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A Context-aware Smart Classroom for Enhanced Learning Environment

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Abstract

Research on smart spaces represents one of the most innovative work being done recently. One of the interesting applications of smart spaces is the smart classroom. It aims at using new technologies and tools to provide adaptive, comfortable and personalized learning which supports and facilitates the learning operation. Often instructors waste a precious time of theirs courses on tasks not directly related to the course content especially adjusting several times both the light system of the classroom which consists of the light bulbs system and window blinds as well as the heating/cooling system and learning tools such as data show, moving board desktop computer. These systems should be adjusted according to the current context which has a high dynamic change. These activities prevent them from focusing on their main tasks and directly affect the proper functioning of the educational process. In some cases, after the end of the lesson and the leaving of the audience, devices of the classroom remain operating which causes an unjustified energy consumption. The aim of this paper is to propose a context-aware automation of classrooms which contributes to improving the quality of the educational process by automating tasks that are not directly related to the content of the courses and consume time and effort that would affect the smooth running of the educational process. The proposed smart classroom will provide a comfortable learning environment that ensures more emphasis on course content by instructor and students.

Keywords

Automation, Adaptation, Classroom, Context-aware, Rule system, Smart space.

Smart spaces have attracted considerable amount of interest over the past few years. They are defined as physical spaces rich in equipment and software services that can interact with people in order to provide intelligent services to the user for improved comfort, energy saving, security, and much more benefits. The Smart spaces vision has become technically feasible with the spread of the recent developments in sensor networks, communication technologies, and devices with computing ability. Several applications of smart spaces have been developed during the last decade among them are smart homes, smart offices, etc. One interesting application of such spaces is the smart classroom where technology can be used to improve the quality of teaching in many ways. It consists of creating a physical environment that allows the successful use of that technology which provides an optimal learning environment. The main goal is to simplify life for instructors, so they can focus on teaching and keeping students more involved and can enhance learning outcomes. Such technology has a positive impact for students and instruc-

tors by making learning deeper, more immediate, and more comfortable. Existing work in the field of smart classroom is oriented towards e-learning application which is defined as the delivery of educational activities or content to learners by electronic means, intelligent environment which is consists of digitization of the ambient issued with an assembly of many various types of hardware and software modules, Tele-education where instructors can give classes to local students and remote students simultaneously using web (respecitvely internet) based distance learning, etc. There are other tasks not related directly to the learning task but have considerable impact on the smooth running of the educational process. Among these tasks there is the preparation of the adequate classroom environment by adjusting equipment and preparation of means for course presentation (PC, data show, etc.). Automation of such tasks will greatly reduce the time spent on these activities and give instructors more time to focus on other important learning activities as well as saving precious classroom time. The aim of this paper is to propose a smart classroom by using a context-aware automation of some tasks related to the learning environment adjustment. The automation uses a simple rule-based system which offer instructors more time to focus on other important learning activities as well as providing a comfortable learning environment for students.

The rest of the paper is organized as follows: the section “Related Work” presents an overview of some existing methods for enhancing learning environment with a focus on classroom automation. The section “Spectification of the Smart Classroom” describes the specification of the intended classroom and its operation. The proposed approach of classroom automation can be found in section “Context-aware Classroom Automation”. Conclusion and future work are presented in the last section.

Related work

Recently, there have been tremendous efforts on developing smart classrooms. Previous works were focused mainly on e-learning, tele-education, and digitalization of classrooms. Among the earliest researches in the field of smart classroom, we can cite the classroom 2000 project (Abowd, 1999) and eClass project (Brotherton and Abowd, 2002; Brotherton and Abowd, 2004). These systems automatically capture and deliver lectures using cameras and audio recording and make them available on the web in order to reduce the workload of students. Shi et al. (2003) described some essential features for a Smart Classroom, especially those may help to get a better user experience. Among them there is the pen-based UI, laserpointer To Cursor together with the voice command, a virtual Assistant that can enhances the speech interaction between the teacher and the system and a smart cameraman module that can automatically capture the proper view of the classroom according to the context of the class as the video feed for the remote students. Chen and Li (2010) and Hsieh et al. (2007) proposed a system where an English language learner can obtain learning content based on his current location. If the learner is in a gym, the application may provide new words related to exercise or gym equipment to enhance his vocabulary learning. Context information can also be utilized in adapting the delivery of content. For example, learning materials can be provided to a learner in a suitable format for his or her device and Internet connection status (Gomez and Fabregat, 2010). O’Driscoll et al. (2008) and Kelly et al. (2009) proposed the Context Aware Smart Classroom (CASC) a classroom that responds to lecturers and student groups based on preset policies and the lecture timetable. Yuanchun et al. (2010) developed a set of key technologies for a smart classroom. The aim of the project was to develop new pervasive computing technologies in the classroom to provide practical natural convenient multimodal interfaces and context-aware applications to assist local teacher, and to develop large-scale remote e-learning interactive application to enhance the class activity between local teacher and remote students. A context-aware application called Smart Cameraman which is used to switch the live-video scene at the remote side based on the situational contexts. They presented a formal context model, which combines first order probabilistic logic (FOPL) and web ontology language (OWL) ontologies. Sergio et al. (2014) presented a context-aware adaptive and personalized mobile learning system, namely the Units of Learning Mobile Player (UoLmP). The system address delivering context-aware adaptive and personalized mobile learning by proposing a mobile system for delivering context-aware pedagogical strategy enhanced educational scenarios via mobile devices. Ana and Srdjan (2012) addressed the potential of using IoT to build a smart classroom, i.e., a classroom that can provide real-time, automatic feedback on the quality of a lecture, i.e., about the current level of interest of the auditorium and the level of satisfaction of the auditorium with the lecture and the lecturer. Such real-time feedback will enable the lecturer to adapt the lecture during the presentation in order to achieve the maximum impact. Myat (2014) proposed and developed the Smart Classroom

