Adaptive Personal Territories for Co-located Tabletop Interaction in a Museum Setting

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ABSTRACT

In this paper, we address the problem of designing for participation and parallel interaction with a walk-up-and-use tabletop system in a public exhibition environment. Motivated by the work practice of territoriality, we implement a novel, tabletop-integrated multi-user tracking system that provides data on a user's location and movement. Based on this robust hardware and software implementation, we present an interaction design that assigns a visually separated display space to each user, the space serving them as a personal territory. These territories can serve as affordances for initiating interactions; most notably they can support the multi-user coordination process during parallel co-located information exploration, which has been observed in our preliminary evaluation.

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General terms: Design, Human Factors

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INTRODUCTION

The tabletop implementation presented in this paper is part of a permanent public exhibition that features the history of German telephony. The exhibition takes place in a public bank building and is distributed within the entire main floor, where multiple exhibits are presented in display cabinets and show cases. The tabletop itself is placed in a central location and plays a major role in the exhibition. It features virtual representations of each exhibit. Known as “information items”, these allow visitors a further exploration of the exhibit by presenting detailed multimedia contents.

Such co-located shared information interfaces can promote visitors' overall experiences in various manners. On the

one hand, a tabletop interface allows visitors to explore information in a self-directed way. On the other hand, it acts as a social medium, which could support parallel co-located information exploration. This is important due to the fact that museums tend to be visited by small groups e.g. family and friends [2].

Our tabletop implementation addresses these characteristics through the concept of personal territories. One design goal is to *create lures that encourage visitors to interact and that lead to a deep engagement* with the information presented. Another design goal is to *support a parallel exploration on equal terms around the tabletop*. Here the focus is on a surface partitioning that ensures every user enough space to discover the available information (Figure 1).

Figure 1: Tabletop with personal territories

BACKGROUND

During co-located tabletop interaction, users gather around a table in varying constellations. People typically preserve various zones or distances at which they interact with other people, and which depend on social relationships. The area that is defined by the length of a person's arm usually establishes an intimate zone, also called private space [3]. When users gather around a traditional table, they each typically reserve a distinct area of the table in front of them. Within this area, users carry out individual work. Tang [7] stated that users establish separate areas on a tabletop to work and interact with task resources. This behavior could be understood as a work practice of territoriality. The approach proposes a distinction between three types of territories: personal, group, and storage. These areas are arranged organically by users through the positioning and orientation of artifacts on the surface [6]. Personal territories are established directly in front of the user and are used for manipu-

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lation, editing, and reservation of resources; group territories provide context for the group task and hold shared artifacts; storage territories are used, for example, for items that do not belong to the current task.

The establishment of territories depends on the user's acquired space and is part of a global coordination and partitioning process. This practice, which usually relies solely on social protocols, can lead to conflicts on interactive tabletops such as "overlap" situations, where one user's interactions interfere with another's [4]. Morris et al. [5] propose a variety of software-level coordination policies that attempt to control a document's manipulation access rights as a means of preventing such conflicts. The selection of such a policy is influenced by the tabletop hardware, among other factors. For example the DiamondTouch table [1] is capable of assigning touch points to specific users, thereby enabling simultaneous access and avoiding conflicts.

BUILDING A REACTIVE TABLETOP

Conventional tabletop systems face one important problem: the system itself does not know how many users there are or where they are located. This imposes certain restrictions on the interaction design. Common problems are, for example, dynamic display partitioning and document orientation. These issues motivate our approach of enhancing state of the art tabletop technology with a novel user-tracking system that provides data on a user's location and movement.

Based on the tracking information, our system can address multiple issues. First of all, such a system can react to an approaching user and provide affordances for initiating an interaction. Furthermore, novel coordination policies can be established. In our case, we partition the available display space into territories, which ensures that every user has enough space to explore the presented information in detail. This is achieved by providing a visually delimited adaptive personal territory to each user (Figure 1).

Tracking Hardware

The tabletop system we built is based on a 65" screen with Full HD resolution and an IR touch frame. Furthermore, the table is equipped with eight speakers that can be controlled separately via a 7.1 sound system (Figure 2).

