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Citation: Tseng, Tiffany, Robert Hemsley, and Mitchel Resnick. "Replay." Proceedings of the 11th International Conference on Interaction Design and Children - IDC '12 (2012), June 12-15, 2012, Bremen, Germany, ACM. p. 320-322.

As Published: <http://dx.doi.org/10.1145/2307096.2307156>

Publisher: Association for Computing Machinery

Persistent URL: <http://hdl.handle.net/1721.1/92410>

Version: Author's final manuscript: final author's manuscript post peer review, without publisher's formatting or copy editing

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Re•play: A Self-Documenting Construction Kit

Tiffany Tseng
MIT Media Lab
75 Amherst St., E14-445C
Cambridge, MA 02139
ttseng@media.mit.edu

Robert Hemsley
MIT Media Lab
75 Amherst St., E14-348C
Cambridge, MA 02139
hemsley@media.mit.edu

Mitchel Resnick
MIT Media Lab
75 Amherst St., E14-445A
Cambridge, MA 02139
mres@media.mit.edu

ABSTRACT

Re•play is a self-documenting construction kit for children to both share their designs with others and reflect on their own design process. Re•play consists of a set of angular pieces that can sense their connection and orientation. A virtual model is rendered in real time as a design is constructed, and an on-screen playback interface allows users to view models from multiple perspectives and watch how a design was assembled. This paper describes the early development of Re•play and describes potential directions for the documentation of physical designs.

Categories and Subject Descriptors

K.3.1 [Computers and Education]: Computer Uses in Education

General Terms

Documentation, Design

Keywords

Construction kit, documentation, design process, reflection

1. INTRODUCTION

Physical manipulatives have remained a popular and effective way for children to engage in design and express themselves creatively. In particular, with modular construction kits such as LEGO bricks, children can build almost anything from their imagination. A clear advantage of these construction kits is their ability to support a wide range of designs, enabling children to build a variety of different models using the same basic set of building blocks. However, in the construction of new designs, old models are often deconstructed, and these old designs are usually lost, or at most, captured with a single photograph. Although photographs can be taken from multiple perspectives, it can be quite difficult to reconstruct a model with only a photograph of its surface features.

What if the construction kit could document how it was put together and provide a blueprint so that children can easily share their models with others in higher fidelity? Furthermore, what if the construction kit could not only capture a final design but also how it was constructed? Such a construction kit would facilitate the sharing of physical designs and could introduce opportunities

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IDC '12, June 12–15, 2012, Bremen, Germany.

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for remixing with physical artifacts. Additionally, documenting children's construction process creates opportunities for children to reflect on their own design strategies.

Re•play is a self-documenting construction kit that generates a virtual model of itself in real time as it is being built (Figure 1). The virtual model can then be viewed through a software interface that enables one to watch how the design was constructed, view the model from multiple perspectives, and view an instruction-guide-like sequence of steps for reconstructing the model.

The Re•play construction kit seeks to encourage playful creation and thoughtful reflection through the following design principles:

1. Enable seamless ways for children to capture their designs in a meaningful way, both so that the design can be added to their own portfolio of work and to make it easy for them to share their designs with others
2. Create opportunities for children to reflect on their own design process by capturing how they construct their models
3. Encourage children to explore and learn from each other by providing a platform to view and remix each other's designs
4. Allow for the described documentation capabilities with a construction kit that is also generative, enabling a wide range of designs

The ultimate goal of the project is to establish a physical construction kit and community that facilitate the sharing and remixing of children's creations in a similar fashion to how programmers share and reuse others' code. This paper discusses the design development of the first and second goals listed above, namely the design of the physical construction kit and software interface for viewing designs.

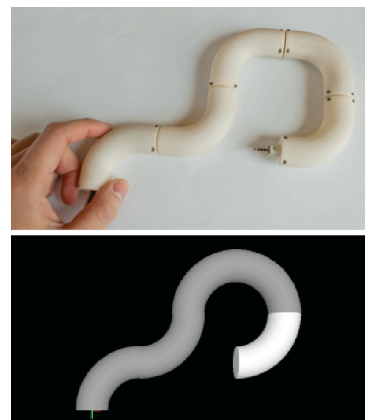


Figure 1. Re•play physical toolkit and corresponding virtual model

2. RELATED WORK

2.1 Construction Kits

There are several examples of tangible construction kits that create virtual models, but existing systems have different goals than Re•play. Most of these toolkits use tangibles as a computer-interface. For example, Posey is a hub-and-strut construction kit that can be used as a direct interface for on-screen applications such as chemical modeling or puppet show animations [9]. Unlike Re•play, the focus of Posey is on using the tangibles to control actions on screen, and the hardware constrained the toolkit to a few large pieces. With Re•play, users focus completely on building the physical model while the virtual modeling is built in the background; the computer is only used afterward for playback of the construction process. Easigami is a tangible tool for creating 3D models using polyhedral building blocks; the topological configuration of the pieces is sent in real time to a host computer, enabling users to more easily construct virtual models [2]. Triangles is a tangible construction kit consisting of triangle-shaped primitives that can be combined to support the design of non-linear narratives [1]. A final example of a construction kit that generates a three-dimensional virtual model is Activecube [8], which consists of blocks that can sense their connections to other blocks in the system. However, the Activecube is limited by its simple geometry since it can only be used to create models consisting of linear, cube-shaped building blocks. Furthermore, scalability is an issue as models are built with only a handful of blocks. All of the described construction kits create virtual models to capture the final design; none of them document the construction process for learning and reflection.

