Towards a Smart School Laboratory

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Abstract. In this paper architecture of a smart school laboratory is proposed. It is based on technologies of Smart Environment and Multi-Agent Systems employed to improve comfort, effectiveness and safety during conducting of laboratory work with any technological equipment (e.g., computers, machine tools and so on).

Keywords: Ambient Intelligence, Smart Environment, Context Awareness, Sensor Networks, Education, Multi-Agent Systems.

1 Introduction

Nowadays many applications of Ambient Intelligence or Smart Environment are developing in different universities and research centres, e.g. for health caring, services for elderly people, enhancement of comfort of offices and home [1-8]. Known different projects aiming to development of smart environment may be divided between two kinds: 1) special smart environment oriented to solve enough narrow tasks such as assisting of elderly or disabled people and 2) general-purpose smart environment for improvement of comfort for home and office.

Examples of first kind of projects are ALARM-NET [9], SOPRANO [10-11], PERSONA [12], SC^3 [13]. Second kind of them are represented by OXIGEN [14], AMIGO [15-16]. All these and another projects and approaches to development of ambient intelligence are based on three basic technologies:

- sensing technology where information on user and surrounding environment are perceived and collected, in particular location sensing technology [17-18],
- context aware computing [19-21] technology where such information are processed and properly presented to users as different services,
- wireless network technologies where information are collected from sensors and distributed to customers – services and users [22].

In our paper we suggest usage of ambient intelligence technologies and multi-agent technology for development of smart school laboratory to conduct laboratory works in universities and colleges. This approach to development of computer-aided learning systems is novel. All current existing or developing learning systems are oriented on support of learning process, including storing and search information, testing of knowledge, combination and coordination of different sources of knowledge, visualization and simulation of real processes, hardware and software for presentation of materials and interaction between students and teacher. Examples of such system are: MetaTutor [23], ACE [24], Pat Online [25] and ISABEL [26]. Last some years any investigators propose so called "ubiquitous learning environment" aiming to provide mobile WEB-based distant learning. This concept assumes usage of technologies of smart environment adapting to workplace and current activity of learner. But this one is oriented on assisting of learning like above computer-aided learning systems. In [27] good review of different approaches to solve this task is offered. In particular, there author wrote summarization of characteristics of context-aware and ubiquitous learning suggested in [28] in the following eight aspects:

- *Mobility*: The continuousness of computing while learners move from one position to another.
- *Location awareness*: The identification of learners' locations
- *Interoperability*: The interoperable operation between different standards of learning resources, services, and platforms.
- *Seamlessness*: The provision of everlasting service sessions under any connection with any device.
- *Situation awareness*: The detection of learners' various situated scenarios, and the knowledge of what learners are doing with whom at what time and where.
- *Social awareness*: The awareness of learners' social relationship, including what do they know? What are they doing at a moment? What are their knowledge competence and social familiarity?
- *Adaptability*: The adjustability of learning materials and services depending on learners' accessibility, preferences, and need at a moment.
- *Pervasiveness*: The provision of intuitive and transparent way of accessing learning materials and services, predicting what learners need before their explicit expressions.

In contrast to approaches wrote in [27] our system can improve comfort and safety of work in laboratory for students and teacher (helps to conduct or organize but not learn) and may be collaborate with learning systems similar to MetaTutor or systems implementing of concept of ubiquitous learning environment. However, all above characteristics must be provided by our system too.

2 Scenarios

The Smart School Laboratory aims to solve following tasks:

- Help teacher to conduct laboratory work with enough large group of students:
    - to inform personally every students about details of work,
    - to advise each student, if necessary,
    - to watch current state of laboratory work as a whole and relating with every student,
    - to estimate results of work of students,

- Help student to make required sequence of steps to make laboratory work,
- Help student to keep orderliness in work,
- Predict and avoid dangerous situations working with equipment,
- Store statistics of conducting laboratory work for estimation by teacher and further analysis.

During conducting of laboratory work may be different activity scenarios of system and participants. Examples of some of them are below.

Scenario 1. Access of student to laboratory work (for case if the laboratory aims to study informaion technologies by computer).

The student sits down on chair in front of computer. By pressure sensor in chair and recognition of student near computer the computer and software for testing of needed knowledge for laboratory work is starting. If student passed test with enough good results the software for laboratory work is starting. Otherwise may be different actions: denied in access to work, repeat test with another set of questions or start of training course to access student to laboratory work. In all cases information about results of testing and decision are saving in Database and transmitting to teacher.

Scenario 2. Absence of student near work place.

If any student is absent near work place during a long time (except time period for rest), e.g. more then 10 minute, system reminds student (through his smartphone) to continue to work and send message about this case to teacher. Besides system keep information about this case in Database.

Scenario 3. Coming of teacher out free laboratory after complicated laboratory work.

In this case system checks close or not windows, sen off of climate control system, light, media projector and another equipment, check of lost flash memory in computers (if it is laboratory for information technologies).

