Tangible User Interfaces... (TODO)

Christian Prossenitsch*
Vienna University of Technology

Karin Pfattner†
Vienna University of Technology

Abstract

In this paperl compare and analyze different Tangible User Interfaces. TUIs move away from the common input devices like mouse and keyboard and towards a direct interaction with physical objects in order to make the operation with devices more natural. This includes for example the handling of physical objects on table-tops, projections of information onto pieces of paper [Holman et al. 2005] or using additional devices to get more detailed data. The examples we are going to cover in this paper include applications in architecture, information visualization and learning tools.

CR Categories: K.6.1 [Management of Computing and Information Systems]: Project and People Management—Life Cycle; K.7.m [The Computing Profession]: Miscellaneous—Ethics

Keywords: radiosity, global illumination, constant time TODO

1 Introduction

In common user interfaces the ineraction is limited to indirect input methods such as mouse and keyboard. A more natural way of interaction would be to be able to directly touch and manipulate the objects of interest. One of the main goals in using Tangible User Interfaces is to combine visualization of data with direct interaction.

In this paper we first give a general overview on how Tangible User Interfaces (TUI) work and what the main challenges are.

In the next section we will give some examples of TUI and describe how some of the challenges can be solved.

2 Typical designs of Tangible User Interfaces

3 Examples of Tangible User Interfaces

There is a wide variety of Tangible User Interfaces (TUIs). Possible applications for TUIs are literally endless. Many systems of TUIs have been explored and published in the past, but still a lot of new a ideas are coming up and new applications for TUIs are going to be explored. In this section, we will give examine some examples of TUIs and give an overview of different domains where TUIs have been successfully deployed.

*e-mail: e0925433@student.tuwien.ac.at
†e-mail: insert email here

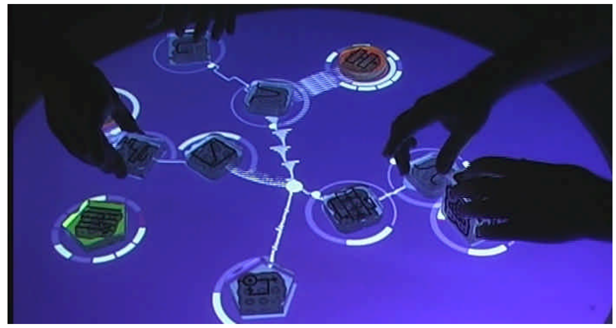

Figure 1: The reacTable in action (compare [2007])

3.1 Table-top environments

Many TUIs rely on table-top environments as their interaction technique. In these environments, a IR camera is set underneath the table-top to track fiducial markers placed onto the table. The camera can also track touch interactions of users. Marker and touch-based interactions are used as user input to the TUI system. The system responds to the user interactions by projecting visual feedback onto the table-top. Figure 1 shows the reactAble in action. Multiple users work together on a digital performance.

3.1.1 reacTable

The reactAble, presented by [Jordà et al. 2007], is a musical instrument based on a table-top TUI. Fiducial Markers represent musical objects, which generate sound according to their relation to each other. The markers are tracked by an IR camera. According to their attached symbol, each object has a dedicated function. The objects can be categorized in six different functional groups: audio generators, audio filters, controllers, control filters, mixers and global objects. [2007]

ReacTIVision, the computer vision system behind reactAble, tracks the fiducial markers and sends the output data to an audio synthesizer. The waveforms generated by the synthesizer, as well as the data from the ReacTIVision tracker are sent to a visual synthesizer. The visual synthesizer projects visual feedback back onto the table-top. The audio lines that connect objects show the real resulting waveforms. Visual feedback is also used to monitor the objects state and internal parameters. Fingers can be used to either modify the objects parameters, or to cut (i.e. mute) audio connections between objects. [2007]

Modular synthesis is used for the sound generation process. Modular synthesis is based on the interconnection of sound generators and sound processor units. In reactAble, automatic connections between objects are made depending on the type of objects involved and the proximity between them. By moving objects around and bringing them into relation to each other, performers construct and play instruments at the same time. reactAble is also a collaborative tool for interactive live music. Because of the rather big size of the table-top, multiple artists can perform together on a single reacTable. [2007]

3.1.2 TARboard

TARBoard is a tangible augmented reality system designed for table-top game environment. The purpose of TARboard is is to let users enjoy games in a more interactive and intuitive way and to make games more realistic and immersive. [?]

Markers are attached to objects or cards used in a game. Similar to reactAble, these markers are tracked on a table-top environment by a camera underneath it. The augmenting camera is placed above the table-top. It provides the video stream for augmenting a game with virtual objects. [?]

