TouchBoard: Collaborative Work over Multi-touch Surfaces

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Abstract. Nowadays it is increasingly common to use digital content in face-to-face meetings despite that these meetings normally lack information systems support. Indeed meeting participants almost always need to connect laptops to screen projectors and take turns while using collaborative software applications. This project proposes to explore multi-touch technology for Brainstorming support, by combining it to a large screen: the TouchBoard. We argue that this technology provides a workable compromise between the flexibility of a conventional whiteboard and the reusable content afforded by desktop software applications. Through paired user tests, we compare the TouchBoard in terms of Brainstorm support efficiency with a typical whiteboard and a mind-mapping application for the PC, CmapTools. Although the obtained results fall somewhat the initial expectations, in that they prove that the Whiteboard is slightly more efficient that the TouchBoard, it is still possible to conclude that there are major advantages in supporting Brainstorming sessions with the TouchBoard as compared to the other alternatives, even though the prototype may require additional tweaking in terms of flexibility in structuring concepts.

Keywords: Collaboration, Face-to-face group work, Multi-touch, Ubiquitous Computing, Brainstorm.

1. Introduction

The information systems that support people interaction and communication, also known as Groupware [1], have always been focusing more on the distributed side of group work. Nevertheless, these distributed systems have never been able to completely overcome some of the crucial barriers involved in those settings, such as the awareness that one needs within a collaborative work environment [2]. In order to counter those difficulties, teams tend to gather in face-to-face meetings whenever possible.

On the other hand, a face to face meeting presents a problem of its own: in order to work with digital media, people always fall for the need of connecting laptops to screen projectors and into taking turns while using software applications. Thanks to the multi-touch technology, information systems are capable of tracking multiple interactions over an enabled surface at the same time, creating the means for a revolution over the way teams work in a shared space.

The main objective of this project is to evaluate the efficiency of Brainstorming sessions supported by a multi-touch interface, and compare it to the ones enabled by the resources commonly employed nowadays, such as the PC or the whiteboard.

In this paper we first criticize the State-of-the-Art related the shared space Groupware, which became a major contribution for the process of designing, building and evaluating a tool meant for Brainstorming support: the *TouchBoard*.

After outlining the key features of the TouchBoard system, we analyze and reflect over the results of the user usability experiments that explored the efficiency of Brainstorming sessions supported by each of the tools involved: the TouchBoard, a typical whiteboard and a noting application for the PC, the CmapTools [3].

2. Related Work

First of all, within the collaborative work support field, it is worth mentioning the Augmented Reality, which revolves around creating an environment where there is little distinction between virtual and physical objects. For example, the MagicMeeting [4] is a tool that involves see-through hi-resolution goggles, supplying each user with its own individual virtual view over a shared object.

Another approach, which is supported by projects like Caretta [5], Pebbles [6], Colab [7], Dolphin [8], Impromptu [9] and TeamStorm [10], consists in separating the individual and group work spaces in a way that its participants feel no inhibition in exteriorizing their ideas. In order to achieve that goal they give each meeting participant a PDA or tablet, which will contain their private ideas, and supply the whole group with a table or board, where it is possible to view the ideas that have been shared.

On the other hand, some studies prove that the use of personal computers or PDA's in face-to-face meetings hugely hinders the group awareness [11]. Since awareness is such an important factor for collaborative work, some researchers [11],[12],[13][14] tried to mimic the work environment around a table or board through a Single Display Groupware [15] tool, which usually converges into a digital table or board. This way, users can be responsive to what their colleges are creating while, at the same time, they can indulge in the advantages of digital content support: a high level of persistence and easy editing, to mention a few.

This last kind of interactive surfaces has also found their way into supporting face-to-face opportunistic meetings, which consist in a type of unplanned reunion, that typically lasts a short period of time, and that usually happens in a public space. Technologies like Ubitable [16], Blueboard [17] and *Dynamo* [18] focus in supporting simple tasks, either involving a group or multiple individuals at the same time, each one with different objectives. Since they are set in public environment, these tools have major concerns in task acceleration and user privacy, which are essential for public impromptu meetings.

We close this section by analyzing the different approaches and deciding on the one that is ideal for creating a tool that supports Brainstorming sessions. First of all, Augmented Reality and the combination of PDA's with a shared screen boast a great advantage in situations where each user needs to have their own, personalized view of a group object. Nevertheless, this feature also interferes with good group awareness, which is indispensable for a productive session. As such, we believe that the multiple types of SDG tools, both the ones situated in either private or public settings provide the best experience for creating an efficient Brainstorming environment.

