

Co-BrainSystem: Supporting Brainstorming to Enhance Collaborative Work in Educational Environments

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Abstract—Engaging students in active learning is an important challenge in today's classrooms. The proposal presented in this paper aims to take advantage of the benefits offered by new technologies in order to increase creativity and expressiveness in educational environments. In order to achieve this, we have designed and developed a system that allows the use of creative learning techniques such as Brainstorming. Co-BrainSystem is a collaborative and interactive system aimed at improving brainstorming sessions in learning scenarios. The system is composed of a shared and a private workspace. The Shared workspace is used to display information, ideas, documents and feedback of what is happening in the session. The private workspace consists of Tangible Interfaces integrating emerging technology, in this case RFID tags and a mobile device that integrates an RFID Reader. The system is based on MDE (Multi-Device Environments) and uses a new mode of interaction called Approach & Remove that allows users to handle Distributed User Interfaces easily.

I. INTRODUCTION

IN RECENT years, teachers have transmitted the teaching-learning process through books in the classroom. However, today education can be achieved in a more creative and less static way with other strategies and scenarios [7]. The group activity in learning scenarios is a technique that helps students to develop a better understanding, encourages them, and, above all, promotes communication and social integration. Synectics and Brainstorming are techniques aimed at improving the expressiveness and creativity of the students. Synectics is defined by William J.J. Gordon [12] and George M. Prince [22] as a problem solving process through stimulation of the mind's creativity. Furthermore, brainstorming is a creativity technique (group or individually) in which users may generate thoughts and ideas in order to spontaneously find a conclusion for a specific problem. The term introduced by Alex Faickney WAS Osborn in 1953 [20].

Carrying out brainstorming sessions in a properly way is not an easy matter. A good coordination among the group members is required, as well as a good system to support the different activities without disturbing from the main goal of the brainstorming session in a classroom.

In this paper we address brainstorming as a creative-expressive technique that we use in learning environments. The objectives we want to achieve are the following: Stu-

dents develop their creativity, overcoming conformity and monotony of classes and discussing new concepts. In this way the brainstorming sessions are used as an alternative strategy to improve the creativity.

In recent years, technology has evolved very quickly. We realize that concepts such as the Ubiquitous Computing paradigm is currently a reality, as Weiser predicted in [29]. Now, the challenge is making technology invisible for users in such a way that they do not need to focus on how to use the technology but just on the tasks they are performing.

In this paper we present an interactive and collaborative system called Co-BrainSystem, developed to improve brainstorming sessions in educational environments. The system is based on MDE (Multi-Device Environments) and in order to facilitate its usage it includes a new style of interaction called *Approach and Remove* to allow users to easily interact with the different devices. In this way users are able to focus on the task and not on the technology, thereby increasing their performance and creativity.

The rest of the paper is organized as follows: Section 2 includes a brief summary of the most relevant related works. Section 3 describes the proposed system in detail. Section 4 presents the evaluation of the system and finally section 5 presents some conclusions and final remarks.

II. RELATED WORKS

The concepts and projects related to this paper are briefly summarized hereby.

Computer-supported collaborative learning (CSCL) is a discipline that studies how people can learn together using technology as their primary means of communication or as a common resource [25]. CSCL can be implemented both in online and classroom learning environments and can take place in a synchronous or asynchronous way. This kind of learning is used in innumerable learning scenarios characterized by the sharing and construction of knowledge among participants. In order to take advantage of their benefits there are several strategies as detailed below.

Collaborative writing is one of the most common approaches to CSCL. The process of writing together encourages students to express their ideas and develop a group understanding of the subject. Some tools like blogs, interactive whiteboards, and some spaces that combine free writing

with communication tools can be used to share work, form ideas, etc. [19], [16].

Technology-mediated discourse refers to discussions and other social learning techniques involving the examination of a topic using technology. It allows participants engage in conversations and build knowledge together [16][1].

Group exploration refers to the shared discovery of a place, environment or topic among two or more people. Students use technology to better understand a physical area and comment their experiences together [14],[18].

Problem-based learning is an activity that consists in the complex problem solving among group students [15],[17].

