

Stud/O: Positioning Toy-block Only by Projection



Figure 1: Overview of the system. Projecting assembly procedure of the model designed by the LEGO building software.

Natsumi Hashimoto
Ochanomizu University
2-1-1 Otsuka, Bunkyo-ku,
Tokyo
112-8610, Japan
hashimoto.natsumi
@is.ocha.ac.jp

Itiro Sii
Ochanomizu University
2-1-1 Otsuka, Bunkyo-ku,
Tokyo
112-8610, Japan
sii@acm.org

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.
UbiComp/ISWC '15 Adjunct, September 7-11, 2015, Osaka, Japan.
Copyright is held by the owner/author(s). Publication rights licensed to ACM.
ACM 978-1-4503-3575-1/15/09.. \$15.00.
<http://dx.doi.org/10.1145/2800835.2800877>

Abstract

Projection mapping uses a compensation technique to project images correctly on 3D buildings or real-world objects rather than on ordinary flat projection screens. In this study, we reverse this procedure in order to assist with toy block assembly and scanning methods. In order to assist with toy block assembly, our "Stud/O" system projects round markers on the studs of a target toy block to indicate the mounting position and direction of the block. When a user places a block in an appropriate location, the stud areas are illuminated exactly, without distortions. These markers are also useful when a user wants to disassemble his/her toy block work to scan the structure. This is an effective and practical system that uses only a projector. In addition, because the user manually adjusts the positions during the assembly and scanning task, no sensing devices to detect the position of the user and toy blocks are required.

Author Keywords

Stud/O, projection mapping, LEGO toy-blocks

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation (e.g. HCI)]: Interaction styles (e.g., commands, menus, forms, direct manipulation).

Overview

Stud/O is a computer system that supports the assembling and scanning of a LEGO model with a cheap, small, and lightweight projector. As shown in Fig. 1, a projector¹ is placed on a working table to project computer images on the tabletop. The projector is connected to a PC², that runs the application program we developed using by Processing 2³. A wireless mouse with two buttons and a scroll dial is used to operate the application.

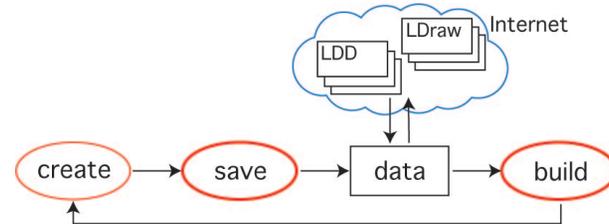


Figure 2: Stud/O can build toy blocks and also save models as data.

Stud/O has two functions to assist the assembling and 3D-scanning of blocks. The 3D-scanning function would be of benefit to users who enjoy creating their own LEGO work. As shown in Fig. 2, users can create their LEGO work and “save” the work by 3D-scanning all of the blocks to a computer file with a standard LEGO construction format. The saved data can be used when users want to re-start their creative building, or when they want to share their work on the Internet. The assembling function would be of benefit to all LEGO lovers including those who enjoy block kits. Users can easily “build”

¹Sanwa Supply Inc. 400-PRJ014BK. DLP(Digital Light Processing). Light source is LED, 85 lumens.

²MacBook Pro. Mac OS X 10.9.4

³<http://www.processing.org/>

block-work from distributed or saved block data. After building their saved work, creative users may want to remodel the work by using their hands, and save the result again by 3D-scanning the block-work.

Positioning by projection

Many commercial projectors have offset optical axes. For this reason, except for the center-bottom point of the projecting area, the projected rays of light are slanted and a position adjustment is required to project the image correctly onto a surface of different height on the table. Our program tries to project markers exactly onto the studs by adjusting the size and location based on the location and heights of the blocks. The program presents the location for blocks based on correctly or incorrectly projected markers.

