TOPAOKO: Interactive Construction Kit

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Figure 1. The TOPAOKO kit is made in laser cut hardboard embedded with circuit.

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Abstract
If you have a laser cutter, you can build your own TOPAOKO. We describe work in progress on TOPAOKO, an interactive construction kit that encourages experimentation and play with pieces of a hardboard based, embedded circuit, kit. We describe each component of the kit and examples of constructions built with it.

Keywords
Interactive Construction Kit, Tangible Interface

ACM Classification Keywords
H.5.2 User Interface: Haptic I/O

General Terms
Design, Experimentation, Human Factors

1. Introduction
In Ishii and Ullmer's vision of "Tangible Bits" [1], tangible user interfaces augment the physical world by coupling digital information to everyday objects and environments. They envision a more human-friendly interface with input/output modalities beyond window, icon, menu and pointing devices. However, long before Ishii and Ullmer's research, the construction kit has been considered a suitable object for augmenting the digital information. Twenty years ago Fischer pointed out that a construction kit was an appropriate human problem-domain

communication interface for controlling and understanding a computer system, especially in user interface design [3]. Later, behavior construction kits such as LEGO/Logo emerged, which not only enabled children to embed computation in machines they built, but also spread computation throughout their world [4]. Construction kits have long been utilized not only as educational artifacts fostering children's creativity but also as a tool to support and encourage engineering and design exploration.

TOPAOKO is a new generation interactive construction kit intended for high school students and college freshmen. Students in these ages are creative and have enough experience making things. Students can learn electronics and make toys while playing with TOPAOKO. It allows the students not only to create buildings or machines, but also to make the kit themselves. Just like color printers, In the near future laser cutters will become more accessible as the price decreases. For example, Craft ROBO[2] is a cutting machine under three hundred dollars which enable users cut thin materials like paper or film in any shape.

TOPAOKO is a construction kit, which is made in 3 mm thick hardboard. The name of TOPAOKO comes from Ch'ing dynasty in China, which means the curio boxes with surprising twists and hidden construction for emperors to store their collections of prized objects or treasures. In this project students can download our TOPAOKO pdf pattern files and use the laser cutter to print them out; also, they can design their own patterns in graphic design or CAD software such as Adobe Illustrator or Rhino. TOPAOKO is a construction kit that allows students to build not only spatial structures but also a "behaving machine" [3]. We introduce how to embed the electronic components in the modular TOPAOKO kit. Also, we briefly describe some TOPAOKO constructions.

2. The KIT

Figure 1 shows our TOPAOKO construction kit. It contains a microcontroller block, an assortment of sensor blocks and actuator blocks, a battery block, and some hardboard pieces. Each component is made of laser cut hardboard. Components can be connected electrically via copper foil traces and embedded magnets keep connections tight.

2.1 HSIN (mind/brain) BOX: The Microcontroller

HSIN, the Chinese character shown on the box represents "mind" or "brain". The central component of an interactive construction kit design is its "mind/brain", usually an embedded microcontroller or several chips. The HSIN BOX consists of a laser cut HSIN-BOX hard board sheet, a printed circuit board (PCB), an integrated circuit (IC) socket, a voltage regulator, two 10 uF capacitor, two 22 pF capacitor, one 10K resistor, a 16MHz clock crystal, and a 28 pin ATMEGA168-20PU microcontroller. Figure 2 (left) shows an inside view of the HSIN BOX. We used five of the microcontroller's 20 pins I/0 for connections between boxes.

Each copper foil trace leads from one of the microcontroller's pins to one of the ports visible on the sides of the package. The entire package is approximately a 42mm cube, made of 3mm hardboard. To employ the microcontroller in a HSIN BOX, first we put an IC socket, a piece of hardboard for circuit (the one with 15*15 holes), and a PCB together to make a sandwich. Then we soldered the circuit on the PCB side. Using the TOPAOKO kit as a base to build a circuit gives us a three dimensional space for the circuit in which the circuit can be embedded stably.