Project-based learning is similar to problem-based learning in that it creates the obligation to establish team roles and set goals. The need for collaboration is also essential for any project and encourages team participants to build experience together [3].

Brainstorming is a technique to improve the generation of thoughts and ideas among a group of people [4]. Using technologies such as email, browser-based systems of text-based chats, may support group systems with specific tools to facilitate this process [9]. It has been demonstrated through multiple studies that the best way to perform brainstorming sessions and get the most of it is carrying it out in face-to-face. Brainstorming can be seen as a cognitive and social process as it involves individuals who think of an idea (individual cognition) and then choose to share the idea with the team (social process) [10]. Therefore, the division between private and shared workspaces is highly recommended; S. Streng in [26] shows the importance of private workspaces in collaborative tasks as they provide confidence to users. Some examples of projects supporting brainstorming in face-to-face are based on touch tables such as *WordPlay* [13], *WeSpace* [30], or digitalized rooms such as *Connectable* [28] and *i-Land* [27].

WallShare [11] is a collaborative system that can distribute the interfaces between different devices such as mobile phones, PDAs, laptops, etc. and a shared space to be displayed via a projector on a surface such as a wall.

Group scribbles [24] is a CSCL system developed in a multi-device environments; it creates flexible shared information easily.

Edistorm [5] is an online system that provides a whiteboard for users to share notes among them. Currently, these projects have an expensive infrastructure and besides, some of them only include a shared space and do not allow users to have their private space. In addition, there are school activities that need to be done in class, face to face.

When developing computer applications to support collaborative learning scenarios, the design of the user interface plays an important role. Regarding Multi-Devices environments, other kind of interfaces such as DUIs (Distributed User Interfaces) are necessary. According to Niklas Elmqvist in [6], DUIs can be defined as a user interface in which its components can be distributed through one or more dimensions. These dimensions are input, output, platform, space and time. Among the situations that support

DUIs we can mention multiple screens, multiple devices, multiple users and multiple displays.

The system we present in this paper supports DUIs and provides an interaction technique to handle it called “Approach& Remove” [23]. This technique consists in bringing the mobile device closer to the Tangible Interface to select the desired function.

III. CO-BRAINSYSTEM: ENHANCING BRAINSTORMING SESSIONS WITH TANGIBLE INTERFACES

Co-BrainSystem is a collaborative and interactive system aimed at improving and supporting brainstorming sessions in learning scenarios.



Fig. 1 Brainstorming session using the “Co-BrainSystem”

Each user has a mobile device (See Figure 1.b) that incorporates an RFID reader and a “tangible interface” (See Figure 1.a). The tangible interface is a physical panel of DIN A4 size, which shows the images corresponding to the tasks users can perform in the system. The inner of the panel contains RFID tags, each one with a unique identifier which is associated with the corresponding function. It has been designed to control the system and manage the shared and private spaces from anywhere. Furthermore, the shared space is projected on the wall so that all users can view the information easily at the same time (See Figure 1.c). The screening includes three types of information: (1) awareness information, i.e. everything that is happening during the session, the users attending the session, etc.; (2) the users’ thoughts and ideas that arise during the class and (3) the shared documents that are hosted on a server in order to facilitate the presentations. Depicted in Figure 1, we can see three users discussing on the document screened on the shared space. Each user has a tangible interface as a physical panel with

all the available functions (in Figure 1 they can be seen placed on the table) and a mobile device.

In the brainstorming session there are two types of users. The teachers are responsible for coordinating the session and stimulating the students and the students are responsible for learning and producing ideas. Next, we explain the roles of these users in more detail.

The teacher's role is aimed at creating a climate of freedom and spontaneity among students. Teachers Coordinate the session and stimulate the production of ideas. The system allows users to easily follow the feedback session that provides the shared screen. To coordinate and motivate users, teachers can put questions in the shared space and can put the corresponding explanation or upload files to help students to understand concepts. At the beginning of the classroom the teacher must ensure that the goal of the lesson is clear for the students. The teacher must create a climate of confidence and relaxation that allows communication in group. The system allows students to send notes in an anonymous way. In Figure 3 we can see the tangible menu showing the functions of the system that can be executed by the teacher in a brainstorming session. The functions are divided into three parts: (a) The first part contains the functions that control the shared screen (b). The second part shows the functions that allow the management of the ideas generated (c). The third part has the functions to manage the files and presentations on the shared screen.

