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Abstract. This paper presents a study that describes the design and implementation of a tabletop system for supporting collaborative design in the classroom. A case study and two experiments are presented in order to evaluate the usefulness of the proposed system for students and educators. Ten educators and fifteen students participated in the experiments. Findings show that the usefulness, as well as the easiness of the proposed system are perceived as good from both, students and educators. These results suggest that the proposed system does have potential to be used in other educational areas or as a baseline for similar approaches.

Keywords: Collaborative design, collaborative assessment, multi-tabletop system

1 Introduction

Developing collaborative working skills is an important aspect for the academic training of students. Employers consider these skills as a fundamental requirement when hiring professionals [1][2]. Several research have been directed at developing proposals for computer-assisted technology, to promote and improve participation and collaborative student learning [3], [4], [5]. However, the way that people work in this and other collaborative environments has not changed significantly over the years. Some studies show that pen and paper still remains widely used in designing [6]. Technology has failed to displace traditional tools mainly for the following reasons: space flexibility; easiness of communication between individuals; and portability [6]. While collaborative work in the traditional way (e.g. on a board or paper) facilitates face to face communication between individuals, it also leads to some drawbacks such as difficulty in documenting the final work, replicate or share these works in digital repositories (it is often desirable to observe a group work) [7].

In a classroom, the traditional tools also create certain limitations; for example, difficulty to monitor the process of preparation and subsequent assessment of collaborative work, as educators usually only have the final version of these. This is a problem because educators might find it difficult to assign a rating, as well as meet the workload invested by students, their individual contributions and the quality of these [4]. Researchers have found that the perception of an unfair assessment should be taken into account in issuing a subject, since it is predictive of motivation, learning, and even aggressiveness that students show towards a particular subject [8].

In recent years, the scientific community has developed some research progress in the implementation of new technological tools, which are intended to facilitate collaborative tasks and solve partially the aforementioned drawbacks. Some authors have developed project of multi-touch surfaces into classroom [5], [9], to facilitate and support collaborative learning among a group of students, in order to lead their own learning, driving engagement, participation and creativity with the use of this technology. In another work, Mercier et al. [10] have developed a interactive board to run experiments with students to support both fluency and flexibility in mathematics called NumberNet; similarly, in [11] they proposed a visual application in multi-touch tabletop for preschool Mathematics called MEL-Vis. Both works present a workable solutions through qualitative and quantitative analysis.

Martinez et al. [12] present a solution called "Collaid". This work has been developed in order to enhance learning and teamwork. Collaid uses a touch screen and support for the participation of individuals in the design of conceptual maps. In addition, it uses information about the position of each person and their verbal interaction, in order to help determine the contribution of each individual and display a list of suggestions on topics that each user might want to use. These users feed information to their collaborative work in Collaid, using their fingers to type on a virtual keyboard. This solution is integrated with a monitoring component of collaborative work, which is used by the orchestrator of the work (the educator) to know the state of development of the work at all times.

Although there are several proposed solutions whose aim is to assist the collaborative work, some problems must be solved yet. Issues such as restrictiing the size of the touch surface using previous solutions, traceability of tasks, the ability to monitor the development of the task, the number of people who can participate, configuration complexity of the work environment, the cost of implementation, and tools that emphasize design software, do necessary research in this field.

Currently, in the literature there are four classes of digital tabletop systems: digital desks [13], workbenches [14], drafting tables [15], and collaboration table [16]. This work focuses on the design of collaboration tables, it describes the design and implementation of a low cost multi-tabletop system (MTS) using computer vision, to improve the analysis of work in a students group. In addition, a case study is presented in order to validate the proposed system. This paper is structured as follows: section 2 briefly describes the system structure. Section 3 presents the proposed implementation. Section 4 describes two experiments

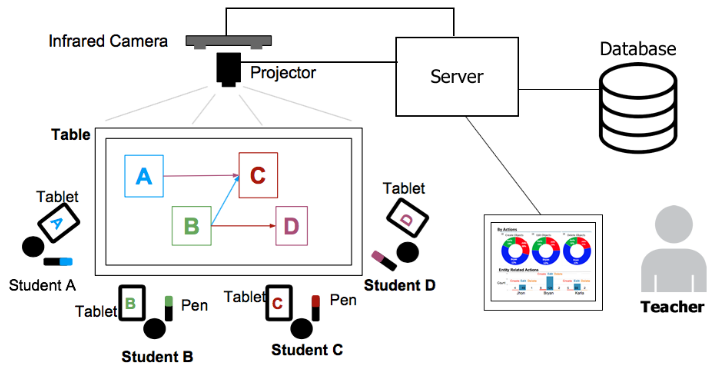

Fig. 1. Physical design of the student side of the proposed MTS.

used to test the system and the obtained results. Finally, conclusions remarks at section 5.

