TangibleRings: Nestable Circular Tangibles

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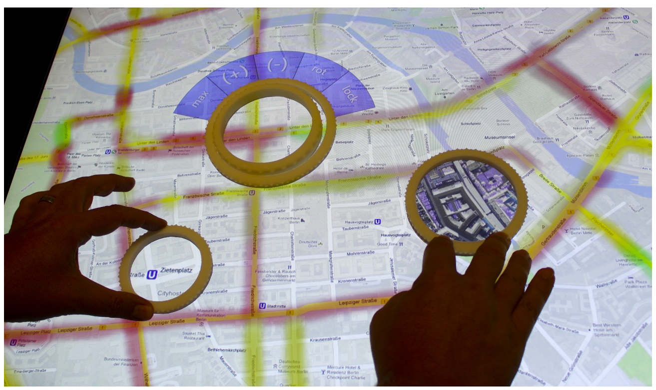

Figure 1: *TangibleRings* in a map application, each controlling different information layers.

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Abstract
The multitouch functionality of tabletop computers is often augmented by the use of tangible objects that offer an intuitive and haptic alternative to interaction and manipulation. However, employing tangibles can also lead to less desirable effects, such as occlusion or lack of precision. In this paper we highlight the design and implementation of ring-like tangible objects: *TangibleRings*. They do not occlude the objects underneath them and also support the detection of touch events inside their perimeter. Additionally, multiple rings may be nested within one another in order to combine ring functionalities or produce more complex filters.

Author Keywords
Tabletops; combinable tangibles; occlusion management; virtual lenses.

ACM Classification Keywords
H.5.m [**Information interfaces and presentation (e.g., HCI)**]: Input devices and strategies, Interaction styles.

Introduction
In recent years, the multitouch functionality of tabletop computers has been augmented by the use of tangible objects. They can be detected when positioned on or close to the tabletop's surface. While these tangibles have

the advantage of providing the user with distinct physical objects that he/she can use to interact with the virtual space of the tabletop, there are also some known issues. One such problem is the occlusion generated by opaque or translucent tangibles positioned on the tabletop, which inhibits a clear detection of the underlying objects and the precise positioning of the tangibles. Furthermore, it is not possible to interact with objects occluded (hidden) by the tangibles.

In this paper, we propose an alternate solution that tackles the above mentioned issues and adds both flexibility and functionality to the tangible-enhanced interfaces. We propose a solution called *TangibleRings*, that consists of a number of circular tangibles that support filtering inside their radii, quite similar to the concept of "virtual lenses" from the visualization field (e.g., [2], [9]). As our tangible rings are hollow, users can still see the virtual objects that are displayed on the tabletop in the center of the tangible (see Figure 1). This aids in improving the precision of positioning or selecting elements with *TangibleRings*. They also allow to perform touch operations inside the rings and to store information through special gestures. Besides in-ring touch operations, users can access various application-specific commands that the ring supports by means of a menu that is strategically positioned along the outer rim of the rings. All this functionality is supported by a ring-shaped marker that is attached to each tangible and that has been designed specifically for the *TangibleRings* to allow precise and unique identification of each ring positioned on the tabletop.

Similarly to stackable tangibles [1], *TangibleRings* can be combined to offer more flexibility to the user and the ability of executing logical operations with views and filters. For this, the diameters of the rings are slightly different, allowing them to be nested into one another. In this case, the combined rings act like the overlapping knobs on old radio devices, allowing the user to still turn each of the individual rings separately.

Related Work

There have been many approaches of tangibles in different application areas [8]. Good overviews on tangible user interfaces can be found in the works of Ullmer [10], Ishii [4]) or Underkoffler [11]. Most of the presented activities rely on the classical approach of tangibles as solid, block-like input devices that are identified by markers on their bottom (e.g., [9]). A drawback of dealing with these kinds of tangibles is that only a few approaches go further in utilizing the space on the tangible to show additional information or are able to offer touch surfaces on the tangible [5, 7, 12].

SLAPbook [13] introduced SLAP widgets, transparent silicone peripheral devices that represent input devices like keyboards, sliders, or turning knobs. However, SLAP widgets are not stackable/combinable and they are also do not feature distinct screen space that can be used as individual information views. The Sensetable approach of Patten [6] electromagnetically tracks multiple wireless objects on a projection-based tabletop. The projector is installed above the table, allowing not only to project on the table but also augmenting the tangibles themselves. However, the tangibles are quite complex and the user's hand can easily occlude projected information.