In the assembly function, our Stud/O projects round markers onto the top of the LEGO studs of blocks or to the baseboard from the projector located above the working table, and indicates the locations where users should place blocks. This is shown in Fig. 3. In this example, the application indicates that a 2 × 2 sized block should be placed at the center. Figure 3(a) shows the projected result before a user places a block. The top surface of the baseboard on which the studs are positioned is illuminated with white round markers by the projector exactly, except for the 2 × 2 studs at the center. However, when the user places a block in the location in which the projection is shifted, the round markers are correctly projected onto the corresponding points on the assembled block, as shown in Fig. 3(b).

In the scanning function, the projection offset of the white round markers is also used to measure the height of each block when a user removes it one by one.

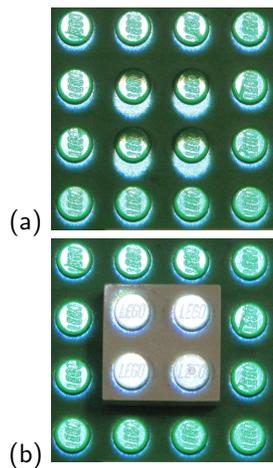


Figure 3: Projecting round markers to LEGO studs. (a)Projection to central four studs is shifted. (b)When the user places the block in an appropriate location, four studs are exactly illuminated without distortion.

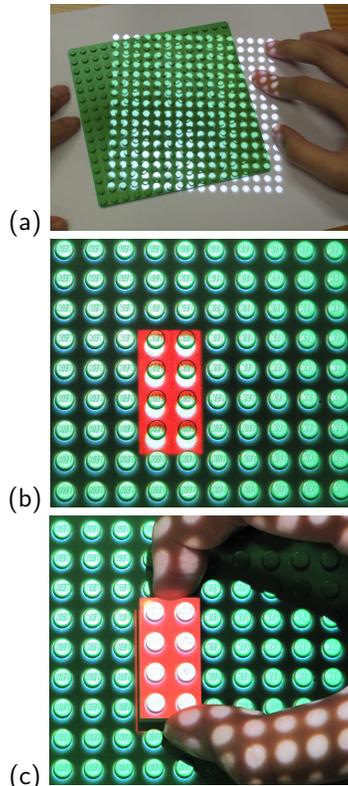


Figure 4: The LEGO assembly procedure by StudI/O: (a) the user positions a plate, (b) instructions for a block position, and (c) the user sets a block.

StudI/O

When a user starts the system for assembling blocks, the projector projects white round markers on the tops of the studs of the baseboard. As shown in Fig. 4(a), the user places the baseboard on a desk so that all studs are correctly illuminated by the projected round markers. No sensing devices to detect the position of the user and blocks are used in this system; only a projector that projects instructions about the procedure is used. The system allows the user to adjust the position of the baseboard manually. When the user clicks on the mouse, the system indicates the location for the next block to be assembled (Fig. 4(b)), and the user assembles blocks from the bottom to the top layer successively (Fig. 4(c)). In Fig. 4(b), for easier positioning, a highlighted rectangle indicating the target block is displayed next to the markers projecting to the studs. Once the user places the correct target block in the correct place, as shown in Fig. 4(c), all of the markers start to illuminate the tops of the studs precisely. Users can easily confirm that they have correctly placed the right block, by checking the correctly illuminated studs. After placing a block, the user clicks on the mouse again. Then the system indicates the location for the next block to be assembled. This cycle repeats until the block-work is completed.

Besides the above-mentioned function of assisting LEGO assembly, StudI/O uses the same setup shown in the Fig. 1 for the 3D scanning of existing LEGO work. In this method, a user records size and location of each block by removing it one by one. The similar method using the projection of round markers on studs, is employed in the scanning function. Before removing a certain block, he/she record the size and 3D position of the block, by adjusting the projected markers so that they exactly illuminate studs of the target block.

