StudI/O: Locating Toy Blocks by Projection

Natsumi Hashimoto
Ochanimizu University
Bunkyo, Tokyo 112-8610,
Japan
hashimoto.natsumi@is.ocha.ac.jp

Itiro Siio
Ochanimizu University
Bunkyo, Tokyo 112-8610,
Japan
siio@acm.org

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 "StudI/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. Before removing a certain block, the user can record the size and 3D position of the block by adjusting the projected markers so that they exactly illuminate the target block.

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
StudI/O; projection mapping; LEGO toy-blocks; human factors.

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

INTRODUCTION
The toy block (i.e., LEGO® block or simply "block") was first created as a toy for children to improve their creativity and imagination in the assembling of models. After a short period, LEGOs were also sold as a kits containing parts and instructions related to a specific model. Both children and adults began to enjoy assembling models from block kits.

ACE'15, November 16–19, 2015, Iskandar, Malaysia.
Copyright 2015 ACM 978-1-4503-3852-3/15/11...$15.00.
http://dx.doi.org/10.1145/2832932.2832974

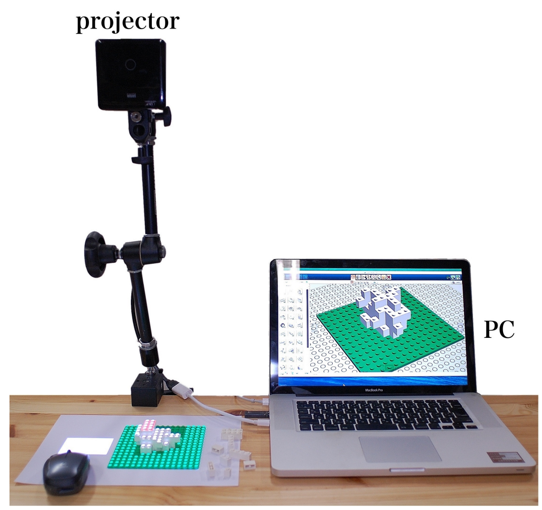


Figure 1. Overview of the system. Projecting assembly procedure of the model designed by the LEGO building software.

However, assembling blocks while reading written instructions is complicated and troublesome for many beginners and impedes their progress in creating sophisticated models and art works.

On the other hand, traditional LEGO enthusiasts prefer creative LEGO construction from the scratch. Some of them use computer applications to digitize their LEGO work and to share the data on the Internet. But, creating a construction data from existing LEGO work is also complicated and troublesome.

Systems have been studied that support the assembly of 3D objects such as machines or the furniture. In many cases, these studies often use a head-mounted display (HMD) or a hand-held display such as a smartphones to present computerized instructions virtually over the working scene, which is captured by an embedded video camera. In addition to HMDs and handheld displays, projectors are also used to display instructions in some computer-aided assembly systems. Projecting images of the real world is also done in the art and entertainment fields using a method known as "projection mapping". Projection mapping uses a compensation technique to project images correctly even on 3D buildings or real-world

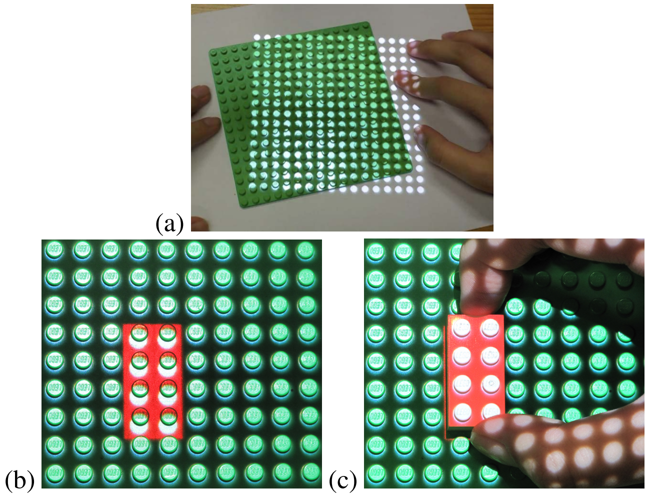


Figure 2. The LEGO assembly procedure by StudI/O: (a)the user posithions a plate, (b) instructions for a block position, and (c) the user sets a block.

