Movement and Space – Exploring the Space in Movement based Interaction

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ABSTRACT
In this paper we explore the space in which movement based interaction takes place. We have in several projects explored how fixed and mobile cameras can be used in movement based interaction and will shortly describe these projects. Based on our experience with working with movement-based interaction we will briefly introduce and discuss how learning, mapping and multi-user interaction are important when designing movement based interaction.

Keywords
Mixed Interaction Space, camera tracking, movement-based interaction, interaction design, ubiquitous computing

INTRODUCTION
Another way of phrasing the shift from desktop computing to ubiquitous, pervasive computing is to notice that computing has gone from sitting to standing or moving. The best places to notice the shift is to search for everyday and work situations where we could benefit from a computer, but where we do not sit down, but move around.

Numerous such situations exist e.g. when visiting a museum, on the way to work, being a tourist in a new city, visiting a library or working in a hospital. We have for some time worked with the last two situations and found that even though these situations are characterised by people moving around and looking and working with physical material traditional sit down computers have been applied. This approach creates a gap between e.g. looking for a book and using the computer or treating a patient and accessing the patient data through a computer.

In several project we have worked with how to bridge this divide between playing and working in the physical world and using computers. We have especially focused on how to actually use mobility and movement as an enabling factor for new interaction technique.

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INTERACTION TECHNIQUES AND SPACES
The projects we will present in this paper all use video tracking to capture movement. One of the properties of using a video camera to track an object is that the camera is only able to track the object as long as the object is within sight, but instead of seeing this as a limitation we explore the space that arise and is bounded by the cameras ability to see the object being tracked.

The space has the shape of an inverse pyramid. Close to the object the space is small and the space expands the further away from the object the camera get until it blurs out when an object gets to far away from the camera.

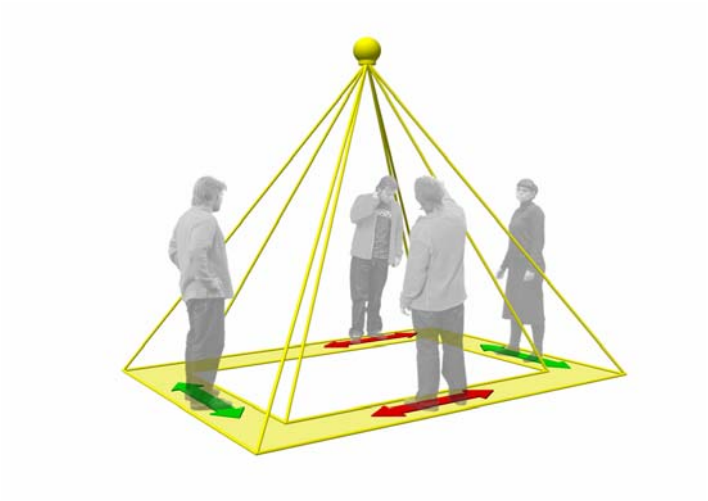
We call this space a Mixed Interaction Space because it is both a physical space you can move around in, but at the same time the movement in the space can be mapped to the digital domain and can therefore be seen as a mixed space.

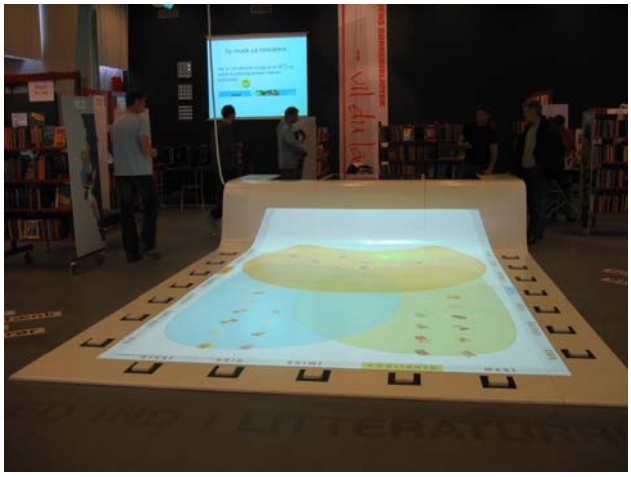
We have worked with two different kinds of Mixed Interaction Spaces. A *Fixed Mixed Interaction Space* is a space where the camera is mounted and the space is static. In the projects *iFloor* and *StorySurfer* briefly described below we use this kind of space for the interaction.