3. TouchBoard Specifications

The TouchBoard consists on a system that supports two types of user interactions: multi-touch gesture recognition and proximity detection. The first was made possible thanks to the hardware available at the Lourenço Fernandes Multimedia lab in IST-Taguspark: a multi-touch table implemented with the Laser Light Plane technique [19] (Fig1.).

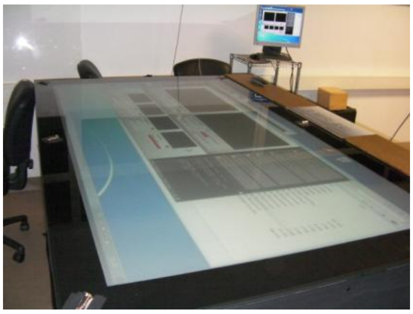

Fig 1. The Multi-touch table at Lourenço Fernandes Multimedia lab in IST-Taguspark.

Although a vertical surface would've been the ideal physical infrastructure due to its better exposure (therefore the name TouchBoard), this table provides a similar experience, as long as the users stand side-to-side and are able to reach the "top" section without much trouble.

In terms of software, we created a multi-touch noting application, in which users are not only able to create, edit and delete notes, but are also capable of linking them amongst each other, creating a conceptual map. In order to diversify the user usability experience, the notes assume two different forms: formatted text and drawing.

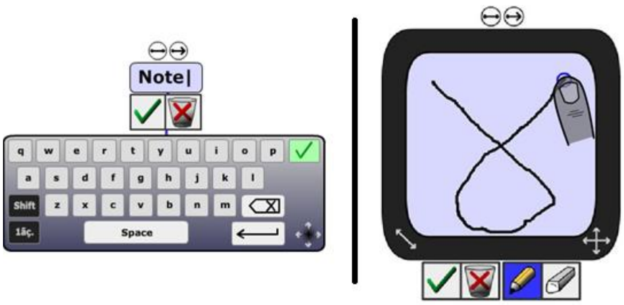

Fig 2. A formatted text note and a digital keyboard (*on the left*), and a drawing note (*on the right*).

As it is possible to acknowledge from Fig 2., the formatted text note is edited through a digital keyboard, providing legible text and an interface similar to the typical PC. On the other hand, the drawing notes were implemented under the influence of the whiteboard, since the users can sketch freely on the designated area.

In addition to the multi-touch interaction modality, the system reacts to the presence of users equipped with a Bluetooth mobile phone, presenting their personal content. Although this type of interaction seams limited, it shows how important it is to predict user actions, either by allowing instant access to their content on a personal tab as they come closer, or closing that same information as they go away. This synchronization also brings forth new application tasks that the user can perform, such as saving current work, restoring previous maps or importing pictures into the group diagrams (Fig 4.). These pictures can then be linked to any note, performing as another type of concept.

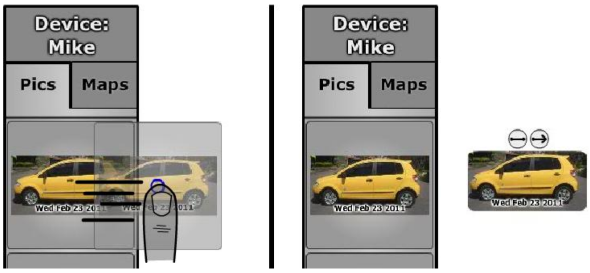

Fig 4. Importing a Picture from the user's wireless device.

In order to complete the development stage with a hi-quality level functional prototype, it was built through three iterations, each one followed by user usability tests. With the final prototype of the TouchBoard completed, we compared it with some of the common tools used in face-to-face collaborative meetings.

4. Evaluation

The main objective of this project was to prove that a tool like the TouchBoard is able to improve the typical Brainstorming work environment, since common resources fall short in either digital content support or multiuser work support. The tools chosen to rival with the TouchBoard are a regular whiteboard and a PC application called CmapTools. This last application was chosen based on its ease to use and on the fact that it is freeware.

The Evaluation process was divided into two sections: the first compares the tools' support in terms of simple diagram creation and the second section compares the tools in terms of collaboration support. This separation in the test process is very important because it's difficult to evaluate these two components all together [20].

