Evaluating an Automatic Rotation Feature in Collaborative Tabletop Workspaces

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Abstract
Tabletops are commonly used for collaboration but would benefit from features that help orient objects to individual users disposed around the display. We propose an approach of automatic orientation based on fingers and hand detection as a proxy to determine the position of the user. To contribute to the discussion of the relevance of automatic rotation, we present a comparison study of pairs of participants engaged in both loosely and tightly coupled tasks. We collected performance measures, questionnaires and analyze interactions from video recordings. The results show that automatic rotation is more suitable when the collaboration is loosely coupled. Conversely, in tightly coupled tasks performance are worse and user ratings low when automatic rotations are enabled. We conclude that features such as automatic orientation on tabletop are important and promising but that they need to be critically assessed with respect to their effects on collaboration in both tightly and loosely coupled tasks.

Keywords
Multitouch, tabletop, automatic orientation, coupling

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces - Graphical user interfaces;
H.5.3 [Information Interfaces and Presentation]: Group and Organization - Evaluation/Methodology

General Terms

Experimentation, performance

Introduction

The simplest way to manage orientation while using digital tabletop systems is to let users manually rotate the items on the tabletop. This is the direct analog of how people orientate items in traditional media, but manually rotating digital objects with digital displays can be more difficult to use and time consuming compared to traditional media [2]. In fact, providing support for orientation is a challenge for tabletop system research [1,2]. Several automatic orientation techniques for documents have been proposed [1,3,5,9] and many tabletop systems have implemented dynamical reorientation in order to rotate an item towards the reader minimizing manual rotations [5,9]. These mostly rely on the position of the document itself and automatic orientation is determined by the position of the document and not by the position of the user.

An automatic orientation technique on a tabletop

We present a new technique of automatic rotation that provides a proxy for the position of the users calculating the hand orientation. This is possible on multitouch tabletops [11] that use infrared computer vision and detect objects near the surface such as fingers. This gives accurate information about the user's hand position and alignment. With this premises, it is possible to implement an algorithm that automatically orients an objects to the user's hand. The approach is to first calculate the relative direction of the hand summing the finger-to-palm vectors and taking the angle from that vector using an atan-function (Figure 1). This results in a vector that is oriented taking into account the length of fingers. An object like a document or a picture usually also has a relative orientation with a direction. For example, in case of text documents the vector can be drawn in the middle of the document from the bottom directed upwards as "f" in Figure 2. The system can identify the position of the hand that is touching the document, calculates the angle "η" between the orientation of the hand "d" and the orientation of the document "f". If the difference is more than a specific threshold ($\eta > 90$), the system can rotate automatically the document on its center parallel to the orientation of the hand "d".

$$\vec{d} = \frac{1}{n}\sum_{i=1}^{n}\vec{a}_i$$

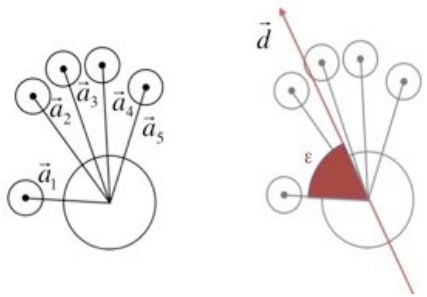

figure 1. Determining the orientation of the hand relative to an absolute direction.

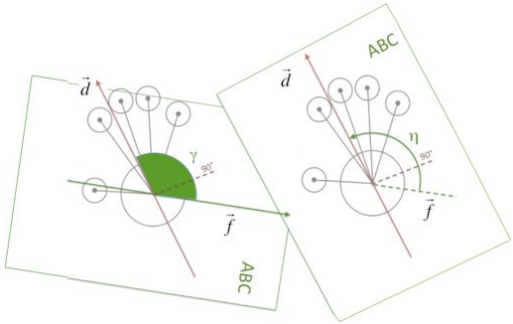

figure 2. Determining the orientation of an object relative to the hand

figure 3. The experimental setting.

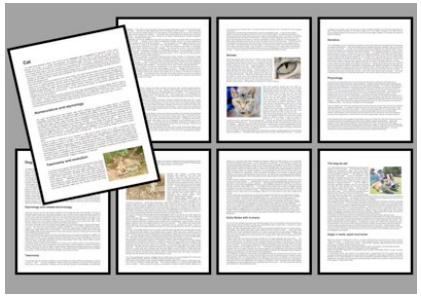

figure 4. An application to browse pages of documents. Pairs of subjects have to order the pages in tight or loose collaboration.

