Interacting Through Spatially Aware Displays

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Abstract

In many real life situations, people work together using their own computers. Such situations always involve exchanging digital objects. It is then a natural idea to enlarge the view of individual virtual spaces so that people may exchange objects in such workspace taking advantage of the collaborators' physical proximity. In this work we propose a means to allow people's collaboration through the interaction with objects in a common virtual workspace. We developed such approach as an application based on tablet PCs using their several embodied resources. The concepts of dynamic multiple displays and real world position tracking were used, and a multiplayer game was implemented to demonstrate how users can exchange information through intercommunicating tablets. Conclusions are drawn regarding the impact of the new paradigm of extended multi-user workspaces.

1. Introduction

Nowadays, many people depend on both computers and information sharing for professional or personal purposes. Significant common tasks are maintaining documents and files, following world news, communicating with other people either for working or friendship, exchanging files in real-time or simply playing games and having fun. In this scenario, the sense of urgency is often present and, many times, the decision making is really dependent on real time information and quick access to other people and documents.

In order to help people to be part of this new reality, a large number of devices and tools are available for reasonable prices. Laptops, GPS systems, mobile and smart phones as well as tools for internet connection, video conference, file exchange tools, and on-line photo albums are examples of the available facilities.

However, even if the real-time collaboration with people that are geographically spread is easily achieved through current communication tools, a number of tasks depend on the interaction among people placed in a common physical space. In these situations, the possibility of a direct contact could avoid the need for computer-based tools to facilitate person-to-person communication. Nevertheless, as most part of the information is digital, there is yet a need of tools to assist data exchange between people during these tasks. A natural idea is to enlarge the virtual space where the digital objects are placed so that people may exchange them in such workspace taking advantage of the collaborators' physical proximity. Matching physical and virtual workspace is also important to allow people to use spatial cues in their digital tasks.

In this work we present an approach to allow the collaboration between people through the interaction with objects in a common virtual workspace by providing: a way to extend the size and resolution of the workspace during a meeting, using public available software and tablet PCs; a technique to support the exchange of objects between persons during a collaborative task in a natural and nonconventional way, sensible to their spatial

Figure 1. Proof-of-concept prototype of an application for file exchange: multiple users can drag and throw files to each other's workspace

position (see Figure 1).

As a demonstration of the proposed approach, we developed a game application focused on collaborative tasks with tablets. Each user/player uses their tablet to visualize and navigate within a common virtual space, which has the same scale of their common real workspace. They can interact with the game individually and, when two or more users get closer to each other in the real environment, they can start to collaborate to reach their goals more efficiently.

The rest of this paper is organized as follows. After a review of previous work in Section 2, we present our approach in Section 3. Section 4 describes the test application. Finally, in Section 5, we discuss our findings and draw some final comments regarding potential future developments.

2. Related work

The rise of tablet PCs brought the power of high-end computer workstations to the mobile world. Tablet PCs also provide an alternative interaction form, in which a stylus is used with a touchscreen. Since their release, many new techniques and applications have been proposed to explore this type of interaction. In particular, the work of Hinckley et al. [3] allows users to connect multiple tablet PCs using pen-based gestures. Rekimoto and Saitoh [7] also explored animated objects between devices on a tabletop with a cursor that can move among laptops and the tabletop itself.

Most of the applications, in turn, aim at pedagogical activities. Pargas [6] proposed a software named OrganicPad with the goal of increasing the students' interest in organic chemistry classes. In the same line, the lecturing system Classroom Presenter [1] enables an active teaching environment. It combines extemporaneous slides and annotations by students and teachers using tablet PCs in the classroom. Although many students have laptops today, very few own a tablet PC. To overcome this limitation, Ubiquitous Presenter [10] expands Classroom Presenter via common web technologies to support non-tablet audiences and enhance student control. A positive side effect of this is that environments with heterogeneous devices are supported.