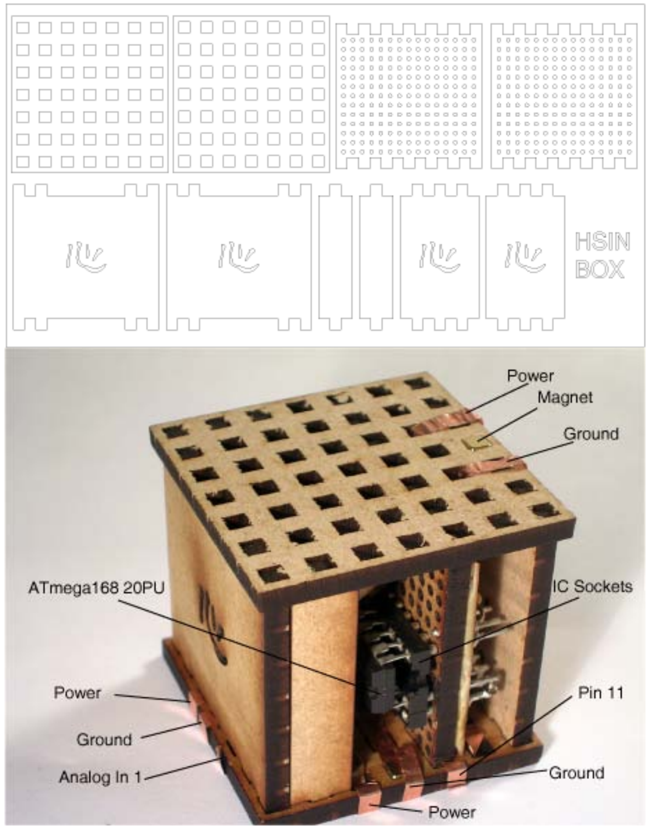

Figure 2: Upper: the HSIN BOX pattern for laser cutting. Lower: microcontroller and electronic components are embedded in the HSIN BOX.

2.2 CHI BOX: Battery Pack

CHI means the energy flowing inside our body. TOPAOKO constructions require power. We designed a CHI BOX pattern to contain a 9V battery, which is sufficient for all of our applications. As shown in Figure 3 two pieces of copper foil tape form our connection ports: power and ground. Each piece of copper foil tape is approximately 3 mm wide, which fits our TOPAOKO grid base kit (The base kit grid is 3 mm square). The CHI BOX can be connected directly to a LI BOX (see below) or connected to a HSIN BOX to drive the microcontroller. We embedded a 3 mm cube magnet to secure the physical connection between two boxes. The complete CHI BOX is approximately 59 x 42 x 42 mm.

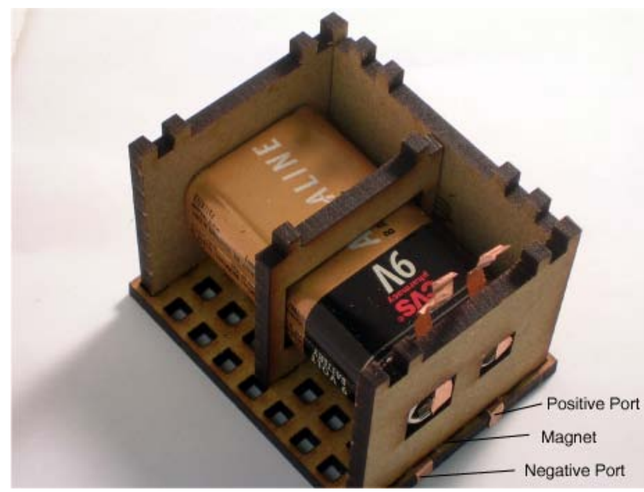

Figure 3: The CHI BOX connection ports on the right side are made by copper foil tape.

2.3 LI BOX: Actuators

LI means force. The LI BOXs are the most exciting boxes: Creating motion and light makes the construction kit come alive. A LI BOX contains one of three different output devices: motors, light emitting diodes (LEDs), and muscle wires. Figure 4 shows these devices and their interior mechanisms. We begin our discussion of output devices by examining the motor box (Figure 4 left). It is made like the HSIN BOX and CHI BOX, using copper foil tape as electrical connections and magnets to connect with other boxes. The LI BOX – motor has three connection ports: Power, ground, and the Enable port to the output pin port on HSIN BOX. The LI BOX package is approximately 42 x 42 x 42 mm. (excluding the bending bronze tube).

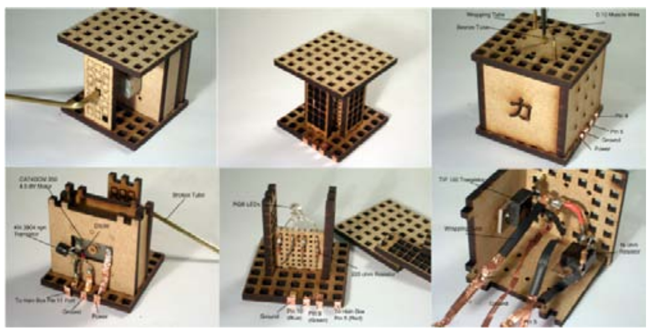

Figure 4: Left column: LI BOX – Motor. Middle column: LI BOX – RGB LED. Right column: LI BOX – Muscle wire.

Figure 4 also shows other output devices included in the kit: LI BOX – RGB (red green blue LED), and LI BOX – muscle wire. The LI BOX – RGB has five ports (Power, Red, Green, Blue and Ground) that attach to the output ports and ground port on the HSIN BOX. The LI – BOX muscle wire uses the same external power circuit as the LI BOX – motor. The actuator consists of two shape memory alloy wires (an alloy that "remembers" its original, cold, forged shape, and which returns to that shape after being deformed, by applying heat) and a steel wire wrapped with a tube. One end of the muscle wire connects through the steel wire to ground and the other end connects to the enable port.

