TUImod — MODULAR OBJECTS FOR TANGIBLE USER INTERFACES

Till Bovermann, Risto Koiva,
Thomas Hermann, Helge Ritter[1]

Abstract

This paper describes the design and construction of TUImod, a modular system of basic elements generated by rapid-prototyping techniques that can be combined in various ways into human distinguishable and computer trackable physical objects with specific physical properties. The described system is used in our tangible desk environment for data exploration applications.

1. Introduction

Tangible computing is a possibility to add digital functionality to arbitrary physical objects and becomes more and more a field of active research. Most applications in this field rely on physical objects in different forms that can be recognized by the hosting computer system. In this paper we describe the design and construction of *TUImod*, a modular system of physical objects with different features. TUImod supports fast prototyping of tangible user interfaces by providing a broad range of elements that can easily be assembled into a variety of objects exhibiting different features. The strength of this system lies in its modular structure, allowing a huge number of object designs. TUImod objects combine the following three element types: *User Interface Elements* (UI) determine the object's identity in the user's view; *Physical Functionality Elements* (PF) add physical functionality to the object; *Computer Interface Elements* (CI) determine the object's identity, position and orientation for the computer.

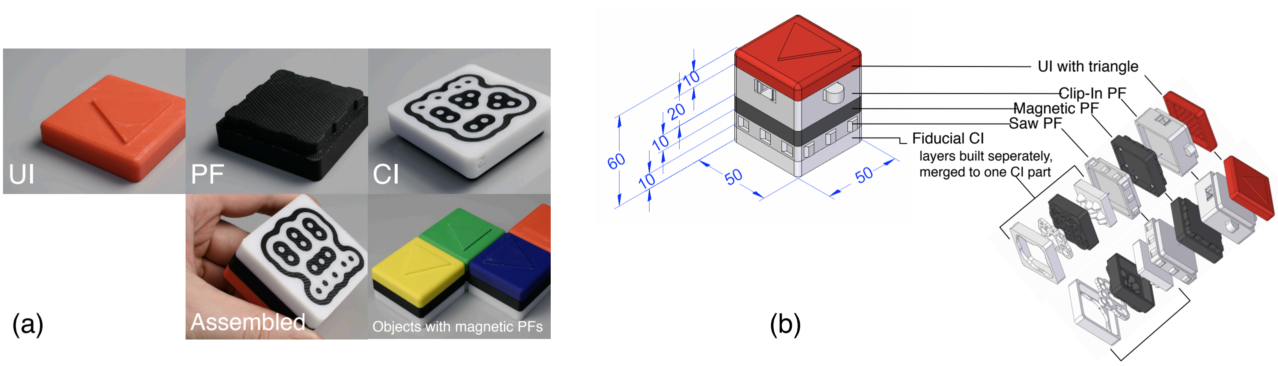

Figure 1. Design and implementation of TUImod elements. (a) TUImod modular design. (b) TUImod object with all PF elements covered by example elements for UI and CI. Left – Assembly, Right – Explosion view.

