Exploring the Significance of Multi-touch Tables in Enhancing Collaborative Software Design Using UML

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Abstract—Encouraging collaborative software design through the use of multi-touch interfaces has become increasingly important, because such surfaces can accommodate more than one user concurrently, which is particularly useful for collaborative software design. In this paper, the potential of using multi-touch MT-CollabUML application for collaborative software design is explored. This exploration is done by looking at how students’ collaboration might be enhanced in collaborative software design using Unified Modeling Language (UML) comparing the traditional paper-based environment with the contemporary multi-touch table environment.

Keywords-Multi-touch table; Software design; UML; Collaborative work.

I. INTRODUCTION

One promising learning technology that facilitates collaborative work among students is the multi-touch table. Several projects have introduced multi-touch surfaces to enhance collaborative learning. Collaborative learning has become increasingly important for several reasons. Multi-touch interfaces can accommodate more than one user concurrently, which is particularly useful for learning through large, shared display systems like tabletops [1, 2]. Using such systems encourages students to collaborate and create an environment wherein they can discuss their findings and integrate their ideas seamlessly with no technological hindrances. In addition, such systems can enhance students’ interaction skills and promote teamwork.

Multi-touch environments offer new possibilities for interaction between humans and computers. Researchers from different educational backgrounds are exploring this area and indicate that multi-touch environments can be successful because interaction through touch is both intuitive and natural [3].

Many studies have shown the benefits of using multi-touch environments to enhance collaborative work. For instance, Rick and Rogers [4] built a system called DigiTile to enhance collaborative learning, which helped students design patchwork quilt blocks. In this study, students use multi-touch surfaces to drag pieces into a quilt block and change colors to design mathematical shapes [4]. Further, multi-touch surfaces were used for collaborative information gathering. In this study, users were provided with a tool called WebSurface, which helped them browse the Web collaboratively to gather information from different websites. Using multi-touch surfaces allowed users to search for information, browse multiple pages at the same time, and easily gather the information they found [5].

The potential of multi-touch surfaces is to enable co-located collaboration activities, which allow small groups to work together collaboratively [6]. This potential might be a result of the ability of multi-touch tables to provide equal opportunities for collaboration in group work [7]. However, there has been little research to determine the potential of using multi-touch tables to enhance co-located collaboration in software design using Unified Modeling Language (UML). However, the level of collaboration in DigiTile [4] and WebSurface [5] is limited and restricted to simple actions performed by users, such as putting words in the right context, arranging items over tables, and simple click and drag actions. However, UML design involves advanced design issues that raise new collaboration needs, such as linking nodes and annotation. To this end, in this paper we explore the potential of using multi-touch technology for software design using UML by comparing it with traditional, paper-based collaborative software design.

In Section II, we briefly describe the related research work in multi-touch tables for collaborative work and in collaborative software design using UML. In Section III, we explain a comparative study between paper-based and multi-touch based environments in software design. In Section IV, we set forth and discuss the results and findings of the comparative study and how multi-touch tables have enhanced collaboration in software design using UML. Finally, in Section V, we draw conclusions from our research and discuss future work.

II. RELATED WORK

A. Multi-touch tables for collaborative work

In the literature on multi-touch tables, there is much interesting work reflecting the role of multi-touch in enhancing
collaborative activities. However, for the purposes of this paper, the use of multi-touch tables to enhance collaborative work is considered. Morris et al. [8], conducted a research study to investigate the effectiveness of utilizing multi-touch tabletops to enhance cooperation during group functions and tasks. The finding was that multi-touch tabletops were particularly useful in enhancing team member awareness. This implies that multi-touch tabletops enhance information sharing among group members. In another study, Harris et al. [9] examined the variation in group task performance between single and multi-touch tabletops. Multi-touch tabletops enhance task performance, unlike single-touch tabletops. Furthermore, another research study [10] examined the efficiency of multi-touch tabletops. Comparison between multi-mouse and multi-touch tabletops was performed. Results show that multi-mice are utilized more than multi-touch tabletops because of the following factors: (1) multi-mice enable users to interact with any part of the display when compared to the multi-touch; (2) users lack of familiarity with multi-touch tabletops; (3) variability in the usage of multi-touch tables. However, the authors note that users of multi-touch tabletops had fewer grammatical errors than those of multi-mouse users. In [11], multi-touch tabletops increase the awareness and common ground of group members working collaboratively to achieve a particular outcome. Moreover, multi-touch tabletops increase the effectiveness of group tasks and obligations [12]. According to the research studies described above, it is concluded that multi-touch tabletops increase group interaction and therefore increase attainment of group goals.