Framework (SCF) which provides an extensible and scalable structure to enable efficient development and deployment of classroom context-aware applications. Aguilar et al. (2015) and Aguilar et al. (2016) defined a Smart Classroom based on the multiagents paradigm, called SaCI (Salon de Clase Inteligente, for its acronym in Spanish). They defined the different components in a Smart Classroom and proposed two types of agents (frameworks), one to characterize the software components and the other to define the hardware components on this environment. The middleware for Intelligent Learning Environments is composed of six levels. Takawale and Kulkarni (2016) focused on finding the effectiveness of smart classroom over traditional classroom in terms of academic performance of students. Perramon Tornil et al. (2016) propose a framework for context-aware assessment of out-of classroom activities, using mobile technologies. Rohini et al. (2016) Proposed to use IoT (internet of things) to build a smart classroom, i.e., a classroom that enables real-time, automatic feedback on the quality of a lecture and the level of satisfaction of the auditorium with the lecture and the lecturer.

Specification of the smart classroom

The main components of a typical classroom are (Fig. 1): (i) a desktop computer used by instructors, a moving board and a data show which can be classified as learning system, (ii) a set of light bulbs and one or more window blinds which can be classified as light system, (iii) a cooler and a heater equipment which can be classified as temperature system and of course a set of desks and chairs for the classroom audiences. The three aforementioned systems should be triggered and operating automatically according to the current context inside the classroom with a minimum intervention from humans and in an unobtrusive manner. These systems should also trigger in a precise sequence, i.e., as soon as a course start time occurs and the classroom perceives the presence of the audience using either an entry/exit counter (respecitvely camera) or a motion sensor it triggers primarily the light system and starts to adjust it according to the current context, then it triggers the temperature system and similarly starts to adjust it according to the current context too. In addition, it turns on the classroom desktop computer by displaying the login page for instructors. Finally, when the instructor triggers a presentation, the data show are turned on, the moving board is set to the appropriate position of projection and the light system is adjusted to a presentation context, i.e., low light environment.

The dynamic behavior of the classroom could be modelled using a simple timed automaton where the states are as follows:

- *Empty:* the classroom is empty (audience number = 0), in this state all the appliances and devices of the classroom are switched off to save energy.
- *Light system on:* the classroom contains at least one person (audience number >0) and a course is started, in this state the classroom should trigger the light system and adjust it according to the current context.

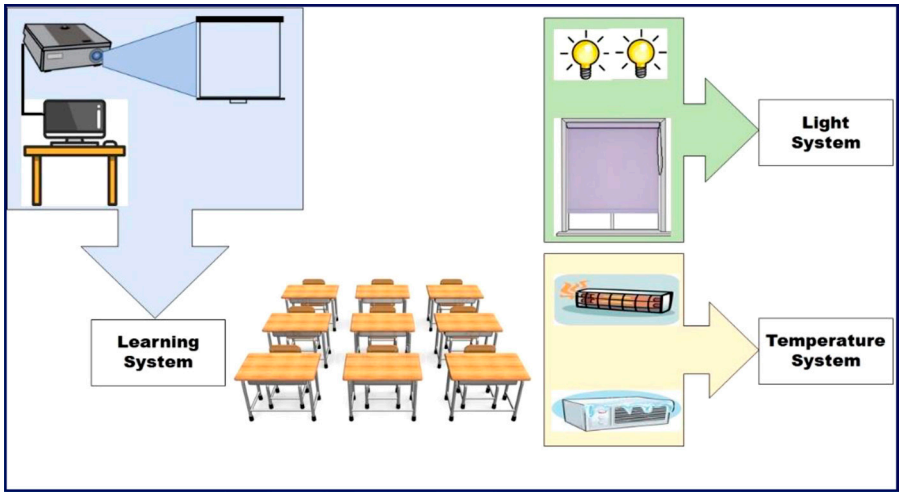

Figure 1: Basic classroom components.