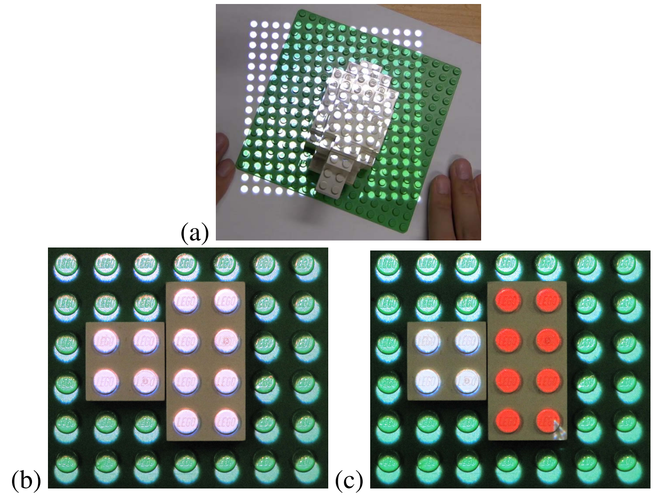


Figure 3. Scanning LEGO procedure by StudI/O: (a)the user posithions a plate, (b)adjusting the height, (c)specifying the size and location.

objects rather than on ordinary flat projection screens. We reverse this procedure to provide toy-block assembling instructions and a destructive 3D scanning function for a user. Our "StudI/O" system projects round markers on studs of a target toy block to indicate the mounting position and direction of the block and to record the size and location of each block.

STUDI/O

StudI/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 Figure 1, a projector is placed on a working table to project computer images on the tabletop. We use a small projector [1] that projects an 854 x 480 pixel image on a screen located 20 to 300 cm away. The projector is positioned 48.5cm above the working table and employs an adjustable arm. The projection area from the table is 30.0 x 16.8cm with this setting. The application can position blocks inside the pyramid formed by the projection area and the projector. Larger and higher block-work can be handled by setting the projector at a higher position. In Figure 1, a LEGO baseboard of 12.6 x 12.6 cm with 256 studs is placed at the center of the projection area. The projector is connected to a PC [2], that runs the application program we developed using by Processing 2 [3]. A wireless mouse with two buttons and a scroll dial is used to operate the application.

Assembly

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 Figure 2(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 (Figure 2(b)), and the user assembles blocks from the bottom to the top layer successively (Figure 2(c)). In Figure 2(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 Figure 2(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. Moreover, many users report that they have felt some feeling of successful achievement when all of the markers correctly illuminate, the target studs.

After placing a block, the user clicks on the mouse again and the system indicates the location for the next block. This cycle repeats until the block-work is completed. In this way, the user assembles LEGO blocks from bottom to top.

Scanning

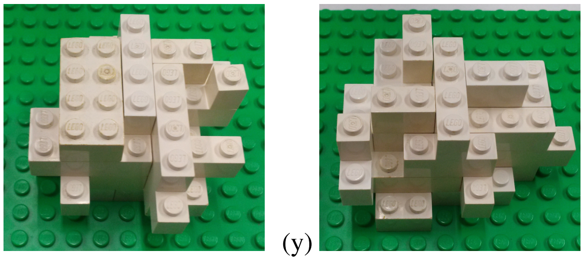
In addition to LEGO assembly support, StudI/O uses the same setup shown in the Figure 1 for the 3D scanning of existing LEGO work. During the scanning process, a user places his/her work under the projector, and records the size and location of each block by removing them one by one. When a user starts the system for scanning blocks, the projector projects white round markers on the tops of the studs of a baseboard. As shown in Figure 3(a), the user places the baseboard on a desk so that all of the baseboard studs are correctly illuminated by the projected round markers. Figure 3(b) and (c) shows the means to specify the size and location of two blocks that are placed directly on a baseboard.