Students can act in an informal session with absolute freedom to express all the ideas they want. The students can only execute the functions more closely related to the brainstorming as is to discuss ideas and upload the files they wish to share with others in order to make the class more dynamic. In Figure 2, the tangible interface for students is depicted. It shows the functions of the system that can be executed by the students in a brainstorming session, such as sharing ideas and documents in the shared workspace and saving ideas.

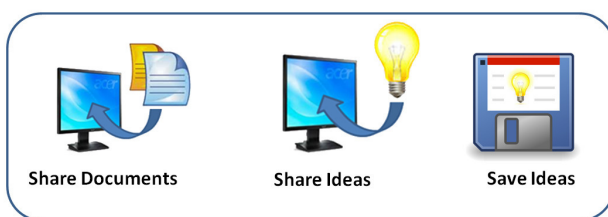


Fig 2. Tangible interface for students.

A. Multi-device environments in learning scenarios

The system is developed in an MDE (Multi-device environment) scenario, i.e., it supports different types of devices.

The brainstorming session is usually composed of a group of heterogeneous students. Everyone has different needs, for this reason users can choose the devices they prefer to use in the classroom (See Figure 4).

The application running on the mobile device is the same as the one running on any other device, laptop, PC, tablet, etc. These devices are connected via wireless and if a user

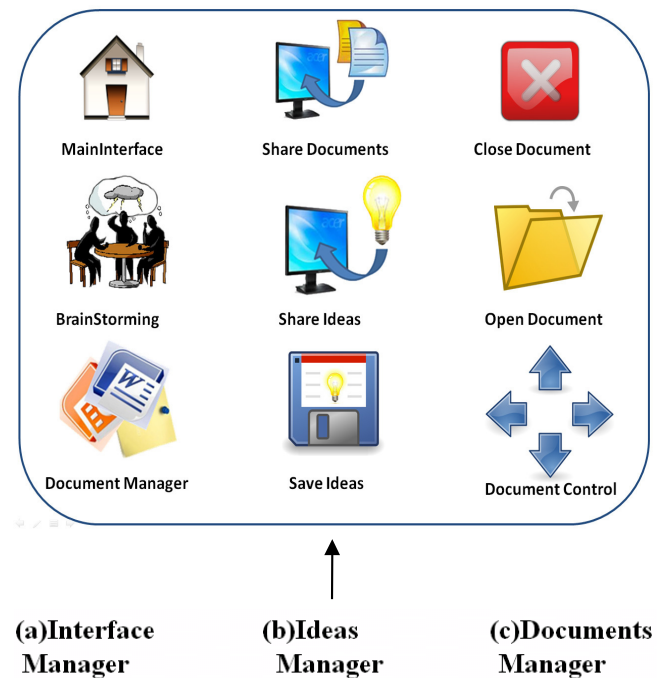


Fig 3. Tangible interface for teachers.

writes a note in a device, it is simultaneously synchronized and displayed in another device.

The mobile device has two functions; on the one hand, we can use it to write down ideas and notes, as a file browser. On the other hand, we can use the mobile phone as an interaction device. That is, if we want to execute any of the functions that the system supports, we only need to bring the mobile device closer to the Tangible Interface to select the task to be executed. This interaction mode is called Approach and Remove, as explained before.

B. Shared workspace

The Shared Workspace represents the collaborative interface. It displays on the projector important information that need to be shared among the participants of the class such as thoughts and ideas, documents and awareness information in the classroom. The Shared workspace is composed of three interfaces described hereafter.

