Drawing in Space using the 3D Tractus

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ABSTRACT

The 3D Tractus (Latin for drawing, space and movement) is a simple and inexpensive physical interface for intuitive and direct exploration, manipulation and inputting of three-dimensional (3D) data. The interface is a straightforward evolution of the non-computerized drawing board, preserving the drawing board physical spatial affordances and enhancing it by allowing the interactive planar surface to be easily moved along the z-axis. The 3D Tractus maintains direct spatial mapping between the physical and virtual spaces by allowing planar interaction on the surface and sensing its height. Much like the drawing board, the first prototype of the 3D Tractus was designed for sketching and drawing applications. The interface can be useful in various tasks that approach 3D space via two-dimensional (2D) planar interaction metaphors, such as evaluation and analyses of 3D medical imaging data. In this paper we present the 3D Tractus design principles and the implementation of its early prototype.

Author Keywords

Three-dimensional input devices; interaction techniques; tablet; drawing; 3D curve modeling; Magnetic Resonance Imaging (MRI); Computer Assisted Tomography (CAT); CAT; Non-Photorealistic Rendering (NPR); physical interfaces.

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces – Input devices and strategies.

INTRODUCTION

We introduce the 3D Tractus (Latin for drawing, space and movement) a simple and inexpensive physical interface that allows intuitive interaction with three-dimensional (3D) data by directly mapping physical space to virtual space. The 3D Tractus interaction is taking place on a physical planar surface that can be used as both display and input and can be easily manipulated and repositioned in space. Following, the user can simultaneously explore, manipulate and edit data using the two-dimensional (2D) planar surface to slice through 3D space. The interface is based on a planar display and input surface which is sensitive to its height, allowing each point on the surface to be spatially mapped continuously in three dimensions.

We designed the 3D Tractus (Figure 1) as an augmentation of the classic drawing board preserving the affordances of a physical tabletop interface and enhancing it by allowing the interaction surface to be easily translated along the z-axis. This approach restricts 3D free-space interaction and binds it to a 2D plane which can be raised or lowered mechanically in order to slice through different parts of the 3D space. We believe that this limiting interaction theme is useful in several applications, such as 3D drawing and sketching, since it provides tactile support to the user actions and associates them spatially to a static physical reference system.

The first-generation prototype of the 3D Tractus presented here is designed to support 3D drawing and sketching. Specifying curves in 3D is of fundamental importance in modeling and animation systems. 3D curves are important when specifying surface patches, branch structures, skeletal shapes, or when controlling shape deformations. The 3D Tractus supports 3D drawing and sketching using a standard pen-tablet interface or a tablet-PC which is placed upon the height-sensitive surface. The user can draw and input data in 3D space using the pen and can change the z-value of the interaction plane by simply moving the surface

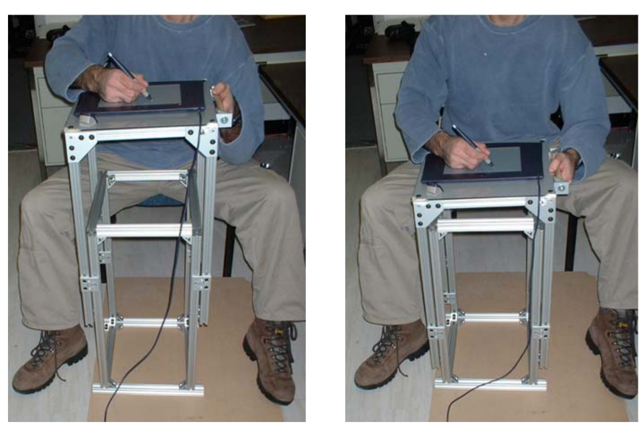

Figure 1. The *3D Tractus*.