In the first step, a user specifies the height of the block by adjusting the white markers that are projected on the blocks and the baseboard. The user can adjust the markers so that they illuminate studs at higher or lower places by rotating the scroll wheel of the mouse. When the user rotates the scroll

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

[2]MacBook Pro. Mac OS X 10.9.4

[3]http://www.processing.org/



(x) (y)

Figure 4. LEGO models we asked the participants to assemble.

dial one step upward, the position of each white round marker changes, and each marker targets at the stud in the one-block height, as shown in Figure 3(b). In Figure 3(b), the 12 markers in the central part illuminate the studs precisely because the 2 x 2 and 2 x 4 blocks are placed there. In this way, the user can specify the height of the blocks.

In the second step, the user specifies the size and 2D positions of blocks at the height level, by changing the highlightied area, as shown in Figure 3(c). The position and size of the highlightied rectangle can be changed by common mouse-dragging operations. Figure 3(c) shows that the 2 x 4 block on the right is highlighted. In this way, the user can specify the size and 2D location of a block. After specifying the height, 2D location, and size of the block, the user confirms this information by clicking the second button on the mouse, and removes the block from the baseboard. The user continues these steps until he/she records the size and location of all of the blocks.

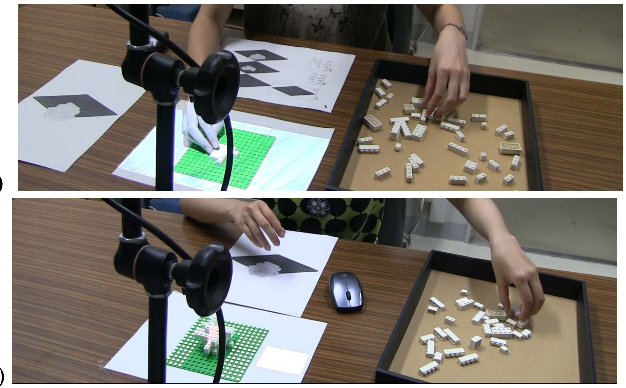
USER STUDY

In order to confirm the practicality of StudI/O, we conducted two user tests for the assembly function and scanning function, respectively. 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 provided by the LEGO company. We asked four graduate students (females, in their 20s) currently majoring in information science to assemble and capture the block structure shown in Figure 4(x) and (y). Both models consist of 21 blocks and four levels of height and have a similar degree of difficulty.

Assembly evaluation

Figure 5 (a) and (b) show the experiment setup. The LEGO baseboard is placed in front of a participant, and a shallow box with blocks is placed on the left side. We printed the illustration of the completed block project on a sheet of A4-sized paper, and put it on the table. Participants were asked to assemble the blocks twice: once using paper-based instructions (Figure 5 (a)) and once using our system (Figure 5 (b)).

Table 1 reveals the required time specified to complete each assembly task. The table shows the participants' working time (in sec), their improvement (also in sec) by using our system, and the average of the two. All participants completed the assembly in less time by using our system, although there is a difference in degree.



(a)

(b)

Figure 5. Assembly evaluation using(a)paper-based manual and (b)StudI/O.

Participants	Order	Manual	StudI/O	Improve
A	StudI/O → Manual	136*	135	1
B	StudI/O → Manual	166	148	18
C	Manual → StudI/O	150	120	30
D	Manual → StudI/O	435	160	275

Table 1. Assembly work time(in sec).

Participant A completed both tasks in a short time regardless of the instruction method employed, as she had prior experience with LEGO assembly. Although her completion time with paper instructions was comparable to that when using our system, she could not assemble all blocks correctly during the paper-instruction session. Participant D required a comparably longer time to assemble using paper instructions because she was unfamiliar with LEGO assembly and hesitated while placing the blocks. However, she achieved steady progress when she assembled blocks using our system, as her working time improved dramatically. Thus, we believe our system helps improve (shorten) working time for those inexperienced in LEGO assembly. In addition, we believe our system helps prevent assembly mistakes, even if the working time is not sufficiently shortened.

