ThePedagogical Virtual Machine: Supporting Learning Computer Hardware and Software via Augmented Reality

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Abstract. In this work-in-progress paper, we propose a general model, ViewPoint, for augmented-reality learning which consists of several components such as a learning design specification, a collaborative environment, an augmented reality view, physical objects and a centralised data server. The learning activities focus on the Internet-of-Things, a paradigm that utilises small networked embedded computers (which are largely unseen) to make pervasive computing applications. The core contribution of this paper is a new paradigm that we refer to as a 'Pedagogical Virtual Machine' that aims to extract learning related information from the underlying computers that make up the education focus. The paper describes the information architecture of the PVM explaining some of the key concepts such as data representations of hard and soft objects. The paper concludes by reviewing the main findings and discussing our future research plans.

Keywords. Mixed Reality, Augmented Reality, Internet-of-Things, Cloud-of-Things, Learning Activity, Mobile Augmented Reality, Buzz-Boards.

Introduction

In a previous paper [1] we examined the way in which Augmented Reality (AR) could be adopted in order to make deep IT technologies (ie invisible IT entities) visible so as to create a valuable view for both learners and developers in terms of gaining better

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insight into the abstract concepts of the technology that is woven into the fabric of our everyday lives. In particular we will focus the Internet-of-Things a paradigm that uses small networked embedded computers (which are largely unseen) to make pervasive computing application. To reveal these invisible processes an AR model called ViewPoint, has been proposed to visualise and interact with a small, self-contained eco-system of a networked embedded system referred to as a Buzz-Board [2]. The approach seeks to enrich developers' and learner experiences by providing a view of the invisible embedded-computing elements surrounding us. Moreover, in support of the suggested framework, a 4-dimensional learning activity task (4DLAT) has been proposed, which assists in structuring the study into a number of different stages, through which progress is made from single-learner-discrete-task to group-learner sequenced-task, based on the scenario suggested. Most of the previous paper was addressed education, whereas this paper will describe the underlying computer science. Thus, as part of this work-in-progress, we introduce a new paradigm, which we refer to as the 'Pedagogical Virtual Machine' (PVM) that acts as a manager for revealing educational learning related functions in the computer. Brad Cox [3] explained that; when he started thinking about object-oriented programming he had the vision that everything in this world can be regarded as an object. This inspired us to think about hardware and software in embedded computer as objects as well. This model implies that all computer objects (hardware or software) contain data that represent the object state and can be communicated with other objects. Using these ideas we have framed the following hypothesis for our Pedagogical Virtual Machine (PVM):

> *"It will be possible to create a synchronous real-time computational architecture that link hardware, software and AR events together in an effective way (i.e. that the real and virtualised views are correctly synchronized). More specific by using either virtual machine or proxy-agent technology pedagogical synchronisation between the embedded devices and learners can be achieved."*

In the following section of this paper we start by describing some related augmented reality and embedded computing work, then we present the conceptual of Viewpoint model system before moving on to explain the PVM, before we, finally, introduce the information architecture used to support it.

1. Related Work/Literature Review

1.1. Augmented Reality

As has been highlighted by Pena-Rios [4], some of the technologies adopted in an educational context, namely augmented reality, mixed reality and the virtual environments, have all impacted on learning and teaching from conventional to more innovative approaches. Establishing a connection between virtual and real domains enables augmented reality to form a reality that is not only augmented but also enhanced [5]. Essentially, augmented reality delivers a number of different opportunities in terms of teaching and learning, as has been acknowledged by Wu [6]. In this regard, learners are able to take advantage of the coexistence between the real environment and virtual objects through a number of different aspects. Primarily, it enables learners to visualise complicated abstract concepts and spatial relationships [7]. Secondly, there is the opportunity for learners to interact with synthetic objects—both 3D and 2D—in the Mixed-Reality (MR) setting [8]. Thirdly, it enables phenomena, which are impossible to be experienced by learners or which otherwise are non-existent in the real world, to be experienced by learners. Lastly, it enables learners to develop critical practices that would not be possible in another learning technology setting [9].

Augmented Reality (AR) is recognised as a technique concerned with virtual object overlay in a real-world domain, and can cause users to feel sub-immersed through the interactions facilitated between the actual and virtual worlds [10]. Thus, AR combines virtual objects in a real-world context. From the viewpoint of the user, the objects are rendered complete and harmonised with reality, including presenting the same contextual environment [11]. As such, it is essential that there be alignment between the real and virtual world, which will enable an illusion to be created. Various AR applications have undergone analysis, namely in regard to entertainment, manufacturing, maintenance and repair, medical visualisation, and robot environmental planning [12]. From these studies it was apparent that accurate scene registration is fundamental to AR, which means the consideration of camera pose estimation, in specific consideration to the 3D environment, needs to be taken into account [13].

