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A Shape-Oriented Approach for Creating Novel Tangible Interfaces

Brian Eschrich, Anja Knöfel, Thomas Gründer, Mandy Keck, Rainer Groh

Chair of Media Design, Technische Universität Dresden

Abstract

Most design methods for developing tangible interfaces apply a user-centered strategy for problem-solving. These methods introduce an analytic approach to identify needs and requirements of the emerging interface. They also require the mapping of interaction to functionality. However, they rarely elaborate how such a mapping can be achieved. In this paper, we describe a shape-oriented method that supports the mapping process by stimulating creative ideas and broaden the variety of solutions.

1 Introduction

With novel devices like Nintendo Wii and Microsoft Kinect, tangible and graspable interfaces have become more popular. To support researchers in exploring new ways of interacting with computers in a tangible way, Jacob et al. proposed a framework for Post-WIMP Interfaces (Jacob et al. 2008). The shift to reality based interaction design depends on the understanding of the world around us. Concepts, patterns, and physical properties are already understood in daily life and it is beneficial to apply them in human-computer interaction. However, it is not sufficient to "mimic the real world" (Jacob et al. 2008) in embodied and tangible interaction, since it leads to problems in interpreting the interface (Shneiderman 2003). Furthermore, the virtual world possesses its own benefits and "magic" (Rohrer 1995), which enhances the interaction experience.

While the benefits of reality based interaction design are obvious, there is a lack of tools and methods that make effective use of this paradigm. Saffer describes several general approaches to design: user-centered design, which focuses on user needs and goals, activity-centered design, which examines tasks and activities of the user, and systems design with an emphasis on existing components of the system (Saffer 2010, p. 33). In the literature about reality based interaction, the focus lies on user-centered design and problem solving. For example, Edge et al. describe an analytical design approach based on four stages: context analysis, activity analysis, mapping analysis, and meaning analysis (Edge et al. 2009). For every stage, they propose questions to identify the problems and evaluate the progress. The same applies to the brainstorm card game (Hornecker et al. 2010), which identifies problems and tasks. However, while using these methods, there is no guideline how to map actions and feedback from reality to the digital world. Inspiration and genius are just vague ideas about how to solve this problem. Döring et al. (Döring et al. 2012) and Groh et al. (Groh et al. 2012) describe ways to use the exploration of substances and materials as foundation to generate new concepts for interaction. With this derived knowledge, the pool of ideas and concepts can be extended to map those properties to digital functions. In this paper we describe another exploration approach based on geometric objects. Section 2 explains the process and section 3 demonstrates practical results.

2 Procedure

Most models of design processes follow the same stages. There is general consent that the analysis of potential users, stakeholders, and competitors leads to more detailed information and insights about the problems and goals at hand (Cooper et al. 2012, Moggridge & Atkinson 2007, Saffer 2010). The outcome of these steps is a structured and weighted list of requirements and functions of the emerging interface. Another step is to identify the constraints that the developed solution has to fulfill. These constraints can be technical, economical, or ethical. Within the following process of ideation, the design team has to develop concepts to transform the essential functions into form and behavior, in order to create the tangible interface.

We propose an object-based analytical process as a suitable next step within the design process, in order to develop new tangible interaction concepts, which are based on a “tacit interaction language” (Svanaes & Verplank 2000). With this strategy, we rely on the assumption that humans have profound tacit knowledge about the physical world and of their own bodies (Jacob et al. 2008). This analysis of physical objects should lead to interaction principles, which are intuitively recognized and more independent from individual, temporary, or cultural background.

2.1 Object Analysis

The initial point of this shape-oriented design process is the analysis of simple geometrical objects like cubes, spheres, cones, or cylinders (see Figure 1, left). Starting with the analysis of geometrical shapes, it is possible to describe the structure of the object, including the number of points, lines, and surfaces. In the three-dimensional context, the number of corners, edges, and surfaces are considered. This basic analysis of geometry is supported by the analysis of proportion, the comparison of size with the human body (see Figure 1, middle), the position in space, the degrees of freedom, which depend on form and size of an object, the hollowness (solid, hollow), and the material (light, heavy, cool, warm, rough, smooth, rigid, deformable). This object analysis is an active, hands-on process, supported by a pool of different, nontechnical objects like diverse balls, boxes, or arts and crafts materials. During the direct interaction with the real physical object, the following questions help to describe the different aspects of form and appearance and thereby account for formal pragmatic and semantic aspects: “What is it?”, “What does it feel and look like?”, and “What might it be?” Each of these three questions should be followed by the enquiry: “… and how can you interact with this object?” The aim is to develop a systematic overview of objects and corresponding interaction modalities.

