# Conceptual Design of a Smart Classroom Based on Multiagent Systems

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**Abstract -** *The smart environments have been used in different domains: home, educational and health centers, etc. Particularly, a smart environment in education must integrate different aspects linked to virtual and presencial education, the profile of the students, to the pedagogical paradigm used, etc., in real time. In this paper we characterize a smart classroom considering these aspects, using the multiagent systems paradigm. Particularly, we define the different components of a smart classroom with their properties. Based on that, we describe these components like agents using MASINA, a methodology to specify multiagent systems. We define two frameworks of agents which describe the different types of components in a smart classroom (of software and of hardware), and give examples of applications of these two frameworks in a device and a software of a smart classroom. Finally, we show an example of conversation in a smart classroom based on our multiagents approach, specifically in a work session.*

**Keywords:** Smart Classroom, Multiagent System, AmI, Middleware

## 1 Introduction

The new advances in information technology, mainly in ubiquitous and pervasive computing, allow us interact with all computation devices as a whole, and express our tasks in a high abstraction level very natural. The research domain in Ambient Intelligence (AmI) is motivated by this idea. In [1] has been defined an AmI for the education as any space where ubiquitous technology helps the learning process in an unobtrusive manner.

Smart Classroom for the education is one of the challengers in the area of AmI. AmI brings new ideas and approaches into educational process at every level of education. Redefine a classroom is an inevitable trend, where is integrating sensor technology, communication technology, artificial intelligence, etc. into classroom. The idea is to exploit the smart environments in an educational process, considering the specific aspects on the educational domain (presencial and virtual education, self-formation, etc.) and the advances in ubiquitous computing, augmented reality, mobile computing, etc.

A previous work has developed a middleware based on multiagent systems to support smart educational environments [2]. This middleware proposes different levels, one for the management of the multiagents community, other to manage the access to services, applications, etc., and the last one to characterize the different components (of software and hardware) of these environments. This specific level can be customized for one particular educational environment.

In this paper we define a Smart Classroom based on the multiagents paradigm, called SaCI (Salón de Clase Inteligente, for its acronym in Spanish). We define the different components in a Smart Classroom and propose two types of agents (frameworks), one to characterize the software components and the other to define the hardware components on this environment. Additionally, we test the capabilities of description of this frameworks in one component of software and of hardware. Finally, we modeled a conversation in the Smart Classroom.

Our Smart Classroom is supported by the middleware to smart environments based on multiagent systems developed in [2]. This middleware is customized, in order to describe the different components of the Smart Classroom. The description of the agents and of the conversations are made using MASINA [3], a methodology to specify multiagent systems.

This work is organized like follow: the next part present some concepts linked to a Smart Classroom, the next section presents the state of the art about Smart Classrooms. Section four presents the middleware, and the next section presents the different components of a Smart Classroom, the frameworks based on agent to describe them, and one example of application of these frameworks. Finally, we present one example of conversation in a Smart Classroom based on multiagent systems.

## 2 State of the Art

There are a lot of works in the domain of AmI, and in the domains of e-learning, cloud learning, etc. that is part of the technology used for education. Additionally, there are a lot of products of software in the education domain (Intelligent Tutorial Systems (ITS), Computer-Supported Collaborative Learning Systems (CSCL), Content Management Systems,

(CMS), Learning Management Systems, (LMS), Virtual Learning Environments (VLE), Learning Content Management Systems (LCMS), etc.). For our case, we are interesting in the works that propose AmI for educational purpose. In this section we present some of these works.

A first work is the state of the art presented in [4], in the area of ubiquitous and context-aware learning in a special type of smart environment: smart workplaces. They introduce the concept of smart learning which include the areas of ubiquitous and context-aware learning. They present several works in the domain of smart offices [4-6] and smart learning (ubiquitous and context aware learning) [4, 7].

Other interesting project is the Smart Classroom project [8]. It proposes a real-time interactive classroom by bringing pervasive computing technologies into traditional distance learning. The goal of this project is to integrate the teacher's experience in tele-education and in the traditional classroom education. They propose a 3D user in an augmented classroom, so that the teacher can interact with the remote students like interacts with the local students.

The AARTIC project [9] proposes an intelligent environment that assists software engineering students in their assignments. The system helps the student to understand concepts using. They propose two agents: the first supervises students' activities in the system, and the second allows the teacher to evaluate the class as a whole and each student.

