), a tensile test was discussed as a Virtual test lab and tensile test at different speeds was also planned to be made in a Virtual environment. An artificial neural network model was established from the data obtained as a result of the withdrawal of the same material at different speeds and from the results needed for the desired pulling rate values. VL have the ability to be informed about others, to cooperate with the others, to prepare tests, and to compare test results with their own models with the help of communication.

Gorai et al. (2016), developed a VL for thermoelectric material design. Their study focuses on the reliable assessment of thermoelectric behavior of various materials. They also developed a web-based interactive VL application which can be seen on (www.tedesignlab.org). One of the other contributions of their work is providing raw experimental open access data for researchers.

Xu, Huang, and Tsai (2014), presented a cloud-based VL platform for network security education. This VL platform focuses on six factors; motivation, knowledge, creativity, collaboration, demonstration, and feedback. They also developed a web-based interactive interface for empirical evidence from more than 1000 students. The findings shows that VLs can provide significant contribution to pedagogical achievements and curriculum design.

Another study focused on educational VL is carried out by Maiti and Tripathy (2013). They discussed challenges in design and implementation of the experiments for VLs. They presented the desired pedagogical features and experiment classifications required for VLs in education. They have also conducted a case study of a VL which is located in Indian Institute of Technology in Kharagpur. Their study shows that VLs especially play critical role on remote students.

3. Methodology

Although there is no single accepted definition of what a conceptual model is, a number of researchers such as Ahmed, Robinson, and Tako (2015), Onggo and Karpat (2011), i Casas (2013), and Onggo (2009) concur on a common thread. Borah (2002) defined CM as "an abstract representation of something generalized from particular instances". There are different perspectives for CM from knowledge engineering and cognitive science. These perspectives imply that "CM involves constructing representations of human knowledge" (Liu, Yu, Zhang, & Nie, 2011). Robinson defines conceptual modeling as "the abstraction of a model from a real or proposed system, which includes simplification of reality and as "a non-software specific description of the simulation model that is to be developed, describing objectives, inputs, outputs, content, assumptions and simplifications of the model" (Robinson, 2006).

Conceptual Modeling (CM) methodology can be expressed with "the bridge" analogy, filling the gap between users and developers. In other words, conceptual models are essentially built for giving a clear understanding of the problem domain. CM is also a powerful tool for abstraction and is independent from model code or software. Perspectives of both users and developers are taken into consideration in CM. Onggo had introduced various methods for conceptual model representation (i Casas, 2013; Onggo, 2009; Onggo & Karpat, 2011).

CM offers solutions to simplification of the problems in the modeling of large-scale complex problems. A conceptual model is of prime importance to provide a practical guidance for researchers who want to conduct practical studies to find a solution to this problem.

MAS offers a way to relax the constraints of centralized, planned, sequential control, though not every MAS takes full advantage of this potential (Parunak, 1994). MAS enhances overall system performance, specifically along the dimensions of computational efficiency, reliability, extensibility, robustness, maintainability, responsiveness, flexibility, and reuse (Stone & Veloso, 2000). MAS is composed of different elements that have different properties and characteristics, and is related using different relationships.

Central management, independent agents in decision making, and synced processing are crucial for MAS. A MAS helps to create self-managed and distributed system elements (humans, VLs, and other server agents). Agents can intercommunicate through a central directory, or can transmit knowledge directly between each other (Kantamneni, Brown, Parker, & Weaver, 2015). Communications, interactions and decision makings in MAS components need to be self-managed. Decision makers should behave autonomously for more efficient management. Feedbacks are important in this autonomous structure. Thus self-learning is possible with internal dynamics.

Cloud computing is used for the aim of gathering all the data in one center. In addition, functions of agents are also stored because they need data storage. A cloud-based structure is formed because data and data packages related to real and VLs needs to be centrally stored and easily accessed. Cloud computing presents synchronization, a solid processing opportunity and platform-free media. In addition to low operation and storage costs, it has theoretical unlimited storage.

4. Proposed model-CIVIL

In this section the conceptual model created with multi-agent-based system approach is presented. Multi-agent-architecture of CIVIL is illustrated in Fig. 1. Multi-agent-based system structures are created with agent determinations related to the conceptual model, agent characteristics, agent identifications, and agent autonomy levels. The agents in the proposed CIVIL model are listed in Table 1. The concepts of data/data packages/reports and other information about communication between agents are listed in Table 2.