
A Design Space for User Tracking around Tabletops

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Abstract

In this paper, we address the problem of designing for participation and parallel interaction with a large-scaled tabletop system. Beginning with a short description of our tabletop-integrated multi-user tracking system we introduce Dynamic Personal Spaces (DPS), which are virtual representations of a user's workspace on a table. Furthermore we provide a number of applications that can be implemented based on the tracking system and DPSs. This collection shall serve as a starting point for people implementing applications that are based on the DPS approach.

Author Keywords

Tabletop, territoriality; multi-touch, social interaction, sensor technology

ACM Classification Keywords

H.5.3. Group and Organization Interfaces – Collaborative computing, Synchronous interaction.

Introduction

Previous research [3, 8, 10, 12] has shown how tabletop users partition the workspace into different zones and that these zones play an important role for coordinating multi-user activities and for mediating awareness information. Furthermore, people working at the same table prefer different spatial arrangements

depending on the task at hand. Thus, one should consider the question of how different spatial arrangements influence group work and vice versa. An early research effort towards this question was carried out by psychologist Robert Sommer, who found that the type of a task influences the preferred seating arrangement of dyadic groups. For example, during cooperation 51% of participants preferred to sit next to each other, whereas for conversation around-the-corner and opposite arrangements were highly favored (88%) [11].

Combining these two insights has led to the idea of Dynamic Personal Spaces (DPS). A DPS is a virtual representation of a user's personal space that can take many shapes. The underlying idea is that a DPS shall appear automatically right in front of the user as she approaches an interactive tabletop. When the user moves around the table, the DPS shall follow all of her movements. And finally, when the user leaves, the DPS shall disappear automatically. The goal of this approach is to provide a personal space to every user of a tabletop in an easy and accessible way.

Transferring the DPS concept to a multi-user scenario means that group members can stand far away from each other during loosely coupled tasks, such that each of them can work independently without interferences by others; and they can move close together for tightly coupled tasks in order to allow for more efficient communication and information sharing. In both cases, each DPS will follow his owner's movements, carrying along the tools and artifacts contained in it and automatically partitioning the table's surface into distinct areas.

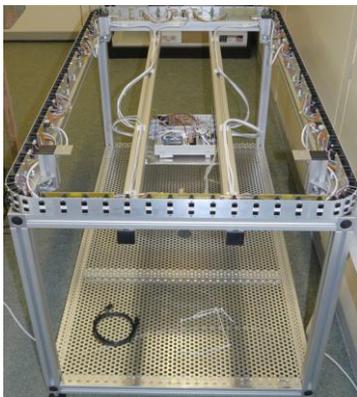


Figure 1. Tracking system

Tabletop implementation

The first step towards DPSs is to implement a tracking system that is able to detect the presence and location of users around an interactive tabletop. 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. 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 [13]. Our implementation of this system is based on an Arduino Uno microcontroller board. The sensor array itself consists of 96 IR distance sensors with a maximum range of 150 cm (Figure 1). Based on this data the tracking software on the PC traces users by analyzing the sensors' distance values [7].

Dynamic personal spaces

The main advantage of a tracking system is that it allows for a very flexible interaction design. In our approach of DPS, 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 she walks around the table (Figure 2).



Figure 2. Personal space following a user's position

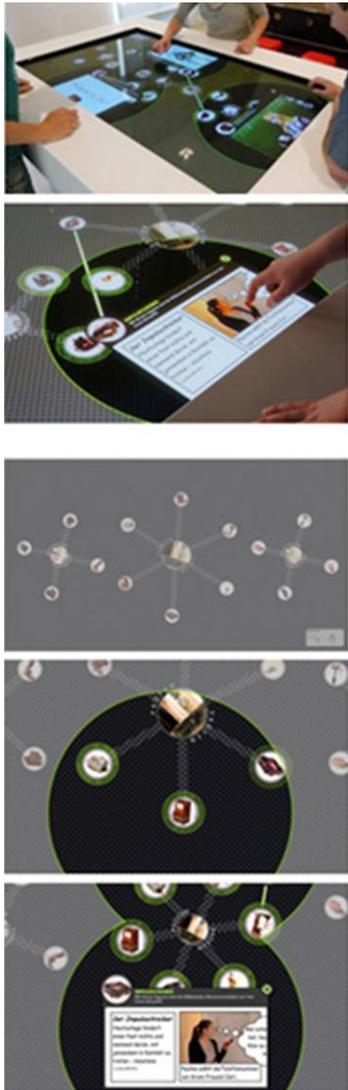


Figure 3. Interaction design example

In this way, we can support movement around the table, for example when a user tries to select an object that is out of reach.