2 Multi-tabletop System proposed

2.1 Functional requirements

The following characteristics were identified for the proposed system with some of them, taken from other similar systems. and include:

- *Multi-user support:* It allows multiple users to use the system simultaneously[17][18].
- *Use of tangibles:* It provides digital and physical objects to the users that allows a more natural interaction with the system. [19].
- *Freedom of movement move and work-space regulation:* It allows users free movement when they use the system. This avoids limiting the creativity of users when static workplaces are defined[20].
- *Interconnection with devices:*It allows data entry through mobile devices like cell phones or tablets [17].
- *Color based contribution distinction:* It allows a person to identify users' contributions by assigning them a color per user.
- *Monitoring and storage user actions:* It provides tools for monitoring and recording activities performed by the users working in multiple groups at the same time[21].

2.2 Physical design

Figure 1 depicts an upper view of the physical design of the proposed MTS. A front projection design was chosen. Both, infrared camera and projector are attached to a tripod. The infrared camera aims to detect the position of the pens on the table (interaction area). Students can use pens or mobile devices to interact with the elements of the collaborative application projected on the table. Each action is tagged by an unique color per student. Students can also use tablets to input data to the MTS. A server is used to process data from infrared camera. Computer vision algorithms are used to identify and tag the pen's movements on the table. All data (objects, its history, student's interaction) are stored in a database. The communication between the tablets and servers is through a private wireless network. On the educator's side, the system allows monitoring student progress in collaborative tasks through a Web application running in the server.

The use of the computer vision approach, in contrast to others such as pressure sensors or capacitive surfaces, results in a portable and lower cost solution.

2.3 System components

Four main components are identified for the proposed MTS:

