Enhancing Tabletops: Multi-Surface Environments for collaborative learning

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Abstract: Today multi-display environments are becoming more and more common in everyday use and allow users to display a large quantity of information. In this position paper we argue that augmenting a tabletop with other visualization displays not only increases the space of information, but may also provide specific advantages in a collaborative learning situation. In particular, we propose that multi-surface environments have the potential to enhance learning on a perceptual, cognitive and social level by utilizing Multiple External Representations (MER).

Introduction

Today multi-display environments are becoming more and more common in everyday use and allow users to display a large quantity of information. These displays can take various forms: desktop displays, laptop screens, image projected on a wall, tabletops, large displays (data wall), and augmented reality systems. In this position paper we will consider an educational context and focus on multi-surface environments including a tabletop system. Traditional tabletops are flat surfaces that offer different way to interact with them: either by multi-touch (Dietz & Leigh, 2001), tangible interface (Ishii & Ullmer, 1997) or both (Microsoft Surface). Until now, researchers have mainly focused their attention on educational benefits of tabletops; in this paper, however, we will point out the weaknesses of a learning system using a tabletop alone, and then propose a way to compensate by taking advantage of the Multiple External Representations framework (Ainsworth, 2006).

Why tabletops are a good but not perfect environment to learn

Tabletop environments are believed to bring benefits in collaborative activity (Rogers & Lindley, 2004). Several empirical studies showed that this premise was correct at least to some extent: multi-touch tables (compared with multi-mice systems) produce higher level of awareness in co-located groups (Hornecker, Marshall, Dalton, & Rogers, 2008), helps users to focus more on the task and less about turn-taking management (Harris, 2009), improve conflict resolution (Stock et al., 2008), communication (Gal et al., 2007), and bring significant learning gain (Rick, Rogers, Haig, & Yuill, 2009). These recent studies suggest that collaborative learning may benefit from those environments. On the other hand, there are several limitations of a tabletop-based learning system. Below we will discuss the potential drawbacks of those systems from three levels: perceptual, cognitive and social.

First, at a perceptual level, Wigdor, Shen, Forlines, & Balakrishnan (2007) showed that graphical elements displayed on tabletop's displays might be subject to visual distortions. He found that users were affected by two perceptual biases: the orientation of the graphical element (e.g. 90°, 180°, 270°) and the user's viewing angle (e.g. objects displayed farther away are perceived as smaller than they really are). In a learning context, complex graphical elements (such as graphs) are already difficult to analyze and understand for novices. Distortions described above may increase users' cognitive load and make them disengage from the learning task.

Second, at a cognitive level, tabletop may constrain reflection and abstract thinking by blocking the learner in an "action mode" (in particular if the interface is using tangibles; Clements, 2000); from Clements' point of view, it is more difficult to keep a distance from an activity when working with physical objects. To our knowledge, there is no empirical result on the question of whether this effect was due to the 3D shape or the haptic feedback of the object. Both multi-touch and tangible interfaces may be affected by this phenomenon and thus hamper abstract thinking if no space for reflection is provided.

Third, at a social level, several points are worth mentioning due to face-to-face (or side-by-side) collaboration: territoriality (Scott, Sheelagh, Carpendale, & Inkpen, 2004) may prevent users from acting on the whole surface of the tabletop; social stereotypes also affect conflict resolution (e.g. people who seem to be more competent, but not necessarily are, are more likely to impose their view; Cudd, Fiske, & Glick, 2008); and finally building an accurate representation of what others know (called Mutual Modeling; Clark, 1996) also influences the quality of collaboration. Most tabletops systems lack indicators such as the KAT system described by Sangin (2009), which provides information about the level of expertise of other people in collaborative contexts.

Potential benefits of a multi-surface environment for collaborative learning

We postulate that these drawbacks can potentially be reduced by integrating Multiple External Representations (MER) across displays. According to Ainsworth (2006), several learning benefits can be expected when using the MER framework:

First, two representations of the same situation can constraint interpretation by reducing ambiguity (e.g. scientific results in the form of text allow ambiguity that a graph doesn't). In the same manner, Widgor et al. (2007) showed that perceptual ambiguity can be reduced on displays with different orientation: "we found that errors of comparison of visual variables across displays were not as severe as those made directly across large up/down distances on a tabletop. We also found that one of the visual variables, position, is even less robust to differing orientations between displays than it is to large perspective distortions on the same display". As a consequence, multiple representations across displays may improve how we perceive graphical elements.

