
Tangible Sketching in 3D with Posey

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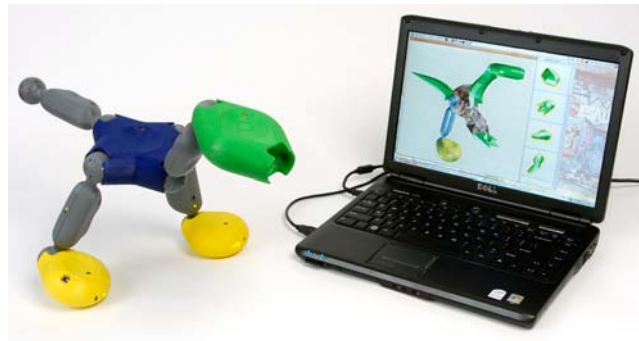


Figure 1. Sketching a woolly dinosaur with Posey Puppet Show.

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Abstract

Posey is a physical construction kit that is instrumented to capture assembly and configuration information and convey it to a host computer. We have used Posey to build applications that deploy a reconfigurable physical model as a tangible interface for various domains. We demonstrate these applications to support a case for computationally enhanced construction kits as a semi-general interaction modality.

Keywords

Construction kit, tangible interaction

ACM Classification Keywords

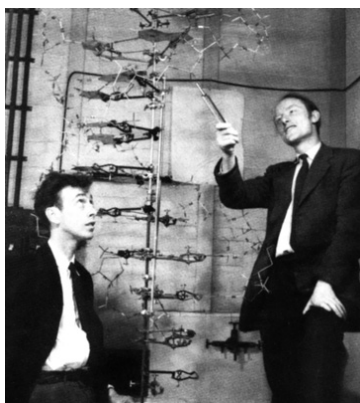
H.1.2: Models and Principles: User/Machine Systems;
H.5.2: Information Interfaces and Presentation: User Interfaces: Interaction Styles.

Introduction

Educators inspired by the tradition of *manipulatives* established by Fröbel [1] have spent nearly two centuries searching for simple, powerful abstractions for the tangible expression of spatial relationships. Each kit provides an intuitive medium that affords representing a class of spatial relationships: Fröbel's kit of wooden blocks lends itself to stacking and tiling; Erector girders and panels to exploring structure and containment; and Tinker Toy sticks and wheels to graph representation. Manipulating these kits, children



Educator Friedrich Fröbel's kindergarten gifts included a set of modular wooden blocks.



Tangible models in chemistry: Chemists Crick, Watson, and Franklin built models to understand the double-helix structure of DNA.

can quickly represent a variety of forms in a sort of 3D sketch. By instrumenting a physical construction kit we can augment the kit with a computational back end, supporting physical model-making with simulation, database retrieval, and interactive behavior. The model-making is quick rather than time consuming, and the models are abstract and disposable rather than specific and precious representations of a domain; we think of the activity as three-dimensional sketching.

To create Posey [9] (Figure 1), we instrumented a hub-and-strut kit to send information on the way the kit is manipulated to applications on a personal computer. Posey's hubs and struts lend themselves to specifying graph structures. By building applications that accept input from Posey we demonstrate that tangible sketches are an intuitive, versatile and powerful interface for specifying spatial information for a variety of domains: for character modeling and animation with Puppet Show; for organic chemistry with Molecule Explorer; and for a finite state machine with Escape Machine [10].

In the following section we briefly describe these applications. We then describe the instrumentation we have developed to capture the changing state of a model made with the kit. Next we contrast Posey with other tangible interface construction kits. We conclude with a discussion of what we have learned in developing the kit and observing people interacting with it, and directions for future work.

Applications

We built Posey as a hardware / software platform for building construction kit applications. To test whether Posey can serve this role, we have (so far) built several

demonstration applications. Our focus is the construction kit and not the specific applications; nevertheless in formal and informal testing we found that these three applications are quite usable by children and adults.

