Magnetic Substrate for use with Tangible Spatial Augmented Reality in Rapid Prototyping Workflows

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Abstract

We present a method for dynamic manipulation and interchanging of tangible objects in a spatial augmented reality environment for use in rapid prototyping. We call this method MagManipulation. This method improves on existing methods in several ways: allows for the use of abstract and non-uniform curves, allows for ease of manipulation on non-tabletop like surfaces, allows for interchangeable tangible objects to be used. Our method allows us to dynamically manipulate tangible objects in a TSAR environment in a manner unattainable with current technologies.

1 Introduction

This paper presents a method for the integration of non-planar, non-uniform substrates with tangible objects in a Tangible Spatial Augmented Reality (TSAR) rapid prototyping workflow using magnetic fields. Current methods of integrating tangible objects in a TSAR rapid prototyping workflow either rely on planar, horizontal surfaces or involve unwieldy or otherwise constraining systems to attach the tangible objects together. By utilising magnetic fields emanating from the tangible object, combined with a ferrous-surface substrate, non-planar non-uniform tangible objects can be easily and dynamically attached and manipulated in the TSAR rapid prototyping workflow, providing numerous benefits over current TSAR workflows and technologies.

2 Background

Ever since Sutherland proposed the Ultimate Display [6], researchers have been striving to integrate Virtual Reality (VR) worlds with reality, through the use of visual, tactile and digital interfaces. In industrial rapid prototyping, Virtual Reality has been used in rapid prototyping for some years [4]. Virtual interaction within the prototyping workflow provides unique capabilities not present in traditional, physical workflows. Spatial Augmented Reality provides additional enhancements [1] to the prototyping workflow not currently present in AR/TAR rapid prototyping systems [3].

Pugh [5] describes a total design made of six steps, from identification of user needs through to manufacture and sales. Tangible Spatial Augmented Reality provides particular enhancements to both the Conceptual Design and the Physical Design steps - that is, through the conception and creation of numerous, wide-ranging ideas and mock-up designs. However, traditional TSAR systems utilise flat, table-top designs[2]. These provide some benifits for applications such as city planning - mock buildings and trees can be placed on the table easily and initiatively. However, it is difficult to attach tangible objects together, and even placing tangible objects on top of non-planar objects such as tabletop displays is difficult. Thus, the table-top design limits the creativity and natural design process by constraining the mock-up to a flat, planar surface. Whilst this is suitable for some applications, such as city planning and the like, it does not lend itself well to many other applications. For example, a mock-up of a car dashboard loses much of its usefulness if the mock-up is not realistically shaped with curved surfaces - but when realistically shaped, attaching tangible objects to the dashboard poses a potential problem.

3 Non-planar non-uniform TSAR substrates

The use of physical mockups and prototypes during the industrial design process is an important feature, allowing the relationships between components to be explored in a much more intuitive manner then the use of CAD models and drawings alone[1]. The use of Spatial Augmented Reality and Tangible User Interfaces has been shown to enhance this process [Porter,

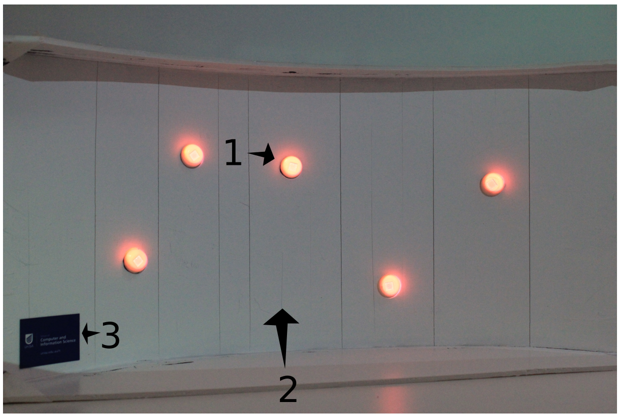

Figure 1: Curved substrate with tracked tangible objects in TSAR environment. (1) Tracked Object, (2) Curved foam substrate, (3) Fridge Magnet.

Porter, Verlinden]. Thomas et. al [7] further extended the use of Tangible Spatial Augmented Reality in the industrial design process through the utilisation of tangible objects acting as intractable parts of the prototype. However, integrating these tangible objects with non-tabletop-like mockups, such as car dashboards containing both non-planar and non-uniform surfaces, presents several challenges. The tangible object must be attached to the substrate in a manner which allows the detachment, as well as high-fidelity placement. For example, while a snap-grid system, such as found on LEGO blocks, would allow the attachment of objects to the substrate, the object placement is limited to the fidelity allowed by the snap grid. Furthermore, the integration of such a snap-grid onto the non-planar, non-uniform substrate presents additional challenges, encumbering the design process. Overcoming these challenges with a method that does not encumber the design process, and allows quick, uninhibited attachment of physical artefacts to a substrate enhances the design process and allows such non-planar, non-uniform substrate models to be used in a manner that is, using traditional tools, quite difficult.

4 TSAR Design Guidelines

Working closely with industrial designers and architects, we have been aiming to extend the existing Pughs Total Design methodology by providing new features into the industrial designers toolkit [7]. The purpose of the features are to allow designers to experiment with a vide variety of potential concept prototypes without the overhead of building the prototypes with complex electronics to provide the functionality. For example, a climate control system on a dashboard required buttons and dials to allow the temperature to be set by the user. Our approach has focused on allowing prototypes to be quickly built using simple construction materials like foam board, timber, glue and nails and to enhance the simple surfaces with a complex computer graphics finish. With this approach the system can still maintain simulated functionality using the TSAR system, but does not require a significant commitment to explore a concept. For these reasons, we have identified the following requirements to be used as a guideline for the development of future features for the methods used during development:

1. The underlying substrate should not include any custom electronic components.
2. The substrate should be painted white to allow for a vibrant surface appearance using the projected SAR system.
3. Light weight
4. Low cost

Following these guidelines, we have extended current TSAR environments to allow the dynamic intuitive manipulation of tangible objects, providing functionality above and beyond existing systems.

5 Concept

We present a system utilising a ferrous coating combined with small magnets integrated into the tangible objects to allow high-fidelity coupling and movement between the object and the substrate. The physical mockup, such as a car dashboard, is created and is then coated in a paint containing ferrous material. Following Thomas et. als' [7] use of 3-dimensionally printed objects, cheap tangible objects of any shape can be created and embedded with a small magnet, allowing attachment of the object to the substrate or to another tangible object.

6 Grouping of tangible objects

In addition to intuitive, dynamic manipulation and placement of tangible objects, groups of tangible objects can be created using a substrate covered with a ferrous material with an attached magnet. Tangible objects can be placed onto the substrate in the desired relative positions, and then the substrate can be manipulated, thus moving groups of tangible objects whilst keeping their relative positions. For example, when prototyping a control system for a car dashboard, the air conditioner controls may be configured into desired relative positions and then the group as a whole shifted relative to the car dashboard. This allows for more intuitive, quick prototyping as compared to current technologies which are cumbersome or manipulate tangible objects as individuals.

7 Conclusion

In this paper, we present a novel concept for improving on existing TSAR rapid prototyping workflows to include non-planar, non-uniform substrates. This concept improves upon existing technologies to enhance the industrial design workflow, allowing the manipulation of both single and groups of tangible objects in a TSAR rapid prototyping environment.

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