Dynamic Mixed Interaction Space is the second type of space and describes spaces that are dynamic due to the camera being mobile. A further subdivision can be made between what is being tracked. Is the camera moving and tracking a fixed-point or is both the tracked object and the camera dynamic? We have in the *Mixis Fixed Point* (fixed-point) and *Mixis Face Tracking* (dynamic camera and object) projects used this type of dynamic spaces. Table 1 shows an overview over the techniques and the projects.

Fixed Mixed Interaction Space	**Dynamic Mixed Interaction Space**	
	Static tracking object	*Dynamic tracking object*
iFloor & StorySurfer	MIXIS-Fixed point tracking	MIXIS-Face tracking

Table 1 Fixed and dynamic mixed interaction spaces.





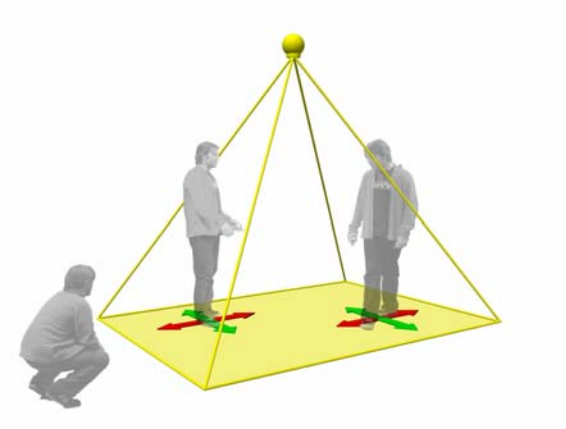


Figure 1: Top row, the iFloor prototype and a figure showing the tracked movements.
Bottom row: The StorySurfer furniture and a sketch showing the movement types being tracked.

MOVEMENT-BASED INTERACTION PROJECTS

We will briefly introduce the four projects we have worked with that uses movement-based interaction.

iFloor

iFloor can be characterized as a chat-floor. The idea behind the prototype is to facilitate the exchange of information between users at the library, as well as to bring some of the QA services that the library offers on the Internet into the physical library.

The questions and answers on the interactive floor are navigated and highlighted by moving your body along the edges of the display. A video tracking system will record the movements and size of the people present and on the basis of this single persons or groups of people will attract a magnifier highlighting the different questions and answers displayed on the floor. The magnifier is a cursor shared between all the people participating, so navigating it is dependent on collaboration between the people present around the floor [6]. The pictures in the top row of figure 1 show the iFloor prototype and the tracked movements.

StorySurfer floor

StorySurfer is a prototype that facilitates children in browsing a library collection of books by displaying projected covers on an interactive floor surface. The covers of the books are evoked by stepping on buttons on the rim of the floor. Each button is associated with keyword. Hitting a keyword button will evoke a cloud-like shape on the floor containing materials associated to the word. Stepping on to the floor enables one to examine the displayed covers. Each person entering is provided with a cursor in the shape of a "magnifying lens"; the "lens" is controlled by your bodily movements. Holding the lens still over a projected book cover causes it to enlarge for better inspection and maintaining the position even a bit longer will cause the image to move across the floor to the interactive table top also being a part of the prototype [10]. The pictures in the bottom row of figure 1 show the StorySurfer prototype and the tracked movements.