Among the works related to objects and individuals position tracking, the one by Osawa and Asai [5] aims at automatically controlling a camera for video-conference transmission. They achieve position tracking using ARToolkit library. Tags are rigidly placed both on the speaker and on the pointer, to define a location of interest for the camera to be placed accordingly. Also using ARToolkit, Fiala [2] controls the position and orientation of objects by a camera and tags attached to robots and obstacles. This allows tracking robots positions to control their action in a delimited space.

Non-surprisingly, other more reliable tracking systems, like Flock of Birds, Vicon and Cyberglove have been avoided most probably because they are expensive, cumbersome or non-mobile. Analogously, GPS cannot be used indoor and lacks accuracy for a number of applications. Nevertheless, new accurate, non-expensive and widely available devices, such as the Nintendo Wii remote controller [9], or the Optitrack system [4] could also be used in this context and techniques based on such devices will be pursued in future work.

3. Interacting through Moving Displays

In a conventional meeting, people are seating around a table and the exchange of real objects (or documents) is performed by dragging and dropping them on the table top near the people who are exchanging them. Now, supposing that people are using their own tablet PCs connected through Wi-Fi, each person will have two workspaces: the real (i.e., the table) and the virtual one (i.e., the virtual desktop within their tablet PC). We propose to consider that each virtual desktop is enlarged (e.g., with the same dimensions of the table) so all the users share the same virtual workspace, and can use, in the virtual workspace, the same metaphor of exchanging documents they use in the real table: virtual documents or objects can be shared and exchanged by dragging and dropping them on the virtual desktop.

In order to allow such manipulation, the position and orientation of each tablet in relation to the virtual workspace must be known. Doing so, each tablet will allow visualization and control over the portion of the desktop it is occupying in the physical world. Consequently, as the virtual world assumptions are the same as of the real world, the focus of the users turns to the documents themselves instead of the computers. The computers become, as in many other situations they already do, pervasive and "invisible".

We present our solution for allowing navigation, selection and manipulation with virtual objects in a collaborative environment. The system runs on top of HP Tablet PCs model 2710p. Basically, a graphics interface has been implemented using OpenGL, and the communication system uses the UDP protocol to exchange messages between the tablet PCs. All tablets host the same application software. They control objects in their portion of the workspace and listen to events in a specific port.

The application environment is 2D, and the visualization and navigation around the workspace is made by position and orientation tracking. A set of tags is fixed on a flat platform placed above the real workspace. The schema shown in Figure 2 illustrates the setup of our technique while in Figure 3 an example of use is shown. We can observe the table area, the virtual workspace (defined by the dashed line), and the outlines of two different subareas of the common workspace which two tablet PCs are visualizing. Real time video containing the tags is acquired by the tablets' built-in webcams, and processed by a control module implemented using the ARToolkit library. ARToolkit uses computer vision algorithms to track a set of trained tags as they move through space. Here we do the inverse operation, using ARToolkit to track the position of the viewpoint (real camera) in relation to fixed tags. As the tablet PCs are placed on a tabletop, the built-in webcams are always facing upwards, having the tagged platform always in their field of view. This setup allows calculating the webcam position in relation to the tags, and consequently the position and orientation of each tablet. Any changes of viewpoint are made by moving the tablet PC in the real world; motion is replicated to the virtual camera of the graphics system. The user can then move a tablet in all directions on the tabletop plane, and rotate it, exploring different parts of the virtual workspace.

