Poster: OverTop: Breaking the Boundaries of Tangible Tabletop Environments

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Abstract

Tabletop computers have been set out to change the way people work by providing a display on the table surface. Still they're only flat displays with digital content behind a glass screen. Tangibles extended the interface into the third dimension. However, the content still sticks mostly to the screen or is projected onto rigid objects. In this work, we present OverTop, a concept for providing a full three-dimensional interaction experience for both content and interface. We introduce three different layers, where both content and interfaces can be presented: *Below*, *On*, and *Above*. Using these three layers, OverTop extends the design space of tabletop interfaces to the area above traditional tabletop workplaces, opening up new interaction and visualization possibilities.

Author Keywords

Interactive Displays; Tangible; Tabletop Computing; Augmented Reality.

ACM Classification Keywords

H.5.m. [Information Interfaces and Presentation (e.g. HCI)]: Miscellaneous

Introduction

Hybrid workspaces consisting of coexisting digital and physical objects provide a tight integration between the

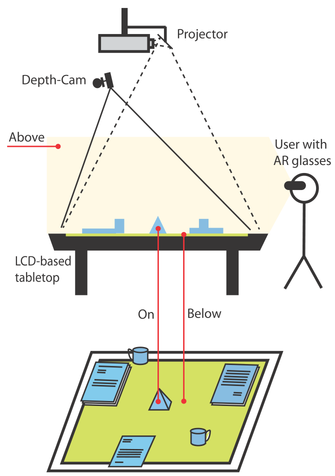

Figure 1: The three-layered interaction space of OverTop and its general hardware setup

	Below	On	Above
Priv./Pub.	public	public	both
Structure	2d	2.5d	3d
Resolution	4K(/8K)	1080p/4K	"full hd"*

Table 1: Summary of the layer properties. *) Non-standard resolutions, roughly equivalent to full hd

two worlds. As a result, research has emerged to foster interaction in such settings [3, 4, 5]. Yet, many of those systems rely on flat display surfaces [2, 5]. While augmented tabletops are versatile, they have posed a new set of problems, such as occlusion of the tabletop display through the physical objects [1].
With the advent of Augmented Reality (AR) glasses, it is possible to break the confinement of flat surfaces and visualize content in 3D on and above the tabletop surface. Adding AR to the conceptual setup allows for both, richer visualization and interaction techniques as the third dimension can be used. For example, a common problem using conventional touch to move objects in hybrid tabletop settings is that the direct path is often obstructed, and one needs to find a way around the obstacles. In 3D space, the object could simply be lifted and moved over the obstacle, as one would do with a physical sheet of paper.
To break these boundaries, we propose OverTop, a concept and a set of interaction techniques leveraging an additional 3D-layer above the usual "flat" projection and display layers to provide more natural and intuitive user interactions.

The OverTop Concept

Conceptually, OverTop splits the interactive space into three layers that each have unique properties and roles. The overall layer-structure and setup of OverTop are depicted in Figure 1.

Below Layer
The *below layer* is basically the display embedded into the table surface and thus, below any physical object placed on the table. While providing an intuitive tabletop display, traditionally it is impossible for the user to move any object on this layer above any object placed on the surface. It serves as the primary layer for self-contained digital objects, like documents. The display surface is inherently flat; hence it is limited to two-dimensional content. However, using an LCD, it provides high-resolution display capabilities. Also, it serves as a public display and can therefore, for example, be used to share content with conversation partners.

On Layer
The *on layer* is an additional content layer that resides on the surfaces of any physical object placed within the interactive space. It can be used to enrich the objects, e.g., by annotations or contextual information. While the projection surface has a three-dimensional structure, the content projected is still two-dimensional. Unlike the below layer, the on-layer must cope with interference from the original texture of the objects. Usually, projection is used for this purpose, the on layer has some drawbacks like shadowing through body parts and tall objects on the table, being prone to daylight and a possibly lower resolution. Just like the table surface, the display space is public.

Above Layer
The *above layer* is provided by an AR system and comprises the space above, and even around, the table. It is used to display three-dimensional information that can be freely placed. While the first two layers are inherently public, the above layer can be used to display both, private and public information since the visualization is displayed by a personal device to the wearing user only. The transition between these three layers can be used to additionally enrich interaction as described in the next section.

Layer Properties
Table 1 summarizes the properties of the different layers that we will discuss in the following.