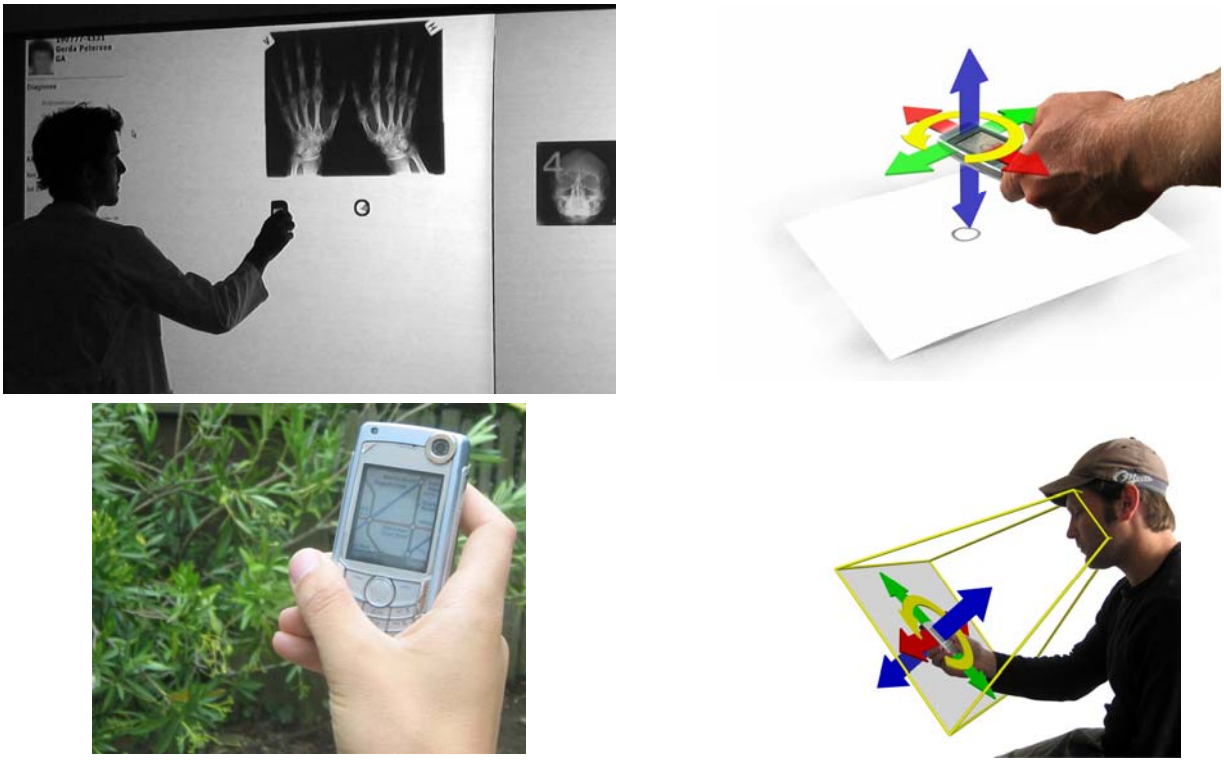


Figure 2: Top row: The Drozo Mixis application (a doctor can drag, zoom and rotate pictures with the mobile phone) and a figure displaying the circle and the movements that are being tracked. Bottom row: The ImageZoomViewer app with facetracking and a figure showing the mixed interaction space and the movements tracked.

MIXIS – fixed point

The concept behind the Mixes project is that instead of limiting the interaction with mobile devices to the device we use the space around the mobile device as input and we are thereby able to create mixed reality applications where the space is used to interact with programs running on the mobile device or on a nearby PC.

The Mixis interaction technique uses the mobile device's camera to track a fixed-point and use the distance and rotation of the device from this fixed-point as input vector to a set of different applications. Depending on how the different movements of the device are mapped to the applications the device can be a 1-4 D input device. In *Mixis – fixed point* we tracked a circle symbol that could be printed out or drawn by hand.

