LightBricks – A Physical Prototyping Toolkit for Do-it-Yourself Media Architecture

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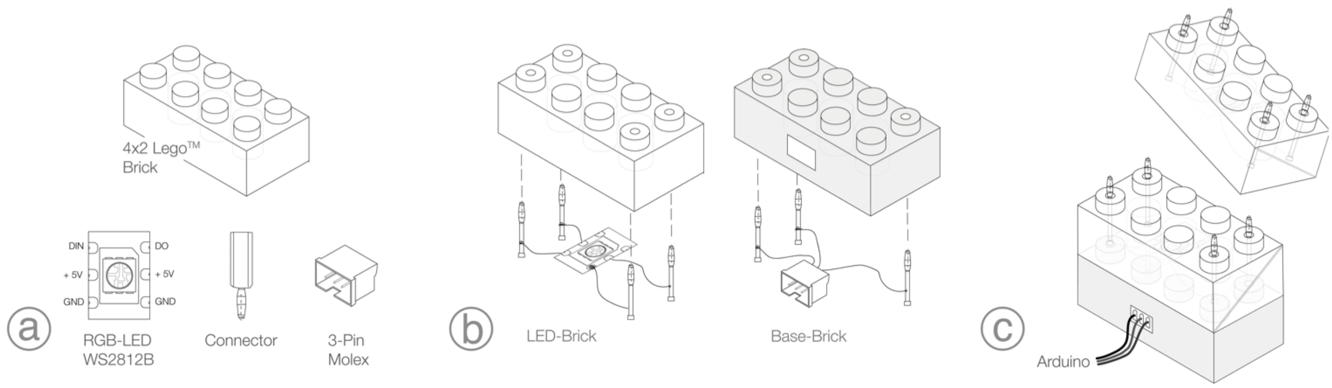

Figure 1. A Step-by-step description how to assemble LightBricks: (a) required hardware components (b) assembling of the LED-Brick and the Base-Brick for connecting with an Arduino (c) setup example with a Base-Brick and stacked LED-Bricks on top.

ABSTRACT
Media architecture is a challenging novel research domain which demands a close partnership between human-computer interaction (HCI), the industry and architects. Using a design-process approach that involves early prototyping is especially in this discipline a mandatory task in order to get any design *right*. However, crafting early interactive prototypes and exploring low-res content, form variations and interaction concepts is still cumbersome, challenging and comes at high cost which is mainly feasible for larger studios. To enable smaller architectural practices start prototyping with media architecture from scratch we present our prototyping toolkit LightBricks. It is intended to build miniature models of media architectural designs and remove technical burdens with a playful approach. It further enables the rapid exploration of possible content applications for low-resolution media architecture in order to assist interdisciplinary design teams in early phases of the design process to envision, demonstrate and pre-test visual or interactive content when working on new projects involving low-resolution media architecture.

Author Keywords
Toolkit, Media Architecture, Prototyping, Design.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

INTRODUCTION
The augmentation of public spaces with technology and its cultural, social and economical impact has been recently discussed under the umbrella term *media architecture* [10]. One subcategory in this research domain describes the idea of transforming buildings into giant public screens [8]. Media architecture can be created using different technical means, inter alia, by embedding light-emitting elements into the outer shell of a building. One prominent example of this new architecture includes the Ars Electronica Center in Linz, Austria. Here, the seamless integration of pixel elements into the architectural structure and the large scale distinguishes media architecture of situated public displays and leads to a media architecture's unique features in terms of size, resolution, shape and display technology [6].