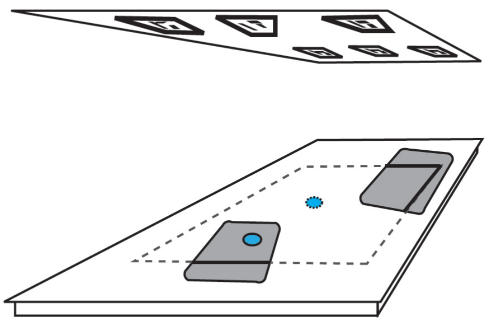

Figure 2. Perspective schema of the system setup. AR-Toolkit tags are placed on the top platform and dashed lines represent the virtual workspace on the tabletop

The tablet PC stylus is directly used for selection and manipulation of objects on each tablet screen. By touching an object with the stylus, and keeping contact, a user can stop it, move it around and throw it at will. The velocity on throwing defines the initial velocity of the object, which decreases along time. The direction of throwing defines the trajectory, and when an obstacle is found, e.g. a wall, the object bounces and follows an intuitive rebound trajectory.

4. Tablet Game Application

In order to demonstrate our proposal, we implemented a game application that can be played in individual and collaborative modes. They are implemented as single-player and multi-player phases of the game. The game consists of a virtual, rectangular 2D room without doors or windows. In the room, there is a ball, which the player must throw or drag to a target which is a circular ring. Figure 4 illustrates the game screen.

As the room is much larger than the display, only part of it fits on the screen at a time. One has to navigate through the virtual room to explore other areas. A mini-map is provided at

Figure 3. Photograph of the system in use. Spotlights are used to improve the quality of the video used for tracking

the corner of the screen to aid in orientation, especially for the untrained user. Both the ball and the target are randomly placed at initialization, and replaced just after a goal is scored. The ball can be grabbed and moved with the stylus, and when it is released it maintains the velocity as an impulse that will decrease as it moves – simulating friction – until it stops. The ball also bounces on the room walls.

As mentioned before the game has two modes: individual (single-player) and collaborative (multi-player) modes. In the multi-player mode or collaborative application, the tablets communicate through a wireless network, and the target becomes the center of one of them in such a way that one of the players moves the target while the other moves the ball. The task of each player is to help on hitting the target with the ball in the shortest time possible and with the least number of attempts. As one player at a time moves the ball and the other moves the target around, they cooperate to accomplish the common goal.

Figure 4. Screenshot of the game in singleplayer mode

5. Discussion and Future Work

In this work we reported an interaction technique aimed at facilitating the collaboration between people through the interaction with objects in a common enlarged virtual workspace. Specifically we propose to extend the size and resolution of the workspace during a face-to-face collaborative task, using publicly available software and tablet PCs. The technique is based on sensing the tablets' spatial position. Our preliminary experiments involved performing a simple task (throwing a ball towards a target, scoring successful hits) in individual and collaborative modes. However, the final goal of this work is to provide a new form of interaction to allow users to perform common tasks, like exchanging files, in a more efficient and/or intuitive way, as well as to create new tasks based on new users' needs.

One specific case of such new form of human communication is to show pictures to friends by dragging them interdevicely. The friend then sees the picture arriving on his/her work area, knows where it comes from, and can now interact with it, zoom in and out, copy to her/his own library, pass to another friend, and so on. We actually extended the game described in Section 4 to prove this concept, as illustrated in Figure 1. Robertson et al. [8] enumerate a number of applications for such device-independent extended work area. The current experience we have with the tablet PCs allows us to argue that they can be easily used for many of these new applications due to their integrated communication and input devices, like the stylus and touch-screen, the foldable displays, the camera, and other peripherals.

As a future work we propose to perform a controlled experiment with a number of users, in both single and collaborative tasks, to access the effectiveness and efficiency of the approach. Such experiment should focus on time and effort spent to perform a task. Future research may also consider comparing the current design to a large horizontal surface with a projected digital image of the entire work surface visible in lower resolution and the tablets providing windows of higher resolution for interaction.

In a world of ubiquitous computing this is just a start. New advances of display technology point to a situation in which everything will be a potential display, from t-shirts to walls, from tabletops to car bodies. Following the same idea, other media like music, links, and profiles can be exchanged based on location of displays, and, for sure, collaborative tasks will arise naturally with the easiness of information exchange.

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7. References

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