Based on the Mixis mobile tracking technique we have built a set of applications e.g. the ImageZoomViewer, an application where the user could pan and zoom on a map or image by moving the device in the interaction space. DrawME is an application where the user could call a person by drawing a symbol on a piece of paper and associate this symbol with a phone number or BlueMix where several users could use their own mobile device to get a course on a shared display or play games on shared displays. The Mixis concept and some other applications are further described in [4, 5]. The top row of figure 2 shows MIXIS – fixed point.

MIXIS – face tracking

In a newer version of Mixis we track the users face instead of a circle. We use a mobile phone with a camera facing towards the user as our platform and have a new situation where both the camera and the tracked object are mobile. Figure 4 shows the concept and the different degrees of freedom we are able to use as input to our applications. We have re-implemented several of the applications from the original Mixis with the face tracking technique and designed some novel applications. The Mixis face tracking project is further described in [3]. The bottom row of figure 2 shows MIXIS – face tracking.

DISCUSSION

In the following discussion we will outline a set of common issues relating to movement-based interaction we have worked with in the four projects.

Learning novel interaction techniques

Since movement and sensor based interface differ a lot from traditional user interfaces [Sensor], a challenge for movement and other sensor based interaction techniques is to tell the user how to use this new interaction technique and how it maps to the different applications. A keyboard and a mouse seems intuitive to use, but watching a new computer user try to figure out how to use the mouse or getting access to some of the special characters on a keyboard, points to some of the tacit knowledge that is required for using a computer.

Playful interfaces, Frustration and Social Interaction

Some of the interfaces we have worked with are easy to learn, but not self explanatory. E.g. first time a user saw the iFloor it was not clear that you could interact with it by just walking up to it. However, as soon as one user got hold of the concept it was easy for this person to tell other users how they should use the interface and help him or her cooperate in the interaction. One way to learn a new interface is by having someone around to tell you how to do it and use social interaction to learn about novel interfaces.

Another way of exploring the possibilities of a new interface is through play. Letting the user play with the interface and learn what kinds of possibilities the interface has to offer. However, there is a thin line between learning by playing and being frustrated and abandon the interface. E.g. having a problem finding the sensor that turns on the water tap in a public bathroom is normally a frustrating experience and the hidden interface is not considered a playful and exploratory interface.

Constraints

Another approach to learnability in sensor based interfaces is to build constraints into the interface. An example is tangible user interfaces. The tangible objects can be shaped in forms that only allow them to be manipulated in a certain way and constraint some unwanted interaction. E.g. a tangible object can be designed as a block in a tray to allow sliding in one dimension, but not free movement in 2D. Ulmer's paper about constraints explores tangible object and constraints in details [11].

However, when using cameras and especially dynamic cameras it is really hard to constrain the interaction and prevent people or objects from moving away from the camera's field of sight. Another option is therefore to visualize the interaction space for the user.

Visualizing the space

Visualization becomes important with sensor interfaces as pointed out by Bellotti et al. [2] in their discussion on sensor interfaces. Visualization is highly important when working mixed interaction spaces since the boundary of the space, and thereby the interaction, depend on what the camera sees and not what the user sees.

With fixed mixed interaction spaces we can use the architecture to visualize the space. In the iFloor and StorySurfer we use a white mat to show where the interaction space starts and ends.

With dynamic mixed interaction spaces we cannot use the architecture to signal the presence of a mixed interaction space and we therefore use digital feedback. In Mixis projects we use the display to overlay information about the position of the device in the space. E.g. in the ImageZoomViewer we draw a thin line from the center to the position of the face or circle in the interaction space on top of the map to help the user in determining where in the interaction space the device is. We found that finding good ways of visualizing the interaction space was crucial for a smooth and easy interaction with the application we build.

Mapping

Mapping is a term that refers to how the data captured by the camera or sensor is mapped to the different applications that relies on the technique. We have worked with a set of different mapping approaches in the four projects.