Markedly, mobile AR is considered a natural platform centred on a number of what are terms to be ‘killer apps’. The work of Wagner *et al*. [14], for example, infers that an interactive AR museum may be defined as ‘a virtual media that annotates and complements real-world exhibits’. In a similar regard, [15] introduced a training application, which facilitates oil refinery employees to review the instructional diagrams located on the top of the tools being learned and used. Various other applications have also been identified, including [16], equipment maintenance [17] and document annotation [18], as well as others. Irrespective of the application, however, there are numerous aspects in common: for instance, all of these applications rest on there being a wealth of data, dynamic and distributed, and there is the necessity to establish all relations between recognisable visual targets and relevant data. These associations will change through the development of the application or otherwise with the development of the underlying data. Importantly, there is the need to ensure a presentation layer is incorporated, which explains the way in which data can be rendered as virtual media. In some regards, it may be advisable to render different combinations of icons, images, texts or 3D objects, although this might ultimately depend on the nature of the data. The precise conversion from data through to virtual content essentially depends on the application type. Different users implementing numerous mobile devices could have the ability to share and collaborate with such data; thus, there is the suggestion that a central data store may be required, which needs to have the capacity to oversee users’ actions, as well as supervising the state of the system overall [19]. Moreover, collaboration in the context of AR may be more valuable, especially when different users discuss and emphasise their views, and interact accordingly with 3D models in unison [20]. On the other hand, in regard to the pursuance of academic development, there have been many studies carried out on collaborative AR, which comprises the use of 3D objects [21,22,23], such as the struct3D tool which, for instance, has the capacity to teach mathematics and geometry[24]; the Web3D instrument, which is adopted to assist engineering students [25]; and magicbook, which can be applied in regard to multi-scale collaboration. The majority of these applications are based on screen-centred AR through the utilisation of transparent displays and head-worn displays. Furthermore, AR can deliver various perspectives of the same object, which can facilitate learners in progressing further than the data available to them would allow [26].

1.2. Internet-Of-Things

Ferscha *et al*. [27] have explained that 'smart things are commonly understood as being wireless ad-hoc networks, mobile, autonomous and special purpose computing appliances, usually interacting with their environment implicitly via a variety of sensors on the input side and actuators on the output side'. As mentioned in the introduction, the concept of deep technologies refers to systems with functionalities that are hidden to humans. Such hidden technologies are incorporated within the environment, and cannot be seen by people but are there nevertheless. They can enhance the perceptions of the users in regard to their surroundings if presented in a natural way. Accordingly, establishing a link between the virtual and the physical world is essential, and can be achieved through utilising a number of different approaches, including AR and mixed reality. For instance, through the work of Ferscha *et al*. [27], a 6DOF DigiScope was developed, which is a visual 'see-through' tablet supporting the investigation of the 'invisible world'. One further illustration of this point is the University of Essex's iClassroom, which utilises a number of different instruments, such as projectors, whiteboards, and wall-mounted, touch-screen and handheld devices, all of which are all networked together to facilitate both teaching and learning [4].

2. System Model

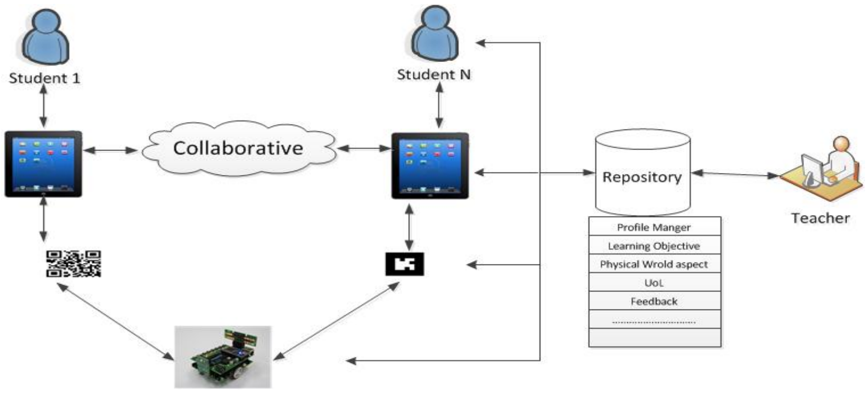

Figure 1 High-Level View of the ViewPoint Model

A high-level view of the proposed model, ViewPoint, is shown in **Figure 1**. This is based on several aspects that integrated together such as the learning design, collaborative environments, the augmented reality, physical objects and the central data that manage the whole system.