With the increasing number of media architecture in the public domain, researchers and designers recently started to investigate the interaction opportunities between user and building, e.g. through mobile devices or stationary sensors [4, 12]. When designing such interactive applications from scratch, they reported on several challenges [4]. For example one being that light-emitting media architecture is only visible during the night, as a result testing is limited to only a few hours a day. Further, media architecture is mostly situated at urban prime locations, which means that on-going work is already visible to the public [12]. Both restrict the amount of feasible prototyping iterations. For this reason, up to now simulation software has been mainly used to pre-test applications before the actual deployment [5]. However, solely relying on simulation software is not feasible since several aspects, such as the *lighting quality*, the interplay of the utilized hardware components, interactivity and the experience with colored lighting itself can not be tackled by pure simulation via a computer screen. Therefore, Halskov and Ebsen present a conceptual framework taking into account the specific qualities of a media architectural screen [7]. Wiethoff et al. investigated the use of various physical prototypes that only differ from the final media architectural design in terms of scale [12, 13]. However, building physical prototypes is still challenging despite a growing number of electronic toolkits, such as Arduino[1], as they still demand high technical expertise. In this vein, Caldwell and Foth emphasized the importance of custom-made prototyping toolkits and platforms as one pillar of do-it yourself (DIY) media architecture [2]. Wiethoff and Blöckner, for example, developed *LightBox* - a miniature lighting lab with a fixed 12x12 light emitting diode (LED) matrix – for pre-testing content on low-resolution media architecture [11]. However, such tools are tailored to a specific project and due to the above-mentioned unique form factors it remains an open question how to transfer their approach to various non-planar media architectural designs. In this work, we therefore investigated a modular, playful and flexible three-dimensional (3D) physical prototyping toolkit for low-resolution light-emitting media architecture that can be adapted to arbitrary projects in terms of size, shape and pixel arrangement. Besides realistic lighting conditions, the scope of the resulting prototype should cover geometrical and spatial relation since they might influence the final outcome. With our toolkit, we aim to empower architects and design teams with limited technical expertise and a tight financial budget to envision, prototype and pre-test interactive applications for media architecture in short time frames and at low cost.

LIGHTBRICKS

Our toolkit, LightBricks, is intended to build miniature models of low-resolution, light-emitting media architecture. Inspired by the tangible prototyping platform *littleBits* [1], LightBricks builds upon a modular approach providing building blocks with embedded electronics to create various non-planar structures easy and fast. By stacking bricks (see Figure 1), respectively pixels, on top of each other, LightBricks lets people rapidly build up multiple miniature design variations of low-res media architecture without dealing with technical burdens such as soldering, wiring or any other electronic knowledge.

[1] http://www.arduino.cc

Our luminous building blocks are made of common LEGO™-bricks that are assembled with a red, green, blue (RGB) LED and contact pins for power and data transmission. The bricks were chosen because they are (a) a playful modular system fancied by designers and (b) already widely adopted by architects to express physical models of initial ideas. Our toolkit consists of hardware modules to i) *sketch* miniature light-emitting media architecture and a software library to ii) map (interactive) visual designs on the physical model. Tackling the issue of **interfacing multiple bricks** and **reprogramming the visual output** using an open-source programming language, our toolkit distinguishes from existing luminous brick products, such as [9], that are self-contained and simply performing a hard-coded lighting sequence. By providing a step-by-step description how to assemble the bricks supplemented by the code that is freely available[2], we invite others to use our toolkit and contribute to further development.

Hardware

LightBricks are built using off-the-shelf hardware components (see Figure 1, a). One set of LightBricks consists of two modules of building blocks: *LED-Bricks* that can be stacked on top of each other and *Base-Bricks* to connect the stacked *LED-Bricks*, for example, with an Arduino-Board[1] (see Figure 1, c). All components can be attached to the bricks without the need for a printed circuit board (PCB). We used standard LEGO™–bricks with 4x2 knobs measuring 32x16x9.6 millimeters. In order to insert the connectors, holes were drilled through the knobs. Since we decided not to fabricate own customized bricks, one challenge was to find an appropriate sized connector: finally, we used PCB female headers with a longer press-fit zone[3], so that they are easily stackable onto each other. After removing the plastic insulator, the connector can be inserted with the pin header facing up and fixed with one drop of super glue (see Figure 1, b).

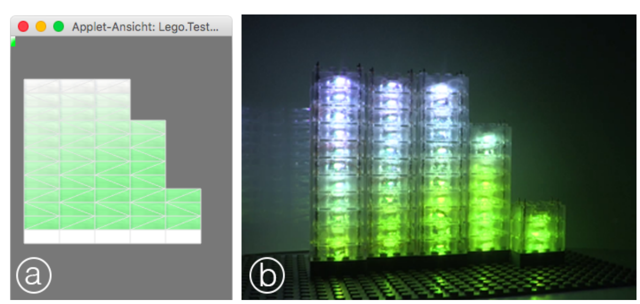

Figure 2. (a) An animation displayed on the Graphical user interface and (b) actual output on the physical model.