- *Temperature system on:* the temperature system is triggered after a moment and adjusted according to the current context.
- *PC turned on:* the classroom desktop computer is turned on by displaying the login page for instructors and waiting for commands.
- *Learning system on:* a course is running in the classroom in the form of a presentation.
- *Learning system off:* a course is running in the classroom in other form.

The classroom has of course a schedule table describing the set of courses to be taught inside it and each course has a start time and end time. Figure 2 summarizes the operation of the classroom using a simple timed automaton.

Context-aware classroom automation

This section presents our approach to enhance the learning environment by the context-aware automation of the three main systems of a typical classroom namely light system, temperature system, and learning system.

Context definition and determination

In order to make a context-aware automation of the classroom, we should first define context and establish its elements. The context has been defined as the set of circumstances or facts that surround a particular event or situation. Several researchers have proposed definitions of context, some of which were based on enumerating contextual information (localization, nearby people, time, date, etc.) like those proposed by Schilit and Theimer (1994), Brown et al. (1997), Ryan et al. (1997), Brezillon et al. (2004), and Najar et al. (2009). Chen and Kotz (2000) showed that general context definitions remain vague and inadequate in a computing environment. Other definitions were based on providing more formal definitions in order to abstract the term, like those proposed by Dey (2001) and Henricksen et al. (2002). They were very general and do not help to limit the set of contextual information. In addition, most of proposed definitions were specific to a particular domain, such as human-computer interaction and localization systems. Miraoui et al. (Miraoui and Tadj, 2007; Miraoui et al., 2008, 2009) have made a survey of existing definitions of context and proposed a service-oriented definition of context for a pervasive and ubiquitous computing environment as follows: “Any information that triggers a service or changes the quality (form or mode) of a service if its value changes.”. They mentioned that the main advantage of their definition is that it is sufficiently abstract and helps to limit the set of contextual information. In addition, they have proposed a process to establish context elements using three steps as follows: (i) make inventory of used equipment (respectively devices), the services that they can provide and set of forms (modes) through which these services can be provided, (ii) determine the set of information which their value change trigger the previous services and (iii) determine the set of information which their value change change the forms (modes) of the previous services. The obtained information set will compose the

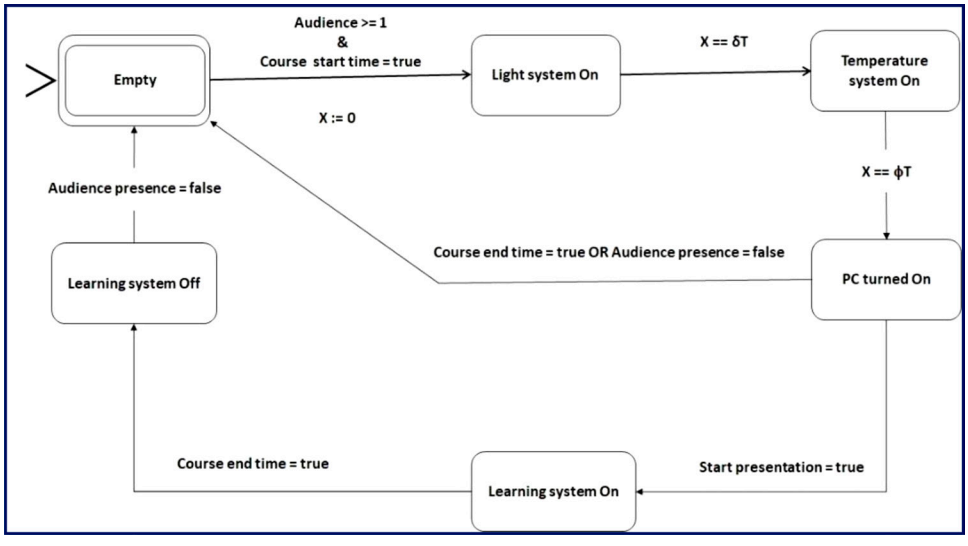

Figure 2: Timed automata of the classroom.

global context. Based on the previous definition of context and establishment process proposed by Miraoui et al. (Miraoui and Tadj, 2007; Miraoui et al., 2008, 2009), we delimit contextual information as follows:

- Inventory of used equipment, services that they can provide and set of forms through which these services can be provided as shown in Table 1.
- Inventory of the set of information which their value change trigger the services as shown in Table 2.
- Inventory of the set of information which their value change modify the forms of services as shown in Table 3.