[1] Neuroinformatics Group, Faculty of Technology, Bielefeld University, Germany

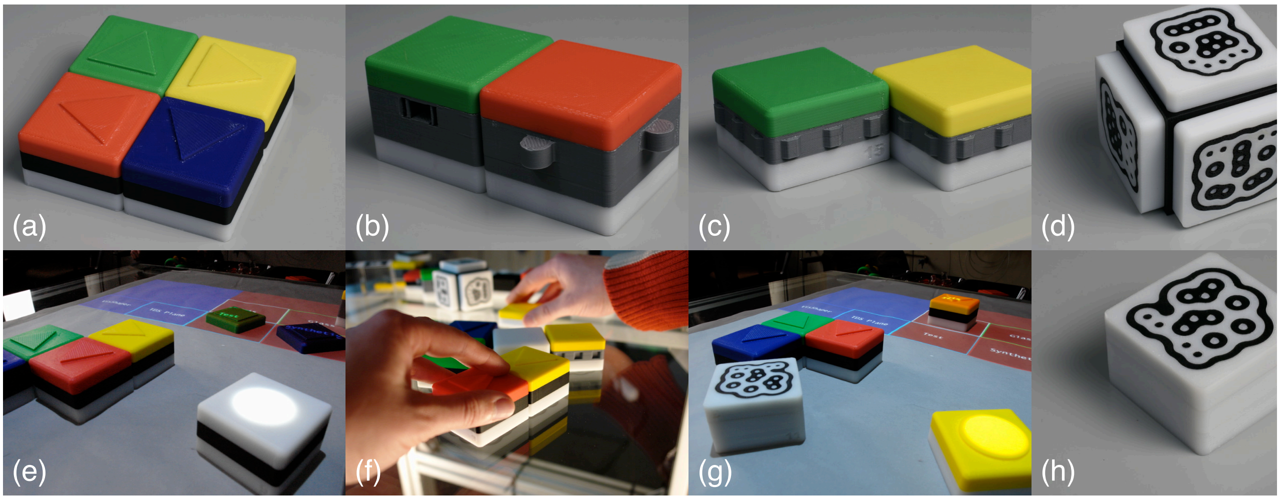

Figure 2. TUImod objects with different PF elements. (a) magnetic, (b) clip-in, (c) saw, (d) cube, (h) two-sided. Images (e)-(g) show examples of the use in the tDesk environment with front-projection.

2. Related Work

Recent publications already focused on design considerations for objects in tangible computing scenarios, though the authors therein focused mostly on a specific task such as controlling a musical interface [1] or testing new electronic interface technologies [6]. The METADESK system is an example for *active* objects that are able to change their position[7]. Although this is a promising and future-directed hardware design, its development and actual implementation remains expensive and its usage is potentially prone to errors due to the many electronic and mechanical components involved. In contrast, the object design of TUImod consists only of passive objects, yet their feature set allow to build complex applications focusing on *direct interaction* [3] with data structures and functionalities. Due to its modular design, however, TUImod objects are open for the integration of such active components in future revisions.

3. Object Design

TUImod objects consist at least of a "sandwich" of two basic elements: a UI responsible for the user's experience, and a CI for robust recognition by a computer. One or more intermediate layers of PF elements can be added, either to change the object height, or to add other physical properties like object-placement constraints, or magnetic forces. The single elements are designed to be stackable, resulting in both, robust interlocking and effortless disassembly. This allows a swift change of configuration and function of TUImod to be used in diverse applications.

At the moment, we have built 20 different CI elements for identifying an object's position and orientation on a surface. We produced UI elements in five different colors (white, red, yellow, green, blue), each with four different reliefs (triangle, circle, square and plain surface; cf. Figure 2). The PF elements can be inserted between CI and UI to equip TUImod objects with different interfacing characteristics such as a different height, magnetic forces that allow only specific inter-object placements (Figure 2a), clip-in functionality for mechanical object connection (cf. Figure 2b), or saw-shaped edges constraining inter-object placements to a discrete set (cf. Figure 2c). Additionally, we built two- and six-sided CI inter-connectors for state-representing objects as shown in Figure 2d, resp. h. As can be seen in Figure 2f, the objects were designed to comfortably fit into a hand's palm.

For the visual object tracking we use the fiducial tracking system [1]. It allows to simultaneously track 2D positions and orientations of up to 90 different markers at a time from below a glass surface.[2] This tracking system closely connects with TUIO, an OSC-based network interface protocol for tangible objects [5], which subsequently is processed in our in-house developed framework for tangible user interfaces SETO.[3] All mentioned software systems are open-source software.

For the production of the TUImod elements we used *fused deposition modeling* (FDM), a rapid-prototyping 3D-Printing (3DP) technology where material is added in layers. With the STRATASYS DIMENSION SST 768 RP-machine using acrylonitrile-butadiene-styrene (ABS) material we were able to produce extremely durable objects that can withstand even the roughest handling. In addition, rapid prototyping allowed us for extremely short idea-to-product time-cycles while keeping the absolute costs for whole production relatively minimal. Unfortunately, the used machine allows only to produce single-colored objects. To get the high contrast required for good visual detection of the CI elements, we developed a design with four interlocking parts of different colors (cf. Figure 1a). The precision of the machine is good enough for the separate layers to be held together without any adhesive by just press fit.[4] All TUImod modules benefit from the ABS' crisp colors and elasticity, which is specially beneficial for the clip-in PF elements. Although the used material was not a decision of design, but given by the constraints of the 3D printer it turns out that it in conjunction with the produced rough surface produces a qualitative haptic feedback.

