Designing Tabletop-Based Systems for User Modelling of Collaboration

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Abstract. Tabletops offer a new form of interaction and create new possibilities for small groups of people to collaborate and discuss tasks aided by the shared use of digital materials and tools. The collaborative affordances of tabletops make them suitable for many uses in public spaces as well as in more restricted environments such as workplaces and learning settings. This creates new opportunities for improving collaboration, particularly by capturing data that can be used to model the nature of the interactions and to present this model to the users in a form that will facilitate improved collaboration. It is timely to establish principles for designing tabletop-based systems in a manner that can facilitate such modelling. These principles should support effective use of data mining tools to create group collaboration models. In this paper, we outline theoretical design principles based on a careful analysis of the nature of tabletop datasets and collaboration.

Keywords: interactive tabletops, group modelling, collaborative learning, collocated collaboration, machine learning

1 Introduction

Interactive tabletops offer a new medium for supporting collocated collaboration. They provide a shared environment for small groups of people to work together, making use of digital materials based on collaborative activities. A well recognised role of tabletops is that they offer new means of interaction with special affordances for small groups. A less recognised possibility is to exploit the user's digital footprints as people make use of the tabletop. These footprints, along with the verbal communication and contextual information related to the users, have the potential to provide new opportunities to build models of their collaborative processes.

Collaboration is critical in a range of areas, from the workplace to learning spaces. However, learning to collaborate effectively is difficult, partly because it involves a long term development of skills. In addition, new collaboration contexts, working with different people and complex tasks, require finer grained monitoring of the collaboration and learning how to make it effective [1]. This means that collaborators need to be able to monitor the effectiveness of the group as a whole and their individual performance as part of the team. One approach that has proven effective in covering such a need is to promote social translucence, an external representation that mirrors objective measures of the group work to help them to be aware on their collaborative process and monitor whether their actions match what they intended [2].

The idea of reflecting overview information back to collaborators by exploiting the huge quantity of data generated by their interactions is not new. Research on user modelling has emphasised the potential of using machine learning techniques to monitor learners' collaborative processes and build adaptive tools that can intercede to make such learning process more productive [3]. Even though the development of collocated collaboration skills is very important in the classroom and beyond, most of the research work on adaptation in collaboration has focused on the use of e-learning tools (e.g. chat, forums, IM, email). However, e-learning and face to face environments are not two separate domains. Nowadays, students are immersed in both experiences: virtual and real worlds. They interact via email or chat, but also have moments in which they have to work face to face. The benefits that tabletops offer to this vision lie in the provision of support during the instants when students have to create understanding in real world settings.

Our work aims to create new tabletop tools to exploit the activity logs and feed them into user models in order to provide adapted support, so that the collaborative process can be more effective and the individuals in the group can each learn to improve their own performance. Currently, there are many tabletop interfaces but it is timely to establish principled approaches to design the key features that should define these learning systems. These range from the design of the tabletop setting to specific user interface features. We propose a top-down approach in which the design of these principles mandates what data should be captured and how it should be exploited to build a model of the group's interactions. Figure 1 shows the elements of our approach. This starts with choosing adequate theories of small group collaboration since they indicate the key elements of effective collaboration and learning. These theories should define the ideal goals and drive the design of the collaborative setting. For example, if we choose to measure symmetry of knowledge based on the definition given by Dillenbourg [4], the system should be designed to capture elements that can give insights on each learner's understanding about a given topic. However, even when these theories establish the ideal aims, the technology tradeoffs between the scope of what is possible to capture and the associated cost bounds the system design.

The rest of the process consists of exploiting the electronic footprints that can be captured as people interact at a tabletop and transform them into a useful data source for these goals. To do this, we consider three elements: *capture of useful data*; *mining the data* to transform it into a set of models of collaboration; and interfaces that make use of these models to offer *adapted feedback* to the group. In this paper, we focus on outlining generic principles for capturing and mining data in tabletop-based learning systems. Further exploration on specific user interface design elements and ways to access to the user models is mandatory, but the details are not important at this stage.

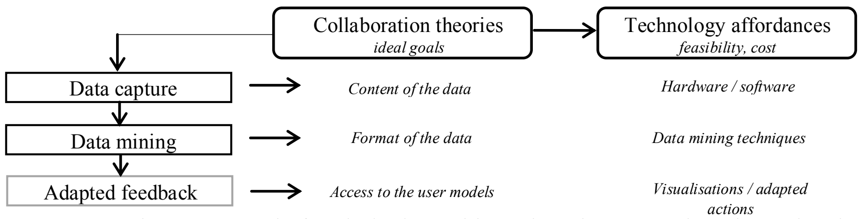

Fig. 1. Top-down approach for designing tabletop-based systems based on the dataset requirements, grounding on theories of collaboration and the affordances of technology.

2 Principles for Capturing Data

Special attention should be given to the architecture of the tabletop-based setting to make the collection of data useful and successful. Next, we outline the key principles of tabletop-based settings design capturing data effectively considering both the learning theories and technology affordances.