Main Interface (Teacher)

The Main Interface is responsible of displaying the users attending the classroom. It controls the time and displays the feedback of all actions being carried out at the classroom. For example, if a user has uploaded a file note or if a user has joined the session, etc. (See Figure 5.a)

Brainstorming Interface (Students + Teacher)

The Brainstorming Interface collects all the ideas that emerge during the session. To this end, the system includes a function for users to send any note they may have written on their device, either a mobile phone, laptop, PDA, etc. (See Figure 5.b)

Shared files Manager (Teacher)

The Shared Files Manager is the interface that displays all the shared files stored on the server. It allows users to open and show these documents. (See Figure 5.c)

C. Private Workspace

The Private workspace is controlled by each individual user. There are two types of tangible interfaces depending on whether it is for the teacher or for the student. It consists of a tangible interface (one for each user) which is a physical panel where all the functions that users may select are placed; and a mobile device, which main function is to send information to the shared workspace. Thanks to the tangible interface the user can manage the system easily and control both the private information on his/her devices and the information shown in the shared workspace.

Interface Manager

The Interface Manager corresponds to the functions shown on the left hand side of the Tangible Interface, as depicted in Figure 3.a. These functions allow users to change the interface depending on the shared space that the user wants to use in that moment. Thanks to the Tangible Interface, this task can be performed remotely from everywhere in the room. The interfaces that can be screened on the shared workspace are the following: main interface, brainstorming interfaces and document manager, described in the previous section.

Ideas Manager

The Ideas Manager is responsible of sharing the ideas that users may have written, or the documents they have in their device with the rest of users present at the classroom (Figure 3.b).

Share Documents. This function is used to send documents to the shared workspace to show and share them with the rest of users.

Share Ideas. This function controls the shared ideas in the shared screen called "Brainstorming". The process is as follows: the user introduces his/her idea right from the mobile device or any other device. Then, when he/she wants to share it with other users, he/she brings the mobile device closer to the corresponding function showed with a metaphor in the Tangible Interface. Then, the document is simultaneously displayed on the shared workspace.

Save Ideas. This function is used to save all the ideas shared in the brainstorming interface in order to keep them for another classroom or discussion session. The main objective is to facilitate the search for a solution to the problem discussed at the brainstorming session.

Documents Manager

The Documents manager is responsible of opening and showing any of the documents displayed on the shared workspace (Figure 3.c). These documents are the ones hosted on the server so that users can navigate among them with the arrows available for that. When a document is open, users can move within it with the arrows.

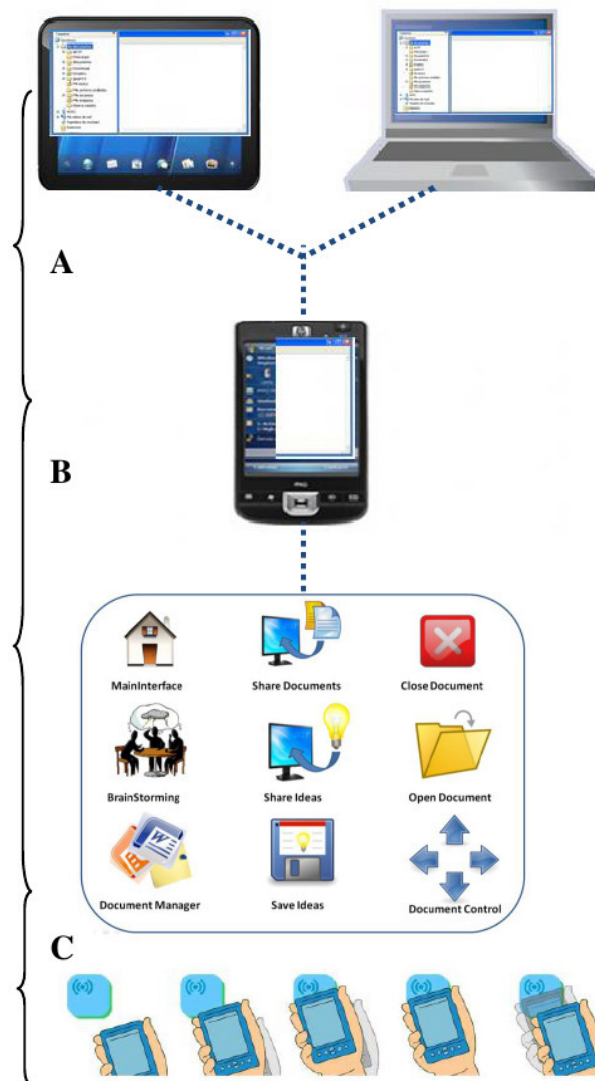


Fig 4. a. Multi-devices (laptop, table, mobile devices) interconnected.
b. Tangible Interface connected via RFID to mobile devices.
c. Approach and Remove Interaction mode