- *Pen tracking:* It uses information provided by the infrared camera to detect and calculate their position and orientation on the table. Each pen has three infrared markers situated in different locations one from another in order to distinguish them. The information about the position of each pen is sent to the Visualization component and collaborative control through a TCP/IP protocol.
- *Mobile data entry:* It is responsible for creating and displaying a graphical user interface for the tablets, which allows data entry. It is used by the collaborative application so that the user can enter text or control application components. It is able to differentiate data entry made by each student through an authentication system. This information is sent to the Visualization component and collaborative control through a TCP/IP protocol.
- *Visualization and collaborative control:* It uses the information provided by the previous components to interact with the collaborative application. This contains control elements and objects that could be manipulated by the users using the pens or mobile devices. Pens movements received from the Pen tracking component are translated to mouse events. Plain text entry and component selection are received from the Mobile data entry component. Additionally, this component has a gesture recognition module to facilitate the user's data input. All information about the state of the work made by students is stored in a file database. The database contains data about the users (identification number, tag color) and actions (create, edit or delete objects or components in the collaborative) performed by them stored in sequential order using the following format:

```
Users   {user id, tag color in RGB format}
Actions {user id, object type, object attributes,
         action performed, time stamp}
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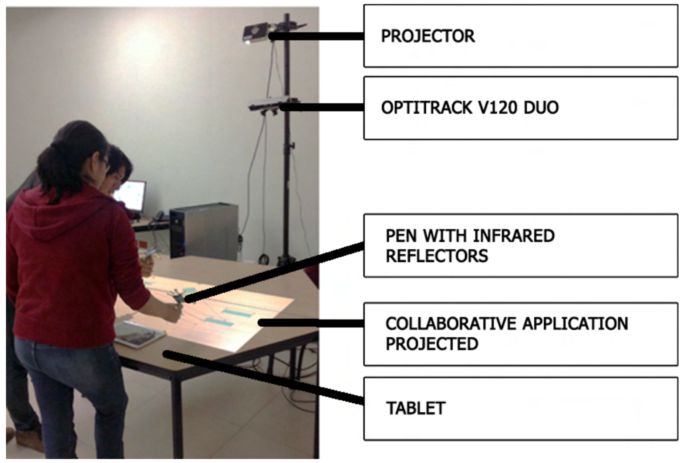

Fig. 2. Implementation of the student side of the proposed MTS.

– *Monitoring:* Uses the information stored in the file database to create useful text and graphical information about the collaborative task made by students using the MTS. The time stamp information is used to make an animation of how the objects and components of the collaborative application were created and manipulated over time by users.

3 Implementation

The proposed MTS is a combination of hardware and software, including a Web-based application for the educator's view. Students interact with the collaborative application using pens and tablets. Figure 2 shows an upper view of the physical scheme of the student side of the system. On the other hand, the educator only needs a device with a browser to access the system. Figure 3 shows some tools provided to educators in order to monitoring student's progress in collaborative tasks.

3.1 Hardware implementation

The MTS was implemented using the following hardware components: a portable projector camera system that works with an Optitrack Motion Tracking V.120 Duo System and a mini projector (Aaxa Technologies P300 Pico projector). Other hardware components of the system are: a computer with CoreI5 2.9 GHz processor - 4GB RAM - 500GB HDD, a Samsung Galaxy Tab 3, and a pen with three infrared reflector markers.

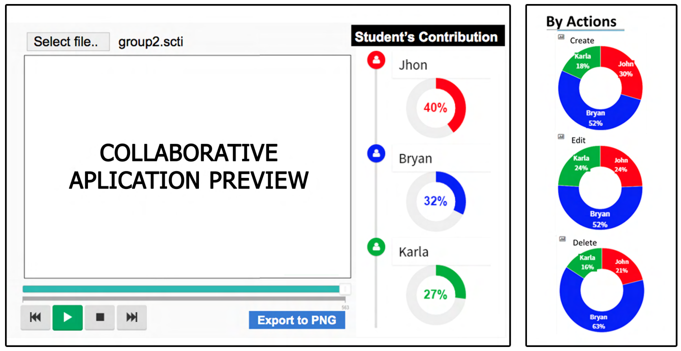

Fig. 3. Tools provided to educators for monitoring student's progress.

3.2 Software implementation

Tracking component: The tracking component keeps track of pens' positions, which are provided by the Optitrack's library Camera SDK. When students draw on the table, a touch event is generated through the TUIO (Tangible user interface) protocol [22], and then sent to the Visualization component and collaborative control.

Mobile data entry component: This was implemented as a responsive Web application, It allows users to authenticate to the system and then interact with collaborative application using a mobile device as a cell phone or tablet. This was developed in Python using Django Framework.

Visualization component and collaborative control: This component was implemented on the open source framework Multitouch for Java (MT4J) [23]. For gesture recognition, each stroke made with pen is processed by the PaleoSketch library[24]. The communication with collaborative application was implemented using multitouch events through the TUIO protocol. Every action on the tabletop and its related information is stored in a JSON file (file database). Elements entered by students are stored using a differently color to identify each member of the group.

Monitoring component: This component was implemented as a Web application using Python and Django framework. This component parses the information stored in the JSON file and show relevant text and graphical information about students' activities performed during the collaborative task.

4 Case study: Database model collaborative design

Database design is a topic covered in the Database Systems I, a course at a Computer Science Program. Regular activities in this course correspond to the design of a database system through real-life case studies, using an Entity-Relationship diagram as a part of the design. Being more specific, design activities are performed in groups from three, up to five students. Thus, it is common that the educator should keep tracking the design process from 4 to 8 groups simultaneously while doing the collaborative activity. As can be perceived, it is difficult for the educator to give a personalized and well established feedback once the activity has finished. In addition, it is common to see that work group students don't equally participate in the collaborative activity, even though they had the same grading points as their co-workers.