In [10] is proposed an ubiquitous learning environment in order to support students doing learning activities. It can detect the physical objects on the environment and provides a recommendation based on it. The students can contact, interact, and collaborate with other students, in order to reach learning goals.

In [1] proposes two ubiquitous devices for an intelligent learning environment: The Experience Recorder which is an embedded system that records the paths followed by a student in a classroom, and an iBand which is a wearable bracelet-like device that has information about the students.

Other smart environment is ISABEL [11], which is a multi-agent e-learning system, where the idea is to divide the students in groups with similar profiles, where each group is managed by a tutor agent. Additionally, there a teacher agent associated to each e-learning site, which provides recommendations to the student agents, active in that site in a given moment.

[12] presents an augmented reality environment to help students in the learning process. The environment, called SESIL, recognizes book pages and specific elements of interest within a page, as well as perceives interaction with pens/pencils, etc. The environment gives an assistance unobtrusive, context - aware of the student. In this way, the learning process can be improved with the presentation of related material.

The SMART Classroom project has like goal to combine the latest technological teaching tools, collaborative teaching and pedagogy, to create an education service environment [13]. They propose three concepts to describe a Smart Classroom: the "Smart Pedagogy", the "Smart Learning Space" and the "Smart Teaching Solutions". The "Smart Pedagogy" is based on the different pedagogical methodologies, because a Smart Classroom must allow the application of different pedagogical methodologies to provide more interactive alternatives that a traditional teaching environment. The "Smart Learning Space" covers both physical and virtual teaching spaces, defining the essential furniture and technical specifications of ideal physical classrooms, and the most important features of virtual learning platforms. This space must allow flexibility and the ubiquity of the learning process. Finally, the "Smart Teaching Solutions" are the different tools and materials for the learning process like the learning objects, games, simulators, etc.

## 3 Middleware used by SaCI

In this work we are going to use the middleware for Intelligent Learning Environments proposed in [2] This middleware propose six level (see Figure 1). The physical level has the different software components to interconnect the different elements of the environment (software or hardware), like APIs, etc. It is connected and worked with the Operating System, for the different activities to be carried out in the environment.

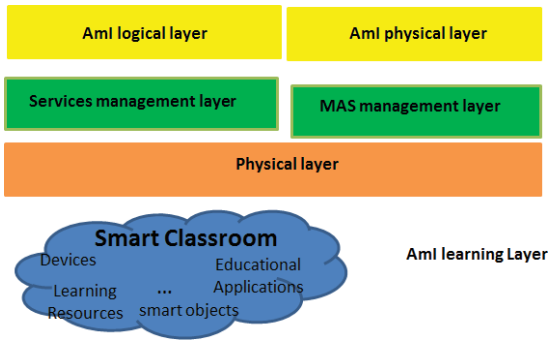



Figure 1. Middleware for Intelligent Learning Environments instanced in a smart classroom.

The multi agent system management level is composed by a multi-agent community to support the execution of multi-agents applications. This level follows the FIPA standard and has been defined in previous papers [14]. The services management layer has the responsibility of finding, searching, etc. services required in a given moment by the applications in the platform. The AmI physical layer represents the different devices present on the environment, represented like agents. The AmI logical layer represents the different software components that are used in the educational platform. This

layer describes the different software components of SaCI like agents, but additionally it has two agents: a profile agent to represent each student in SaCI (its capabilities, learning style, etc.), and the tutor agent to represent the professor in SaCI. Finally, the AmI learning layer is where are deployed the different devices and software of SaCI.

In this paper we are going to define the agents that compose the AmI physical and logical layers. For that, we are going to define a general type of physical agent (framework) to represent the different devices in the educational platform (intelligent or not). Similarly, we are going to define a general logical agent (framework) to represent the different educational softwares, or the individuals present on the environment.

# 4 Agents Specification for SaCI

In this work we are going to use the middleware for Intelligent Learning Environments

In this section we specify the agents of SaCI, basically they define the physical and logical layers of the previous Middleware. At the beginning we define the physical layer of SaCI, starting with the list of the different devices in SaCI, then we define the framework to represent the devices like agents, and finally we give an example of utilization of the framework in a device of SaCI. Next, we define the physical layer of SaCI following a similar procedure.

## 4.1 Agents of the AmI physical layer

### 4.1.1 Characterization of the devices of SaCI

In this section we present a list of the possible devices in a smart classroom like SaCI. These devices can be or not in a given moment in the environment. Table 1 presents this list, and for each device we define their capabilities, tasks in the learning process, their components, and their interactions with other components of SaCI.