Comparing orientation in loosely and tightly coupled tasks

To contribute to the discussion of the relevance of automatic rotation, we present an experiment that evaluate the new technique comparing two versions of a collaborative task that required different levels of coupling: a first task involving a tightly coupled work where participants cannot do much work before interaction, and a second loosely coupled task where the participants can work independently without reliance on ongoing interaction with the other person.
Studies of coupling on tabletop showed that individuals frequently and fluidly engage and disengage with group activity through distinct, recognizable coupling states with unique characteristics [9]. Previous works has shown that users use orientation not only to help themselves view the items but also for sharing and communicating information with others [2,3,6,7].
We therefore posit that the efficacy of automatic rotation in a collaborative setting depends on the task at hand in particular whether the task is tightly or loosely coupled.

Methods

Four pairs (eight participants: six males, two females; mean age 29 years) were recruited.
In order to complete the task, the participants had to put different pages of a scrambled document in the right order: 8 pages were presented scrambled in random orientations on the tabletop surface and participants could freely manipulate and sort the pages (Figure 3).
Two task versions were used: a tightly coupled and a loosely coupled one. During the tightly coupled task the participants had to rearrange 8 pages of a common theme in collaboration while during the loosely coupled condition the participants had to rearrange two documents of different themes (each composed of 4 pages) independently. The task was deemed complete when all the pages were in the correct order (tightly coupled task) or when both participants finished rearranging his/her document successfully (loosely coupled task). In assembling the documents used in the study, attention was paid to the order of contents, length of paragraphs and number of pictures, in order to create similar documents and to avoid repetitions of structure and layout that may facilitate the tasks.
Our study used a 2 (loosely coupled task vs tightly coupled task) x 2 (automatic rotation deactivated vs automatic rotation activated) within-subjects design. The presentation order of the conditions was partially counterbalanced using a Latin square design. Every pair participated in all four conditions: in two conditions the automatic rotations was deactivated and participants could use only manual rotation gesture; in the other conditions users could use not only the manual rotation but also the automatic rotation gesture.
Participants first filled out a questionnaire to collect demographic data. They were then given a short tutorial on how to use the table display and general instructions on the task. Participants then performed the four tasks using the document browsing applications (Figure 4). For each task, the participants were informed about the task version and the presence or absence of the automatic feature.
After each task, participants completed a post-task questionnaire that gathered preference data. We collect performance and rate of touches (number of touches divided by the time required to complete the task) and analyze interactions from video registrations.

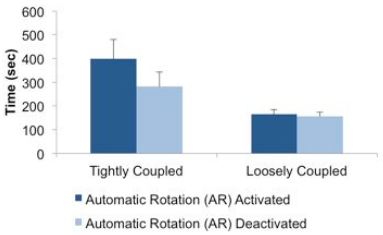

figure 5. Mean time to complete the task by experimental conditions

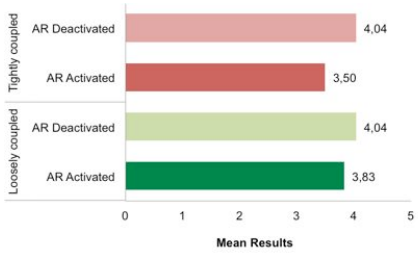

figure 6. Mean results regarding ASQ questionnaire

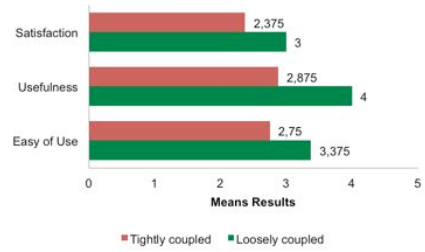

figure 7. Mean results regarding automatic rotation questionnaire

Results

The analysis of time and rate of touching did not show statistically significant differences between the automatic rotation conditions. The trend suggested that participants spent more time on solving the task in the tightly coupling condition with the automatic rotation feature activated compared to the condition with the feature deactivated (Figure 5).

Questionnaire

After each task, participants were asked to rate their experience on a Likert-type scale of 1 to 5 (1= Totally disagree and 5=Totally agree) about the system and the automatic rotation gesture (only in tasks with the feature activated). ASQ - After Scenario Questionnaire [4] was used to assess the user's experience with the system (Figure 6). The results from the ASQ showed high participants' ratings in both automatic rotation conditions during loosely coupled tasks. Concerning the tightly coupled tasks, user's ratings were lower when the automatic rotation was activated compared to the condition with the feature deactivated ($t(7)=3.87$; $p<.01$). These findings confirmed a drop off in ratings specifically for the tightly coupling task when the automatic rotation is enabled.