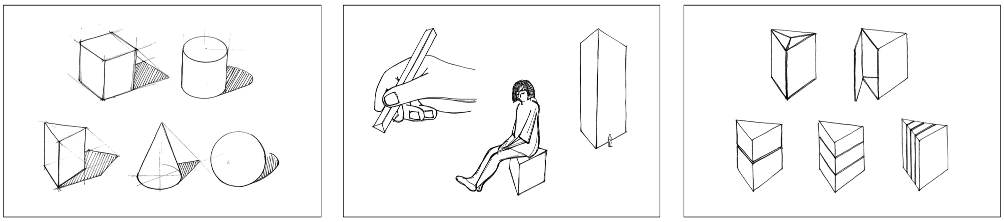

Figure 1: Basic geometrical elements used for object analyses (left), proportion analyses of a prism as part of the object analyses (middle), object transformation: more complex objects created from basic objects by cutting and recombining (right)

2.2 Object Transformation

The procedure of object analysis is followed by a systematical transformation from basic into more complex objects to extend the pool of possible interaction modalities. In order to develop the greatest diversity of variations, this should be done first on a basis of two-dimensional sketches or by using paper prototypes (see Figure 1, right). In a second step, the results can be improved by means of three-dimensional, virtual models and particularly with the use of real physical mock-ups made of different materials. With these more complex physical objects, the procedure of object analysis should be repeated to refine the results.

When comparing objects of basic geometrical forms with various sizes or materials, the different behavior of the objects based on the established features becomes apparent. Furthermore, the interaction with real physical objects equally reveals that each object prompts different actions. These actions are based on our knowledge about the physical world and of our own bodies.

2.3 Object Structuring

The final step of the process is to structure the object's interaction properties in a suitable overview. We propose to map common operations in a digital context to interactions of the investigated objects. Operations and interactions should correspond on an abstract level. For instance, discrete operations like opening or closing, or continuous manipulations like rotating. Further operations can be mapped, for instance choosing or erasing something as well as the modification of data (see Figure 2).

We suggest introducing this analytic shape-oriented process to students in order to sensitize future developers of interface technologies to aspects of tangible interaction. We propose that this method enhances the design process concerning tangible interaction and enriches the diversity of tangible and graspable interaction devices.

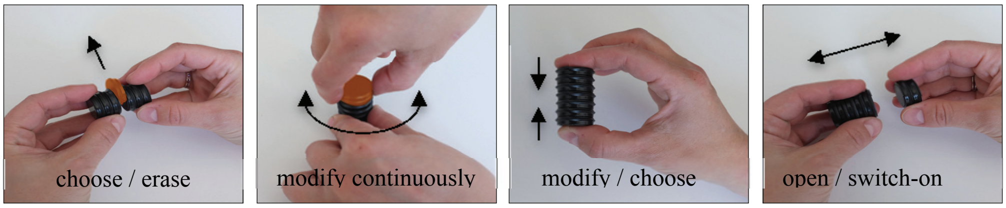

Figure 2: mapping of object interactions to operations in the digital world

3 Examples

In this section we describe the results of a workshop with undergraduate students, which used the introduced approach. The objective of this workshop was to create tangible interfaces for controlling a smart home or a car. We started with the analyses of basic geometrical objects and determined their properties, affordances, typical states, and state transitions. This led us to a "construction kit" of various inherent design variations and interaction techniques that is free from any constraints of a particular problem domain. Next, we followed common design strategies by analyzing the problems and requirements of the final goal. Consequently, the main question was identified: "…how does a remote control for such an interactive smart home or car look like?" By answering the question, constraints such as size, functions, users, and environment conditions of the emerging product were defined. In a third step, the results of the object and the problem analyses were fused by finding suitable interaction techniques and shapes, which can be mapped to the determined subtasks.

Tophat2k (see Figure 3) is a control for private car sharing, which can be used to quickly access information about the car's status. It uses coins that can be stacked to form a cylinder. Each coin has a specific function, which is activated when the coin is on top of the stack. The idea of stacking coins, which are flat cylinders that form a taller cylinder, has been developed during the object analyses (see Figure 3, left). The side of the stack forms the interface of Tophat2k. Each coin represents a pixel that shows information about trunk space in the car or booked reservations. The position attribute of the cylinder has been used as well. While standing, the stack is in passive mode, providing information like a fuel gage when using the fuel coin. If brought in horizontal position, the active mode is enabled. When the fuel coin is on top of the stack, it can be rolled across a map, to check if sufficient fuel is left for a specific trip.