B. Technologies for collaborative software design using UML

There are many research efforts to facilitate collaboration among users in software design using UML, such as COLLECT-UML [13], CoLeMo [14], CAMEL [15], and AUTO-COLLEAGUE [16]. Unlike COLLECT-UML and CoLeMo, AUTO-COLLEAGUE does not support collaborative drawing for UML diagrams, but offers a chat system as its main collaboration tool. These systems, however, are designed to support distributed collaborative work, not a face-to-face collaboration style. With the exception of the Software Design Board [17], which is a shared whiteboard application, research has produced few outcomes supporting collaborative software design.

III. COMPARATIVE STUDY

As mentioned above, software collaborative design using multi-touch has not been widely explored; to the best of our knowledge there is no multi-touch collaborative UML design tool available. So, for purposes of this study, a multi-touch enabled tool called “MT-CollabUML” was developed to encourage students to co-locate collaborative software design using UML.

A. SynergyNet lab

This study was conducted in a specialized laboratory called SynergyNet at Durham University in the United Kingdom. The SynergyNet lab has a set of multi-touch tabletops, specially designed furniture, and software that integrate physical components into a comprehensive environment to support collaboration (see “Fig. 1”).

Figure 1. SynergyNet lab

B. Participants

Twelve MSc program students volunteered to participate in the study. Participants, at the time of conducting this study, were studying a module called “Software Engineering for the Internet.” This module was chosen specifically chosen because students were required to design software using UML collaboratively in groups. All participants had successfully completed the UML part of the “Software Engineering for the Internet” module before conducting this study. Involved students were asked to form four groups of three; each student joined his or her preferred group.

C. Experiment design

To investigate MT-CollabUML’s strengths and limitations in supporting collaborative design for UML diagram design, a within-subject experiment was conducted to compare how the participants used paper with how they used multi-touch surfaces in terms of collaboration. Similarities and differences were examined in terms of quantitative performance and qualitative behavior in the four groups of three students, who worked on creating UML-state diagrams. The goal was to identify differences in the level of collaborative design process across experimental conditions.

To ensure the validity of our investigation, we decided to compare the MT-CollabUML system with the traditional paper-based condition currently used for collaborative UML design. In both the MT-CollabUML and traditional paper-based conditions, we ensured that participants could work collaboratively; they had the same size work space and the same display orientation, and all group members could work at the same time. To maintain comparable conditions, we provided two similar tasks with the same difficulty and complexity.

The tasks were designed with clear and measurable learning outcomes and with the aim of integrating students’ reflections and discussions. We opted to use a collaborative group condition because the students involved were required to work in groups to perform software design using UML.
We provided two experimental tasks that required the participants to create UML-state diagrams. The course tutor was consulted to ensure that both tasks were of the same level of complexity. Each task consisted of several activities, including planning, discussion, decision making, drawing diagrams, and reflection.

Repeated measures design was followed in this study to help keep the variability low and make the experiment more efficient with a manageable number of participants. In this study, the four groups of students were arranged into group pairs; for every pair of groups, we gave one group a UML design task and asked them to complete it using pen and paper “Fig. 2”. We asked the other group to complete the same task using the multi-touch table. We then switched the groups and asked them to perform the second task using paper and multi-touch conditions “Fig. 3”.