[2] http://www.github.com/HoggenMari
[3] http://wppro.com/content/de/produkte/buchsenleisten/raster-254mm/product/153pf-38.pdf

LED-Bricks

The LED-Bricks are made of transparent LEGO^{TM}-bricks and contain a high-power, intelligent control: the *WS2812B* RGB LED[4]. The utilized LEDs are operated with 5 volts and each pixel offers 24-bit color depth, resulting in a total of potentially 16.7 million different colors. The LED modules can be cascaded and communicate via a one-wire interface (for more detailed technical information read the provided datasheet[4]). With the control circuit already integrated into the surface mounted device (SMD) 5050 package (5x5mm), the component is suitable for a minimal design illustrated in Figure 1, b. In total, each LED-Brick requires four connectors: (1) power, (2) ground, (3) digital-IN and (4) digital-OUT. Since we utilize stackable, one-component connectors to dispense with a circuit board, we had to build two different designs with reversed pin out for the data line and shorten the female header of the digital-OUT (see Figure 1, b). Since the mechanical interfacing of our design does not prevent from connecting incorrectly or reversed, we marked the LED-Bricks with a diagonal line: if the bricks are connected correctly, a zigzag line is apparent on the *short* side of the bricks (see Figure 1, c). However, a wrong connection does not damage the electronic components, since the *WS2812B* does support intelligent reverse connect protection.

Base-Bricks

To connect the LED-Bricks for power and control purposes, we built *Base-Bricks* made of an opaque brick (see Figure 1, b). The Base-Brick has three connectors: (1) power, (2) ground and (3) digital-OUT that are soldered with a 3-pin Molex socket to connect a stack of LED-Bricks, for example, with an Arduino-Board. With multiple Base-Bricks arranged in a horizontal row and LED-Bricks stacked on top, one can easily build any arbitrary matrix.

Software

For *mapping* the visual content on the LightBricks-hardware, we developed a library that can be directly embedded in the Processing Development Environment (PDE). Processing[5] is a Java-based scripting language for visual design that we considered ideal for the fast development of prototypes. Due to the easy integration of our toolkit into Processing, designers can create visual content in a well established development environment while using LightBricks as an output medium. Since the current hardware does not support automatic calibration of the LED-Bricks, the software helps to adapt the *mapping* to the physical arrangement of the bricks. The software then sends the RGB values of the generated graphics to an Arduino-board to which one or more Base-Bricks are connected. In addition, we implemented a graphical user interface (GUI) to monitor the visual output in Processing's display window and to control whether the bricks are stacked correctly (see Figure 2).

[4] http://www.adafruit.com/datasheets/WS2812B.pdf

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

PRELIMINARY INVESTIGATION

In order to demonstrate the practical use of our approach, we developed two initial applications with our prototyping toolkit LightBricks. To do this, we prepared 44 LED-Bricks and 6 Base-Bricks that we connected with an Arduino Mega 2560 (see Figure 3+4). We then implemented two interactive example sketches in Processing, which support different input devices. The first *software sketch* triggered a virtual firework animation when a connected infrared (IR)-sensor detected an infrared signal, (e.g. by a flashlight or lighter). The second *software sketch* produced a simple animation whose color and brightness levels were controllable via a mobile device (here Apple's iPhone 5S). We presented our prototyping toolkit and the above described example *software sketches* within the scope of an international conference on media architecture to receive initial insights into the practical use by architects. To do this, we used LightBricks during a half-day workshop on prototyping interactive media architecture with a total of 10 participants. First, we gave them a one-and-a-half-hour lecture on our research domain (media architecture and prototyping), followed by a one-hour explorative session in which they experienced the above described prototype and developed own ideas for interactive media architecture applications. Without giving a prior instruction to the system, the participants assembled the provided sets to create different miniature models of low-resolution media architecture. Since the participants were not familiar with the pin assignment, one participant began to stack the bricks offset, which exemplified that one could expect the usual constructive versatility of common LEGO^{TM}-bricks. The overall feedback on our prototyping toolkit was very positive as the participants appreciated the simple, and playful method to explore media architecture and interactivity rapidly and by themselves.

