Configurability in and Integration with the Environment: Diverse Physical Interfaces for Architecture Design

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ABSTRACT
We present several physical interfaces and how we assembled them to develop an environment for learning architecture design. Among others we are developing applications with barcode scanners, touch sensors, RFID tags, infrared remote control, video tracking, GPS receivers, and sensor boxes with electronic compass and acceleration sensors. In the environment input and output components are connected through an infrastructure. In a first round of experiments we have co-developed the components with the students for their practical design projects. We reflect on which features of the diverse prototype we developed contribute to understand configurability and integration with the environment.

Categories and Subject Descriptors
H.1.2 [**Information Systems**]: User/Machine Systems – *Human factors.*

General Terms
Design, Human Factors.

Keywords
Physical interfaces, configurability, integration, field study.

1. INTRODUCTION
Despite the advances and the large interest in physical interaction technologies, field studies of everyday use are rare. On one hand technology is presented and there are approaches to implement it, on the other hand serious ethnographic studies of current work stress the importance of the physical environment and the limits of desktops centric development. The contribution of our paper is to be placed in the scarcely populated area in between where field studies inform the development of prototypes that are experimented in everyday settings. In our research we are prototyping systems that have the ambition of freeing people from the desktop computer (or avoiding constraining them in front of it). However our primary interest is not the technology itself but to design for a particular community of practice and learn from field studies how new technology can be integrated seamlessly in everyday practices.

The case we present is part of a design project to develop a ubiquitous and mixed media environment for inspirational learning. One of the application sites is the architecture department at the Academy of fine Arts in Vienna. After careful observations of student projects at the Academy, we have prototyped various applications to be experimented by the students. We have experimented with several technologies to support physical interaction: among others barcode scanners, touch sensors, RFID tags, infrared, remote control, video tracking, GPS receivers, and a sensor box with electronic compass and acceleration sensors. In particular we describe: physical interfaces to digital media, the texture painter, the tangible image query, a mobile application to record path and organize media from visits.

Which features of these prototypes contribute to configurability? Which features contribute to explain their different integration in the user's environment and activities?

2. THE SETTING
We have observed seven student projects in the first half of 2002. After this period we introduced and observed the use of several tangible computing prototypes (see [2] for a detailed report on the field study). We will now describe the setting and the student projects. In the projects, groups of students have to work out designs of interventions for remote physical locations. During the project they concretise solutions experimenting with several representation techniques. Visit at sites are frequent and there are weekly feedback meetings with staff and external reviewers. The goal of the students is to be creative in getting ideas and develop them into a convincing solution.

The diversity of material and media is an important characteristic that is exploited in the handicrafts they produce. Students work with and produce texts, diagrams, comics, videos, sketches, models, screenshots, virtual models, and prototypes – material of different degrees of abstraction, different scale and materiality.

We used participant observation to study current practices and the use of prototypes. We set out to observe the students not

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only in topical events as presentations or meetings but also in everyday work. Inspired by interaction analysis we used a digital still camera and a video camera to record audiovisual material to analyse selected episodes.

3. TECHNOLOGICAL COMPONENTS OF THE ENVIRONMENT

3.1 Infrastructure, Configuration and Database

The environment we are developing is composed by a variety of interaction components (physical inputs, media playing and projecting applications, described in paragraphs 3.2 and 3.3), a configuration component, a hypermedia database, and an Infrastructure to connect all components. The infrastructure provides registration for all components and messaging between them. The configuration component is answering the need to have a consistent and transparent management of associations between input and output components. As the same input might be used by different people (or the same person) to trigger different actions, there is a need to store the configurations in a central place from where they can be loaded at anytime from any computer. The hypermedia database (HMDB) provides a shared database of digital media and meta-information. The multimedia objects can be grouped and organized hierarchically and can be linked using region and time based anchors.

3.2 Physical Interfaces to Digital Media

3.2.1 Animating bAR code

This interaction technology provides a way to link physical objects and digital material. Media files can be associated to physical barcodes in the environment. A barcode scanner is attached to a PC through the keyboard wedge. The input component running on the PC is able to capture one or multiple barcodes and send them in a message to other components in the environment. This technology has been used to animate physical models and diagrams with digital media. This is achieved by sticking barcodes on the models or diagrams to which users previously have associated media files as videos, sounds or pictures. Users can then scan the barcodes on the models during presentations or discussions and trigger the playing of media files. Users can associate to a media file a defined series of barcodes, so that the scanning of two physical objects in a different sequence or the scanning of the two objects different times can play different media.