[?] implemented a card game as a prototype for TARboard. Each player has cards which represent mystic creatures. The marker on the bottom of each card is tracked by the tracking camera. When the players flip a card and place it near the battle zone, the creatures get augmented on the battle zone and fight against each other.

3.2 Urban Planning Workbenches

In urban planning, designers usually employ three forms of representation: Two-dimensional drawings on sheets of papers, three-dimensional physical models and computer models, which can be two and three-dimensional. Each of these representations are created and displayed independently. Urban planning workbenches try to bridge the gap between these forms of representation, by simultaneously layering 2D drawings, 3D physical models, and digital simulation over each other. First, the 2D drawings and sketches are laid out on a table. Next, the 3D models are placed on top of the drawings. Finally, video projectors project digital simulations onto the surface. Video cameras capture the activity on the table and adjust the dynamic representation according to the position of the drawings and models with optical tags. [Ishii et al. 2002]

The advantage of urban planning workbenches lies in the combination and fusion of digital and analog content. The dynamic simulation of features like shadows, traffic and wind bring the analog content placed on the workbench to life. Users gain a more thorough understanding of the implications of their designs. Furthermore, the two- and three-dimensional physical representations together with the digital projection add to a more realistic simulation of an urban design space.[Ishii et al. 2002]

3.2.1 Urp

Urp is an implementation of an urban planning workbench. Urp is classified as an luminous-tangible interface. The accurate casting of shadows and reflections of the 3D models is a very important part of the system. The Urp urban planning workbench consists of the following five key functions:

- Shadows: Urp casts accurate shadows of the 3D models onto the projection table. With a clock object, the user can change the position of the computational sun and see how the shadows of the models change accordingly.
- Distance Measurements: With the distance-tool, a line between two buildings can be drawn. The drawn line connects two structures, with the lines length displayed beneath. This number continuously changes as the connected structures are moved.
- Reflections: When a user touches any building with a transparent wand, its facades become glass, so that solar reflections are generated and projected onto the table.

Figure 2: Students using the Luminous Table (compare [2002])

- Wind Effects: Urp is able to project an airflow simulation onto the workbench. The user can choose between eight quantized wind directions. The simulation is displayed as a regular array of white segments, whose direction and length correspond to the instantaneous direction and magnitude of the wind at that position.
- Site Views: Since the model buildings 3D forms are already resident in the system (because of the shadow generation), they can be rendered in perspective and with simple shader arguments. Placing a camera object in the workspace results in a real-time rendering of the current arrangement of buildings in the site, viewed from the height of a pedestrian and the position and orientation of the camera. [1999]

Urp can also simulate traffic on roads, when traffic strips are placed onto the workspace. When two plastic strips cross each other, the simulation creates an intersection with implicit traffic-control signals. Cars come to a halt in one direction, while the traffic in the other direction flows. [1999]

3.2.2 The Luminous Table

The luminous table is based upon the Urp urban planning workbench, but extends its functionalty to a more mature form. The luminous table software allows more flexibility in the computation of shadows by allowing users to interactively change the latitude (Urp has a fixed latitude) and set the time of the simulation more precisely. The traffic simulation in the luminous table is also more advanced compared to Urp. Users can change the road length, road width, traffic density and traffic cycle time of the simulation. Furthermore, the luminous desk supports more geometry formats for models of urban structures and implements the ability to save and restore work. Figure 2 shows students interacting with the luminous table. [2002]

3.3 Other forms of Tangible User Interfaces

There are many other different forms of Tangible User Interfaces for a variety of devices. We will discuss some of them in this section.

3.3.1 Portico

Portico is a portable system for enabling tangible interaction on and around tablet computers. Two cameras mounted on small, foldable arms are positioned above the display to recognize a variety of physical objects. These objects can be placed on the tablet or around it. The cameras have a large field-of-view, so the interaction can be extended beyond the tablet. The prototype developed by [Avrahami et al. 2011] uses a 12" inch tablet, but the interaction space is six times the size of the tablet screen. Portico allows tablets to increase both their interaction space and sensing capabilites, without sacrificing portability. Portico can be used for games or educational purposes. Because physical objects are more graspable than touch surfaces, Portico would be suited as a learning device for young children. [**?**]

3.3.2 Paper Windows

Paper Windows simulates the use of digital paper displays by projecting digital content onto physical paper. IR cameras track the motion and the shape of the paper for an accurate projection. Pens, fingers, hands and other objects are also tracked by the computer vision system to allow enhanced interaction with the paper documents. [Holman et al. 2005] introduce a set of new interaction techniques to allow interactions between different paper documents. The rubbing technique for example allows users to transfer contents between paper documents. The flipping interaction allows users to navigate through the document by flipping the paper in their hands. Paper can also be stacked to organize them in piles on a desk. On the paper document itself, items can be selected through a one handed pointing gesture. Interactions like Copy & Paste, Scrolling, Browsing and Sharing are also possible. [2005]