Previous to each experiment, the users were enlightened on the different features of the tool to be tested, as well as prepared for the task at hand. Since Brainstorming is a common activity inside any group work process, the users' selection was as diversified as possible. Random people from the IST-Taguspark campus, friends and family were all involved in this evaluation, creating a group that involved both genders, and with ages comprehended between 12 and 57 years old. In terms of academic achievements, most of the users that participated on the trials had achieved a bachelor, a master or a PhD degree. They were all at ease with working with a computer, and about a third of them had already experienced with multi-touch, prior to this evaluation. All of the tests occurred in a controlled environment: the Lourenço Fernandes multimedia lab in IST-TagusPark.

4.1. Comparison in terms of diagram creation support

The first stage of the face-off between the TouchBoard, a whiteboard and CmapTools was an important step in comparing the selected tools in terms of diagram creation, discarding collaboration tests to a second phase.

At this point, we asked each user, individually, to criticize sets of eight elements and then separate these along two dimensions. The sets, or themes, selected are: Animals, Cars and Beverages; since all of them are easy to analyze. Each user performed three tests, in which every test involved a different tool and theme, assigned in a round-robin fashion. This stage involved a total of 14 users, with ages comprehended between 12 and 49 years old, and an age average of 27 years old.

Table 1. Brief tool comparison after mono-user tests. C.T. stands for Completion Time.

Tool	Average C.T. (min:sec)	Minimum C.T. (min:sec)	Maximum C. T. (min:sec)	Number of Different Representation Types	Number of Fuzzy Diagrams
Whiteboard	03:31	01:49	05:16	7	3
TouchBoard	05:19	02:41	10:03	4	3
CmapTools	06:22	04:05	09:25	4	4

As one can acknowledge from Table 1, statistically the Whiteboard revealed himself as the best diagram creation support tool, mainly due to its user familiarity. Next up, we have the TouchBoard in which, even though a big section of the users completely understood how to perform the different tasks, they still presented some difficulties in expressing as freely as it occurred when working with the Whiteboard. Finally, the users felt less at ease with the Cmaptools, since they were forced to adapt to the technology and not the other way around.

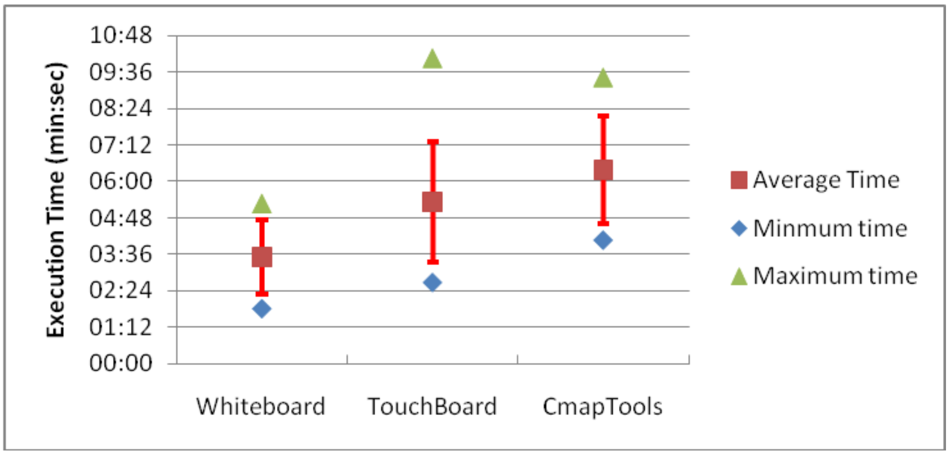

Fig 5. Tool comparison in terms of minimum, average and maximum execution times.

Focusing first on the execution times presented on Fig 5., we highlight the discrepancies between the minimum and maximum execution times obtained with the TouchBoard and the CmapTools, 7:22 and 5:20 respectively. After analyzing those sets of data, we verified that the worse results in terms of completion time belonged to the users that had never used a digital diagram creation tool (6 amongst the 14 users).

Another interesting comparison is in terms of the representation flexibility that a tool enables. Once again, the Whiteboard presented the best results by allowing users to create two more representation types than the CmapTools or the TouchBoard combined, for example, Braces and Lists of elements. We believe that this extra flexibility was crucial for the Whiteboard in obtaining the best results at this stage.