3.2.2 Infrared Remote Control

This component is operated from a mobile devices giving the possibility to control application from anywhere in a room. The infrared remote control is used to send to other components messages as “Play”, “Stop”, “Forward”, “Up”, “Down”, “Right" or numbers. An infrared receiver is attached to a PC where an input component is running that receives the signals and sends them to components in a message. This component has been used to navigate through multimedia material. Users are able to navigate through linked media objects. With the forward button users will skip to next anchors and by pressing play the link of the current anchor will be used to open the linked media object.

3.2.3 RFID Tags

The RFID Tag/Tag reader combination is a component, which allows students to tag objects in the studio. This component consists of numerous tags, which can be attached to the objects, and several tag readers placed around the working environment. Whenever a tag is placed on one of the tag readers a specific action is triggered. This technology seems very suitable for selecting among various choices, e.g. students having small tagged objects with different video files associated, and can select a file by simple placing the appropriate object on a tag reader.

3.2.4 Touch Sensors

Touch sensors we are using are small sensors based on “qprox” [4] technology. The sensors are actually small copper plates which have to e covered with an insulating material. This makes it possible to integrate the sensors in students’ models. Sensors remain invisible, but they react if someone touches the model at the certain place. In this way touch sensors offer an alternative to barcodes or tags. They support physical – embodied - interactions with the artefact into which they have been integrated for retrieving and displaying media files. They proved effective in presentations since they introduce an element of surprise. Their invisibility, which is the main advantage, is a disadvantage at the same time. Namely, student has to now where the sensors are in order to activate them. It is possible to mark the sensor positions on the surface, but it is not always convenient from the students’ point of view. On the other hand, an unknown model (which is supposed to be equipped with sensors) invites the users to play with it, and explore it. There is a wireless communication between touch sensors and central computer. In this way the models equipped with sensors do not differ from conventional models from outside at all.

3.2.5 The control cube

The control cube emerged from the touch sensors idea. We put the sensors in a cube, added 6 tilt sensors, and made it possible to recognize which side of the cube is facing up. Such a device can be used for selection between six choices. The student simple turns the cube, and the side facing up determines which action will be triggered. Touch sensors integrated in the cube can be used to browse through a set associated with a cube side. E. g. if there are six collections of images, the user can select collection by turning the cube, and then, once a collection is chosen, the user can navigate through the collection using two touch sensors, one for “next” and one for “previous” image.

3.2.6 Different physical inputs

Barcodes are particularly suitable for animating physical models and diagrams with digital media, as barcodes can be attached in the environment. However barcode scanners have a limited range because they are attached through cable to the PC. Similarly RFID tags can be easily attached to objects, whereas users generally move the tags on the reader (instead users move the scanner to the barcode). Note that this is actually inverse process, if we are using barcodes we are walking around holding the barcode scanner in the hand and shooting the barcodes. In the RFID approach, tag readers (equivalent to barcode scanner) are more or les fixed, and we have to move objects. The third possibility, touch sensors, are similar to a bar code in a way that we do not have to move the object, but we do not have to carry the bar code reader around neither. Actually although all those technologies offer similar functionality they have significantly different qualities and each of them is used in different situations.

The infrared remote control is completely different device, it is not directly bound to the models, although it can trigger actions which will enhance the environment.

3.3 The Texture Painter

Using a brush, which is tracked, this application allows 'painting' on objects such as models or parts of the physical space, applying textures, images or video, scaling and rotating them (Figure 2). Students started animating their models with the help of the Texture Painter. One student studied soccer games to identify the most exciting camera views and to understand which kind of atmosphere the players need. He used the camera views to find out where to place few spectators so that the stadium looks jammed. He built a simple model of a stadium and used model and images together with the Texture Painter for projecting different atmospheres into this 'fragmented stadium'. Another student painted images of his interventions into projected images of two residential buildings, projecting detailed plans into the space between them.