3.3.3 3D Tractus

[Lapides et al. 2008] present a three-dimensional user interface to monitor and control a team of independent robots in a spatial tasks. The 3D Tractus is a tangible user interface, which allows to change the height in a three-dimensional environment. It is a mechanical device consisting of a table surface that slides up and down on four vertical tracks. A tablet is placed on top of the table surface to control a 2D map. The user can move the table surface up and down to change the height in the environment. The purpose of the system is to control a robotic team inside a three-dimensional building, where a bomb has to be defused. A single human operator controls multiple robots by giving them instructions on the tablet PC. The tablet provides a topdown view of the building. [2008]

4 Tangible User Interfaces in Visualization

5 discussion

References

ALMGREN, J., CARLSSON, R., ERKKONEN, H., FREDRIKSSON, J., MØLLER, S., RYDGÅRD, H., ÖSTERBERG, M., AND FJELD, M. 2005. Tangible user interface for chemistry education. In *Visualization, Portability, and Database. Proc. SIGRAD 2005*.

AVRAHAMI, D., WOBBROCK, J. O., AND IZADI, S. 2011. Portico: tangible interaction on and around a tablet. In *Proceedings of the 24th annual ACM symposium on User interface software and technology*, ACM, New York, NY, USA, UIST '11, 347–356.

HERMANN, T., BOVERMANN, T., RIEDENKLAU, E., AND RITTER, H. 2007. Tangible computing for interactive sonification of multivariate data.

HOLMAN, D., VERTEGAAL, R., ALTOSAAR, M., TROJE, N., AND JOHNS, D. 2005. Paper windows: interaction techniques for digital paper. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, CHI '05, 591–599.

HORNECKER, E., AND BUUR, J. 2006. Getting a grip on tangible interaction: a framework on physical space and social interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, CHI '06, 437–446.

ISHII, H., UNDERKOFFLER, J., CHAK, D., AND PIPER, B. 2002. Augmented urban planning workbench: Overlaying drawings, physical models and digital simulation. 203–211.

JORDÀ, S., GEIGER, G., ALONSO, M., AND KALTENBRUNNER, M. 2007. The reactable: exploring the synergy between live music performance and tabletop tangible interfaces. In *Proceedings of the 1st international conference on Tangible and embedded interaction*, ACM, New York, NY, USA, TEI '07, 139–146.

JUN LEE, YOUNGTAE ROH, J.-I. K., AND WOOHYUN KIM, SUNGPIL HONG, H. K. 2009. A steerable tangible interface for multi-layered contents played on a tabletop interface. In *DVD of ITS '09*, ACM.

KOIKE, H., SATO, Y., KOBAYASHI, Y., TOBITA, H., AND KOBAYASHI, M. 2000. Interactive textbook and interactive venn diagram: natural and intuitive interfaces on augmented desk system. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, CHI '00, 121–128.

LAPIDES, P., SHARLIN, E., AND SOUSA, M. C. 2008. Three dimensional tangible user interface for controlling a robotic team.

SHAER, O., AND HORNECKER, E. 2010. Tangible user interfaces: Past, present, and future directions. *Found. Trends Hum.-Comput. Interact. 3*, 1–2 (Jan.), 1–137.

SHAER, O., KOL, G., STRAIT, M., FAN, C., GREVET, C., AND ELFENBEIN, S. 2010. G-nome surfer: a tabletop interface for collaborative exploration of genomic data. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, CHI '10, 1427–1436.

SPINDLER, M., TOMINSKI, C., SCHUMANN, H., AND DACHSELT, R. 2010. Tangible views for information visualization. In *ACM International Conference on Interactive Tabletops and Surfaces*, ACM, New York, NY, USA, ITS '10, 157–166.

ULLMER, B., AND ISHII, H. 1997. The metadesk: models and prototypes for tangible user interfaces. In *Proceedings of the 10th annual ACM symposium on User interface software and technology*, ACM, New York, NY, USA, UIST '97, 223–232.

ULLMER, B., ISHII, H., AND JACOB, R. J. K. 2003. Tangible query interfaces: Physically constrained tokens for manipulating database queries. In *Proceedings of Interact'03*, 279–286.

UNDERKOFFLER, J., AND ISHII, H. 1999. Urp: a luminous-tangible workbench for urban planning and design. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, CHI '99, 386–393.