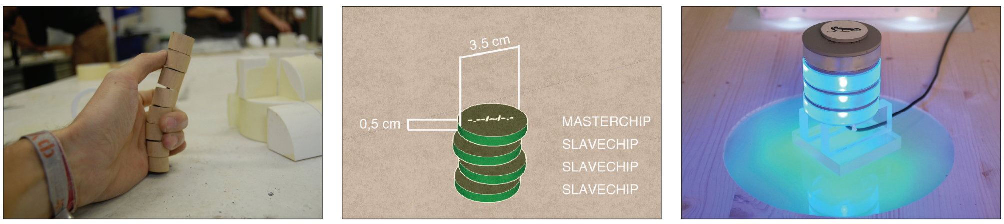

Figure 3: Tophat2k - evoled from a basic cylinder (left) it consists of a stack of chips where the topmost chip sets the selected function (middle). The final prototype provides its information through a led display on the side (right)

The prototype is manufactured of acrylic plates using led-lights for visualization and magnetic contacts for stacking (see Figure 3, right).

The tANGibLE (see Figure 4) uses the basic shape of a cuboid. During the object analysis, various shapes based on the angular nature of the cuboid and typical interaction techniques such as moving, rotating, and stacking were observed. The student team designed an angled interaction object with similar properties, which offers various states and relations (see Figure 4, left). Two of these objects are used to combine various iconic or symbolic compositions, for instance, a U-form symbolizing a bath tub (see Figure 4, middle & right). All these combinations access different functions of a smart home, such as filling the bath tub, activating the alarm clock, or controlling the home heating. The prototype is built of plastic and acrylic plates with magnetic bipolar contracts on the sides, which allows the identification of different stages and permits a simple and playful interaction.

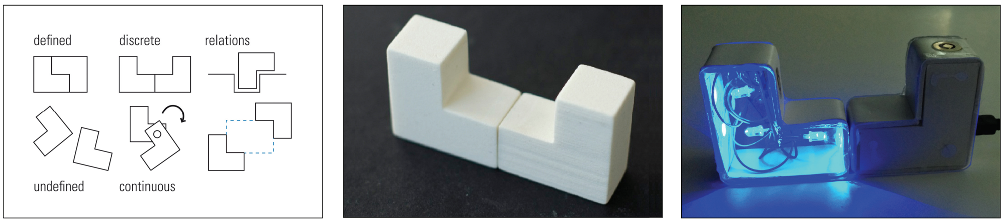

Figure 4: tANGibLE - after various combinations and states have been identified (left), the final design consists of two angled interaction objects (middle), which react on the users input with light and vibration (right)

The Gerät (see 5) is a device for outdoor tours with a car. Its shape is more evolved from basic shapes than Tophat2k and tANGibLE. The group started with exploring a cone. After the analysis and modification process, the cone was truncated and divided in two connected parts (see 5, left). These two parts can be rotated. Markers on the side show fixed positions. The analysis of the outdoor scenario required a portable, durable tool, which can be attached to other outdoor equipment. These requirements led to a kind of bracelet with the interface on top. The rotation of the two elements served as basic interaction technique (see 5, middle). Through a rotatable button (see 5, left), all functions can be accessed in fixed steps. This button is also used as an interface displaying information via led light. For instance, a compass shows where the car is parked while being on a hike.

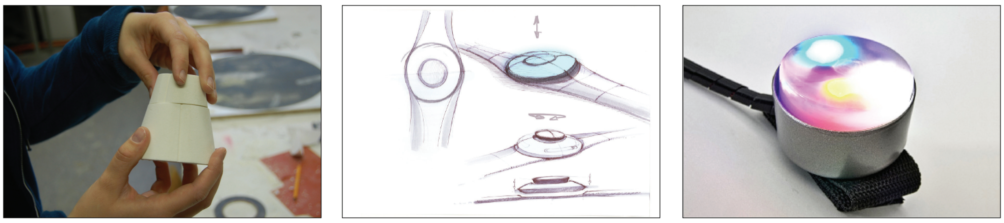

Figure 5: Gerät - started from a truncated cone (left) it developed to a wearable device (middle). It displays information like the position of the car via compass through an led display (right).

4 Conclusion and Future Work

The general design process of tangible interfaces consists of two main strategies. First, there are methods to determine problems and requirements of the emerging artifact. Second, there is a process that determines the function mapping from real objects to virtual data. While the methods to identify problems and requirements are well described in the literature, such as weighted lists, methods for ideation are rarely formulated. We presented the method of shape-oriented design, which supports the mapping of compatible interactions with tangible objects. This method comprises steps that experienced designers follow implicitly when creating interfaces. Hence, it serves to teach students how to generate capable, useful interaction mappings in an interface. Shape-oriented design as part of teaching how to develop tangible UIs can lead to more profound results when students become practitioners.

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Contact Information

Technische Universität Dresden, Fakultät Informatik, Institut für Software- und Multimedia-technik, Professur für Mediengestaltung, 01062 Dresden. brian.eschrich@tu-dresden.de