After the completion of each diagram, we analyzed the legibility and comprehension of the same, in which the Cmaptools presented the worse performance when compared with the rest. While using this application for the PC most of the users used a Graf representation for the concepts, creating links that overlapped each other, in case they were not careful enough, resulting in diagrams with a weak legibility. The diagrams created with the TouchBoard and the Whiteboard were equally affected in terms of intelligibility by this flaw that sometimes comes with the Graf representation, in which the latter, specifically, presented concepts with an incomprehensible hand-writing.

4.2. Comparison in terms of collaboration support

The last evaluation step served the purpose of testing and comparing the three tools in terms of the collaborative environment set by each one during Brainstorming sessions with two users.

We asked each pair of users to conceptualize the human body as completely as possible during ten minutes. The only test restriction, besides the time, was that each group was obliged to include three organs belonging to the digestive system and another two organs belonging to the respiratory system. In general, this is an activity that requires some collaboration to be completed with quantity and quality.

At this point, the user population involved a total of 30 people, with ages comprehended between 25 and 49 years old, and an age average of 33 years old. We obtained the following results from the five tests per tool:

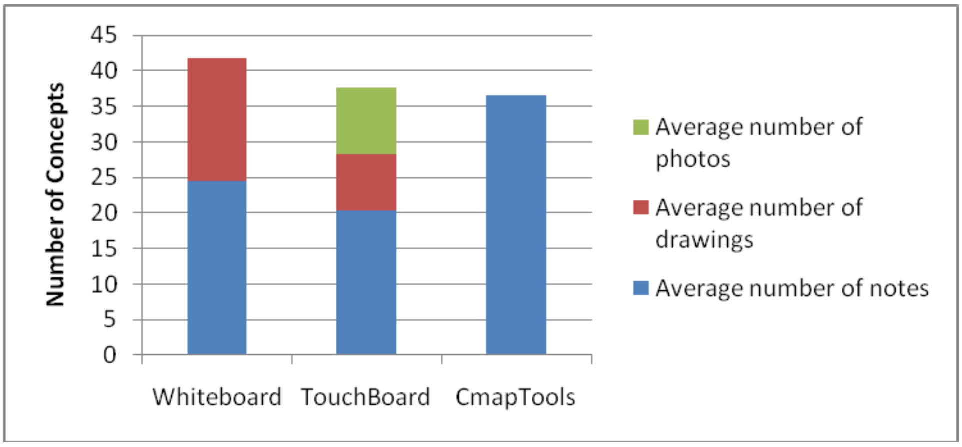

Fig 6. Tool comparison along the number and type of concepts created.

Since we are dealing with a relatively small sample (only five tests per tool), we performed a t-Student test to the result distribution of each pair of tools with a confidence interval of 95%, 8 degrees of freedom and null hypothesis of "Each pair of results are not significantly different". Due to the high variance of the CmapTools associated results, we obtained p-values of 27,3% and 82,6%, when tested with the Whiteboard and the TouchBoard respectively, becoming impossible to reject the null hypothesis and, therefore, to compare the CmapTools with any of the other tools on the number of produced concepts. On the other hand, the p-value associated with test on the results of the Whiteboard and the TouchBoard is 4,4%, allowing the rejection of the null hypothesis and the comparison between these two tools.

As it had happened in the first set of tests, the Whiteboard presented, once again, the best results in terms of efficiency which is represented by the number of concepts created by a pair of users during ten minutes. The efficiency difference between the Whiteboard and the TouchBoard is mainly due to the fact that the first of the two allows more flexibility in terms of structuring and representation than the second one.

By looking at the activities performed on the Whiteboard, we verified some cases where the users depicted different body parts after drawing a more general picture of the body (Fig 7. *left*). Unfortunately, that simple and flexible way of characterizing a composite drawing is not technically possible on the TouchBoard, creating some inefficiency on both the work and mental process of the users. On the right side of Fig 7., we show an user attempt in recreating that structure on the TouchBoard, becoming frustrated by the fact that the links don't go beyond the concept border, into the respective parts of the body. Some users tried to overcome that difficulty by taking several pictures of the individual body parts, enhancing the general process efficiency.