Computationally enhanced construction kits such as LEGO Mindstorms and Topobo enable more complex constructions by introducing many pieces of various shapes [4, 5]. However, they do not dynamically capture the configuration of the pieces, making it difficult to capture exactly how a design was assembled.

2.2 Example-Based Communities

Online communities for sharing designs are common for programmers. For example, on the Stack Overflow website, users can share their code in response to others' programming questions [7]. More specifically for children, the Scratch programming environment enables children to create their own interactive media using a drag-and-drop programming language [6]. The programming environment is complemented by an online community in which children can share and download each other's projects. Through the Scratch website, children learn from one another: They can learn how others use particular blocks by downloading their projects, and they can get inspired by what others in the community are creating by viewing shared projects on the website. Additionally, they have the opportunity to showcase their own work through online galleries.

There are also online communities for sharing projects made in the physical world. Perhaps the most popular example of this is Instructables, where users can describe how they made projects ranging from food recipes to hardware projects [3]. Through Instructables, users can upload text, photos, or video to describe their projects. However, it can be more difficult to determine exactly what someone did because, unlike code, the design is not necessarily embedded in the documentation; for example, a photograph of a coffee table may not necessarily convey how to create the necessary miter joint needed to construct it. Although a self-documenting toolkit is necessarily more constrained than

most projects on Instructables, it is a step toward creating materials with embedded hardware designed specifically for documentation. The principles developed in the design of Re•play may potentially be applied to better design documentation tools in other domains.

3. TOOLKIT

3.1 Tangibles and Hardware

The Re•play construction kit consists of a set of angular, plastic pieces that can be connected in a chain. Each piece has one degree of freedom and can rotate 360 degrees at each connection. The pieces are connected using an audio jack and connector coupling. The audio jack in each piece is physically coupled to a potentiometer that measures the piece's orientation. The pieces each contain a microcontroller and communicate using an I²C protocol; the master is connected directly to the computer via USB and transmits the sensor values from the slaves to the computer through serial communication.

3.2 Software Interface

The software interface consists of a recording and playback application. The application records how the model is put together and creates a virtual model of the assembly in real time. Each session with the construction kit can be saved and opened for playback (Figure 2). With the playback interface, one can watch how the model was built using a movie-player-like timeline that enables rewinding, fast-forwarding, and pausing. One can rotate or zoom in on the model at any point by using a mouse. Finally, tags are automatically marked on the timeline and indicate when a new piece was added to the assembly. In this way, the user can progress through the construction using steps similar to an assembly guide. The application was created using Processing.

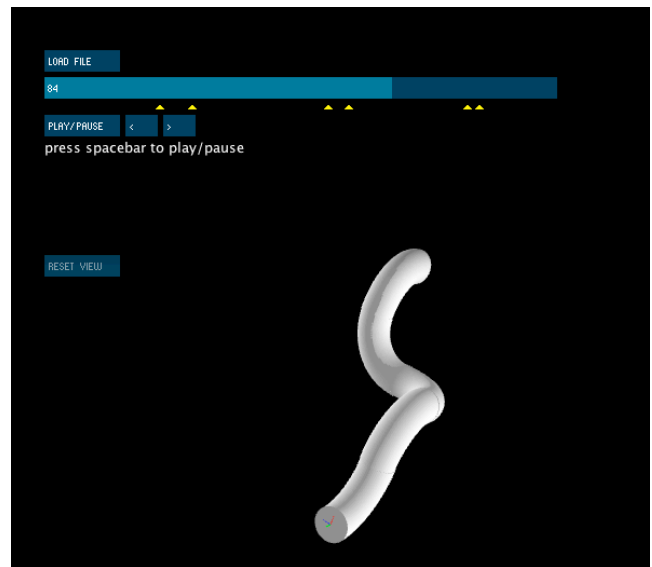


Figure 2. Playback interface with timeline for fast-forwarding and rewinding through documentation.

4. FUTURE WORK

The immediate next step is to observe how children interact with the toolkit and how they react to viewing the construction of their design through the playback interface. Testing with children will

reveal usability issues as well as opportunities for improving the design of the toolkit.

To create a more generative toolkit, different types of pieces are being designed. In particular, a cube-shaped piece that enables building at multiple angles is in development.

Finally, the design of an online community for sharing and remixing models made with Re•play is underway to enable children to share their designs with others online.

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