Scenario 4. Recognition of dangerous noise from equipment.

This scenario may be used if laboratory contents any machine tools. I this case system must be learnt to recognize strange and dangerous noise which may be result of predangerous situation. In case of recognition of this one the system must recognize concrete equipment as source of noice and shut down this equipment.

Scenario 5. Climate control.

During laboratory work the system gets information about temperature and humidity from corresponding sensors. If these parameters exceed the bound of determined values for enough comfort the system set on or off climate control equipment.

3 Proposed Architecture

Structure of hardware for smart laboratory for study of different information technologies is shown in Figure 1. Here are local wire and wireless networks.

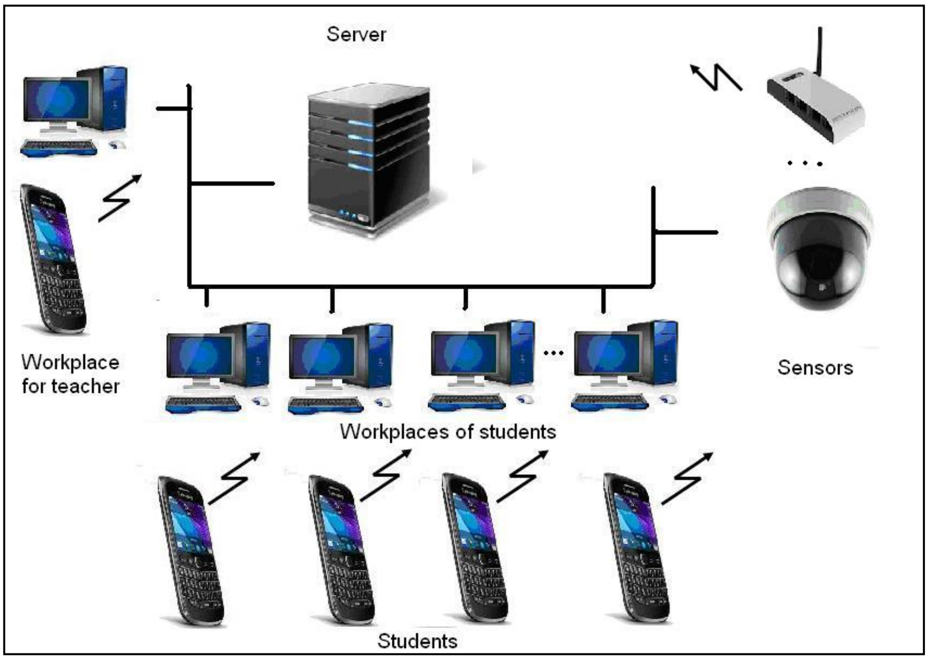

Fig. 1. Hardware of smart laboratory.

Proposed architecture of middleware consists of knowledge and some subsystems (Figure 2).

Knowledge consists of knowledge base for decision making in respect to possible scenarios and context describing current situation.

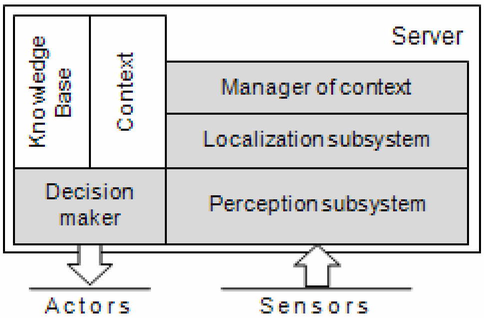

Fig. 2. Architecture of smart school laboratory.

Decision making aims to manage smart objects by actors. In this architecture we mean as smart objects computers or computer based equipment (actions with any programs, output of messages and so on), switches (of light, hitting, energy and so on), media projector, smartphones and so on.

Decision maker may be implemented as hybrid expert system (HES) using frames and rules connecting with linguistic variables recognized by perception subsystems. Architecture of such hybrid expert systems ESWin was developing in [29-31]. In particular, in [31] was shown possible usage of ESWin for implementation of smart home. Decision maker is oriented on solving of such kinds of task as:

- high level of object or situation recognition,
- issue of recommendations to make laboratory work and to avoid disadvantages or dangers relating with equipment,
- prediction of dangerous situations and shutting off different equipment in these cases.

For example, any rule used in decision maker corresponding to scenario 2 may be looked as “If Student X is absent and Time of absence X > 10 minutes then send message to student X ‘please come back to work place’ and send to teacher ‘Student X is absent more than 10 minutes’”. Besides information about this case writes to database to keep for further analyzing.