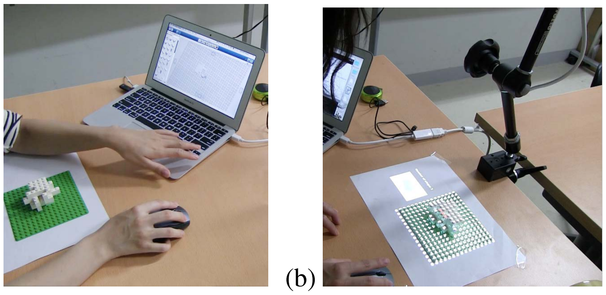
Scanning evaluation

Participants captured and saved the two block structures using LDD (Figure 6(a)) and our system (Figure 6(b)). We measured the time required to finish capturing, and the number of the mistakes made during each task.

Table2 reveals the required time specified to complete each capturing task. The table shows the participants' working time (in sec), their improvement (also in sec) by using our system, and the average of the two. All participants completed the capturing task with our system in half the time of using LDD.

Participants	Order	LDD	StudI/O	Improve
E	StudI/O → LDD	364	191	173
F	StudI/O → LDD	683	218	465
G	LDD → StudI/O	510	226	284
H	LDD → StudI/O	731	179	552

Table 2. Saved work time(in sec).



(a) (b)

Figure 6. Scanning evaluation using(a)LDD and(b) StudI/O.

	Order	LDD	StudI/O
E	StudI/O → LDD	5	2
F	StudI/O → LDD	1	0
G	LDD → StudI/O	13	1
H	LDD → StudI/O	0	1
Ave.		4.75	1

Table 3. Number of mistake blocks.

Table 3 shows the number of blocks that were caputured incorrectly. As shown in this table, no participant could finish both of tasks without making mistakes. In StudI/O, most of the mistakes occurred when a user specified the size of the target block by using a mouse-dragging operation. For example, some users incorrectly specified a 4 x 1 block as a 3 x 1 block. Since our application displays selected block shapes on the table (outside the baseboard), this kind of error might be reduced if users carefully compare the removed block and the display.

On the other hand, in the LDD experiment, dominant errors occurred when participants try to pile blocks on other blocks using LDD user-interface. Many participants tried to capture each block layer separately and to pile the blocks later. Errors often occurred in the process of piling a layer of blocks by placing them in incorrect directions or on incorrect places. Arranging blocks on a surface seems easy, but placing them at directed heights appears to be difficult. Unlike our system, LDD requires keyboard operations in addition to be mouse to capture blocks. Some participants also complained about the difficulty in the key-mouse combined operation.

RELATED WORK

Many studies have been conducted on systems that support construction tasks by projecting information about the real world using a projector. FabNavi[2] 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. FabNavi is designed to support remote cooperating work, and is not suitable for precise and 3D assembly like we aimed.

Hiura et al[3] developed a remote-work support system by projecting distorted images onto a real-world object. Rivers et al [1] 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. This system could be used without employing an HMD such as our system uses. However, 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 (CAD) 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 Artec3D[4] can capture the 3D information of an object more intuitively. However, the process of generating a 3D model from the point cloud captured by the scanner is sometimes difficult. Moreover, 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 assembly using projection and implemented it in the support of LEGO block assembly and scanning. Our StudI/O system projects round markers onto the surface studs of a target LEGO block.

Based on our user study, we confirmed that our system is easy to use, is able to work with few burdens, and helps to shorten the working time compared with paper-instructed assembly and graphical user interface (GUI)-based capturing.

In the future, we will improve our system by displaying additional instructional information to support more effective assembly and scanning. 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. Alec Rivers, Andrew Adams, and Frdo Durand. 2012. Sculpting by numbers. *ACM Trans. Graph. 31*, 6, Article 157 (November 2012), 7 pages.
2. 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*. Barcelona, Spain (July 2014), 10 pages.
3. Shinsaku Hiura, Kenji Tojo, and Seiji Inokuchi. 2003. 3-D tele-direction interface using video projector. In *ACM SIGGRAPH 2003 Sketches Applications (SIGGRAPH '03)*. ACM, New York, NY, USA, 1-1.

[4] http://www.artec3d.com