Figure 2: Ad-hoc data visualization for selected content

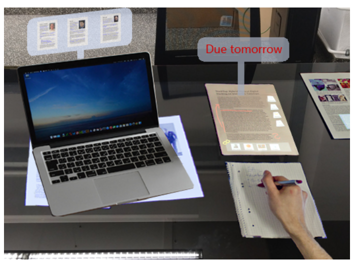

Figure 3: Displaying indicative labels for occluded content

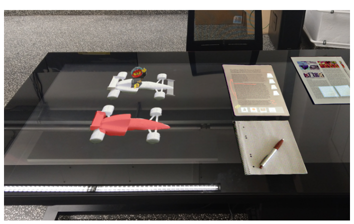

Figure 4: Altering object appearance by changing color or adding object parts

Private/Public Interaction Besides the possible use as personal desk, tabletops are also used collaboratively with multiple users. With parallel users, privacy of information becomes an issue in collaborative settings. In our basic concept, only the above layer may be private, while the other two are public. Since the above layer can overlay content on the other two layers as well, this is not a practical issue. Further, the use of inherently public display technologies or surfaces poses a set of advantages, especially in asymmetric scenarios like presentations: the presenter can see additional information through AR on the above layer while the rest sees the presentation on the below and the on layer without the need for AR glasses.

Display Structure The different layers have different structures that need to be taken into account when choosing where to display information. The *below layer* is two-dimensional since it is a flat display. Leaving the flat surface, the on layer extends display space to structured surfaces that protrude from the table surface. While, as a result, the display surface now has a three-dimensional structure, the displayed content is still two dimensional. Therefore, we consider the *on layer* as 2.5-dimensional due to the added height. The *above layer* in contrast provides full three-dimensional display capabilities that allow displaying 3D content natively.

Resolution Contrary to the increasing degrees of freedom in display structure, current technology leads to a decreasing resolution of the layers from below to above. While the technology may improve in the future, currently and in the near future one will have to consider the resolution of the layers when assigning content to them (e.g., concerning readability). The tabletop itself provides a very high resolution for the *below layer*. For the *on layer* a full-HD to 4K resolution is possible with today's common projection technology. Lastly, the *above layer* realized using AR-glasses has the lowest resolution with roughly full-HD being common today.

Technical Implementation
While we currently use an LCD-based tabletop for the *below layer*, a projector for the *on layer* and a HoloLens for the *above layer*, the concept is generally technology agnostic as long as it is possible to implement the respective layer properties.

Interactions Enabled by OverTop

In this section, we describe a set of interaction techniques leveraging the possibilities of OverTop.

Ad hoc Data Visualization
When reading documents, there are cases in which the given representation of data is not practical for the current intention of the user (e.g., one might find a table of sales figures that is difficult to grasp if one just wants a quick glance at the development of sales). We, therefore, propose to provide an ad hoc way of selecting data from documents (c.f. [5]) and generate 3D visualizations thereof (e.g., diagrams or simulations). The *below layer* is used as document display for digital documents, the *on layer* is used to augment highlights on physical documents to visualize the selection process and the *above layer* is used for the actual display. Figure 2 shows an example of visualizing sales numbers from a selected part of a physical document.

Label Display
Displaying labels over real-world scenery is one of the common and well explored standard use cases of AR. However, we combine it with tabletops to leverage the third dimension in complex settings (e.g., occlusion through tall 3D objects) to display labels indicating content hidden

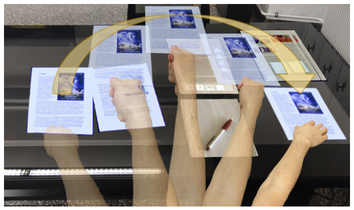

Figure 5: 3D Hypermove allows to naturally move digital content across obstacles

Figure 6: The 3D clipboard is used to store and spatially group content (images and a text fragment) around the workspace

behind the object using labels hovering above the content instead of moving them to an unoccluded space on the table (see Figure 3). Further, we can leverage the private aspect of the AR display to show additional individualized information for objects. For instance, the actual purchase price for the merchant during a sales talk, while the customer sees his current price or availability information.

Altering and Adding Object Appearance

Objects (e.g., tangibles) can be interactively configured on digital tabletops. Simple customizations like changing texture can easily be visualized using the on and below layer. If we add or remove parts, e.g., a spoiler on a car model, the above layer can be used to visually add them or blend over them so that they seem to be removed. Further, the object's texture can be altered by projection. Figure 4 shows an example of adding a driver figurine to a 3D-printed formula one car model that is textured via the *on layer*. Further, it is possible to expand content from the screen into the third dimension that is inherently 3D like CAD models or similar things.

3D Hypermove

In hybrid settings, moving digital content across the tabletop is often difficult since a direct path is blocked. Despite 2D techniques have been developed to move digital content across physical obstacles [3], they are still limited since the object is bound to the 2d surface. In the physical world, we grab an object in such cases, lift it and put it back down at the target location. Using OverTop, this real-world interaction can be easily implemented by augmenting the digital object while being held and moved across the surface (see Figure 5) or even to other devices.

3D Clipboard

Digital clipboards are often only usable for single bits of information, which is invisible while being in the clipboard. One cannot always be sure whether a copy operation was successful, leading to surprises when pasting the information. Using OverTop, we propose a three-dimensional clipboard that allows the user to select a piece of information (e.g., contact data, a passage of text, etc.) and actually move it out of the physical or digital entity containing it into the above layer. It is then visualized as a 3D object, that can be freely moved, grouped and stored in 3D space. Later, it can be placed back at a target location to paste it (see Figure 6).

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