Figure 2: Exploded view of the tabletop hardware

The basic idea of the tracking system is to detect users by means of an array of proximity sensors, which are arranged around the table [8]. Our implementation of this system is based on an Arduino Uno microcontroller board. The sensor array itself consists of 96 infrared distance sensors with a maximum range of 150 cm (Figure 3).

Figure 3: A partial view of the tracking system

Tracking Software

The tracking software on the PC tracks users by analyzing the sensors' distance values. At first we focused on tracking a user as quickly and precisely as possible, so that both slow and fast movements could be processed accurately in real-time. While this is sufficient for most tracking scenarios, a territoriality-based tabletop application demands special functionality and configuration.

The main advantage of a tracking system is that it allows for a very flexible interaction design. In our application, personal territories are represented as circular shapes that appear right in front of the user. Personal territories can be added and removed dynamically depending on the number of users around the table and their location. Furthermore, a personal territory will follow a user as the user walks around the table (Figure 4). In this way, we can support movements around the table, for example, when a user tries to collect an object that is out of reach.

Figure 4: Personal space following a user's position

When two or more users are standing close together, the corresponding personal territories can intersect. Since this can be confusing for the user, intersection is only allowed to a predefined extent. To implement this behavior, our tracking system checks if the associated space will intersect with any other before any user position is updated. Figure 5 shows different multi-user constellations that can occur at the table. When a user (blue) approaches the table at a position where no new territory can be generated without overlap, the user will not receive a personal territory (a). In case a neighboring user (green) is making more room for that user, a new territory will appear (b).

Figure 5: Multi-user constellations at the table

When two adjacent users move towards each other (e.g. to look at each other's contents), their territories remain at a position such that they do not overlap. In this way, users can browse contents together while still having the chance

to return to their own territory (c). If two users are standing close together for a longer time (15 sec.), we assume that they explore the contents as a group; therefore we remove the territory that has been left before (d). Due to the table size, a maximum of six concurrent personal territories is supported.

Finally, our system also supports dynamic sound output. Since there are eight speakers distributed around the table, audio contents are played back only from the speaker that is closest to the corresponding user. In this way, we can minimize dissonances that might occur when multiple users listen to different audio contents simultaneously.

INTERACTION DESIGN

One main objective of the interaction design specified below is to ensure that visitors are able to explore, in parallel and in a convenient manner, the multimedia information that is presented for the exhibits. Furthermore, the selection process and the positioning of the information presented are designed to be as simple as possible due to the fact that some of the visitors will have had no previous experience of touch interfaces.

The interaction design shows one opportunity to utilize the tracking system for parallel co-located information exploration. The dynamic personal territories are represented by accentuated ellipses that provide a user-centered view onto the group space (Figure 6). The design was chosen because we wanted to achieve a clear distinction between the personal and the group territory, while at the same time guiding the user's focus towards their personal territory. The creation, placement and removal of these visual personal territories are based on data from the tracking system. We excluded storage territories from our interaction design because they are not required for the given scenario.

Figure 6: Application Design

Each exhibit is represented by a circular information item. These items are located within the group territory and are animated with the help of a physics engine. Therefore, they can also collide with each other and be attracted by force fields. Each information item is assigned to one of three force fields, which represent different locations of the exhibition. In this way we enable the visitor to connect the exhibits presented in the real exhibition space with their virtually presented counterparts.

When an information item moves into a personal territory, it is highlighted to attract the user's attention. If users want to explore this item in detail, they need to select it by tapping the item once (Figure 7).

Figure 7: Selection of an information item

Furthermore, users can drag items from the group territory into their own territory in order to select it. After an item has been selected, the corresponding multimedia content is opened within the personal territory, where it can be explored in detail. If a user moves around the table, the respective personal territory, and thus its current content, follows the user. When walking round a corner, the territory and its contents are automatically realigned towards the user.

Through the visual representation of a personal territory, the user's affiliation to the system is directly mediated when approaching the table. At the same time, personal territories can support the distribution process of multiple users around the table.

