Mechanix: An Interactive Display for Exploring Engineering Design through a Tangible Interface

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ABSTRACT
Mechanix is a low-cost, interactive system for children to design and explore mechanical systems using computer-vision-tracked, magnetic components. It employs a semi-transparent magnetic surface that supports the placement and tracking of magnetic simple machine pieces and acts as a projection screen. A back-mounted webcam captures the position of the pieces using visual tags, while a projector depicts virtual components in user-generated challenges and solutions. Designed as a museum exhibit and grounded in constructionist learning theory, Mechanix combines a virtual library of user-generated content with a tangible interface to enable asynchronous and synchronous interactions.

Author Keywords
Tangible interfaces, constructionism, simple machines

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: User Interfaces: K.3 Computers and Education

General Terms
Design.

INTRODUCTION
Discovering physics principles underlying simple machines helps children appreciate how things work, inspires them to engage in creative design, and encourages analytical thinking. We introduce Mechanix, an interactive display for engaging children in learning about mechanical systems through the use of tangible, simple machine components. These components are arranged on a vertical magnetic surface while a webcam behind the surface tracks the position and orientation of the pieces to provide feedback and record new designs. Designs are added to a library of user-generated challenges and solutions that may be projected onto the surface during subsequent use, enabling new users to learn from past examples.

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The design of Mechanix emerged from a review of museum-based engineering installations, which revealed four opportunities for design: **(1) Lower cost**: Similar exhibits use large displays and expensive touch surfaces [4]; Mechanix uses a low-cost LED projector, webcam, and a magnetic mesh. **(2) Combining tangible and on-screen interaction**: Many installations rely solely on on-screen interaction [2] despite evidence that tangible interfaces offer a more engaging entry point for children to learn about engineering [3, 8]. Mechanix supports learning through tangible simple machine components and virtual projections of user solutions and formal tutorial content. **(3) Trackable, open-ended design challenges**: Existing methods for teaching about simple machines tend to rely on scripted curricula, which limit opportunities for children to create their own designs. Mechanix allows for free-form construction and, due to its built-in tracking system, scaffolds designs with recommendations to help learners. **(4) User-generated content to facilitate learning:** With traditional construction kits such as LEGOs, children often do not have immediate access to others' work and resort to using external references such as online forums. The Mechanix library of exemplars enables novices to view and test others' examples while constructing their own designs.

Figure 1. Middle school students using Mechanix.

LEARNING THEORY
Mechanix is informed by constructionist and social constructivist learning theories. Social constructivism [7] suggests that learning can be augmented via socially mediated scaffolding; interaction with a more experienced peer can help

realize the learner's full cognitive potential. Mechanix incorporates this principle in two ways: (1) By using a large visual display and multiple tangible parts, it invites simultaneous involvement among users of varying skill levels, and (2) it enables asynchronous access to user-generated challenges and solutions. Mechanix is also aligned with a main tenet of constructionism: learning happens best in a context where the learner is consciously engaged in constructing a public entity that can be discussed, examined, and admired [6]. As children gain familiarity with the tangible components, they combine and test them in an exercise of personal knowledge construction by generating unique solutions to the challenges. This public expression of ideas makes them concrete, which refines corresponding knowledge structures [1].

HARDWARE

The primary interface for Mechanix is a toolkit of tangible magnetic components arranged on a semi-transparent vertical display. The vertical surface is composed of projection material, a steel wire mesh, and acrylic backing. The wire mesh was designed to be fine enough to allow image detection but dense enough to enable a strong magnetic grip. All graphics are back-projected onto the display. The Mechanix toolkit consists of magnetic components and command pieces. Each component represents a particular type of simple machine, such as a wheel and axle or inclined plane. Command pieces are used to save and view challenges. Each magnetic piece has a fiduciary marker on the back, enabling a camera behind the screen to detect the location and orientation of each component. A Java-based system employing the reacTIVision library [5] processes the camera input to record simple machine configurations and respond to commands.

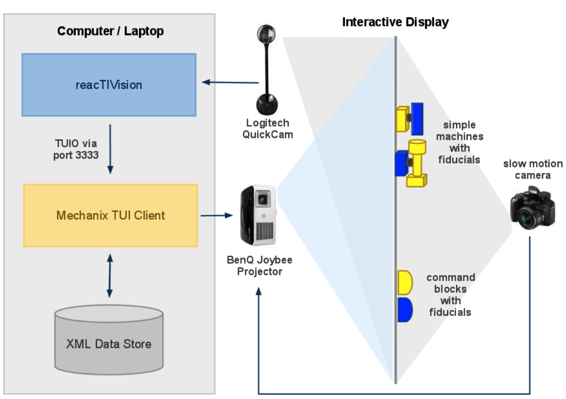

Figure 2. System overview.

INTERFACE DESIGN

When users approach the wall, they are invited to "Take a Challenge" by placing the corresponding command piece on the wall and rotating it to cycle through user-generated challenges containing mandatory start and end pieces. After selecting a challenge and lining up the initial physical components with their projected images, children freely arrange the remaining simple machine components to guide a physical ball from start to finish. When a successful design has been completed, the user is able to save the design to the library of exemplars. If a user needs help, she can access prior solutions from the library. The "View a Solution" piece may be rotated to cycle through all saved solutions, while "# of Pieces" can be rotated to slowly reveal the components in a solution. With this design, children are able to recreate and test others' solutions, enabling asynchronous social learning. Once a user has saved a design, she is invited to create challenges for others to solve.

CONCLUSIONS & FUTURE WORK

Mechanix presents an engaging experience for a variety of age groups. One recurring issue, made evident by our informal user studies, is that children would like to leave a personal touch on their design; a tagging system is being developed to enable children to express ownership in this way. New methods for users to interact with their designs after leaving the museum is another key element being explored. One proposed idea is to link a challenge with an email address so that a user can be notified when others have created solutions to their challenges. Finally, the Mechanix toolkit represents only one application that may be achieved by the described framework. Future work includes abstracting and defining the generic framework in order to develop novel interactive toolkits for learning topics ranging from musical composition to optics.

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