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Procedia Computer Science 21 (2013) 132 – 139

Procedia Computer Science

The 4th International Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN-2013)

Interaction System Based on Internet of Things as Support for Education

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Abstract

The Internet of Things is a new paradigm that is revolutionizing computing. It is intended that all objects around us are connected to the network, providing "anytime, anywhere" access to information. This concept is gaining ground, thanks to advances in nanotechnology which allows the creation of devices capable of connecting to the Internet efficiently. Nowdays a large number of devices are connected to the web, ranging from mobile devices to appliances. In this paper we focus on the education field, where Internet of Things can be used to create more significant learning spaces. In this sense, we propose a system that allows students to interact with physical surrounding objects which are virtualy associated with a subject of learning. We conduct an experimental validation of our approach, yielding evidence that our model improves the student's learning outcomes.

Selection and peer-review under responsibility of Elhadi M. Shakshuki

Keywords: Internet of Things, ubiquitous learning, NFC, QRCODE

1. Introduction

The Internet of Things (IoT) (or Internet of Objects) is a new paradigm [10] which has been gaining space, thanks to advances in telecommunications such as the expansion of broad bands, the new IP protocol version 6 and nanotechnology integrated into countless electronic devices, ranging from mobile devices, vehicles, appliances and more. The idea of the Internet of Objects is to integrate all these devices into the network, which can be managed from the web and in turn, provide information in real time (we can know their status and features on line) and also allowing the interaction with people who use it.

Education, as any human activity nowadays, has not been immune to this phenomenon dating from the e-learning, m-learning [9] up to the u-learning [2], this finally as the leap to the pervasiveness of knowledge. The potential of ubiquitous learning is reflected in increasing access to learning content and collaborative learning environments supported by computers anytime, and anywhere. It also allows the right combination

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Selection and peer-review under responsibility of Elhadi M. Shakshuki
doi:10.1016/j.procs.2013.09.019

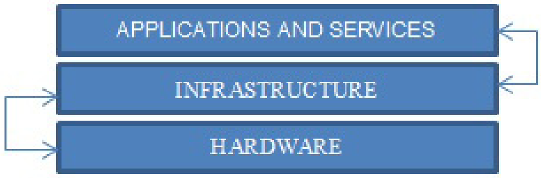

Fig. 1. Internet of Things basic layers.

of virtual and physical spaces. The purpose of ubiquitous computing technology is basically improving learning processes. It is trying to adapt learning resources to different contexts of use of apprentices. Being in this area where the internet of objects plays an important role in learning processes in formal and informal education.

This paper proposes a system that allows students to interact with a set of physical objects in the surrounding. Each of these objects has associated one (or more) virtual object which provides information that allows the student to reach a learning achievement, as how they work, how it can be used, etc. This content is what we would add to the internet of objects. The purpose is to allow the students to manipulate the objects (both physically and virtually) in order to increase their understanding of the issue. It can be found several academic programs where it is necessary the interaction of the students with the objects around them, varying from health studies where the students can learn about some devices used in the clinical practice to mechanical engineering studies where it is necessary the understanding of the inner workings of a combustion engine, for example.

In this paper, we have taken a step forward in our initial research, where the main ideas of our proposal were outlined [7]. Particularly, we have implemented a working prototype with the aim of validating our proposal. In this sense, we use as reference the introductory course in system engineering (related to computer hardware) at the University of Córdoba, Colombia. Since it is an introductory course, it is quite frequent that the students do not capture the main concepts, even receiving conceptual information of subject by the teacher and using some technological tools. In our experiments, the internal parts of the computer were tagged with NFC (Near Field Communication) and QRCODE (Quick Response CODE) allowing the association with virtual objects. In order to validate our proposal, the students were divided into two independent groups, control and experimental. The experimental group had access to the Internet of Objects whereas the control group received traditional lectures. The experience showed that students who had access to the Internet of Objects improve their academic results.