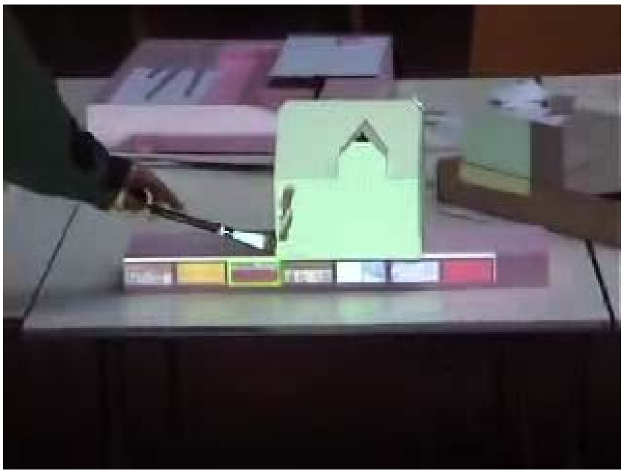

Figure 2. Painting objects electronically using a physical brush

3.4 Tangible image query

This is a physical interface for browsing the HMDB in an interactive way. It consists of a web camera integrated into a small table. A user may use small coloured cubes to specify a colour layout that is used to search in the HMDB for similar images. The search is based on the Visual Image Query method described in [5]. It is also possible to use colour on a simple sheet of paper or any set of reasonably sized coloured objects for creating colour patterns. This resonates with observed practice – architects often using material that is at hand for illustrating ideas and qualities, such as density, fragility, opaqueness, etc. Since the definition of the colour layout is done in a rather rough way, the results of the search are a source of surprise and inspiration for the user.

3.5 Sensors recording walking path and directions

The e-Path for iPAQ Pocket PC is an application to support visitors in organizing media material created during visits. With the e-Path application users can log the path of a visit through GPS, log position and direction for recorded media like photographs and sounds, and create a "hyper document" of the visit that can be used to store the media files and information of the visit in the HMDB.

Figure 3. Mobile unit to record paths and directions

The e-Path can currently make use of external sensors (optional) like a CompactFlashGPS reader card and the VTT SoapBox (Figure 3). VTT Electronics has developed a general-purpose SoapBox module (Sensing, Operating and Activating Peripheral Box, [3]) that is a light, matchbox-size device with a processor, a set of sensors, and wireless and wired data communications.

4. DISCUSSION

The diversity of tangible computing application that we developed brought us to consider how they can relate differently to the environment and to user practices. To further detail these relations we analyse how the prototypes can be differently integrated in the environment and how configurability is supported. This analysis provided us with four characterizing features of the diversity of the prototypes.

Integration with artefacts and environment. The physical interfaces vary in the way they are integrated in the environment and on artefacts. *Invisible* – as touch sensors were inside the models. *Virtually connected* – as in the Texture Painter application that is projecting images on objects. *Aesthetically or functionally integrated*. In some cases the barcode was part of the diagram that student created in an aesthetical and functional role. *Detached from the environment*. Even though the Infrared Remote Control is a physical interface it is detached from the environment.

Distributed Intelligence. What kind of intelligence is behind the application and where it resides? The answer to this question contribute to explain how far computing has been distributed away from the desktop computer, and to which extend it is embedded in the environment. *The PC backstage*. Although hidden in the interaction the PC is present in different ways in almost all of the applications (texture painter, tangible image query). *Embedded in objects*. The Control Cube contains sensors and a radio sender to communicate signals to another computing unit. *Mobile devices*. The e-Path runs on a Pocket PC, other examples of devices are the Infrared Remote Control, the RFID tag reader.

Component Structure. **T**he applications can be composed by more or less independent components or be more like an organic stand alone application. Analysing this aspect is important when developing configurable and tailorable solutions. *Component Structure:* As in our case barcode scanner, tag reader, touch sensors infrared remote control can be configured to control the same applications. *Stand Alone:* As in the Texture Painter application.

Bodily Actions. The bodily interaction with the applications was differently characterized. *Reader to Object – Object to Reader* we experimented with two types of readers. With the RF-ID reader the actor moves a tagged object on a fixed "reader", with the barcode scanner the actor moves the reader to the tag. While both technologies can be made worked either way, the two approaches are conceptually different. *Sensed – Performing Body*. In the case of the e-Path the actor performs a path and points to directions all of which is recorded. In the Texture Painter the actor performs movements with the brush that are sensed by a video camera or infrared tracking. *Remote Control* – the Infrared Remote Control and the Control Box are examples of a mobile control device that can be operated moving in the environment.

We have observed in the field study how the physical environment is in constant reconfigurations. Configurability is not only supported by producing software in component structure and providing platform for configuration (e.g. the infrastructure and configuration component). As the applications have physical interfaces the physical realm needs to be considered as well. While we have not precise guidelines for digital-physical configurability with our analysis we suggest at considering as features to be considered how computing is distributed in the environment (embeddedness) and to which extend the physical interfaces are integrated in the environment and physical artefacts. Finally the diverse bodily interaction with the prototype is a characterizing feature to understand how physical interfaces become part of a a social environment and of people activities.

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