Theses aspects can be described as follow:

a) *LD Specification:* the teacher creates the unit of learning, the learning objective, the expected learning outcomes and specifies the task that should be completed by the students. Furthermore, the students perform a sequence of actions to achieve the goal of the activities that set by the teacher. In addition, they would be able to see their performance and score for the task which would be retrieved from their personal content profile and could also can be seen by the teacher.

b) *Collaborative Environment:* This is where multiple users with separate smartphone/tablets can communicate, collaborate and share data during the learning activities. Furthermore, the environment can notify other users for the updating data/information.

c) *Augmented Reality:*

This consists of the following components

- *AR Display:* This is the user interface/ the client application/ the output device where users can see things superimposed onto images of the real devices' being studied and digitised by a camera. The images can be overlaid by virtual content such as text annotation, icons, video, image and 3D models.

- *Visual Targets:* These are markers used in order to identify and interact with the real and virtual objects. The interaction can be undertaken by diverse technologies such as Quick Response code (QR), Bar Code, Near Field Communication (NFC), Video Markers, Computer Vision (object recognition), Global Position System (GPS), interactive sensor/effector systems and computer networks (e.g. micro sub-nets).

d) *Physical Objects:* These are the objects the users want to study, track, visualize and manipulate. The physical objects could range from the things that we use in our daily life such as cars, washing machine, TV, aeroplane, robotics, mobile technologies or, in our case, Buzz Boards (**Figure 2**).

e) *Central Data:* This is the repository where the whole system is managed. It contains all the Units of learning, assessments, Roles for users (teachers and students), shared data, virtual content and the physical objects functions/representations.

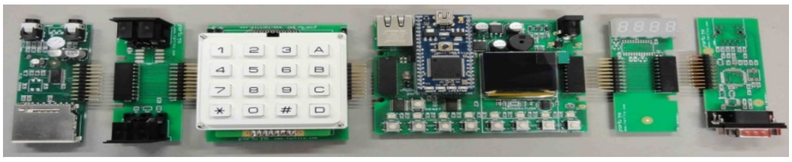

Figure 2 Some BuzzBoard Internet-of-Things Components (an Internet Radio)

2.1. Pedagogical Virtual Machine

The primarily aim of this research is to develop a 'Pedagogical Virtual Machine' *(PVM) which, in simple terms, is* an entity that interprets and communicates the hidden (deep) computational processes for the purpose of helping students or developers visualise functions in a computer. An important aspect of this machine is the unification of the pedagogical needs with the architectural capability. For instance a student/learner would need to be aware (via visualization) of the active software and hardware behaviours. The idea of the pedagogical virtual machine is to provide a platform-independent interface for students and teachers to access information that is pertinent to learning. In this respect it has some similarities with ideas of virtual machine used to support mobile code in web systems (eg the Java Virtual Machine). However, it does not execute code (in a programming language sense) but rather responds to a set of generic commands that gathers system information (or instrumented data) from the underlying hardware about the software executing. It aims to provide students and teachers with a portable, common and familiar interface irrespective of the underlying hardware (in that sense it acts as a virtual machine – the machine being the monitoring apparatus). In addition, it will include some customisable features that allow teachers to filter exactly the type of pedagogical information they need for a particular topic or lesson.