This paper is organized as follows: the next section presents the related work. In Section 3 our approach is described. A case study is presented in Section 4 and in Section 5 we discuss the obtained results. Finally, Section 6 presents the concluding remarks.

2. Related Work

The concept of Internet of Objects was proposed in 1999 by Kevin Ashton and aims at the exchange of information. The origin of the term is derived from ubiquitous computing, which was conceived in Olivetti Research Ltd. and Xerox PARC laboratory, in order to increase the use of computers, making them available throughout the physical environment but also making them effectively invisible to the user. It is also called Pervasive Computing [3], being Mark Weiser (1991) one of the leading researchers who contributed to the development of this area [12]. Ubiquitous computing is characterized by small computers that communicate spontaneously, which are integrated in almost everyday objects thanks to their small size.

The Internet of things still has challenges that are inherent in its three layers (hardware, infrastructure and applications and services), in Figure 1, you can see the basic layers [5].

- First level: Hardware, that allows the interconnection of physical objects through sensors and related technologies. The challenges associated to this layer are related to miniaturization. Internal components should be smaller and more efficient, although today they are equipped with devices with processing, storage and connectivity capability. Capacities that might be expected to be increased in the near future.

- Second level: The infrastructure level corresponds to the connectivity capacity for internet access, which is currently with 3G and 4G networks. The great challenge is to connect billions of devices on a wireless network, being necessary the expansion of bandwidth and the electromagnetic spectrum. As telecommunications infrastructure is currently not suffice to support the inclusion of a large number of electronic devices, it is a challenge that has to be solved as soon as possible.
- Third level: Applications and services level, which is plenty of opportunities to offer solutions to supply and provide information, from the physical to the virtual objects, as well as the interaction with people, making life easier and more efficient all the time.

Focusing on services and applications level, there are lot of works that have been developed and is still posing new solutions to enable people interact with the internet of objects. Han et al. [8] proposed a framework to compute optimal transfer routes and communication parameters. They use the interrelationships between the layers in the Internet of Things. Bao and Chen [1] present a dynamic management protocol of the Internet of Things with the aim of provide an accurate and resilient trust assessment on trust level of Internet of Things entities. The dynamic trust management protocol is based on multiple social relationships among device owners. In response to changes in a community-based environment (by knowing the status of the nodes and their operations), the protocol can adjust the settings with the aim of maximize the application performance.

Regarding the educational field, the objective is to contribute to enhance teaching and learning through Internet of Things. It can be found experiences proposing an interactive English teaching [11] that integrates voice and visual sensors to acquire the pronunciation of students. According to Wang, Internet of Things has characteristics such as motivation, the playful and allows teachers to teach students according to their aptitude. Teachers can choose the basic materials to suit students. Students also learn at their own pace according to their capabilities, so they are not limited by a one-size-fits-all program. González et al. [6] proposed a basic architecture for introduce Internet of things into the learning spaces. This infrastructure uses NFC technology to enable mobility and interaction with physical spaces. The paper discuss about some possible applications, they outline a prototype but no evaluation was given. Domingo and Forner [4] present a work in progress at the Open University of Catalonia (Spain). It is based on an user-centered design, that includes the Internet of objects and E-learning, with the aim of improving learning experience. In general terms, the Internet of Things has been proved to be a fun tool that allows students to learn in a better way.

3. Proposed Model

The proposed system aims to increase the learning outcomes of the students by taking advance of their interaction with physical objects that surround them in a learning space as well as their interactions with those executed applications. In this case, the physical objects are enriched with context using the Internet of Objects perspective. Resources are augmented with visual tags NFC and QRCODE. Each tag contains a unique data that identifies the object and can be used as a link to the virtual one. The system supports multimedia resources such as hypertext, audio, video, animations, etc. The mobile device has an interface that integrates NFC and QRCODE technology identification, allows the interaction of objects with the students. The access to the server is done via WebSocket in order to minimize latency issues between the client, server and HTTP. The internet access is achieved by Wi-Fi or 3G mobile device. Figure 2 shows the description of the system's architecture for Internet of Objects.