For implementation of decision maker employing tool ESWin above rule can be formalized as:

```
RULE 1
=(Student. Name; Any)
=(Name. State; Absence)
>(Name. Time of state; 10)
DO
MS(Action. Message to student; Please, come back to work place)
MS(Action. Message to teacher; Student ‘Name is absent in laboratory)
=(Name. Event; Absence more than 10)
ENDR
```

Here first condition of rule aims to connect any student with his frame. Name of frame (Name) is replaced by name of student and rule began to work with frame describing of any concrete student. Last conclusion in rule aims to keep of remark about behavior of this student during laboratory work to use in future. If frame describing of student is connecting with data base then this remark is appending in table as record describing event dealing with this student. Message “Absence more than 10” is wrote into pole “Event” and another poles are filling by information about time and data of the event.

For implementation using ESWin the context consists of frames describing states of different objects and agents of smart laboratory, for example, frame with information about any student:

```
FRAME=Ivanov
    State: Present
    Time of state: 35
    Step of work: 2
    Number of workplace: 4
    Balls for ready to work: 70
    Balls for completed work:
ENDF
```

This frame-instance is produced from frame-prototype (Name is replaced by real surname of student):

```
FRAME=Name
        State: (Present, Absent)
        Time of state (number):
        Step of work (number):
        Number of workplace (number):
        Balls for ready to work (number): 70
        Balls for completed work (number):
ENDF
```

Perception subsystem aims to recognize images (objects, situations, activity and so on), obtained from different sensors through wireless sensor network. We mean as sensors following devices: video or photo cameras, light and temperature sensors, pressure sensors in chairs, sensors in doors and windows, RFID sensors and so on. Beside as sources of information for this subsystem may be computer or smartphone. In this case data for recognition and decision making may be already previously processed by corresponding “intelligent sensor” and may be ignore and transmit to another subsystem by recognition subsystem without processing. Recognition subsystem may be implemented as set of neural networks or as Bayesian network.

Localization subsystem aims to recognize, store and track of location of students and teacher, appearance and disappearance of students and teacher inside room. Te recognize location may be used approach based on neural networks recognizing location described by signal strength vector from some sources [32-33]. But instead radio signals proposed in these articles may be used ultrasound signals. Alternative approach to calculate location may be based on distributed visual system [34].

Context manager uses recognized information to append and change context in which the decision maker, localization and recognition subsystems are solving their tasks.

Context contents description of states of dynamically changing parameters of laboratory such as: locations of each student and teacher with their identification information, current step of laboratory work on every equipment, relations between students and equipment, list of students whom must work this laboratory work and information about absence of anybody, recognized activity of students and teacher (e.g., sitting, writing, reading, coming to another equipment or student, coming out room, coming into room, producing of strong noise by student, any another unknown/unrecognized activity and so on).

This architecture may be implemented as multi-agent system. For example, for laboratory of information technologies we can select following main kinds of agent: Computer, Visual Sensor, Audio Sensor (microphone), Pressure Sensor, Light Sensor, Smartphone, Window Agent. Any agent can produce messages and be in any states. Agents can be implemented as software inside corresponding smart objects or in server. Possible messages and states are shown in Table 1. Some of them are active agents (e.g., Computer and Smartphone) which can solve of any tasks or parts of tasks of subsystem Decision Maker.

Besides some agents from Table 1 can receive and execute commands from system, e.g. Computer and Smartphone. Such agents are combination of sensors and actors. Besides there are some agents-actors, for example, Light Switch, Climate Control and so on.

Table 1. Messages and states of agents.

Agent	Messages	States
Computer	Turn on or off. Insertion of flash memory or taking out. Start of any program. Complete of any program. Enter of string from keyboard. Try to start software being foreign for laboratory work.	Is working or no. Flash-memory is connected or no. Running any determined program or no.
Visual Sensor	Appearance of user. Disappearance of user. Any activity is recognized.	User is existing or no. One user or more. Recognized activity of user.
Audio Sensor	Loud noise. Recognized any phrase.	Turn on or off. Speech. Noise (not speech)
Pressure Sensor	Set on. Set off.	Anybody is Sitting. Free.
Light Sensor	Increase of light. Decrease of light.	Low, normal or high level of light.
Smartphone	Question (command) from available set to access to system.	Inside or outside room. Location in room.
Window Agent	Opening or closing window.	Opened or closed window.

To prepare such system to use is serious problem. This system joins symbolic knowledge represented by rules or/and frames and trained different classifiers based on neural networks or/and Bayesian networks. These knowledge are very varied from one application to another. So important part of this system will be any software to help of building of smart laboratory (Smart Laboratory Builder), combined capabilities for teaching of system and formalization of knowledge. Building of SLB may be based on principles employing context and natural language suggested in [35-36] and set of frames and rules like in expert toolkit Eswin [29-30] with alternative or additional tools based on ontologies [37].

4 Conclusions

Proposed architecture of smart school laboratory will provide improvement of organization of conducting students and teacher work; will increase safety using different complex and dangerous equipment. Such system may provide for teacher opportunity to have 2-3 classes simultaneously using smartphone for real time communication with smart laboratories and students.

Now experimental development and implementation of this architecture is planning. As experimental testing area we intend two school laboratories: for study of information technologies and for study of technological machines.

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