**E. Data collection**

All collaborative design activities were video recorded and transcribed for analysis. For the paper-based condition, we set up two cameras to focus on the table from two directions to ensure all group members could be seen. The multi-touch condition was conducted in the SynergyNet lab space shown in “Fig. 1”, where ceiling-mounted cameras recorded the multi-touch table from two angles and the screen capture was saved for future analysis.

**F. Data analysis**

Participants adopted different collaboration patterns as they designed UML diagrams in paper- and multi-touch table-based conditions. At times, they worked on the same problem, even adding nodes or annotations or using a digital keyboard; at other times, they separated work on different problems such as editing many nodes at the same.

To investigate the similarities and differences between the conditions in terms of collaboration style, the collaboration style coding scheme of Isenberg [18] was adopted with modifications to fit with our study’s needs, as explained in Table I. For the purpose of this study, three collaboration styles were selected out of the proposed eight styles of collaborations by Isenberg [18]. The selected collaboration styles are: 1) Discussion (DISC), 2) View Engaged (VE), and 3) Disengaging (D).

The reason behind choosing these particular styles is that our participants performed that during the experiment. During the experiment, sometimes the participants stopped working and engaged in discussion (DISC) to explore different ways of solving the problem. At other times, some participants just engaged in watching (VE) what other participants were doing and gave them advice on how to proceed. Also, sometimes some participants were disengaged (D) during the experiment. These three collaboration styles (DISC), (VE), and (D) were common in our study and in Isenberg study [18].

Two new styles of collaboration were identified by the researcher, namely Shared Work (SW) and Working Individually (WI); these are not mentioned in Isenberg work [18]. It was observed that participants sometimes work together on the same diagram, but in different nodes or editing different areas; we call this Shared Work (SW) style. On the other hand, sometimes, especially in the paper-based condition, participants work individually (WI); each of them was creating different diagrams for the same task, so we consider WI as a style of loose collaboration. However, Isenberg mentions five other styles not relevant to our study, so we exclude them.

We calculated each collaboration style percentage for each group according to the total task time spent in both conditions. In the DISC, VE, and SW collaboration styles, participants collaborated closely by discussing and working together; some only watched, but they at least engaged in discussion. However, we considered the WI and D styles to be a loose collaboration, because one or more participants either worked separately or were completely disengaged during the task.
TABLE I. COLLABORATION STYLE CODING SCHEME (STYLES WITH DIFFERENT COLOR ADDED BY AUTHOR)

<table>
<thead>
<tr>
<th>Collab. Styles</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISC</td>
<td>Active discussion about the task.</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>VE</td>
<td>One person is actively working; the other watches and engages in conversation and comments on the observed activities but is not interacting with the table or paper.</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>SW</td>
<td>All persons share the work to solve the same specific problem.</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>WI</td>
<td>Working individually; each person is creating his/her diagram.</td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>D</td>
<td>Disengaged. One person is actively working; the other is watching passively or is fully disengaged from the task.</td>
<td><img src="image5.png" alt="Image" /></td>
</tr>
</tbody>
</table>

IV. STUDY FINDINGS AND DISCUSSION

This study explores the benefits of using a multi-touch table as a tool to encourage students to work collaboratively in software design using UML. In the case of multi-touch tables, students showed better and closer collaboration, and the use of multi-touch facilitated collaborative software design.

Qualitative analysis of the level of collaboration was performed as mentioned in Section III. The multi-touch finding showed that the percentages of task time that the participants spent in each collaboration style were: DISC (discussing), 26.31%; VE (view engaged), 30.82%; SW (shared work), 39.59%; WI (working individually), 0.00%; and D (disengaging time), 3.28%.

However, in the paper-based condition, the findings were: DISC, 41.86%; VE, 27.01%; SW, 5.35%; WI, 14.78%; and D, 11.00%. These findings are summarized in Table II.