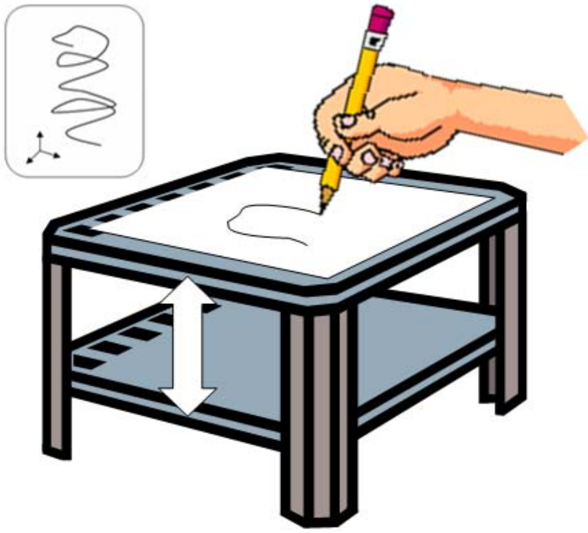

Figure 2. Drawing with the *3D Tractus*.

up or down (Figure 2). This paper discusses the design and implementation of the prototype, but does not present detailed user studies results which we did not perform yet.

BACKGROUND

The 3D Tractus interface we propose should complement existing 3D curve input methods by providing additional flexibility for directly sketching non-planar curves. The user keeps drawing over a 2D tablet, thus leveraging skills that many artists and designers have developed from work with pencil and paper. For the third dimension of the curve, the user simply slides the tablet up or down while still drawing across the tablet. This solves the problem of drawing spiraling shapes and other complex branch structures such as trees and hands.

Curve Input in 3D Space

Existing methods for 3D curve input usually require the user to edit the curve from different viewpoints, as present in modeling systems such as Maya™. Cohen et al. [1] proposed a different approach for specifying 3D curves with 2D input from a single viewpoint. The user first draws the curve as it appears from the current viewpoint, and then draws its shadow on the floor plane. The system correlates the curve with its shadow to compute the curve's 3D shape. The authors observed two main limitations to their approach; first, it can be quite hard to determine how the shadow should look like for complex 3D curves; second, users, even with artistic training, have difficulty drawing 3D spiraling shapes on 2D planar surfaces. McGuffin et al. [13] describe a volumetric visualization tool that includes a tray metaphor for interaction with layered data. However, unlike the 3D Tractus, the tray is a pure virtual entity that does not have a physical embodiment, and is controlled by 2D mouse movements and a set of GUI widgets.

User Interfaces in 3D Space

Interaction in 3D space using a planar surface dates to the Sach et al. early 90s 3-Draw interface [2]. Free-space 3D input devices were designed using 6 degrees of freedom (DOF) tracking of the interaction surface and a stylus, often for Virtual Reality (VR) applications [2-5]. Immersive VR environment provided a visual reference system for these interfaces, so users could view the 3D drawing as part of the VR display. The disadvantages of these methods are the need for comprehensive VR environment and interfaces (such as HMD, shutter glasses, several trackers for the input devices and the user head). We also argue that 3D drawing in free-space might be less intuitive for most users, artists and designers.

The Interaction Table and CAT [6,7] allow direct interaction, navigation and manipulation of VR environments, offering high physical affordances. However, while the interfaces were designed for isotonic orientation control, the translation control is isometric, so physical pressure rather than mechanical movement is converted to translation in the virtual 3D space.

ArtNova and inTouch [8,9] allow direct editing, painting and designing in 3D using a haptic interface, SensAble Technologies' PHANTOM. Interaction is restricted in physical space by the limited force feedback workspace of the PHANTOM arm, and is not following a planar surface interaction metaphor.

The Boom Chameleon [10] uses a touch flat-panel LCD screen mounted on a large counterbalanced arm for spatially aware display, viewpoint and annotation input. The system allows large scale direct mapping of virtual and physical spaces, but as far as we know was not used for 3D drawing.

Unlike free-space 3D interfaces the 3D Tractus closely follows a more intuitive drawing board metaphor, restricting the user to planar, "space-slicing" interaction on one hand and providing a static, physical, drawing board-like reference to the interaction on the other. The 3D Tractus supports isotonic translation control and direct mapping between physical and virtual spaces and is unique in its simplicity and affordability.

IMPLEMENTATION

The 3D Tractus (Figure 1) was constructed with simplicity and affordability in mind and was assembled from off-the-shelf components for a total cost of a few hundred dollars (excluding PC). The 3D Tractus is using a standard pen-tablet interface or a tablet-PC for the planar surface interaction and is "tracking" the remaining DOF, the surface height, using a simple potentiometer-based sensor. The 3D Tractus was designed as a self-contained interface and can be operated by simply placing a tablet-PC on its top and connecting it via a USB connector (other than that, there is no need to supply power or perform calibration).