The server is a system that has augmented learning objects, which are managed by the teacher (via internet). The client has an application that is installed on the mobile device of the student.

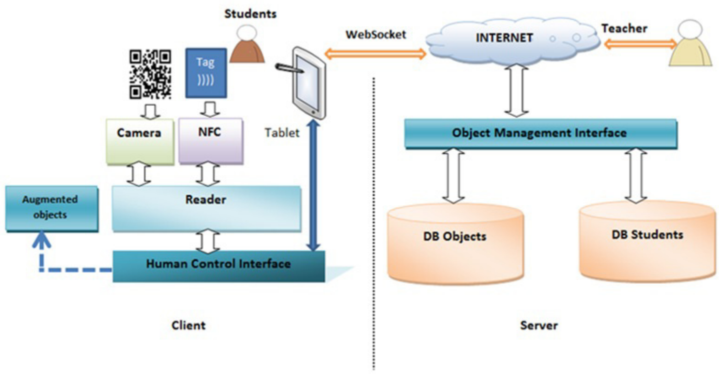

Fig. 2. System Architecture for Internet of Objects.

3.1. Server Roles

The object management interface provides information of augmented objects concerning the learning activity, according to the teacher's preset settings. In order to deliver the information to the student, the system will take into account two different sources (stored in two databases): On the one hand, the database which contain student information along with their profiles (a record of the learning activities and assessments results) and, on the other hand, the second database will contain information about the augmented learning objects.

3.2. Components of the client application

It has a hybrid interface based on NFC and QRCODE that allows interaction with physical objects. In a first step, when students bring their mobile devices near to tagged objects, they must select the mode of interaction in the interface, which can be NFC or QRCODE. If students choose the option of NFC reading, the device immediately obtains the information found within the physical object tag in NDEF format (NFC Data Exchange Format) containing the identification of the augmented object on the server. In other words, an algorithm is used to decode the NDEF and throws it to the server. As consequence, the virtual object will be displayed, using a graphical user interface, in the mobile device. In the case of QRCODE reading the performance is similar, the reader decodes the tag information and the user interface displays the learning resource, which can be an animation, a website resource or simple text or audio contents.

In case of being necessary, the student can complete some learning activities and their results are finally transferred to the server by the mobile device.

4. Working System and case study

The case study was a pilot experience with the students enrolled in the course "Introduction to Systems Engineering", at the Faculty of Systems Engineering of the University of Córdoba, Colombia. The duration of the course was one term (first semester). The teacher plans a practical activity called "Identifying hardware and computer operations". We selected this task because the students usually have several difficulties to understand how the main elements in a computer work. The task was designed as follows:

- Learning Objective: to know the most important hardware devices of a computer system and understand the basic operation of each device.
- Activities before practice: the system provides learning objects about the computer hardware. The students must have studied this information before coming to practice; their prior knowledge will be evaluated.

a) Interaction with objects

b) Main Board with QRCODE

c) RAM memory reading with QRCODE

d) Reading with NFC.

Fig. 3. Illustrating how the system works.

- In practice: the student comes to the lab with the purpose of identify and understand the main hardware components of a computer. The lab itself is labeled with an NFC tag, which transfers the information to the mobile device. At this moment, the system recognizes that the student is already on site, so the student (the device) has instant information about those physical objects in the lab and the system start to show the activities that have to be fulfilled by the student.

  The student immediately makes the different readings of those NFC or QRCODE tags attached to the inner parts of a computer. The system, as far as the learner interacts with the different objects, sends to the mobile devices the associated augmented objects, that might use video or animations engineered to illustrate the device at work. Thus, each augmented object will explain how each component of the hardware operates, how it should be installed for normal operation, etc. In Figures 3.a through 3.d you can appreciate the student's experience.