Usage scenario

The tabletop hardware presented was part of a permanent public exhibition. It featured a number of so-called "information items" such that each item corresponded to one exhibit. These information items contained detailed multimedia contents and thereby allowed visitors to extend their knowledge by exploring the multifaceted information. The interaction design shows one opportunity to utilize the tracking system for parallel co-located information exploration. The dynamic personal territories are represented through accentuated ellipses which provide a user-centered view onto the group space (Figure 3). When an information item moves into a personal territory, it is highlighted to draw the user's attention. If she wants to explore this item in detail, she needs to select it by tapping the item once. Furthermore, a user can drag items from the group territory into her 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.

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 could support the distribution process of multiple users around the table.

Evaluation of DPS

Throughout the exhibition, interaction logging was applied in order to collect quantitative data from the users. By means of the tracking system, it was possible

to achieve a kind of user-centered interaction logging. 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. This data has of course to be interpreted with caution because we cannot always assume that each interaction within a personal space has been triggered by that very user. Despite this restriction, the personal territory based logging has a number of advantages over traditional logging. First of all, one can see how many visitors are coming to the table in total (2415 sessions), for how long they are staying (Avg. duration: 111.28 sec.), and how much and with which items they interact (Avg. # of selected items: 9.72). Therefore we can also distinguish between bystanders (47.54%) and interacting users. Finally, we can use the data to analyze the movements of users (average user walked approx. 137 cm in total) as well as distribution patterns of multiple users around the table.

In all the logging data, the distribution of values is very wide. Furthermore, the logging data can not reveal under which circumstances and with which goals and intentions these movements occur. In order to answer these questions, a lab study has been conducted that focuses on these basic conditions of user movements. This controlled evaluation of the tracking system and DPSs showed that people make use of the possibility to move around an interactive tabletop freely if this movement is supported by the system. One finding of this lab study was that a large majority of movements was initiated by an intrinsic nonverbal trigger (94.62%). This means that participants mostly moved around the table simply because they decided to do so and without justifying this decision before the other participants. This result can be interpreted as an

indicator that moving around a table during group work was perceived as a natural process that does not require further explanation by the participants. The fact that movements seem to be perceived in this way argues for the approach of DPSs because this technique can support such processes in an easy and unobtrusive way. However, this evaluation is very basic, addressing only the fundamental aspects of this technology - "to use or not to use".

Applications based on user tracking

In the following, a number of applications and use cases based on user tracking will be presented. The sum of all of these applications forms a continuum in multiple ways. Firstly, applications described in the beginning are rather simple, whereas those towards the end become more elaborate. Secondly, the initial applications can be employed for single user settings (even though they also work for multiple users), whereas the later ones are intended for multi-user scenarios.

Luring users to interact (Figure 4a)

One problem of publicly installed tabletops is the novelty of such systems [1]. Tabletops cannot yet be considered an everyday technology. Thus, users approaching a tabletop might be confused about the purpose of such a system and what to do with it. By means of user tracking, a tabletop system can dynamically lure arriving users. These lures can be designed to introduce users to the system and motivate interactions [5]. A simple example is a basic welcome message that is displayed in front of a user when she approaches the table (e.g. "Welcome! Please touch an icon to begin."). Using dynamic lures instead of static ones can have a number of advantages. First of all,

users might feel a higher degree of involvement with the system because it actually responds to their presence. Secondly, dynamic lures allow for diverse implementations, e.g. using auditive elements. This is not feasible for static systems since it would require constant playback of the audio file. Finally, visual lures can be designed freely because they appear and disappear dynamically and therefore do not clutter the interface, as would be the case with static ones.

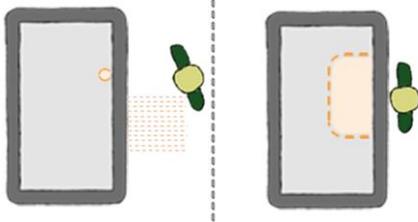
Automatic document orientation (Figure 4b)

One property of tabletops is that they can usually be accessed from every direction. Since the system knows where a user is located, it can automatically orient documents towards the user [2], thereby reducing the user's workload.