Open Document. This function allows users to open a selected document. In this way the user can present the document to the rest of users.

Document Control. This function facilitates the navigation among different documents. It also allows users to handle the pages of an open document, for instance, to go forwards or backwards.

Close Document. This function allows users to close any open document.

D. System Architecture

The system is based on a client-server architecture. This is a distributed application model in which tasks are divided among resources and services associated with the application server and the client (in our case the mobile device and computer software). They perform queries to the server and it responds with relevant information. Among the hardware



Fig. 5. Shared workspace composed of (a) Main Interface, (b) Brainstorming Interface and (c) Shared files Manager

devices we have mobile, tangible interfaces, computers, projectors and a server. The communication among devices is performed through RFID and wireless technology. We have used a client-server architecture based on web services, thus allowing any computing device (mobile, computer...) to easily connect and access the available resources.

Mobile devices, in this case, are used as interaction resources. They communicate with the tangible interface (physical panel) via RFID and with the server and the projector via Wi-Fi. The operation mode used to communicate with the panel is as follows (see figure 7): Using the *Approach&Remove* Interaction style described before, the user brings the device closer to the selected function in the panel. Then, the RFID reader in the mobile device reads the RFID tag hidden in the panel to identify the corresponding function. The ID tag read is then decoded and sent to the server via wireless. The server translates the information sent from the mobile device and executes the function corresponding to the tag read. The projector connected with the computer where the collaborative application runs, displays it on the wall in order to provide visibility to all users. Finally, the server is responsible for controlling the logic of the system. It is a computer connected to the mobile devices and the computer via Wi-Fi technology. It is responsible for hosting the files and information related to the classroom. One of its most important components is the Web Service. It is a computer program that processes a server side application performing bidirectional connections and / or unidirectional and synchronous or asynchronous with the client generating and giving an answer in any language or client side application. It is responsible for interpreting the information that the client sends and executing the corresponding function. The server has the following functions:

- Translation of the RFID tags identifiers to identify the function to be performed.
- Transfer of files and information between the mobile device and the shared workspace.
- Providing updated information about the status of users and activities.



Fig. 6. Communication between the mobile device or other devices with WebServices and the shared workspace..

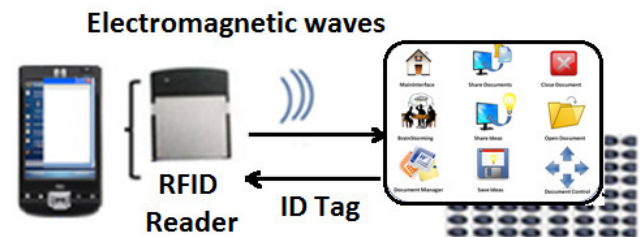


Fig 7. Communication between the tangible interface and the mobile device.

IV. EVALUATION

This section describes the evaluation of the system performed with real users to verify the benefits of the system in learning environments. Another goal is to identify the strengths and weaknesses of the system using distributed user interfaces and the new interaction style.

The goal is to answer the following questions:

- Does brainstorming technique enhance creativity in students when used in the classroom?
- Does the system encourage collaboration among users?
- How does the user feel when interacting with different devices?

A. Method and Protocol

Twenty students participated in the experimental study (12 men and 8 women). The age of the participants ranged from 13 to 16 years. In order to carry out the study twenty mobile devices were used, each one containing the software applications and an RFID reader, the tangible interfaces and

a laptop that was connected to a projector to run the shared application.