- Technology used: tags RFID ISO1443A, NFC readers, Tablet PC, tags QRCODE, Samsung Galaxy S3 Smartphone with NFC, Nokia 700 with NFC, Wi-Fi, Web Server that contains the augmented objects.

5. Results

In our experiment we use the results obtained by 50 students enrolled in the course "Introduction to Systems Engineering". The principal aim of the research is to describe how the use of Internet of objects

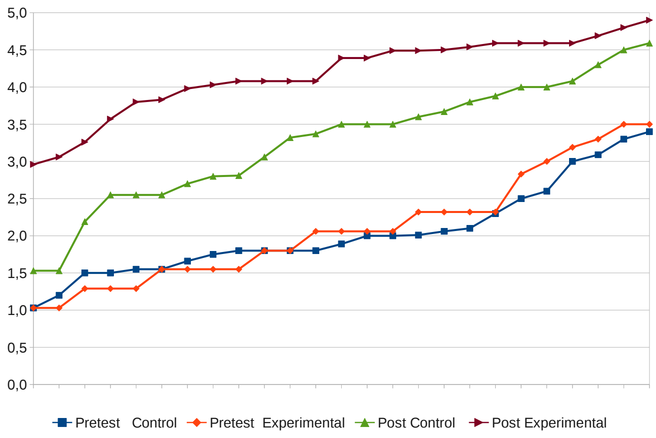

Fig. 4. Control and experimental groups scores in the pre-test and post-test (sorted by score value).

changes the outcomes for the students. In order to evaluate these changes, the students were randomly splitted into two independent groups (25 students in each group): control group which only received traditional lectures, and experimental group that work with the interactive system of the internet of objects. So, teaching resources are set to the independent variable, being academic performance the dependent variable.

We have designed two different tests which includes several questions about the cognitive objectives described earlier. The score obtained in the tests, in a range from 0 (bad score) to 5 (good score), reflects the knowledge acquired by the students. To measure the improvements in learning, we provided the same tests to both groups. The first test, pre-test, evaluates the previous knowledge of the students (before assisting to the learning unit) and the second test, post-test, was used to evaluate the students at the end of the unit's lectures .

In order to evaluate the results, we represent in Figure 4 the raw scores obtained by each student in each test for the two groups. Note that in this case the students were sorted according to their academic scores in each test, therefore there is no one-to-one relationships between the points in the graph. Nevertheless, this graph allow us to say that we can obtain better results employing the new tools of internet of things, better scores have been obtained in the post-test. In the next sections we will analyze statistically the results.

Secondly, we will focus on the graph in Figure 5. In this case, we present a scatter plot that displays the results obtained by each student in the two groups, control (blue squares) and experimental (red triangles). This graph also shows the regression lines for each group. Thus, in the horizontal axis we represent the scores obtained by each student in the pre-test whereas in the vertical axis we represent the learning improvements for the same student, measured as the difference between the scores obtained by the student in the post-test and the pre-test, i.e. $score(post - test) - score(pre - test)$. In this case, we can see again that better results were obtained with the experimental group in general. In this sense, the average learning improvements for the control group is 1.1276 whereas the average improvements in the experimental group is 2.0716. Moreover, we can see that greater score's improvements were obtained for those students who obtain worst results in the pre-test, fact that is interesting from a pedagogical point of view.

5.1. Analysis of the pre-test experiment

This comparison determines whether the baseline scores for the two groups, experimental and control, were comparable in the experimentation. This comparison is done in order to validate the obtained conclusions. As there is evidence of normality of the data in the pre-test for the two groups, a parametric test hypothesis was applied. Table 1 shows the statistical summary of the data.