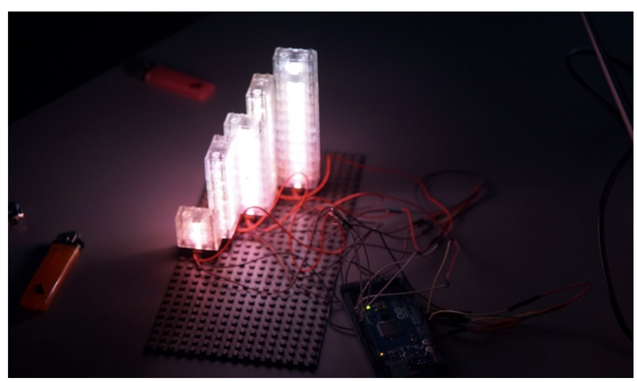

Figure 3. Initial setup of LightBricks presenting two interactive example sketches (Image © Wolfgang Leeb).

DISCUSSION

In this work we present a modular prototyping toolkit, which supports architects and designers to envision 3D shapes and interactive content for low-resolution media architecture. With our toolkit we provide building blocks

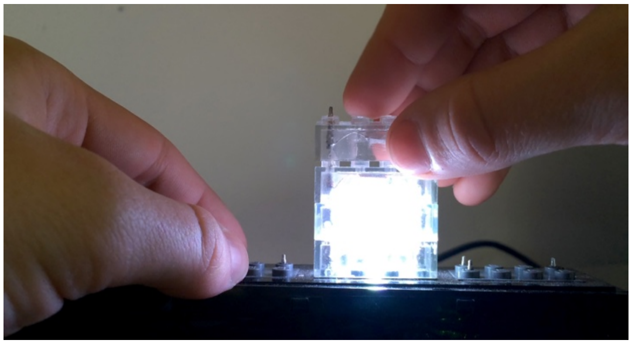

Figure 4. Building a miniature model of a media architectural design with LightBricks: A user stacks LED-Bricks on top of each other.

with embedded electronics which potentially empowers novice users to easily build miniature models of low-resolution, light-emitting media architecture and *map* visual content correctly onto a physical prototype. Such tools foster a design process which is coined by hands-on explorations and iterative prototyping on a small-scale before going full-scale. Our approach is replicable and allows also the transferability to various low-res media architecture projects.

Limitations. Our simple design which is mainly using off-the-shelf hardware components (*WS2812B* RGB LEDs, and common PCB headers) comes with limitations regarding the constructive versatility, e.g. the building blocks can only be stacked vertically without offset. Moreover, the brick deign itself hinders the creation of more complex and organic shapes.

However, to ensure an easily replicable and low-cost approach we avoid using additional microcontrollers and electronic components for each module as well as printed circuit boards as described in [3] and work with a widely familiar product. To overcome the previously described issue of our prototyping toolkit, we are currently developing a press-fit design using 3D-printing, with the benefit to i) avoid soldering, ii) having a single design-version of LED-Bricks to dispense with the reverse pin-out and iii) reducing the brick size (2x2 knobs). We therefore consider the distribution of an industrial manufactured version of our toolkit in the near future.

Benefits of LightBricks. To sum up, we see the following benefits of our approach:

- modular and flexible toolkit that can be transferred to various media architectural designs
- quick physical model making that covers geometrical and spatial aspects
- integration into a widespread programming environment for the exploration of different visual designs and interactivity
- off-the-shelf hardware at low cost

CONCLUSION AND FUTURE WORK

The systematic development of media architecture comes with several challenges, one being that prototyping still demands high technical expertise. Our toolkit helps to remove technical burdens, offers a playful approach and empowers designers and architects to start prototyping from scratch. In the near future, we plan to further substantiate and develop our toolkit further to address the aforementioned limitations. We envision a modular system that is even more flexible in terms of shape and material, in order to build more precise and organic physical models. Developing prototyping tools as the one described is an important step towards our vision of a more systematic design process in this emerging domain.

ACKNOWLEDGEMENTS

The project was partly funded by Lehre@LMU, we thank the University of Munich for supporting this project.

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