The method used for evaluation was direct observation. The purpose of this kind of evaluation is to enable designers to better understand how users make use of the systems in their natural environments. Data are collected in informal and naturalistic ways, with the aim of causing as little disturbance to users as possible [21]. Three teachers were present during the assessment and identified the problems. They answered the SUS usability test (System Usability Scale) [2].

B Task and procedure

Firstly, the users (students and teachers) received a brief explanation of the new interaction style and the functions offered by the system. The teacher was responsible for starting the classroom. The task was carried out as follows, the teacher proposed a topic, explained some slides on the shared screen and the students sent notes to the shared workspace.

During the tests, the evaluators took notes of the time spent, the number of errors occurred and any other relevant information. At the end of the testing session teachers were asked to perform the SUS usability questionnaire. The System Usability Scale (SUS) is a simple, ten-item scale test giving a global view of subjective assessments of usability. The questionnaire consisted of the following questions.

1. I think that I would like to use this system frequently
2. I found the system unnecessarily complex
3. I thought the system was easy to use
4. I think that I would need the support of an expert to be able to use this system
5. I found the different functions were well integrated
6. I think there was too much inconsistency in this system
7. I imagine that most people can learn to use this system very quickly
8. I found the system very cumbersome to use
9. I felt very confident using the system
10. I needed to learn a lot of things before I could get going with this system.

C Results and discussions

The level of subjective satisfaction obtained from the use of the system, as measured with the SUS test, can be regarded as quite usable. The scale yields a single composite number representing the measurement of the usability of the system under study. The system scored 87.1 (out of 100) with a standard deviation of 6.13 exactly. All the participants had a positive view of the system (i.e. the system rated over 50).

The notes included in the evaluation were the following:

-Seventeen out of the twenty participants sent notes to the shared workspace.

-Three out of the twenty participants were distracted during the session.

-Six out of the twenty participants sent files to the shared workspace.

-Only two participants asked for help in the first part of the classroom.

-The time required to learn how to use the system was quite little. The system was capable of guiding them along and motivating interaction, as they found it intuitive.

-The participants repeated the session because the first time they had enjoyed with their classmates. They also realized that they did better than before and were therefore more satisfied and motivated.

- Everyone saved the shared notes. In general, students showed interest, were motivated and cooperated with each other easily. They focused more on providing ideas than in using the system. They learned how to use it quickly. The application offered the option of adding their names on the notes or sending them anonymously. Eight out of the seventeen notes were anonymous.

After reviewing the results of the evaluation, we can say that the system was regarded as simple and easy to use by the users. The user interface was considered effective and aesthetically appealing. The participants experience with the system was described as very useful and fun. The new interaction style was very nice and attractive and the users were able to feel immersed in the brainstorming session.

V. CONCLUSIONS AND FINAL REMARKS

This paper presents Co-BrainSystem, a collaborative and interactive system based on RFID to improve brainstorming sessions in educational environments. This proposal supports a new mode of interaction with Tangible Interfaces used like expanded menus to facilitate the different tasks available in a Brainstorming session. The interfaces developed allow users to handle the system in a more natural and flexible way. Besides, it is possible to remotely control the shared workspace from the Tangible Interfaces. The possibility of having a private and a shared workspace allows users to handle their private information and the shared one in a different way. It is also worthy to note that the deployment cost is very low, for this reason the system is easily scalable. The main advantages of the system are the following: It provides a simple and intuitive mode of interaction, where users do not need prior learning to use the system. All they have to do is to bring the mobile device closer to the Tangible Interface. The highly Interactive, dynamic and friendly interfaces encourage users to use the system and make the most of the advantages it offers. The cost of the physical panels (Tangible Interfaces) is very low, as passive RFID tags are very cheap. The system allows and encourages the participation of all students, increasing camaraderie and creativity.

ACKNOWLEDGMENT

This research has been partially supported by the Spanish CDTI research project CENIT-2008-1019, the CICYT TIN2011-27767-C02-01 project and the regional projects with reference PPII10-0300-4174 and PII2C09-0185-1030-1. We would like to especially thank Jesús Serrano Navarro for his collaboration on this project.

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