When the LI BOX receives an enable signal from the HSIN BOX, it starts actuating: LI BOX – motor rotates the gears; LI BOX – LED turns the light on; LI BOX –muscle wire bends the steel mast. The amount of actuation (speed, brightness, and angle) depends on the voltage provided by HSIN BOX.

2.4 GUANG BOX: Sensors

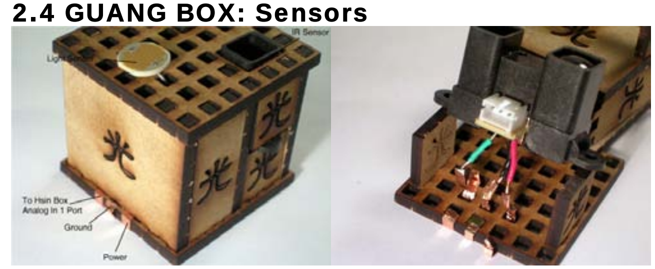

Figure 5: The GUANG BOX consists of a photocell sensor and a infrared ray sensor.

In Chinese, GUANG means light. Any kind of signal in our physical world is transmitted in a form of light. The GUANG BOX is a signal receiver that responds to real-world stimuli (Figure 5). It contains a photocell and an Infrared Radiation (IR) light sensor. Working as a variable resistor, the GUANG BOX transmits voltage (brightness and distance) provided by sensors to HSIN BOX through its three connection ports: power, ground, and voltage input. The embedded magnets enhance the connection between GUANG BOX and HSIN BOX. The complete GUANG BOX is approximately 42 x 42 x 42 mm.

3. Application of the Kit

To explore the range of constructions that can be built with the TOPAOKO kit, we put together a few simple and playful constructions. This section describes: the Moving Machine, Moving Robot, and Moving Creature.

3.1 CHI BOX + LI BOX: Moving Machine

The first application (shown in the top two rows in Figure 6) is Moving Machine. It uses only two kinds of TOPAOKO BOXes: the CHI BOX and LI BOX. As in Figure 5 the student can connect CHI BOX to LI BOX – motor or LI BOX – LED. For most users, seeing the motor spinning or the LED shining is the simplest but surprising part of the TOPAOKO construction kit: power + actuator = moving machine. For novices who have no electronic experience this is a fun application they can start playing with.

3.2 CHI BOX + GUANG BOX + LI BOX + HSIN BOX: Moving Robot

This application includes all the TOPAOKO BOXes: CHI BOX, GUANG BOX, LI BOX and HSIN BOX. These BOXes represent four basic devices for building a robot: Power, Input, Output, and Controller. The program in this "Moving Robot" application transmits the input signal received from the GUANG BOX to the LI BOX. In the third row of Figure 6 we connected GUANG BOX – IR sensor and LI BOX – muscle wire. The GUANG BOX senses the distance between the approaching object and the GUANG BOX itself, and the LI BOX actuates the movement. The closer the hand, the more bent the muscle wire actuator will be. The construction in this application is more like a robot than the Moving Machine application.

Figure 6: Some TOPAOKO constructions. First and second row: Moving Machine. Third and Forth row: Moving Robot. Fifth row: Moving Creature.

3.3 CHI BOX + GUANG BOX + LI BOX + HSIN BOX + Random: Moving Creature

The Moving Creature application (Figure 6, bottom row) includes a random function in the program. When something approaches the construction, LI BOX – LED shines and the LI BOX – muscle wire swings back and forth. The color of LI BOX – LED and the movement of LI BOX – muscle wire are randomly generated. The randomness makes the construction unpredictable. Compared to the Moving Robot application, the Moving Creature is more interesting to interact with.

4. Related Work

The TOPAOKO project builds on previous work in several disciplines. Buechley's Electronic – Textile [5] is a "Build Your Own" construction kit in fabric. LEGO MindStorms NXT [6] has the most applications but is limited to the plastic bricks manufactured by the LEGO Company. Topobo, [7] is an interesting example of programming robotic structures. Students create a behavior robot by twisting plastic creature body parts. Osaka University's Active Cube [8] project focuses using actual physical cubes as tangible interfaces to interact with a virtual 3 Dimensional environment. Schweikardt's roBlocks system, [9] comprised of a kit of robotic blocks and a software package, encourages users to program by connecting blocks, analyze their constructions via on-screen tools, and eventually reprogram their creations. Speech-Enabled Alphabet Blocks [10] is a computationally-enhanced construction kit. They can be arranged in orders to construct words and be transmitted to computer and be pronounced through synthesizer.

5. Final Remarks

The current TOPAOKO needs further development in both hardware and software design environment so that students with little electronic experience can build the BOXes and programs more easily. Developing software that enables students to design their own kit in a three-dimensional virtual environment is another goal. We will include user testing in the further design, and based on how our target users would use the kit, we will create more kit components and applications to increase the "playability".

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