In applications with tight couplings between the physical movement and the movement in the application natural mapping is accomplished, which is a term suggested by Norman [7]. Natural mapping uses physical analogies or cultural meanings to bring about immediate understanding of the relationship between the physical and digital movement. An example of this is the application for map navigation with MIXIS on a mobile device, where moving the device to the left, right, up, or down pans an image, and moving the device closer or further away from a fix point zooms in and out. With StorySurfer moving the body to the right moves the cursor to the right. This resembles Norman's example of natural mapping in which turning a steering wheel to the right make a car turn right [7].

However, we also explored some more advanced types of mapping e.g. in the StorySurfer, where the position of several users determined how the applications behaved and the mapping was a form of collaborative mapping.

Multi User Spatial Interaction

The fundamental design of the computer with a single keyboard and a single mouse has been the general standard since the early 1970´s. Most applications involving more than one user are based on collaboration from the distance over network.

In research today there is a struggle to develop technologies where several people can interact simultaneously and as natural as possible. New hardware developments such as multi-user touch-sensitive tabletop surfaces offer new possibilities, which often mean a complicated and expensive setup such as the MERL DiamondTouch [8], SMART DViT [9] or other systems that requires specialized hardware.

PDAs and mobile phones can be used to implement *simultaneous inputs*, but even more interesting is the capability of *tracking and distinguishing users* which allows the application to associate actions to a specific user.

Interacting in public space adds new challenges to the input devices used on public displays. As the traditional computer does not support simultaneous co-located multi-user use, the technology in use today lacks functionality for interaction with large public displays as listed by Ballagas and Rohs in [1]. Using MIXIS the portability in public space increases since the user is able to connect to a range of different displays with a personal ID giving the user the possibility to retrieve data from the display to the personal

device whereas the floor interaction does not have an ID and is not attached to the actual user.

MIXIS and floor interaction has a high degree of *serendipity*, offering the user to spontaneously interact with a large display by connecting its Bluetooth unit to the system and accept the application or by stepping out on the floor. Thereby, MIXIS supports *intentional* interaction initiation, the user has to initiate and accept the application, while floor interaction does not.

MIXIS has a high degree of *portability* even though the interaction device is not a part of or on the body, but since the mobile device is personal and ubiquitous. The portability in floor interaction is very high, since the interaction device is the body of the user, and is therefore very suited for public interaction.

Since the mobile phone is personal, the *sanitation* aspect with MIXIS and floor interaction is very high; the user never touches any common controls. The *physical security* is therefore high, and the input controls to the system are not a problem for vandalism, so no *maintenance is* needed for the input controls.

With MIXIS there is only one hand required for operation of the device, and none with floor interaction so the degree of *dexterity* is very low.

With MIXIS the *information security and privacy* is high, since what is communicated is an ID from the specific Bluetooth device in the mobile phones, and no other data is sent. No participant or by-passer can identify which cursor belongs to what user, and the privacy is therefore secured. What could be a problem is that the Bluetooth unit has to be activated, and therefore open for other Bluetooth devices to contact. With iFloor the cursor is shared and not user specific, meaning there is no ID for the user. In Story Surfer each user has its own cursor and the privacy around user identity is very low.

MIXIS and floor interaction has a high degree of *social acceptability* since it is a very discrete interaction technique with no embarrassing or disturbing noise, light or gestures

MIXIS and floor interaction are both *multi-user* interaction techniques that support a large number of simultaneous co-located users. With MIXIS *interruptability* is cooped with in the sense that the application supports input units to disappear during action and can also be replaced by a new unit without interfering with the co-users. With iFloor the cursor behaves differently depending on the number of user, and when people leave the tracked are, then the remaining users/user has to adjust the interaction to that, but the system follows. With Story Surfer the cursor is individual, and does therefore not affect the other user at all.

CONCLUSION

In this paper we have presented the concept of Mixed Interaction Spaces as a room for movement based interaction. We have described four projects we have worked with that all uses movement based interaction. And based on the project we have highlighted three issues we find important when designing movement based interaction systems based on cameras. We have presented our initial reflection on how you learn to use novel movement based interfaces, how you map between movements in the physical world and the digital realm and how movement based interaction can be used to design multi-user interaction.

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