Puppet Show

Children can use Posey's hubs and struts as a construction kit to build puppet skeletons (Figure 1). Once a skeleton is made, a child can skin it as a computer graphics character. The child uses an on-screen menu to associate body parts (of a teddy bear, a dinosaur, etc.) with the Posey hubs and struts, and then manipulates the Posey model to animate computer graphics characters on screen. The screen graphics are updated with every change to the Posey model, providing a tangible direct-manipulation interface to the puppet show application.

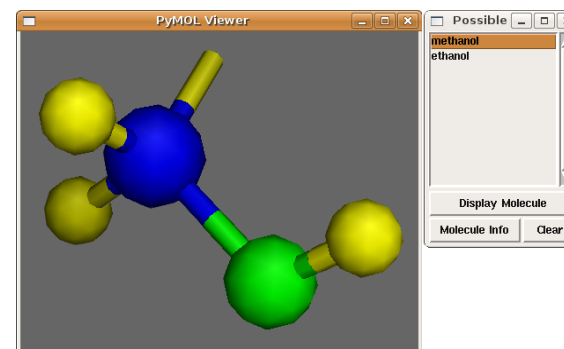
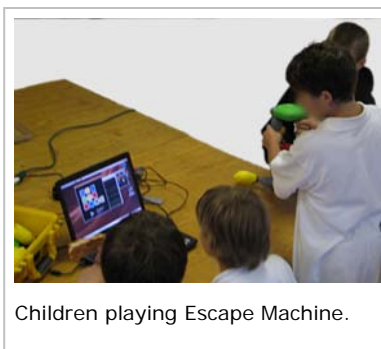


Figure 2. A model of methanol in the Molecule Explorer.

Molecule Explorer

Organic chemists use physical models of molecules to tangibly display the spatial structure of atoms and their bonds. In the Molecule Explorer application Posey's

hubs and struts represent atoms and bonds. Molecule Explorer monitors the model that the user makes with Posey and displays a 3-D view of the molecule under construction (Figure 2). It also matches the Posey model against a library of organic molecules, displaying the list of retrieval hits on screen; and the user can indicate to the Molecule Explorer which molecule is being attempted. Molecules in the library are also linked to Wikipedia entries, providing additional information about the molecules.



Children playing Escape Machine.

Escape Machine

A “bizarro” (alternate universe) version of the traditional Pac-Man computer game challenges users’ wits. The game characters (ghosts and Pac-Man agents) move in a maze of colored rooms according to a state machine that is defined by a Posey configuration (see Figure 3).

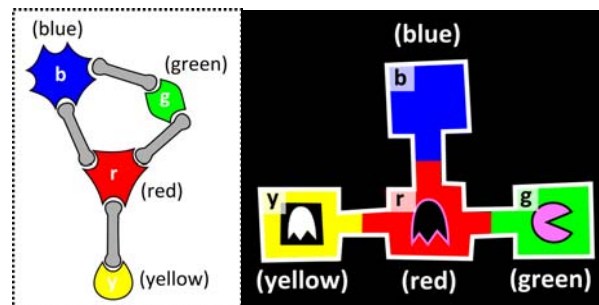


Figure 3. Escape Machine uses a Posey model as a state machine to control the movement of characters in a Pac-Man maze. (For clarity the figure shows only a small sample maze; in the game a maze has many more rooms).

The colors of the Posey hubs correspond to the colors of the maze rooms, and characters can only move between neighboring rooms if the correspondingly

colored hubs are adjacent in the Posey state machine. To play the game users pull the Posey model apart and put it back together in different configurations and reorient it in space. The pace of this puzzle game is slow as players must project the effects of different state machine configurations on the ghosts and Pac-Man players.

Instrumentation

Posey’s plastic hubs and struts (Figure 4), printed on our fused deposition model printer snap together and pull apart using ball-and socket joints. The joints allow considerable angular movement yet they are designed to hold a position that the user sets. The hubs and struts detect and communicate connect and disconnect events and angle-change events through optical couples in each ball-and-socket joint. Eleven infrared LEDs in each end of each strut blink a unique identity code; four light sensors (phototransistors) in each socket sense blinking LEDs (Figure 5).