The final set of the global context will contain the following six elements: audience presence, course start time, course end time, start presentation, outside light, inside temperature. The automation will be done according to the previous context elements.

We have used a rule-based system for the adaptation mechanism as the context of the smart classroom has a small set of elements and require few rules, it provides high accuracy with less error rate, cost effective, and easily maintained.

Light system automation

The light system of the classroom is composed of two sub systems: (i) light bulbs set and (ii) window blinds. It is triggered when a course time starts, and the classroom system perceives the presence (resp. entrance) of at least one of the course attendees (resp. instructor). When triggered the light system starts to adjust the luminosity level inside the classroom according to the current context composed basically of the outside light. This system considerably contributes to energy saving by rely largely on natural light outside the classroom coming through windows. Table 4 shows the set of rules used for the light system adaptation.

Temperature system automation

The temperature system of the smart classroom is composed of two equipment: heater and cooler. It is triggered compulsory after the light system. When triggered the climate system starts to adjust the temperature inside the classroom according to the current context which composed basically of one context element namely inside temperature. Table 5 shows the set of rules used for the temperature system adaptation.

Learning system automation

The learning system is composed of three main equipment: (i) desktop computer, (ii) data show, and (iii) moving board. The computer desktop will be turned on (login page for instructor) when a course time starts, and the classroom system perceives the presence (respectively entrance) of at least one of the course attendees (respectively instructor). Once the instructor starts a presentation, the data show will be triggered, and the moving board will be adjusted the appropriate position for display. Table 6 shows the set of rules used for the learning system adaptation.

Table 1. Equipment services and their forms.

Equipment	Service	Forms
Light bulbs	Lighting	Dark, low, average, high
Window blinds	Lighting	Totally opened, closed, mostly opened, half-opened, mostly closed
Cooler	Cooling	Off, low, average, high
Heater	Heating	Off, low, average, high
Desktop PC	Computing	Sleep, turned on
Data Show	Presentation	Off, On
Moving board	Display	Rest position, presentation position

Table 2. Service triggering information.

Service	Information
Lighting	Audience presence, course start time
Cooling	Audience presence, course start time
Heating	Audience presence, course start time
Computing	Audience presence, course start time
Presentation	Start a presentation
Display	Start a presentation

Table 3. Service forms changing information.

Service	Information
Lighting	Outside light, start a presentation, course end time
Cooling	Inside temperature, course end time
Heating	Inside temperature, course end time
Computing	Start presentation, course end time
Presentation	Start a presentation, course end time
Display	Start a presentation, course end time

Table 4. Light system adaptation rules.

Outside light	Window blinds	Light bulbs
Dark	Closed	High
High	Mostly closed	Off
Average	Half opened	Off
Low	Mostly opened	Low
Very low	Totally opened	Average

Whole system automation

The overall classroom automation is achieved using the set of the following rules that control the operation of the three basic components:

1. *If ((course start time = true) AND (audience presence = true)) then (light system = on)*
2. *If (light system = on) then (temperature system = on)*
3. *If (temperature system = on) then (desktop computer = turned on)*
4. *If (start presentation = true) then (light system = presentation light)*
5. *If ((course end time = true) OR (audience presence = false)) then (light system = on)*
6. *If ((course start time = true) AND (audience presence = true) AND (learning system = on)) then (learning system = off)*
7. *If (audience presence = false) then ((light system = off) AND (temperature system = off))*

Table 5. Temperature system adaptation rules.

Inside temperature	Cooler	Heater
Very low	Off	High
Low	Off	Average
Almost low	Off	Low
Average	Off	Off
Almost high	Low	Off
High	Average	Off
Very high	High	Off

Table 6. Temperature system adaptation rules.

Start a presentation	Data show	Moving board
True	On	Display position
False	Off	Rest position

We have used the SWI-Prolog tool for the implementation of the rule-based system of the smart classroom. We have simulated the equipment of the smart classroom. The obtained results of the implementation are very motivating.

Conclusion and future work

The aim of smart classrooms is to provide an adequate learning environment by improving the comfort inside classrooms and automating services intelligently and unobtrusively with minimum human intervention. This research paper is our attempt

to address this issue. We have used an automatic context-aware adaptation of a classroom equipment which consume precious class time if done manually and prevent instructors (resp. students) from focusing on their main tasks. The adaptation was done using a rule-based system and implemented with simulation of classroom equipment. Our future work consists of implementing a real smart classroom and evaluate our approach on real classroom equipment.

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