System

For planar input on top of the 3D Tractus we currently use a standard Wacom pen-tablet [11] although the tablet can be replaced with any tablet-PC. The tablet can be situated freely on top of a mechanical apparatus with no need for calibration or specific positioning.

The mechanical structure (Figure 3, top) was designed and assembled using inexpensive modular aluminum framing components [12]. The structure is designed as a drawing board with the user seated in front (Figure 1). The structure allows easy adjustment of its height using one hand while the other hand can draw or interact with the top surface. The tablet placed on the top surface is quite sensitive and the user does not need to apply considerable pressure on the stylus while drawing on it. The aluminum frame is reasonably light and the resulting sliding action of the top surface is smooth and effortless. The current structure allows 50cm of dynamic range in height adjustment and support medium tablets. However the 3D Tractus design does not restrict the height of the mechanical structure or the size of its top surface; future devices can be as wide and high as the desired.

A key component in our design is a simple sensor for the 3D Tractus height. Rather than using a tracker that will be an overkill given our design approach we sense the surface height using a string pot, or string potentiometer (Figure 3, bottom). A string pot is based on a rotary potentiometer sensor which is attached to a measuring point using a string and an attachment loop, much like a miniature measuring tape. The string pot base is attached to the lower part of the 3D Tractus, and its loop is attached to the adjustable top surface of the interface. Following, when the user changes the height of the 3D Tractus the resistance measured across the string pot will change accordingly. We use a simple external USB 16 bit Data Acquisition Interface to supply 5V voltage to the string pot and for online A/D readings of the string pot's output voltage. A standard Pentium III PC running Windows XP is currently used to host the 3D Tractus peripherals and as the interface display. However, in the near future we plan to replace it with a tablet-PC that will serve as both input and output space for the 3D Tractus actions and will treat the interface as a USB device. In this setting the user will simply place the tablet-PC on top of the 3D Tractus and connect the interface to one of the tablet-PC USB ports to start exploring, manipulating or inputting 3D data.

Application

We are currently looking at the use of the 3D Tractus for drawing tasks involving complex branch structures. We focus on adapting the 3D Tractus as a main interface serving a sketch-modeling system for botanical elements (trees, plant spatial distributions and arrangements) in landscape architecture applications. Figure 4 illustrates the process, where a pen-tablet is placed on the 3D Tractus surface. Red marks represent (x, y) positions of the pen on the tablet and the dashed blue lines the path connecting the

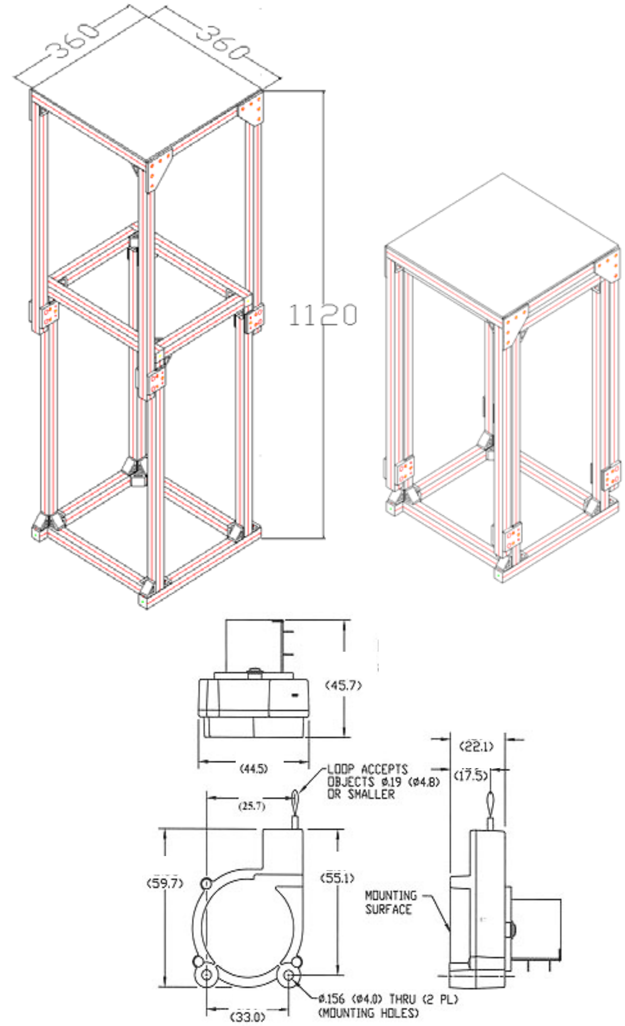

Figure 3. The *3D Tractus* prototype (top), Sensing height with a string pot (bottom). All dimensions are in millimeters.

red marks as the user slides the tablet along the Tractus height. The resulting 3D lines are shown on the right.