### 4.1.2 Agent Model for the AmI physical layer

In this section we propose a general model (framework) to describe the different devices of SaCI (intelligent or not) like agents. This general model has general information of each device, and information about its tasks and intelligence (The framework is based on MASINA models [3], specifically the models of agent, task and intelligence). The framework is composed by the next templates, one initial template with the basic information of a device (see Table 2).

Because the middleware is based on the idea of services to be provided between the agents, the list of services given by the agents is very important. Now, we need to describe how the services are given by a device. For that, template in Table 3 describes the different tasks that must be executed in a device (physical agent) in order to give the set of services previously defined. For that, it is necessary fill out one task template for each task.

| Device | Tasks | Components | Intelligent Capabilities | Interaction with other components of SaCI |
|---|---|---|---|---|
| Student Board | Represent the virtual student in the AmI | Video camera, screen, processor, wifi, bluetooth | Detect the presence of a student.<br><br>Recognize and adapt to the mood of the student | Smartboard LVE |
| Smart board | Display learning contents<br><br>Allow students - educational contents interaction | Touch support, Display high-resolution processor, wifi, bluetooth | Adapt educational contents to context | LVE Student Board Smart cameras Interactive desk |
| Smart camera | Show who speaks in the physical environment<br><br>Follow the activities in the environment | Processor, wifi, bluetooth, | Follow active objects in the environment (moving, talking, etc.) | Smartboard Student Board |
| Interact desk | Show educational multimedia contents (photos, videos, etc.)<br><br>Enrich contents | Processor, Display high-resolution wifi, bluetooth, stereo speakers, microphone, touch support | Adapt educational contents to users | Smartboard LVE |
| Social Robot | Recognize emotional states in the environment<br><br>Motivate and arouse interest in activities to learn | Vision System; Recognition System of Face, Gesture and Speech; Music Player; Object Tracking; Obstacle Detection; etc. | Adapt to the context surrounding it | Smartboard LVE |
| Augment Reality System | Enrich contents | Processor, Video Beam | Adapt educational contents to users | Smartboard LVE |

Table 1. List of the possible devices in SaCI

Finally, some of the devices can be intelligent. In this case, we must define an intelligent template (see Table 4) with the basic information about that.

**ID device:** the physical identification of the device,
**Type device:** the type of device.
**Name Agent:** the name of the device in the multiagent system.
**Description:** describes the general characteristic of the devices.
**Components**: a device can be composed by other devices.
**Goal:** what is it the main function of this device in the educational environment.
**Services:** list of services given by this device in the educational environment.

Table 2. Basic Information of a Device

**Task Name:** name of the task.
**Objective:** goal of the task.
**Description:** describes the task.

Table 3. Tasks Template

**Learning mechanisms:** if the device has learning algorithms.
**Reasoning mechanisms:** if the device has reasoning algorithms.
**Ontologies:** list of ontologies (domains, contextual) used by the device.
**Historical Information:** if the device keep historical information.
**Source:** where is stored the data used by the device (database, etc.).

Table 4. Intelligent Template

#### 4.1.3 Example of Specification of a device of SaCI like Agent

In this section we show how to specify the SmartBoard like agent using our framework (See Tables 5, 6, 7 y 8).

**ID device:** SB001,
**Type device:** Smart Board,
**Name Agent:** Smart Board,
**Description:** Board with intelligent capabilities to interact with users, etc. The Smart Board operates as part of a system that includes a interactive whiteboard, a computer, a projector and collaborative learning software for education.
**Components**: whiteboard, a computer, a projector, touch system
**Goal:** Students are able to work more collaboratively on a single workspace where the contents are shown.

**Services:** display learning contents, allow the interaction students-contents

Table 5. Basic Information of a Smart Board

**Task Name:** Display learning contents
**Objective:** allow to see the contents.
**Description:** this task is for allow to show the educational contents and interact with them

Table 6.Task Template for the task "Display learning contents"

**Task Name:** Allow students - educational contents interaction
**Objective:** allow the interaction among the students and the contents .
**Description:** The dives need an interface (like a touch system) in order to allow the interaction amongo the contents showed and the students.