4.1 Experimental setup

Two usability experiments were designed to test the usefulness of the MTS. Fifteen students enrolled in Database Systems I course (second academic semester - 2014), were invited to participate in this experiment, as well as 10 educators (4 female, 6 male) with knowledge in topics covered in data modeling and 10 years of teaching experience.

- **Experiment 1:** Ten educators participated in a pre-post test experiment. Educators were asked to fill in a questionnaire, which contains three questions to measure the following variables: ease of grading individuals and groups; and, equality of individual's participation. The easiness (first and second question) was measured using a likert scale, being (1) very difficult and (5) very easy. Likewise, the equality (third question) was measured using a likert scale, being (1) completely unequal and (5) completely equal. A Pre-test was applied, to observe educators' perceptions in the design activity. Before the session started, educators answered the questionnaire. During the demonstration, educators observed how a group of students interacted with the MTS. When the demo finished, a summary with the students' contribution was presented to educators in an web application. At the end, educators answered a post-test questionnaire, in order to explore their perception when using the MTS.
- **Experiment 2:** Fifteen students were invited to test the usefulness of the MTS. Students conformed groups of 4 to 5 members to work collaboratively. Before the educator assigned a task to be designed in the MTS, the research group explained a general introduction of the use of the MTS and how to perform main actions. Then, for each student, an usability test was applied, which consists in the execution of twelve tasks (e.g. add an entity, edit an entity, add an attribute, etc) in the MTS. This test included three variables: easiness to perform a task (likert scale, (1) very difficult and (5) very easy); perceived satisfaction (likert scale, (1) unsatisfactory - (5) very satisfactory) and perceived usefulness (likert scale, (1) useless - (5) very useful) of the MTS. In addition, students took the time used to execute all tasks.

Table 1. Statistics for educator's perceptions.

Variable	Median Pre-test	Median Post-test	z-value	p-value
Easiness to grade individuals	2	5	-2.859	0.004
Easiness to grade groups	4	5	-2.333	0.020
Equality of participation	2	4	-2.372	0.018

4.2 Experimental results

- **Experiment 1:** Wilcoxon signed-rank test resulted in significant differences for the three measured variables. Table 1 summarizes the descriptive statistics with the corresponding z and p values.
- **Experiment 2:** Results showed that 91% of students (mode: 5, SD:0.62, median: 5) agreed that the MTS was easy or very easy to use. Also, all students reported positive responses (mode: 4, SD:0.49, median: 4) about satisfaction, meaning that none of them feel frustrated when using the MTS. As for the usefulness, most of the students (mode: 4, SD:0.70, median: 4) perceived that MTS was useful (50%) and very useful (40%). In addition, an average time of thirteen minutes was used to perform all the tasks.

5 Discussion and future work

This paper aims to describe the implementation of a low-cost multi-tabletop system to support collaborative design assessment. Collaborative design activities are difficult to assess due to the hard effort that educator should put when observing each student while performing collaboration activities. Furthermore, it is desirable to have a tabletop system that would help to assess quantitatively these activities by showing a report about the actions performed with the MTS per student and an overall performance per group. Two experiments were conducted to measure the perception of students and educators while using the MTS system.

It has been proved from experiment with students that the proposed MTS is effective and useful for tracking individual contributions of students who are involved in collaborative work of data design. Students perceived that the use of MTS is more desirable than traditional approach (e.g. pen and paper based, whiteboard). Most of students expressed that it was not difficult to perform common actions in the MTS, meaning that the proposed design fits the needs of users.

In addition, the perception of educators about fairness for grading individuals indicated that, even though the presented work is a first prototype, it has a great potential to help educators giving an on-time feedback. Results showed that other means of collaboration in a work group do not support the design assessment, which in contrast, the proposed MTS gives the proper information.

Although, the contribution of a student is measured quantitatively, the quality of the contribution should be added to the contribution in order to have a more reliable and realistic measure. Quality can be measured by performing a deeper analysis of the student's interventions while doing the collaborative design; which implies a multimodal analysis of speech, gestures and input's actions to the system.

The presented approach lowers considerably the costs an the portability among other solutions. Non-specialized hardware was used in the implementation of the system. A detailed process for implementing the MTS was described to serve as a baseline for similar systems.

It would be interesting to consider the collaborative surfaces for design activities that are involved in software development. For instance, the development of UML diagrams, flowcharts, BPMN diagrams, among others. Also, in other engineering design activities, such as mechanical or industrial design.