Data Structure

To represent LEGO blocks for assembly and scanning by our system, we used LDraw⁴ which is an open-standard data format for a LEGO design program. From the LDraw data representing LEGO projects, StudI/O calculates the coordinates of each stud and projects a marker onto it, in the assembly function. In the scanning function, specified blocks and their 3D positions are saved in a computer file in the LDraw data format. The LEGO company also offers a widely used free software program called LEGO Digital Designer (LDD)⁵, and many LEGO projects are shared in LDD format. The difference between the LDD and LDraw data formats is not considerable, and conversion functions are commonly provided. Therefore, a user can produce a LEGO project using widely shared LEGO data that are prepared by these common LEGO design programs.

Evaluation

In order to confirm the practicality of StudI/O, we conducted two user tests for the assembly function and scanning function, respectively. We asked four graduate students (females, in their 20s, majoring in computer science) to assemble and scan LEGO blocks. In the assembly function test, we compared our system with conventional paper-based instructions. In the scanning function test, we compared our system with operations using the free computer software package LDD. All participants completed the assembly and scanning tasks with our system in 60% and 50% of conventional methods, respectively. We also confirmed that our system is easy to use, is able to work with few burdens compared both with paper-instructed assembly and graphical user interface (GUI)-based capturing.

⁴<http://www.ldraw.org/>

⁵<http://ldd.lego.com/>

Related work

Many studies have been conducted on systems that support construction tasks by projecting information about the real world using a projector. FabNavi[3] used a projector and a camera positioned above the work table and projected assembly procedures onto the table surface. By projecting parts to be used in an assembly task in their actual size, a user can assemble while comparing the projected part with the real one. Tojo et al[1] developed a remote-work support system by projecting distorted images onto a real-world object. Rivers et al [2] proposed a method that allows users to create an accurate clay replica of a digital 3D model. Rivers used a projector-camera pair to scan a work in progress, and then projected multiple sets of instructions onto the object. These systems use computer-vision techniques to detect objects, and require cameras and calibration processes.

Many methods and devices that create 3D data are in practical use. Three-dimensional computer-assisted design software, including LDD, uses a keyboard-and-mouse combination to manipulate 3D models on the computer screen, but these operations are generally difficult for novices. A 3D scanner such as Artec3D⁶ can capture the 3D information of an object when a user holds it and moves it around the target object. Although the 3D scanning process is easy and intuitive, nondestructive 3D scanning does not provide the internal structure of objects such as the block position inside LEGO projects. Our StudI/O, which uses destructive scanning, can capture the information of internal blocks.

The uniqueness of our system compared with previous studies is that we project markers onto characteristic parts (i.e. studs) of the assembly and scanning. This simplifies

the task for users to detect slight differences between the positions of target parts and correct positions as defined by the assembly manual. This method requires only a projector and PC and effectively supports 3D LEGO assembly and scanning.

Conclusion

We proposed a system to support 3D positioning using projection and implemented it in the support of LEGO block assembly and scanning. Our StudI/O system projects round markers onto the surface of studs of a target LEGO block. In the future, we will improve our system by displaying additional instructional information to support more effective assembly and scanning. Providing attractive audio and visual effects projected onto the block surface when parts of the assembly are completed will motivate young children. Furthermore, we plan to explore the possibility of deploying of our system for the assembly and scanning of block toys other than LEGO blocks.

References

- [1] Shinsaku Hiura Kenji Tojo and Seiji Inokuchi. 2002. 3-D Tele-direction Interface using Video Projector. *Transactions of the Virtual Reality Society of Japan* 7, 2 (2002), 169–176.
- [2] Alec Rivers, Andrew Adams, and Frédo Durand. 2012. Sculpting by Numbers. *ACM Trans. Graph.* 31, 6, Article 157 (Nov. 2012), 7 pages.
- [3] Koji Tsukada, Keita Watanabe, Daisuke Akatsuka, and Maho Oki. 2014. FabNavi: Support system to assemble physical objects using visual instructions. In *10th Fab Lab annual meeting*.

⁶<http://www.artec3d.com>