PRELIMINARY EVALUATION

A common problem of multi-touch interfaces is that touch points cannot be assigned to a specific user. This leads to a problem during user-centered interaction logging. Nevertheless, some approaches have been published to overcome this problem (for example, by using an overhead camera [9]). By means of the tracking system, it is also possible to solve this issue at least partially. When a user approaches the table, a new logging session is started in which all interactions within the personal territory as well as the user's movements are recorded. Currently, we assume that each interaction within a personal space has been triggered by the owning user. This data has of course to be interpreted with caution, because the basic assumption may not always hold true, one example being when neighboring users interact within each other's territory.

Despite these restrictions, logging based on personal territories has a number of advantages over traditional logging. First of all, one can see how many visitors come to the table in total, for how long they stay, and how much and with which items they interact. We can therefore also distinguish between bystanders and interacting users. Finally, we can use the data to analyze the movements of users as well as the distribution patterns of multiple users around the table.

We equipped the museum application with interaction logging for a number of reasons. First of all, interaction logging is the only method that enables the collection of quantitative data over such a long time span without much effort. Secondly, the exhibition takes place in a public bank building during day-to-day business, which restricts the

number of methods that can be applied in situ because of German privacy laws and the restrictions that such studies or observations would impose on bank customers.

Results

The interim results we are presenting are based on logging data that has been collected over 54 days and that contains 968 user sessions. The variance within some dimensions of the collected data is very high; in session duration or number of interactions, for example. We assume that this is due to the location of the exhibition: there are customers who are simply waiting for the next free bank clerk, as well as museum visitors who are focusing on the exhibition. Both groups have very different goals and intentions, which is of course also reflected in the user's behavior when interacting with the system.

Out of the 968 user sessions, 257 users were bystanders who did not interact with the system at all (26.55%). The average duration of all sessions was 163.73 seconds (SD 278.88), with an average of 17 interactions per session (SD 26.60). Most interestingly, when looking at user movement, the data revealed that the average user walked 0.86 times the distance that corresponds to the long edge of the table (approx. 170 cm) (SD 0.98). We can therefore argue that supporting such user movements with dynamic personal territories is a useful technique in certain scenarios.

One problem that becomes apparent when analyzing the logging data is that it only reflects those users who are standing directly at the table. Hence, we cannot make any assumptions about other users that might be standing back from the table and waiting for a free space. In order to gather additional, qualitative data, we conducted an informal observation during a public event in the exhibition. We observed that, during situations where many users wanted to access the table simultaneously, our approach of dynamic personal territories leads to a self-regulating process. For example, bystanders who do not receive their own personal space will either try to find another space at the table, or wait and observe until another user leaves or makes more room (Figure 8).

Figure 8: Multi-user constellations around the table

Substantiated observations of this self-regulating process are hard to conduct and record manually. Hence we are going to carry out a comparative experiment with and without personal territories to get deeper insights into this complex coordination process.

OUTLOOK AND CONCLUSION

In this paper we have presented a novel technical solution for tracking users around a tabletop. This hardware implementation is complemented by robust tracking software that includes policies for avoiding overlap situations. Based

on this hardware and software implementation, an example interaction design was introduced. This design features adaptive personal territories that can serve as an affordance for the user to interact with the system. Furthermore, it supports parallel information exploration and dynamic display partitioning. Finally, the system we introduced allows for user-centered interaction logging, which helps to analyze the users' interaction behaviors on a per-user basis. However, the logging data is insufficient when it comes to analyzing the multi-user coordination process. An informal onsite observation indicated a self-regulating coordination process which we will address in future research.

The system as it is currently used in the exhibition is designed for parallel information exploration, so there is no real group task that is to be achieved. However, we think that the concept of adaptive personal territories is highly beneficial for such tasks. For example, personal territories can be used to provide task- and user-specific tools and to increase the efficiency of a group's workflow. Furthermore, personal territories could be combined with methods for user identification (e.g. RFID) in order to support personalization and heterogenic user roles. These concepts and ideas will be addressed in our future research.

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