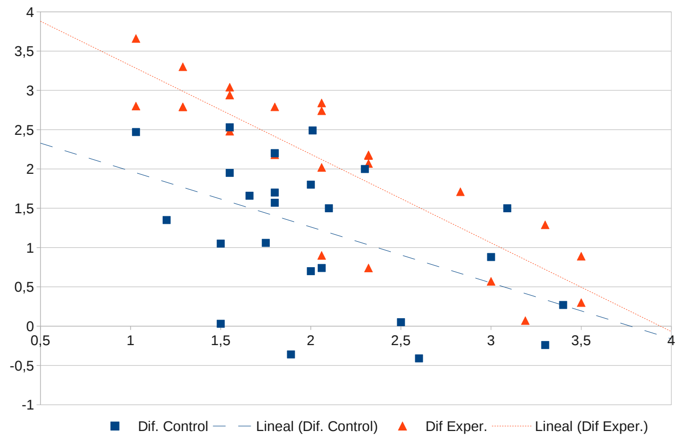

Fig. 5. Relating pre-test scores (x-axis) with learning improvements (y-axis) for each student in the experiment.

	Control Group	Experimental Group
Recount	25	25
Average	2,0476	2,1028
Confidence intervals (95.0%)	[1,7902;2,3050]	[1,7905;2,4151]
Standard deviation	0,62354	0,756607
Coefficient of Variation	30,4522%	35,9809%
Minimum	1,03	1,03
Maximum	3,4	3,5
Range	2,37	2,47

Table 1. Pretest summary statistics

Particularly, we will use T-test for comparing the mean scores of the two groups. In our case, the null hypothesis is that there is no difference between the scores in the two groups. The student's t-test will tell us if the data are consistent with this or depart significantly from this expectation. Thus, assuming equal variances we obtain $t = -0.281507$ being p-value is 0.77953. Since the calculated p-value is not less than 0.05, we cannot reject the null hypothesis. In other words, the results show that there is an initial equivalence between experimental and control groups.

5.2. Post-test analysis

The details for the statistical summary for the post-test evaluation are presented in Table 2. In this case, the normality test of the data states that they do not come from a normal distribution. Therefore, a non-parametric hypothesis test was used for comparing the academic performance. Particularly, we use W Test Mann-Whitney (Wilcoxon) to compare medians. This test is constructed by combining the two samples, sorting the data from the smallest to largest, and comparing the average of the two samples in the combined data. Again, the null hypothesis is that both data have the same distribution. In this case, we obtain the values, $W = 517.5$ and p-value= 0.000071, therefore the differences between control and experimental groups are statistically significant using W-test with a confidence level of 95.0, which validates our below conclusions. Finally, we want to say that similar results have been achieved when considering the learning improvements for the students in the control and experimental group. As the p-value is 0.01529, we reject the null hypothesis, and therefore we can conclude that, at 0.05 significance level, the learning improvements for the two groups are nonidentical populations.

	Control Group	Experimental Group
Recount	25	25
Average	3,2752	4,1744
Standard deviation	0,834387	0,527479
Medians	3,5	4,39
Coefficient of Variation	25,4759%	12,636%
Minimum	1,53	2,96
Maximum	4,59	4,9
Range	3,06	1,94

Table 2. Post-test summary statistics.

6. Conclusions and Future work

The obtained results show evidence that the Internet of Objects, applied as a tool to support the teaching process, improves student academic performance. Furthermore, using real objects and associate them as a learning resource through the Internet of Objects facilitates meaningful learning, as it allows to link specific knowledge to a real context. Regarding the use of the system Internet of Objects in the experimental group, showed that students improved their learning, which was evidenced by the results of measuring academic outcomes compared to the control group.

The road in front of the Internet of Objects and their applications in education is just beginning, so in the future we plan to integrate the virtual objects with a recommendation engine.

Acknowledgments

This work was jointly supported by the Spanish Ministerio de Educación y Ciencia and Junta de Andalucía, under projects TIN2011-28538-C02-02 and Excellence Project TIC-04526. We also want to thanks to the Systems Engineering program at the University of Córdoba (Colombia), for allowing us to perform the experiments in their courses.

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