4. Application of TUImod in the TDESK Environment

TUImod is part of TDESK [2], a tabletop working environment for tangible computing. It consists of a 70 cm × 70 cm glass surface resting on four legs at a typical table height of approximately 80 cm. Every corner of the glass surface can be effortlessly reached, allowing for pleasant interactions within tangible applications, possibly in a group of users surrounding the TDESK. The CI parts of the TUImod objects are captured by a digital camera mounted below the clear glass surface. Eight loudspeakers arranged in an equidistant ring of 4 m in diameter surround the table and thereby all participants can experience a spatial auditory display directly coupled to their interaction with TUImod objects. For visual augmentation a projector is mounted high above the table, pointing downwards to the desktop. This allows to project arbitrary visual information on top of the TUImod objects (i.e. the UI elements).

In previous work we have developed numerous tangible computing applications for the tDesk environment without TUImod objects. In [4] we demonstrate a tangible computing system for the interactive control of real-time multi-channel data sonification. Physical objects serve here as graspable representations for data series such as EEG channels. As a second system AMBID, an ambient interaction system [2] allows to control display properties of real-time data streams within an ambient multimodal environment by changing relations between physical objects. Both applications use different object types to mediate their functionality. To distinguish the therein used acrylic cubes, we attached human-

[2]Please note that replacing the Fiducial-Tracking system, e.g. by a system based on electronic marker detection would not affect the user's experience.

[3]http://tuio.lfsaw.de/seto.shtml

[4]There are other machines for multi-color 3DP, where a special powder material is fixated in layers. Unfortunately this technology does not produce objects nearly as strong and flexible as those using FDM process and ABS material.

readable and computer-perceptable markers printed on paper. The outwearing marker design can now be replaced by the much more robust TUImod objects. Although none of these applications makes yet use of the constraints introduced by the PF elements, we regard their explicit usage for application design as highly promising. On our website (`http://tuio.lfsaw.de/tuimod.shtml`) we present a video demonstrating TUImod and show among others an application for experiencing physical relations between object shape, resp. constraints and sound-inherent features. Furthermore, all definitions of the TUImod elements in the STL-format are provided there for free download.

5. Conclusion

With TUImod we have introduced a modular, versatile and extensible design for tangible objects aimed to be used in prototyping environments for tangible computing applications. We described the design and assembly of the elements, as well as the resulting objects and their features. Adaptation of previously developed tangible computing applications is straightforward. The rapid prototyping allows us to develop now a collection of basic TUImod elements that offer the appropriate physical implementations for most needed functionalities (e.g. modules with moveable "hardware sliders," or even malleable PF elements integrating springs. With such a set of building blocks, Tangible Computing applications can be rapidly prototyped. Our current interest is to investigate relationships between physical shapes and auditory gestalts via interactive sonification.

We want to thank Eckard Riedenklau and René Tünnermann for their valuable input on object design and lively discussions.

References

[1] R. Bencina, M. Kaltenbrunner, and J. Sergi. Improved topological fiducial tracking in the reactivision system. In *Proceedings of the IEEE International Workshop on Projector-Camera Systems (Procams 2005)*, San Diego, USA, 2005.

[2] T. Bovermann, T. Hermann, and H. Ritter. A tangible environment for ambient data representation. In *First International Workshop on Haptic and Audio Interaction Design*, volume 2, pages 26–30. multivis, Aug 2006.

[3] P. Dourish. *Where the action is: The Foundation of Embodied Interaction*. MIT Press, 2001.

[4] T. Hermann, T. Bovermann, E Riedenklau, and H. Ritter. Tangible computing for interactive sonification of multivariate data. In *Proceedings of the 2nd Interactive Sonification Workshop*, February 2007.

[5] M. Kaltenbrunner, T. Bovermann, R. Bencina, and E. Costanza. TUIO: A protocol for table-top tangible user interfaces. In *Proceedings of Gesture Workshop 2005*. Gesture Workshop, 2005.

[6] H. Newton-Dunn, H. Nakano, and J. Gibson. Block Jam: A Tangible Interface for Interactive Music. *Journal of New Music Research*, 32(4):383–393, 2003.

[7] J. Patten and H. Ishii. Mechanical constraints as computational constraints in tabletop tangible interfaces. *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 809–818, 2007.