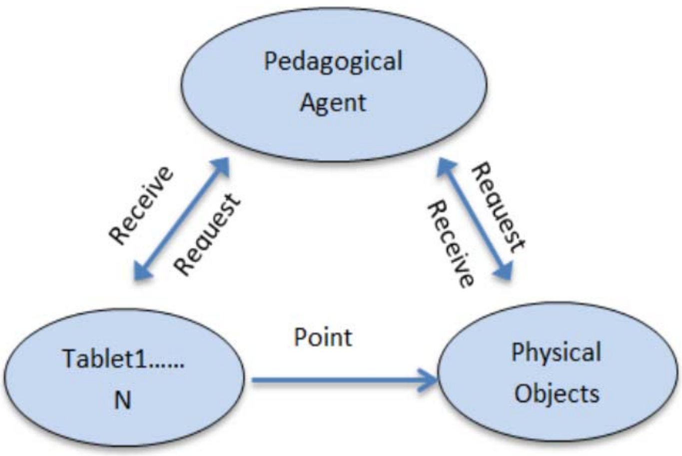

Figure 3 High-Level Conceptual View of Pedagogical Virtual Machine

However, while the details of this component form the focus of our coming research, we have been able to propose the following conceptual view of the main components of the PVM **Figure 3.** A key innovation arising from the use of BuzzBoards is that they provide an internal hardware network that both provides both user driven events (eg plugging different boards together) and signals deep soft and hard behaviors (used by the PVM). Both of these features play a key enabling role in this scheme as they provide a way to get essential system information from the learning objects, without disturbing the system, which most forms of instrumentation would cause. In relation to Figure 3, the main components of the Pedagogical Virtual Machine can be described as follows:

a) Tablets/Smartphones: these contain the augmented reality user interface /client application that allows learners/developers to point at the physical objects via the built-in camera in order to visualize the deep entities/functions/process of the physical objects. Furthermore, each learner can use his or her smartphone
b) Physical Objects: these are the objects that learners can recognize/track so as to reveal the learning related functions within them.
c) Pedagogical Agent: this acts as a bridge between the smartphones/pad and the computing objects, extracting pertinent educational learning related information from the platform under study. Research challenges include defining the pedagogical functions and then determining the best mechanism to gather data from the computational objects under study. For instance, when the learners' point their smartphones at the physical object, and the physical object is functioning, it notifies all the smartphones of this function. Therefore, the learners will be aware of the behaviour of the physical object and aid them to understanding the deep (hidden) functionality of the object concerned. This is similar to the Model, View, and Controller (MVC) design architecture (see 2.2).

2.2. Information Architecture

To support the PVM, there is a requirement for an information architecture to deliver content for complex learning tasks. This is derived from both the technical and pedagogical domains. In the technical domain, the information representation uses an object-oriented approach for defining the physical object data (both software and hardware behaviours). Furthermore, both software and hardware are treated as an object. Thus, the defined physical object contains information such as *<Id, Name, Description, Network IP> and has services/behaviours <input, output>*.

In the user-interface, delivering the content for learners will utilise the Model, View, and Controller (MVC) design architecture **Figure 4 [**28]. The description of this component is as follow:

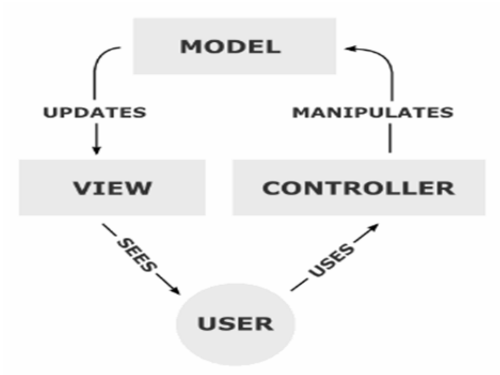

Figure 4 The Model-View-Controller Architecture

- The Model: This contains the 'representation data' for the objects that are managed by the system, such as hard and soft object data, learner profile, learning activity content, learning progress.
- The View: This contains the presentation structure and format that appears on the client/learner display system. The information/data that needs to be presented to the learner is requested from the model. The View consists of a Camera View, AR View, Login View, the main page, and the learning content.
- The Controller: This acts as a bridge between the view and the model. It can send a request/command to the view in order to change the presentation of the model. In addition, if the model presentation is changed in the view, it notifies the model to update its state.

3. Conclusion and Future Work

In this paper we proposed and explained a general model, ViewPoint, which consists of several components such as a learning design specification, a collaborative environment, an augmented reality view, physical objects and a centralised data server. Furthermore, to support the proposed model, we produced a new concept that we refer to as a 'Pedagogical Virtual Machine' that aims to cater for learning or development needs. To support the PVM, we describe an information architecture for the data representations of hard and soft objects.

For our future plan, we aim to continue developing the PVM using the buzz board system as a physical object and pedagogical test-bed for our experiment work. Clearly, this is a work-in-progress paper as there is still much research to be done especially in respect of creating effective AR based learning design activities as well as exploring the learning interaction procedure for deep (invisible) technology. In addition, finding the appropriate techniques for visualizing embedded technology requires further investigation. Furthermore, the evaluation of our work is a crucial factor which we will take it into consideration on our future progress.

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