One of the most relevant approaches for our work is Lumino, developed by Baudisch et al. [1]. They used block-like tangibles filled with glass fiber bundles that can transport light through the tangible. Hereby, multiple blocks can be combined and the surface of a block can be used for simple touch events. The main application of Lumino lies in the possibility to build and track 3D tangible arrangements on a tabletop. In comparison to Lumino, our approach is less complex, easier to implement, and preserves the multitouch in the interior of the tangibles. "CapStones and ZebraWidgets" [3] extends Lumino's concept of structured transparency to capacitive tangibles consisting of multiple parts. This approach is only targeting devices with capacitive touch screens and cannot be used on tabletop computers that are based on diffuse illumination.

Our Approach

In order to address the requirements for combinability as well as highly functional tangibles, our method is based on circular-shaped tangible objects. These rings offer a variety of advantages that can be exploited to enhance interaction with multitouch applications. In particular, they minimize the number of occlusions on interactive surfaces. If conventional solid tangibles are used for interaction, important information is likely be hidden underneath them. Users then have to move the tangible or remove it from the surface before they can identify an occluded item. Naturally, this problem worsens the more tangibles are involved in a scenario and the bigger their size becomes. Our circular tangible user interface (TUI) offers an elegant way to address occlusion. Since the center area of the tangible is spared, it occupies only a small fraction of the display. Furthermore, our coding scheme enables us to build rings with very narrow rims.

In addition to minimize occlusions, the display area covered by a ring tangible can be used for further visualization and interaction and thus features new ways to manipulate and display data. Conventional tangibles basically "block" the display area they occupy, i.e., they reduce the area on which data can be visualized and that users can interact with. With the help of our approach, however, tangibles remain active parts of the surface. Gestures can be performed both inside and outside the tangible and can be processed in different ways. Outside-the-ring events can be used to interact with context menus that surround the tangible. Inside-the-ring events can trigger actions whose influence is limited to the inner radius of the tangible; for instance, the inside can be used to examine different levels of detail of an data set, i.e., it can act like a semantic lens that can be moved across the display surface. That way, users can investigate data sets without affecting other collaborators.

Another important aspect of our approach is the ability to combine tangibles by placing them inside each other. Placing one tangible inside another tangible results in a compound object which, in the simplest case, integrates the functionality of both rings, i.e., if ring $R1$ is associated with a particular filter $f1$ and ring $R2$ is linked to another filter $f2$, then the combination of both rings implements $f1\&f2$. In our map-based application (see below) we are using this feature to combine several map parameters.

A major benefit of tangibles is their ability to provide passive haptic feedback to users. Although interaction with multitouch surfaces is very intuitive (e.g., pinch-and-zoom), certain basic operations are not typically supported through multitouch gestures. For instance, an intuitive and scalable gesture for defining orientations does not exist. Due to their shape and the haptic feedback, our ring tangibles can be employed to easily carry out certain operations by using them like a control button or knob. For instance, they can be used for quickly defining numerical values, angles, and orientations. Many features

Figure 2: Prototyping with real-world objects and final ring tangibles.

of our application make use of this idea and it furthermore demonstrates the ability to nest multiple tangibles.

Tangible Design

When designing the tangibles, a major requirement was that our rings must be easy to reproduce. Many methods propose complex setups in terms of hardware and materials which make it difficult to quickly build new tangibles. Furthermore, the more complex the design is, the less likely it can be reproduced by other research groups. Therefore, we avoid using any kind of electronics and exotic materials for building our tangibles.

By choosing the form of a ring as the tangibles' shape for our approach, we had to start from scratch and prototype our own customized ring objects. For the early prototypes, we used slightly modified, ring-like real-world objects, that can be found in supermarkets, home-improvement markets, or toy stores (see Figure 2). These objects revealed rough requirements for the needed diameters and minimum rim width for placing our markers. Based on these findings, we went on to the final prototyping step: we modeled the rings in 3D and plotted the resulting as a three dimensional solid object using a 3D printer. Instead of modeling plain and smooth rings we decided to create a non-slip surface in order to improve the usability of the tangibles. We created three customized rings, which differ from each other in size and height. These rings can be used standalone or stacked inside each other.

Tracking the Tangibles

The tracking of our ring tangibles has to fulfill several requirements: unique IDs for multiple tangibles, detectable orientation for each tangible, detectable position and radius of each tangible, interaction and gesture recognition inside the tangible, and detection of concentric positioned tangibles.

For the implementation of the *TangibleRings* concept we are using the Microsoft Surface 2.0 platform. It already comes with a working tangible recognition for unique id, position and orientation. These markers have been designed for classical closed tangibles (squared form, minimal size of $2x2cm$ for stable detection). Considering the relation in size and screen occlusion in contrast to our final marker approach, it is easy to see that these tags are way to large for usage with the narrow rims of *TangibleRings*. As the MS Surface is very stable in recognition of fingers and gives us access to the raw image of the built-in IR-detectors, we decided to keep using the finger detection of the MS Surface framework and use the programming library OpenCV for interpretation of the raw-image and detection of our own markers.