Table 7.Task Template for the task "Allow students - educational contents interaction"

**Learning mechanisms:** the device has learning algorithms in order to learn the behavior of the users.
**Reasoning mechanisms:** the device can use the knowledge to reason about the .
**Ontologies:** this devices need ontologies about the environment (contextual). The information about the users (profile, subject studied, etc.) are asked to other agents
**Historical Information:** not apply.
**Source:** the device has internal databases.

Table 8.Intelligent Template to Adapt educational contents to context

### 4.2 Agent of the AmI logical layer

#### 4.2.1 Characterization of the software components of SaCI

In this section we present a list of some of the possible softwares in SaCI. These softwares can be or not in a given moment in the environment. Table 9 presents this list, and its characteristics.

| Software | Tasks | Components | Intelligent Capabilities | Interaction with other components of SaCI |
|---|---|---|---|---|
| Virtual Learning Environment (VLE) | Manage educational contents<br><br>Store information about the user's profile<br><br>Enable tutors and students to exchange messages with other participants, teamwork, download educational resources, consult the teacher, etc. | Courses<br><br>Educational resources<br><br>Interactive tools | Adapting to the user profile<br><br>Learning the user's learning style and adapt instruction to it. | Smartboard<br><br>Smart cameras<br><br>Interactive desks |

| | | | | |
|---|---|---|---|---|
| Repository of learning objects | Manage educational resources in different formats. | Database<br><br>Ontology to describe the learning objects<br><br>Resources web server | Discovery new learning objects | VLE<br><br>Smartboard |
| Recommender system of educational resources | Suggest educational resources to students according to their learning style<br><br>Provide personalized answers to the user | Educational Resources<br><br>Knowledge base | Provide resources adapted to the learning style | Repository of learning objects<br><br>Smartboard<br><br>VLE |
| Academic System | Register students performance | Curricula<br><br>Student Records | Not apply | VLE<br><br>Recommender system of educational resources |

Table 9. List of the possibles softwares in SaCI

### 4.2.2 Agent Model of the AmI logical layer

Like the previous phase, we propose a framework to describe the different software of SaCI like agents. This framework has general information of each software, and its tasks and intelligent behavior, and like the previous framework is based on MASINA models [3]. The framework is composed by the next templates, one initial template with the basic information of a software:

**Name software:** the name of the software,
**Software Type:** the type of educational software (VLE), management, etc.,
**Framework:** if the software is based in a framework, etc.,
**Name Agent:** the name of the software in the multiagent system,
**Description:** describes the general characteristic of the software that is represented
**Components**: maybe this software can be composed in other subsystems
**Goal:** what is it the main function of this software in the educational environment.
**Services:** list of the services given by the software in the educational environment.

Table 10. Basic Information of a Software

Now, for each service we describe the tasks that must execute each software. For that, we use the same task template defined in the previous section (table 3). Finally, some softwares can be intelligent systems. The basic information about this aspect is defined in the same intelligent template defined in the previous section (table 4)

### 4.2.3 Example of Specification of a software of SaCI like Agent

In this section we show how to specify the VLE like agent using our framework.

**Name software:** Virtual Learning Environment (VLE)
**Software Type:** Educational management
**Framework:** NA
**Name Agent:** VLE,
**Description:** This system allows access to courses in which the student is enrolled and supports the teaching-learning process by providing educational and resources tools that are presented to the user based on their profile.

**Components**: Courses, Educational resources, Interaction tools, Video collaboration software, and other own interaction of VLE such as: internal mail, chat, forum, course management module, etc.

**Goal:** Facilitate student interaction with the main actors of the learning process: teachers, educational resources, and media.

**Services**: Manage educational contents, Store information about the student's profile, Enable tutors and students interaction.

Table 11. Basic Information of VLE

Now, we only specified its task to manage educational contents.

**Task Name:** Manage educational contents
**Objective:** it manages the sequences of presentation of the contents according to the curricula. Additionally, it uploads and updates documents in different formats.
**Description:** Each course has a sequences of educational contents to be used. This system controls the advances in the presentation of these contents. Additionally, this resources can be updated.