Future work for the MTS will implement the multimodal capture of student's gestures and speech in order to improve the assessment of the collaborative design. Furthermore, the hardware implementation can also be improved by changing the actual optical tracking system with a computer vision approach. Additionally, an open source distribution will be released for the research community as a way to share and test this prototype in similar contexts.

References

1. Kaplan: Graduate recruitment report: Employer perspectives. Technical report, Kaplan (2014)
2. of Colleges, N.A., Employers: The skills and qualities employers want in their class of 2013 recruits. Technical report, National Association of Colleges and Employers (2013)
3. Rick, J., Marshall, P., Yuill, N.: Beyond one-size-fits-all: How interactive tabletops support collaborative learning. In: Proceedings of the 10th International Conference on Interaction Design and Children. IDC '11, New York, NY, USA, ACM (2011) 109–117
4. Martinez Maldonado, R., Kay, J., Yacef, K., Schwendimann, B.: An interactive teacher's dashboard for monitoring groups in a multi-tabletop learning environment. In Cerri, S., Clancey, W., Papadourakis, G., Panourgia, K., eds.: Intelligent Tutoring Systems. Volume 7315 of Lecture Notes in Computer Science. Springer Berlin Heidelberg (2012) 482–492
5. Dillenbourg, P., Evans, M.: Interactive tabletops in education. International Journal of Computer-Supported Collaborative Learning **6**(4) (2011) 491–514
6. Hilliges, O., Terrenghi, L., Boring, S., Kim, D., Richter, H., Butz, A.: Designing for collaborative creative problem solving. In: Proceedings of the 6th ACM SIGCHI Conference on Creativity &Amp; Cognition. C&C '07, New York, NY, USA, ACM (2007) 137–146

7. Geyer, F., Pfeil, U., Höchtl, A., Budzinski, J., Reiterer, H.: Designing reality-based interfaces for creative group work. In: Proceedings of the 8th ACM Conference on Creativity and Cognition. C&C '11, New York, NY, USA, ACM (2011) 165–174
8. Chory-Assad, R.M.: Classroom justice: Perceptions of fairness as a predictor of student motivation, learning, and aggression. Communication Quarterly **50**(1) (2002) 58–77
9. Higgins, S., Mercier, E., Burd, E., Hatch, A.: Multi-touch tables and the relationship with collaborative classroom pedagogies: A synthetic review. International Journal of Computer-Supported Collaborative Learning **6**(4) (2011) 515–538
10. Mercier, E.M., Higgins, S.E.: Collaborative learning with multi-touch technology: Developing adaptive expertise. Learning and Instruction **25** (2013) 13 – 23
11. Tyng, K.S., Zaman, H.B., Ahmad, A.: Visual application in multi-touch tabletop for mathematics learning: A preliminary study. In: Visual Informatics: Sustaining Research and Innovations. Volume 7066 of Lecture Notes in Computer Science. Springer Berlin Heidelberg (2011) 319–328
12. Martínez, R., Collins, A., Kay, J., Yacef, K.: Who did what? who said that?: Collaid: An environment for capturing traces of collaborative learning at the tabletop. In: Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces. ITS '11, New York, NY, USA, ACM (2011) 172–181
13. Wellner, P.: Interacting with paper on the digitaldesk. Commun. ACM **36**(7) (July 1993) 87–96
14. Cutler, L.D., Fröhlich, B., Hanrahan, P.: Two-handed direct manipulation on the responsive workbench. In: IN: SI3D '97: PROCEEDINGS OF THE 1997 SYMPOSIUM ON INTERACTIVE 3D GRAPHICS, ACM Press (1997)
15. Buxton, W., Fitzmaurice, G.W., Balakrishnan, R., Kurtenbach, G.: Large displays in automotive design. IEEE Computer Graphics and Applications **20**(4) (2000) 68–75
16. Ståhl, O., Wallberg, A., Söderberg, J., Humble, J., Fahlén, L.E., Bullock, A., Lundberg, J.: Information exploration using the pond. In: Proceedings of the 4th International Conference on Collaborative Virtual Environments. CVE '02, New York, NY, USA, ACM (2002) 72–79
17. Jones, A., Moulin, C., Barthes, J., Lenne, D., Kendira, A., Gidel, T.: Personal assistant agents and multi-agent middleware for cscw. In: Computer Supported Cooperative Work in Design (CSCWD), 2012 IEEE 16th International Conference on. (May 2012) 72–79
18. Sinmai, K., Andras, P.: Mapping on surfaces: Supporting collaborative work using interactive tabletop. In Baloian, N., Burstein, F., Ogata, H., Santoro, F., Zurita, G., eds.: Collaboration and Technology. Volume 8658 of Lecture Notes in Computer Science. Springer International Publishing (2014) 319–334
19. Shen, C., Ryall, K., Forlines, C., Esenther, A., Vernier, F.D., Everitt, K., Wu, M., Wigdor, D., Morris, M.R., Hancock, M., Tse, E.: Informing the design of direct-touch tabletops. IEEE Comput. Graph. Appl. **26**(5) (September 2006) 36–46
20. Xambó, A., Hornecker, E., Marshall, P., Jordà, S., Dobbyn, C., Laney, R.: Let's jam the reactable: Peer learning during musical improvisation with a tabletop tangible interface. ACM Trans. Comput.-Hum. Interact. **20**(6) (December 2013) 36:1–36:34
21. Martinez Maldonado, R., Dimitriadis, Y., Kay, J., Yacef, K., Edbauer, M.T.: Orchestrating a multi-tabletop classroom: From activity design to enactment and reflection. In: Proceedings of the 2012 ACM International Conference on

Interactive Tabletops and Surfaces. ITS '12, New York, NY, USA, ACM (2012) 119–128
22. Kaltenbrunner, M., Bovermann, T., Bencina, R., Costanza, E.: Tuio a protocol for table-top tangible user interfaces. (2005)
23. Laufs, U., Ruff, C., Zibuschka, J.: Mt4j-a cross-platform multi-touch development framework. arXiv preprint arXiv:1012.0467 (2010)
24. Paulson, B., Hammond, T.: Paleosketch: accurate primitive sketch recognition and beautification. In: Proceedings of the 13th international conference on Intelligent user interfaces, ACM (2008) 1–10