Participants were asked to rate the ease of use, the usefulness and the satisfaction with the automatic rotation. Results show that automatic rotation gesture during the loosely coupled task compared to the tightly coupled conditions was rated more useful, satisfying and easy to use (Figure 7).

Video analysis

In order to get an overview of the tasks and further interpret the performance data we conducted video recordings of the study sessions.

Styles of collaboration

As a first step, we identified coding categories based on collaboration activities. Generally participants worked independently across loosely coupling tasks. They collaborated only during the first part of the task (30% of the time): they begin the activity assigning the two themes and dividing the materials accordingly. When pages were assigned, the participants continued the task without conversations, working independently until the task's completion. Differently, we observed that participants adopted strategies involving collaboration during tightly coupled tasks, working together about 84% of the time and working independently only for the remaining 16%. Video analysis showed that interactions during tightly coupled tasks involved more active verbal communication and teamwork than the loosely coupling conditions.

Patterns of Interactions

Subsequent coding passes were driven to identify the rotations gesture performed by each user and the automatic rotations. We observed that during loosely task, users performed the automatic rotation gesture especially during the first part of the task to easily reorient the documents towards themselves. We observed that automatic rotations could be activated while manipulating the document: e.g. an involuntary automatic rotation can orientate a document in the 'right way up' while the user is holding and moving the document towards himself/herself. The video analysis shows that the automatic rotation gesture is a particularly useful feature especially when the documents' desired alignment is towards the users, therefore during individual work and loosely coupled tasks. During loosely coupled tasks participants mainly used rotation to orientate items towards themselves,

while during tightly coupled tasks they also orientated pages towards the other person or to the group. Further analysis was performed to evaluate the automatic rotations when the users try to orientate an object at any angles different from the arm alignment.

Orienting an object to the other person or to the group
The outcome of the first analysis was subjected to a second stage of coding to identify the number of rotations performed by the users to orientate a document to the other person or to the group**.** The orientation has indeed also an intentional communicative role. For instance, an object can be orientated in a compromised angle that makes the item visible to both people even if it is not well aligned for any one person (Figure 8).

figure 8. Examples of pages oriented in a compromised angle. Orientation is used as a communicative action.

Our observations confirm that the automatic rotation feature influences the usage of a compromised angle orientation during the tightly collaborative tasks. When the automatic rotation feature is disabled all four groups but one orientate objects in a compromised angle at least 2 or more times. When the feature is turned on, only one group showed acts involving rotations of items to a compromised angle. None of the other groups carry out such a type of collaborative actions when the feature is activated. The orientation is also used to orient items to the other person: e.g an user want to pass on a document that could interest the other participant (during the loosely task) or to show a text passage (during the tightly coupling task). Even in these cases, the usage of rotation as communicative action is influenced by the activation of automatic rotation. During the tightly coupled task with the automatic rotation activated, only in two groups did users rotate the documents to the other participant. When the feature is disabled, in all groups users rotated the documents to the other participant at least 4 times during the task. The video observation suggests that the act of showing a particular text passage to the other person is typically performed by orienting the document to the other when the automatic rotation is disabled while it is often followed by reading aloud the text or deictic actions when the automatic rotation is enabled.

Discussion and Conclusions

Tabletop and surface computing are excellent platform for collocated interaction and collaboration. However given that objects can be oriented in all direction and users can collaborate around the table, this provides a design challenge compared to desktop interface design. We proposed a technique that uses the orientation of a hand to approximate the position of users around a tabletop to orient documents accordingly. Our study contributes by evaluating this automatic rotation technique in a two-person collaborative scenario. For loosely coupled tasks, results demonstrate that time performance and rate of touches are similar between rotation conditions. Questionnaire data show that users rated with high scores the system and gave high

ratings for the automatic rotation's ease of use, usefulness and satisfaction during loosely coupled tasks. For tightly coupled tasks, the results suggest that automatic rotations lead to worse performance, increased completion time and lower users' ratings compared to the condition without automatic rotations. Video analysis shows that it is more difficult to rotate objects to the other or to use a group orientation, thus participants tend not to use the orientation to communicate. In a collaborative setting, a straight-on orientation aligned with the user's arm is not always desired and it can hinder the interaction. In sum, we have proposed a new feature in tabletop systems for automatic rotation that is promising since it was received positively and has some improvement potential given implications from the study. Participants generally use different styles of collaboration and orientations according to different conditions. The new automatic feature reduced the patterns of interactions and communication in the tightly coupled condition, indicating that interaction technique has an impact on collaboration. We imply that comparison studies with tightly and loosely coupled tasks are particularly useful in evaluating new features and interaction on tabletops. We believe that our study is a first step towards future developments and deployments of such interaction technique.

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Citations

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