Table 12. Task Template to manage educational contents of VLE

**Learning mechanisms:** This software doesn't use learning algorithms
**Reasoning mechanisms:** This software doesn't has reasoning algorithms.
**Ontologies:** not apply
**Historical Information:** The VLE stores historical information on each course, such as, actions on the tools (forums, chat, messaging), reading and downloading documents, student score, consultations to the teacher, etc.
**Source:** Databases, academic system

Table 13.Intelligent Template of VL

# 5 Conversations in SaCI

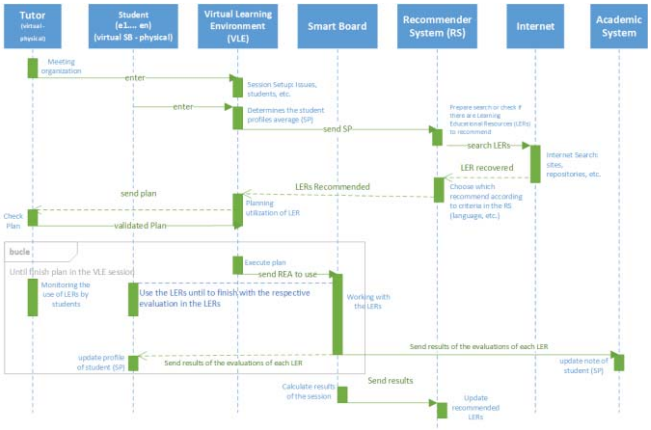
A main aspect in a multiagent system is the capability of interaction between the agents. During the execution of a multiagent system there are several occasions where the agents need interact to reach one specific goal. Each set of interactions to reach a given goal in the system is called in MASINA conversation. We keep the same idea to describe the interactions in SaCI.

In this section we describe one of the conversations in SaCI, and how is specified using the conversation model and the interactions diagram proposed in MASINA. We will analyse the conversation linked to the online tutoring process in SaCI. We start defining the conversation model (see table 14).

| |
|---|
| **Conversation Name:** online tutoring process<br>**Goal:** help the students during their processes of learning<br>**Agents:** VLE, a smart board, a recommender system of learning resources, an academic system, a tutor, and several students.<br>**Beginner:** tutor and students<br>**Precondition** A new subject to be covered in the curriculum by the students.<br>**End condition** When the student finish the interaction with the resources of learning planned by the VLE and tutor for this session<br>**Description** This conversation describes the different activities on the AmI to support the online support to the students. These activities are carried out by different agents according to their roles. For example, VLE plans the learning resources to be used during the session, and monitors its utilization during it. Also, it demands to search the learning resources according to the students´ profile and the subject of the session. |

Table 14. Example of conversation in SaCI

In the conversation are involved different types of agents of SaCI: one device type, and the rest of software type: VLE, students, etc. Figure 2 shows the interaction diagram of this




conversation.

Figure 2. Conversation "online tutoring process in SaCI"

In Figure 1 the process of tutoring in SaCI is represented like a conversation between SaCI agents. SaCI adapts the online tutoring process to the requirements of a specific session. For that, VLE determines the subjects to learn and the students´ profile, and immediately asks an intelligent search (that is carried out by the recommender system) of learning resources, which are shown into the environment by the smart board according to the planning defined by VLE. Then, the students interact with these learning resources via the smart board, and VLE monitors the work of the students (normally, the learning resources have an evaluation phase before to finish with their utilization, that VLE must guarantee the students carry out). This is a cyclical process that is done in each tutoring session. At the end, VLE establishes a student's score (evaluation), and updates the learning profile of the students in function of these results (learn) for the next session.

# 6 Conclusions

A flexible way to model AmIs is very important, in order to extend its utilization in different domains: home, classroom, museums, etc. This modelization must consider the main aspects on these environments: the intelligent capabilities of the components and the interactions between them. The multiagent paradigm supports very well these requirements of modelization.

But in order to model a smart classroom using agents, it is necessary define a middleware to support the community of agents that describe the AmI. The work defined in [2] solves this problem. In this way, the main aspect is to describe the different components of the AmI, and like they are represented on the middleware. That is the goal reached in this work for the case of a smart classroom.

Particularly, we see as SaCI can be described very easy based in our multiagent framework. Additionally, the dynamical behavior (described by the conversations) are also described very well. In this way, the components and the conversations in SACI are describe without problem.

In general, the scalability and flexibility properties of an AmI can be studied in our model, as well as more complex properties like the emergence and the self-organization will be able be analyzed in next studies using this modelization.

Our templates give the main information of the agents of software and hardware, but if more details are required in order to be implemented (for example, about the language of knowledge representation, the type of coordination in a conversation (for example, auction), etc.) the template can be extended using the models defined in MASINA.

Next work must analyse the emergence and the self-organization of SaCI using this model, and the specific problems of implementation (multiagent platform, communication protocols, etc.). The middleware defined in [2] is a good base to start this implementation.

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