There are two different levels of collaboration, namely close collaboration and loose collaboration, as explained in Section III. For example, DISC, VE, and SW are considered close collaboration, and WI and D are considered loose collaboration. In this research, we found that the total percentages of task time spent in close collaboration styles were 96.72% in the multi-touch based condition and 74.22% in the paper-based condition. However, total percentages of task time spent in loose collaboration styles were 3.28% in the multi-touch based condition and 25.78% in the paper-based condition. Indeed, the multi-touch MT-CollabUML tool has played an important role in increasing the level of collaboration among students.

TABLE II. PERCENTAGE OF TIME SPENT IN EACH COLLaborATION STYLE IN MULTI-TOUCH AND PAPER-BASED CONDITIONS

<table>
<thead>
<tr>
<th>Collaboration Style</th>
<th>Multi-touch based</th>
<th>Paper-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISC (discussing)</td>
<td>26.31%</td>
<td>41.86%</td>
</tr>
<tr>
<td>VE (view engaged)</td>
<td>30.82%</td>
<td>27.01%</td>
</tr>
<tr>
<td>SW (shared work)</td>
<td>39.59%</td>
<td>5.35%</td>
</tr>
<tr>
<td>WI (working individually)</td>
<td>0.00%</td>
<td>14.78%</td>
</tr>
<tr>
<td>D (disengaging)</td>
<td>3.28%</td>
<td>11.00%</td>
</tr>
</tbody>
</table>

In the close collaboration styles, the participants engaged in active sharing of information and discussion regarding the task. They worked together as a team solving the same problems and pursued similar questions.

In the multi-touch based condition, the participants spent more time in close collaboration either by working actively on the same task (SW style) or by having one user actively drawing while the others contributed through discussion and comments on the ongoing design process (VE style).

In both multi-touch and paper-based tasks, participants spent a considerable amount of time in discussion prior to the actual design process (DISC style). Most of this discussion was conducted at early in the design process in order to agree on an initial design before committing to the design.

In the paper-based condition, it was difficult to revise the drawings on paper because the groups would have to redraw the whole design on a new sheet if the paper became messy. This explains why the participants in paper-based tasks spent more time in discussion before drawing. In contrast, the ability to easily revise and edit the UML design by using hand gestures in the multi-touch based condition made the participants probably feel more confident in contributing to the drawing process, because it was easy to redo and amend actions. This resulted in more active engagement by all group members in the multi-touch based condition.

In the paper-based condition, participants spent more than a quarter of the task time either working individually (WI) or disengaged (D). Participants sometimes worked individually, where each of them built different diagrams on a piece of paper and then showed their solutions to each other to decide which one was correct. As another strategy, one participant created a diagram while the others just watched, and then the active participant showed the diagram to them to discuss it. However, the results indicated that participants never worked individually in the multi-touch based condition, because the work space did not facilitate individual work. Therefore, the overall collaboration pattern results indicated that the multi-touch
based condition was better than the paper-based condition in terms of encouraging collaboration.

V. CONCLUSION

In this study, we investigated the differences in collaborative work in UML design among groups of students working in paper and multi-touch table based conditions to determine the potential of the multi-touch table. Results indicated the benefit of using the multi-touch MT-CollabUML tool in making a noticeable enhancement of the collaborative software design using UML.

The multi-touch MT-CollabUML tool allowed students to work collaboratively much more closely compared with the traditional paper-based work environment. The improvement in collaborative work between students in the multi-touch environment is a direct result of the facilities provided by the multi-touch MT-CollabUML tool in which students engage in active sharing of information and discussion of the task.

The multi-touch MT-CollabUML tool has played a role in minimizing working individually and encouraging group members to work collaboratively. On the other hand, the paper-based setting decreases the level of collaboration and encourages individual work due to the single person domination of the activity and practical difficulties in sharing the workspace and pens. Furthermore, in the paper-based condition, the correction of mistakes was to some extent difficult compared with the multi-touch table setting, and sometimes participants start the work from scratch after making mistakes. Indeed, the use of a multi-touch table helped students to better work together and enhanced and facilitated the collaborative software design of UML. More research should be done to compare between desktop-based collaborative software design and multi-touch based design to further explore the potential of multi-touch tables.

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