Capture speech/video information. The analysis of peer communication is very important for analysing the collaborative processes and it should be instrumented in tabletop settings. The data that is useful to capture depends on the collaborative learning theories underpinning the system. It can include just the *presence* of voice to measure the participation of learners [5] or more detailed information like tone, volume or, as most learning theories state is crucial, the speech content [4]. Current solutions to record verbal interactions in collocated settings range from the use of individual wearable audio recorders to the use of directional microphone arrays. Detection of affective states in learners may also be considered by exploiting video and sensors information [6].

Identify users (authorship of actions*).* As the collaborative setting becomes more sophisticated, and the provision of certain types of adaptation are required, identifying users' actions becomes mandatory for updating the model of the group [7]. Current solutions for identifying the authorship of each touch on the tabletop include high-priced hardware devices such as the DiamondTouch[1] or encumbering learners by attaching gadgets to their hands (e.g. gloves or pens). There are also software based solutions that constraint the design of the collaborative task, such as the assignment of roles, resource ownership, personal territories, fixed production lines or individual lenses [5].

Interconnection with other devices. In collaborative environments learners can make use of multiple devices. Interconnected devices provide added speciality and flexibility for specific tasks that come up during a collaborative session [8]. The interconnection of all these as sources of information, can potentiate the use of tabletops as a shared device in which all group members can work at the same time contributing each to the group task. An example of this is using a digital whiteboard to brainstorm ideas to afterwards store the results on a personal device or share them on the tabletop to its revision.

Integration with services. Tabletop applications can also be integrated within a larger scale system that can give continued support to the learning process of the students. Current online e-learning and project management tools support asynchronous collaboration in the form of wikis, chat and forums. Using tabletops as an added interface to these pre-existent online collaboration tools can extend the collaboration facilities provided by these services and compensate the lack of face to face collaboration of the e-learning environments [9].

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[1] MERL- Diamond Touch.: http://www.merl.com/projects/DiamondTouch/

3 Principles for Formatting and Mining Tabletop Data

Once the datasets are collected from the tabletop and before starting to use data mining tools, the data has to be transformed into a suitable format for data mining techniques. In this section, we propose a number of principles to ease the formatting of the data according to the data mining requirements and the theoretical goals.

Define the logging granularity. The lowest level in which the tangible actions on the tabletops can be recorded corresponds to logging the coordinates of each touch point on the tabletop. Analyses of learners territoriality can be conducted using this raw data. However, higher-level data logs, such as activity dependent information (e.g. move object, press a button, delete an element), should be logged to get meaningful insights on the strategies followed by groups. Besides, it could be required to set up even higher-levels of abstraction by giving meaning to sets of basic actions based on heuristics specifically created for the task. For example, basic actions, such as dragging objects, inserting text or resizing images, in conjunction can be related with higher level group strategies like brainstorming, agreement, or formalisation of a solution.

Add user and contextual data. The user model of a group working at the tabletop can be enriched by the incorporation of learner information that is *normally* beyond the boundaries of the system, such as personal details or outcomes reached in related academic activities [10] (e.g. the familiarity between group members, parts of each learner model or the marks of previous assignments). Additional data can also be generated by other systems related to the tabletop application (e.g. vertical displays, smart-phones, laptops) [11] or if the tabletop is used after other technologies [12]. A possible solution to ease the formatting of the data is to adhere to a common user modelling framework which can give support to multiple services.

Define the focus of attention. The raw tabletop log data can contain detailed contextual information about each action that users perform and it is normally formatted as a very long sequence of events. It is very important to define the focus of attention of the user modelling to capture and format the adequate contextual data to fulfil the learning goals. Researchers on collaborative learning or the learners' facilitators can specify this focus of attention. It can be directed to specific users, the spatial position of resources, types of users or the disposition of learners around the tabletop. For example, if the analysis is focused on the resources present at the tabletop the dataset should identify and keep track of such resources along with the stream of events.

Define the format of the data according to the data mining technique. Finally, the data need to be extracted in the required format of the data mining technique to be used. This is important because different algorithms need might require specific contextual information. For example, sequential pattern mining algorithms need data formatted as a detailed sequence of elements. Other techniques might require the historical status of the objects at the tabletop to measure the progress of the group.

4 Conclusion

Tabletops are an emerging form of interactive device for small group collaboration, in educational and other settings. In order to design adaptive applications in collocated settings where horizontal tabletops are present, it is crucial to establish the design principles required by user modelling and machine learning techniques –two core scaffoldings to offer such adaptation. We discussed a number of elements that should be addressed by the architecture of collaborative tabletop systems. We look forward to explore the possibilities of tabletops as supporters of learning and hope this position paper can initiate a discussion regarding the technology and social issues that must be addressed towards the provision of adapted support through tabletops.

Acknowledgements. This research was carried out as part of the activities of, and funded by, the Smart Services Cooperative Research Centre (CRC). We thank Dr. Anthony Collins for his suggestions.

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