Physical-Virtual Tools for Spatial Augmented Reality User Interfaces

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ABSTRACT

This paper presents a new user interface methodology for Spatial Augmented Reality systems. The methodology is based on a set of physical tools that are overloaded with logical functions. Visual feedback presents the logical mode of the tool to the user by projecting graphics onto the physical tools. This approach makes the tools malleable in their functionality, with this change conveyed to the user by changing the projected information. Our prototype application implements a two handed technique allowing an industrial designer to digitally airbrush onto an augmented physical model, masking the paint using a virtualized stencil.

Keywords: Spatial Augmented Reality, User Interfaces.

Index Terms: H.5.2 [Information Interfaces and Presentation]: Graphical User Interfaces—Input Devices and Strategies; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction Techniques

1 INTRODUCTION

Virtual design has the potential to greatly improve the dialog between designer and client. We have been collaborating with industrial designers from the Louis Laybourne-Smith School of Architecture and Design at the University of South Australia to investigate future industrial design tools. These tools will facilitate designers and clients in visualizing and engaging in the design process within a large-scale Spatial Augmented Reality (SAR) environment [4]. This paper presents our initial investigation into a new user interface methodology, Physical-Virtual Tools (PVT), to support interactions within this application domain and a large-scale SAR environment. PVT is designed to encompass the entire UI for SAR applications. While we have focused on industrial design, a key principle in developing PVT is its applicability to other domains. The user interface is based around physical tools. The operation modes supported by a tool are defined by the shape of the tool itself; picking up a pencil like object will perform pencil like operations [2]. The use of SAR allows for an understandable overloading of the tools' operation. The active mode is conveyed to the user through visual feedback projected directly onto the tool itself. No user interface controls are projected onto the artifact, walls, floor, or ceiling. The user can view and interact with the design artifact from dramatically different viewpoints, such as from either side of a car. Users can interact with the artifact by either touching the object or through just out of arms reach interaction, using physical tools which can be held in both hands.

2 RELATED WORK

We base our investigations on Shader Lamps [4], a SAR technology that utilizes digital projectors to augment physical objects with computer generated images. Shader Lamps has been used to simulate different materials, and the system has been extended to allow the user to paint onto physical objects using a tracked brush [1]. Our system also provides a paint function, however the focus of our work is experimenting with two handed interaction with augmented physical tools. A tracked stylus has also been used in a projector based AR system for programming motion paths for industrial robots [8]. A 2D GUI is provided on a tablet PC for controlling the application, and motion paths are visualized in 3D with a HMD. A tablet PC is not required for our system. WARP [7] allows designers to preview materials and finishes of products by projecting onto rapid prototype models. This system uses a standard graphical user interface, with a keyboard and mouse used for user interaction. We do not project onto a fixed area; all feed back is projected onto the tools. Physical props have been employed in previous VR and AR systems. Surface Drawing [5] allows a user to sculpt 3D shapes using their hands. Spray modeling [3] uses a mockup of a physical airbrush to allow the user to sculpt 3D models by 'spraying' matter onto a base mesh. Our system enhances physical tools by projecting status information onto them. Changing the projection allows us to overload a single tool with several functions.

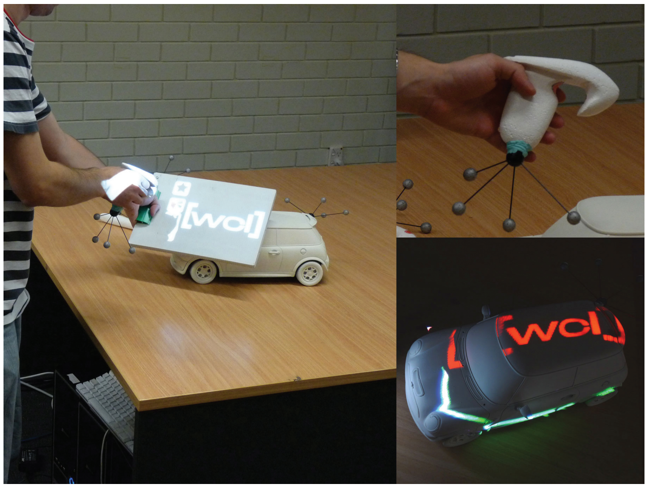

Figure 1: A user stencils paint onto the car using the airbrush tool (top). The result of the paint operation is shown (bottom)

3 PHYSICAL-AUGMENTED TOOLS FOR SAR

Physical-Augmented Tools is our new user interface methodology for SAR user interfaces. Our interface consists of a toolbox of physical tools, augmented with computer graphics. The tools are designed with form factors accommodating different tasks. The active mode of operation is conveyed to the user through computer graphics projected onto the tool. We have chosen this approach for several reasons. The tools are more flexible; a single tool can perform multiple operations, reducing the number of tools required to use the system. The user can interact from anywhere in the room without having to return to the toolbox to change tasks. Projecting information directly onto the tool allows the user to view the sys-

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tem state without looking away from the task at hand. Anybody can pick up the device and immediately know the state of the tool. Our goal is a balance between the correct physical design of the tool and the flexibility of overloading the device for multiple tasks. We have developed a prototype application demonstrating three input devices. Our prototype runs on two desktop computers, each driving two projectors. A six camera Vicon MX motion capture system is used to track the position and orientation of objects.