The particular combination of which sensors see which LEDs is collected by an onboard (ATMega 168) microprocessor and transmitted wirelessly (Zigbee) to the host PC, which uses a lookup table to determine which hub is connected to which strut, as well as their three-dimensional angle. A 3-D accelerometer in one of the hubs provides a gravity vector, and this enables the software to orient the internal computer model as the user moves and manipulates the physical model. Figure 5 shows the hardware inside a two-socket hub.

Technical details of the instrumentation and the software API are described in [9].



Figure 4. Posey consists of hubs and struts that connect in ball-and-socket joints that are instrumented with an optocoupler.

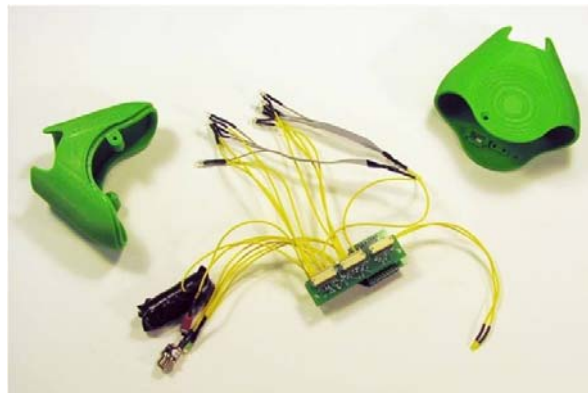


Figure 5. Inside each Posey hub are phototransistors (4 per socket), battery and a microprocessor and Zigbee transceiver mounted on a custom circuit board.

Related Work

Posey belongs to the growing genre of computationally enhanced construction kit tangible interfaces that include the well-known Topobo [7], Senspectra [6], and Triangles [3] kits. Among others are Buechley's Boda Blocks [2] and some interesting relevant older work reviewed by Sutphen et al [8]. These kits vary along several dimensions: whether they are stand-alone or serve as an interface to a host computer; whether they are 2-D or 3-D; whether they capture and report dynamic geometry of the physical model; and whether they afford input only or both input and output.

For example, Topobo's constructions directly capture and replay motion, but do not sense the full topology of the model. So while Topobo is a compelling example of the power of 3-D sketching interfaces, it is not instrumented to provide the information needed to serve as an interface to applications on a host computer. Senspectra captures the connectivity of its hubs but only captures geometry indirectly (through strain). It uses colored LEDs to display information directly on the kit's parts. Triangles captures information about the 2-D configuration of pieces (but not 3D), and captures connections but not the dynamic geometry. Posey occupies a unique point in this space in that it captures both the topology and the dynamic geometry of 3-D models that users make with the kit and transmits this information to a host computer on the fly.

Discussion and Future Work

Although advances in electronics and physical prototyping have made it much easier to build tangible interfaces like Posey that employ embedded sensing and computation, development is still a major

undertaking. Highly specific tangible interfaces will be appropriate only when the application is either widely used (such as in consumer electronics) or low volume but mission critical (e.g., air traffic control). But for other applications the cost and effort of building tangible interfaces can be daunting.

One approach is to provide tangible interface-building kits such as Phidgets [4] and d.tools [5] that enable designers and developers to quickly prototype new interfaces. These kits make it easier for a developer to configure a physical design with sensors and actuators and connect them to an application on a PC that simulates the standalone tangible interface. In contrast to designing a highly-specific interface, these prototyping tools enable a developer to experiment quickly with a tangible interface design. Still this requires considerable attention to the details of hardware embedding and physical design, and the object of this process is to arrive at a design for a single specific device and application.

Another approach, the one taken with Posey, is to try instead to design a construction kit that offers specific affordances that can support 'sketching' in a range of domains. Using a single physical kit with embedded hardware a developer can implement interfaces to various applications. Posey, for instance, is appropriate for domains that can be modeled as a graph, especially when the geometry of the nodes and edges is relevant in addition to the graph connectivity. By getting the abstraction right, a *semi-general tangible interface* like Posey can offer a middle ground for building interfaces for sketching in 3D.

Acknowledgements

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