Second, learning is described by Ackermann (1996) as a dance between 'diving-in' and 'stepping-out': "while effective learning about a domain does involve engaged task-focused activity, it can also involve periods of more objective reflection where knowledge is abstracted and conflicts are resolved". Multi-surface environments have the potential to enhance learning by providing a space to 'step out' of the "action" mode described by Clements (2000). For example, in Figure 1 one user is 'diving in' and exploring the tabletop's resources, while two other colleagues are 'stepping out' and discussing the results of the search. Designing activities to allow the three users integrate those two representations may lead to learning benefits because of their complementary functions (see Ainsworth for a review on the functions of MER). Another example is the EDC system described by Fischer (2001), where an action space is defined on a tabletop and a reflection space on a vertical display. It was conjectured that this setting offers the possibility to blend action and reflection (Schön, 1983) and thus improve collaborative processes.

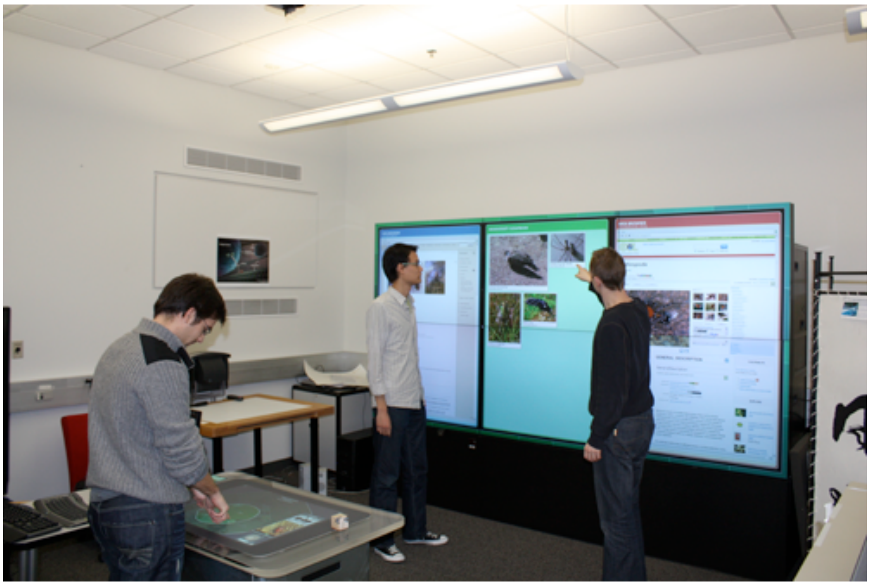

Figure 1. A multi-surface setting. One user on the left is exploring some content on the surface, while two other users are discussing the same content (displayed on a complementary way) on the wall.

Finally, according to Ackermann, conflict resolution and collaboration processes need to be carefully managed to bring potential benefits. One of our assumptions is that since vertical and horizontal displays seem to promote different collaborative behavior (Rogers, 2004), offering multiple spaces where users can present their point of view on a slightly different way has the potential to improve collaborative processes (e.g. in fig.1, the same problem won't be discussed and solved in the same way on the tabletop and in front of the large display). This proposition is also the basis in Fischer's work in using multi-surface environment to mix communities of practice in order to solve a common problem (Fischer, 2001) In addition, since large information spaces are available, indications about the level of knowledge of participants can easily be displayed and thus improve mutual modeling processes and reduce social stereotypes (Sangin, 2009). Taken together, those elements have the potential to deepen understanding, which is a crucial function of MER (Ainsworth, 2006).

Conclusion

The purpose of this paper was to underline potential weaknesses of tabletop systems and propose one potential solution using a multi-surfaces environment. Future empirical studies will test whether our assumptions are valid, continue to examine advantages and disadvantages of such systems and continue to seek ways to take advantage of a multi-displays situation in educational contexts.

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