3.1 Stenciling with Digital Paint

We have implemented a technique for digitally airbrushing against a virtual stencil, as shown in Figure 1. This is an exemplar example of using PVT. Two physical tools have been developed to accommodate this task: the Stencil tool and Airbrush tool.

The physical tool of the *Stencil* is a tracked board held in the user's non-dominant hand (Figure 1). A stencil shape is projected onto the board, masking areas from the paint. It operates in two modes: either the shape masks the paint, or the entire tool is the mask, with the shape acting as a hole allowing paint to pass through. The appearance of the tool changes depending on the stencil mode. A set of geometric shapes is provided, including straight edge and French curve shapes. The user can paint in a similar way to how an artist would use a real airbrush to create a gradient color effect by moving a straight edge and airbrushing simultaneously[1]. A physical object gives the user passive haptic feedback against the object being painted, providing a more natural experience.

In addition to the shapes provided, the user can create custom stencil shapes at runtime. New stencils can be created by drawing onto the tool with the airbrush. An outline of the shape is projected onto the tool as it is being drawn. When a closed loop is detected, the previous stencil is replaced with the custom one. This offers the user more flexibility, as they can create shapes for specific situations. An alternate approach is to use dedicated tools for each stencil shape. The shape of each tool would precisely match the stencil. We have chosen to use a single physical tool to provide the form factor and haptic feedback to the user, while projecting virtual stencils. This is a trade off between multiple physical tools that precisely match the task, and a single tool that can approximate all stencils. Virtualized stencils allow us to implement additional functionality. It would difficult to allow the user to draw custom stencils at runtime without virtualization of the stencil shape.

The *Airbrush* is a pistol shaped device (Figure 1). The top of the device is flat, providing an area for projection. This device is held in the user's dominant hand and is used with the stencil for airbrushing onto objects. In its default mode, an arc is projected onto the tool filled with the current paint color. As with a physical airbrush, the further one holds the airbrush away from the spray surface, the wider the painted area. The angle of the arc represents the spray angle of the brush when painting. We have chosen this representation so the user can quickly see the brush mode. When painting, the top of the tool lights up with the paint color, indicating a paint operation is in progress. This gives the user feedback that painting is occurring, even if the user has the device pointed away from any objects. The airbrush also acts as a *virtual laser pointer*. The projection onto the device changes to an arrow pointing towards the tip of the tool, indicating laser pointer mode. We could have provided a tool for each of these functions; however as the form factors of the tools would be similar we have chosen to combine the functions onto a single virtualized tool.

3.2 Annotation

Annotation directly onto objects is supported through the use of the stylus tool. The *Stylus* is an easy to hold pen-like device that requires minimal pressure of the user's grip to hold and manipulate. While it is possible to use our application only using the airbrush, the stylus is provided for tasks where the pistol grip is less suitable, such as annotation directly onto an object. The pen color is projected onto the top of the stylus. While the airbrush projection changes when painting is in progress, this is unnecessary for the stylus. The user activates the annotation by touching the stylus to the object. The user is made aware of the change in state through passive haptic feedback.

3.3 Personal Interaction Panel

With few exceptions (e.g. [8]), previous SAR systems have projected user interface controls at a fixed location such as a table top or wall. These systems require the user to be located in a position where they can see and use the system. We provide a PIP [6] user interface. We use virtualized tools by placing the user interface controls onto the same physical board of the stencil tool the user is already using, rather than providing another device for the PIP.

4 CONCLUSIONS

We have presented the PVT methodology for creating user interfaces for SAR systems. Three physical tools have been developed, overloaded to provide five logical tools. The current mode of operation is conveyed by projecting visual information directly on the tool. The user is made aware of the state of the system without having to look away from the task at hand. Users do not need to be tracked to be able to use the system, making collaborative work easier. We have developed a prototype application to aid the industrial design process. A two handed technique allows a designer to digitally airbrush onto an object using of a semi-virtual stencil for masking areas from the paint. In the future we will produce rapid-manufactured version of these tools containing embedded electronics for buttons and other sensors. These additions will allow us to explore more advanced interaction techniques than what is currently possible with our system.

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[1] This interaction was inspired by hearing a keynote speech of Bill Buxton.