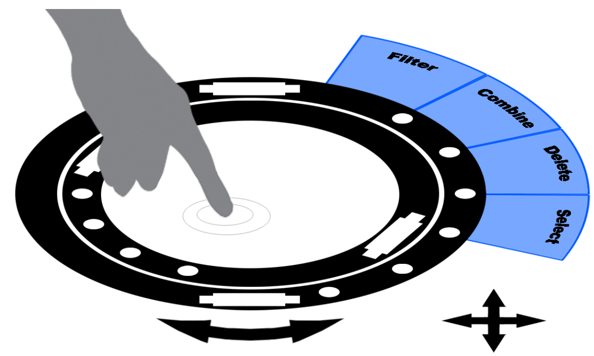

Figure 3: Ring features: translation, rotation (independent for multiple concentric rings), interior touch surface, ring menu.

The basic idea for our markers is to keep them as simple as possible. Therefore we are using a unary coding for the ID along the ring utilizing small blobs of maximal reflective white color, where the number of points along the ring encodes the ID of the ring (see Figure 3). To uniquely detect the rings, we use two types of marker

Figure 4: Opacity, zoom factor, and traffic density plus heat map controlled by TangibleRings.

elements: ring markers to identify radius and position, and ID markers to retrieve ID and orientation. The ring markers are positioned face to face, providing us diameter and center of the ring. In combination with the positions of the ID markers, we are able to distinguish and identify multiple and nested rings. The relative positions of the ID markers to the center of the rings and their asymmetric design let us determine the unique orientation of the ring. In the end, our detection is robust enough to scale with an arbitrary number of concentric rings, though we think that more than two or three concentric rings would not be very useful or user friendly.

Applications

For demonstration purposes we have built a number of small applications that use our *TangibleRings* concept. For the paper at hand, we have chosen a map-based scenario in which users can easily manage different information layers and filters. It is a simple but powerful demo that presents some of the possibilities of the new ring concept (see Figure 1). It basically shows a satellite image of an area. Each ring used has a defined function and shows different information in its interior, e.g. classical map view, street names, heat map, traffic or population density, air pollution etc. In the sense of collaborative work, multiple users can use multiple rings on the tabletop to control, combine and share this information. If rings are combined and nested into each other their information is also combined. If the user for example is interested in the combination of traffic density and heat map, he/she can visualize those attributes by combining the associated rings (Figure 4).

Although all users are working on the same screen, the screen space inside the rings offers an individual view for each user. Here, he/she can zoom in and out using a ring menu or a gesture inside the ring and explore the data set without interfering with other users. By default, the rotation of the rings controls the opacity of the connected information layer. If rings are combined, the opacity of each layer information can be controlled individually. Additionally, we can use the rotation of the rings in a different way. Using the ring menu, it is possible to change into a rotation mode that allows to rotate the screen inside the ring. This is useful when a user wants to read textual information which is upside down from his perspective and makes collaborative work easier if the users are positioned around the tabletop.

A 'lock' function can fix the window shown inside a ring. This way a user who found some important information can select and save this part of the information and can 'give' it to other users in a intuitive way. Since the information is stored in the system and associated with the ID of the ring, the user can even remove the ring from the tabletop. If it returns to the tabletop, the information will be restored for further analysis.

Sometimes the local view inside a ring seems to be too small for an overview especially if the whole group of users need to discuss the information inside. For this case to share information with all users around the tabletop, we added a function that maximizes the information layer and applies the connected layer (or layers if multiple rings are used) to the full screen. This way it is possible to have a global overview over the data. In this mode a ring no longer acts as a lens but still as a controller and the opacity of each layer can still be regulated by rotation of the associated ring. In addition, rings can still be added to or removed from the maximized rings.

Conclusions

In this paper, we presented *TangibleRings*, a new sort of tangibles developed to overcome some of the major disadvantages in using tangible user interfaces on tabletops. By choosing ring-shaped objects, we are able to reduce screen occlusion and allow the usage of virtual lenses and multitouch interaction within their interior. In addition, this concept of combinable rings offers an intuitive way to merge and manipulate the associated data, e.g. by adjusting settings or selecting items by turning the tangibles. One of the major benefits of our approach is the ability to reproduce this method in an easy and affordable manner. Future work will include the extension of our concept as well as the application and evaluation in more application areas.

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