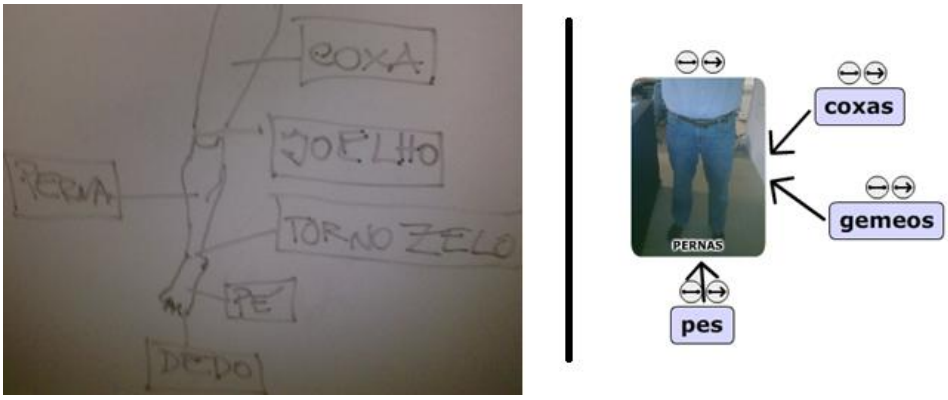

Fig. 7. Composing a leg on the Whiteboard (*left*) and on the TouchBoard (*right*). Image descriptions are written in Portuguese.

Looking at the Cmaptools, since it has a typical mono-user interface, its users had to assign different roles amongst themselves, like one user being responsible by the mouse and the other by the keyboard. Even so, since it only allows creating text notes, it happened to be with this tool that the users depicted a bigger diversity of body parts.

In terms of collaboration, the workflow on the Whiteboard typically started with a brief discussion on the way the users would represent and better appropriate the surface space, since repositioning elements on the board required some erasing. The same didn't happen with users on the TouchBoard, in which they only felt the need to separate the body parts each one was responsible for. At last, on the CmapTools, the best results usually belonged to pairs of users that had a good synergy while controlling different input devices, in which case the leader was usually the one controlling the mouse.

Next up, we present Table 2 that compares the three tools qualitatively, involving some characteristics that were not targeted with our formal tests and which values range:

🚫 Inexistent ✖ Bad ★ Normal ★★ Good

Table 2. Feature comparison between the Whiteboard, the TouchBoard and the Cmaptools.

	Whiteboard	TouchBoard	CmapTools
Efficiency	★★	★	★
Familiarity	★★	★	★
Representation Flexibility	★★	★	★
Ease in saving and restoring work	✖	★★	★★
Drawing support	★	★	🚫
Support in integrating digital content (photographs)	🚫	★	🚫
Ease in repositioning elements	✖	★★	★★
Proximity detection of wireless devices	🚫	★	🚫

The big advantage of the TouchBoard is its digital infrastructure, allowing users to quickly and easily reposition objects, save/restore the product of their work and incorporate parts of documents and real objects in the work space by taking pictures of them. Furthermore, thanks to the Bluetooth sync system, the system can infer and react on the presence or absence of a user, by showing and hiding their personal content respectively.

Analyzing the Whiteboard, which is clearly the main competition of the TouchBoard, we believe that it is due to its familiarity and representation flexibility that it is the most efficient tool, according to our evaluation. While familiarity depends on the multi-touch massification, the flexibility enhancement is within reach on the next version of the TouchBoard leading, theoretically, to bigger support in terms of efficiency.

7. Conclusions and Future Work

In this dissertation we pick pointed the problems with the face-to-face meeting support tools and how they can be improved. Relevant literature in the area was extracted, selected, analyzed and criticized, leading to the construction of the related work.

Afterwards, we defined an architecture based on the combination of a large proportion multi-touch screen with a wireless device sync application and a noting application, resulting in the TouchBoard: a system with the objective of supporting Brainstorming sessions. Finally, through paired user tests, we compared the TouchBoard in terms of Brainstorm support efficiency with a typical whiteboard and a noting application for the PC, the CmapTools.

Although the obtained results don’t match the initial expectations, since they prove that the Whiteboard is slightly more efficient that the TouchBoard, it is still possible to conclude, from Table 2., that there are major advantages in supporting Brainstorming sessions with the TouchBoard when compared with the rest, even though it requires some future tweaking in terms of concept structuring flexibility.

Besides improving on the tool flexibility, future work includes transitioning from a LLP table into a FTIR board [19], enhancing the visibility of the work space and the consistency of the interactions on the screen, respectively. I hope this Project sparks future work around this type of shared surfaces, as means of supporting face-to-face collaborative work.

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