FUTURE WORK

Following the early and inspiring work of Hinckley et al. [4] we plan to explore the use of the 3D Tractus in applications involving medical images such as produced by Magnetic Resonance Imaging (MRI) and Computer Assisted Tomography (CAT). These images consist of hundreds of image "slices" through the body. We are exploring ways to use the 3D Tractus to display, navigate and annotate through the 3D volume formed by these images. Figure 5 illustrates our proposed system with a tablet-PC placed on the 3D Tractus surface as an integrated input and output medium. Each slice of the medical image is displayed as the user slides the Tractus surface up and down. The full volumetric model is also displayed with indications of where the Tractus surface is. For this application we also plan to include simple interactive means (such as touchpad, mouse or joystick) for changing the 3D orientation of the data in relation to the 3D Tractus. Following, the user will gain control over the orientation of the volumetric data and will be able to define cutting planes that are not necessarily perpendicular to the Z-axis, without sacrificing the physical affordances of the planar drawing board.

CONCLUSION

We presented a prototype for the 3D Tractus, a simple and inexpensive physical interface affording exploration, manipulation and inputting of three-dimensional data. The 3D Tractus supports one-to-one mapping between the physical and virtual 3D spaces, and follows a drawing board metaphor—exploiting existing skills of users, designers and artists who are accustomed to planar, tabletop interaction.

The 3D Tractus is based on a mechanical structure that enables easy changes of height. The interface senses its height using a simple, potentiometer-based sensor. The 3D Tractus planar interaction is taking place on its top surface using a pen-tablet interface or a tablet-PC.

We are currently pursuing several applications that can benefit from slice-based approach to 3D data, such as sketching of complex tree structures and interactive exploration and analysis of 3D medical imaging data.

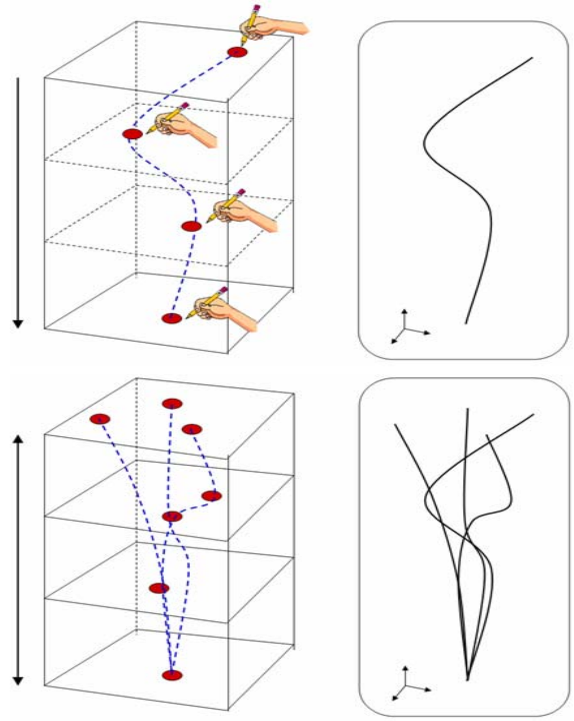

Figure 4. Input of 3D branch line structures with the *3D Tractus*.

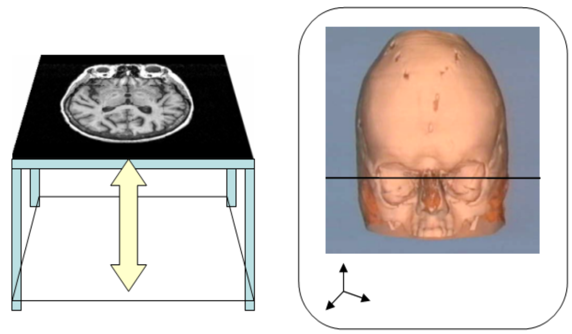

Figure 5. Using the *3D Tractus* for medical imaging.

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