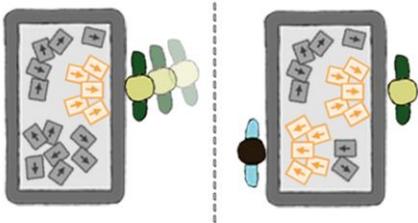
Private toolbars and menus (Figure 4c)

Many applications rely on some kind of menu or toolbar in order to control the available functions. Usually, menus are displayed continuously at a fixed position whereas toolbars can be switched on and off and moved to different positions. This paradigm is well-suited for desktop applications, however a number of problems occur when applying it to tabletop applications. First of all, users may position themselves at any location around the tabletop. A fixed menu therefore means that users might have to read menu items upside down or that these menu items are not within reach from the user's position. Secondly, physical and psychological conflicts may arise during multiuser sessions when multiple users try to access a menu or toolbar item at the same time [9]. These problems can be bypassed with the tracking system: toolbars and menus can be multiplied, depending on the number of users, and displayed dynamically at each

4a) Luring users to interact



4b) Automatic document orientation



4c) Private toolbars and menus

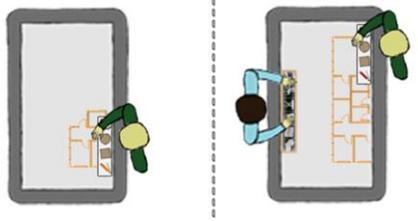


Figure 4. Applications based on user tracking

user's position. In this way, conflicts are avoided while at the same time increasing the readability of the menu items and minimizing the time needed to access a menu item for each user.

Inverse tracking (Figure 5a)

The idea of "Inverse Tracking" is that a DPS moves by itself in order to motivate a user to move to another spot. One scenario of application is in public settings where many concurrent users are expected. Visitors might not always approach a table such that the space around it is used in an optimal way. A PC can easily calculate an optimal arrangement based on the number of users, their location and the size of their DPSs. If the distribution is suboptimal, a DPS can be animated to move to another place that is more suitable. A user might then follow her DPS, which in turn results in a better arrangement of users that provides a larger working area or that can accommodate more users. If a user does not follow her DPS within a certain time it moves back to the user automatically.

User Authentication & Role Support (Figure 5b)

When people work together at a multi-touch table, they might have different roles. For example in an exhibition fair scenario, there are customers and salesman. Whereas customers should be able to use the system without additional requirements, salesman could optionally authenticate such that they can access special functions of the system. Such functions might be concerned with maintenance (e.g. maintaining digital contents, operating system access) as well as with interactions that are only available to special users (e.g. realigning the contents, switching global views, accessing additional information). Beside on-screen PIN authentication [6], technologies like RFID and NFC can

make the authorization process very easy. As soon as someone is carrying an NFC tag for example, approaching the table is sufficient because the tag is identified by antennas and the authorization process is executed automatically.

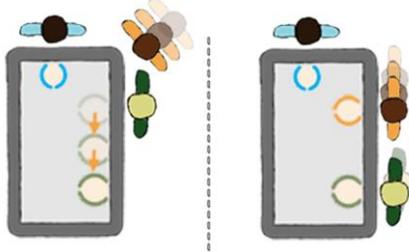
Arrangement-based functions (Figure 5c)

Based on the results of Sommer (1965), different arrangements around a table are preferred for different types of dyad activities [11]. For example, most people prefer to sit opposite of each other for competitive tasks, whereas a neighboring arrangement is preferred for cooperative tasks. These results should also be considered when designing multiuser tabletop applications. For example, Hartmann et al. (2009) propose different interaction techniques based on the arrangement of multiple keyboards on a tabletop [4]. When two users are interacting with the system, each user can enter his own search terms with his own keyboard. In this case, the system generates two independent queries. If however the users move their keyboards next to each other, the queries are joined. A similar approach is proposed for multiuser editing of a document. Such behaviors can also be implemented with the tracking system. The system can automatically recognize the arrangement of users and switch between different modes. In this way, the need for explicitly switching modes through user interactions is removed, allowing for a more natural transition between different settings and interactions.

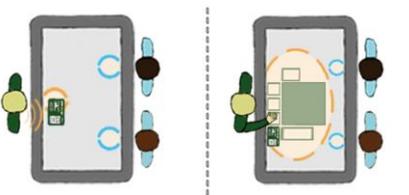
Application of the design space

The previous sections have provided a number of applications that can be implemented based on the tracking system and DPSs. A beneficial property of these applications is that they are not mutually

5a) Inverse tracking



5b) User Authentication & Role Support



5c) Arrangement-based functions



Figure 5. Applications based on user tracking

exclusive. Instead, as the continuum builds up, more and more possibilities evolve because all of the techniques can be combined. This collection shall serve as a starting point for people implementing applications that are based on the DPS approach. However, it must be clear that this design space is dynamic and therefore evolves over time. As new technologies will be developed and more mature products evolve, new applications will evolve that combine these new technologies with the DPS approach.

Conclusion

The work presented builds a thorough basis for future research: on the one hand, there is a robust implementation of a tracking system that can be employed in a variety of settings. On the other hand, the use cases presented at the end provide a starting point for future research. This future research will hopefully not only produce some more interesting insights, but most importantly lead to better products, to new interaction styles for groups, and last but not least to systems that support co-located collaboration in a natural and seamless way.

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