UNIVERSAL MODULAR KIT FOR TEMPORAL INTERACTIVE PLACE IN PUBLIC SPACES

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ABSTRACT

This paper introduces a novel way to enable users to create temporal smart surroundings easily at open-air events. The final goal of this research was to support social activities in public spaces, such as festivals, camps, and outdoor-ceremonies with ubiquitous computing technologies. We designed and developed universal modular units called "I/O-CRATEs", which are box-shaped units embedded with microcomputers, sensors, actuators, and batteries. We demonstrated the possibilities of our units with a one-night special event. Through this practical experience, we found "I/O-CRATEs" could easily be used to create smart and enjoyable surroundings in many places.

1. INTRODUCTION

Due to recent innovations with microcomputers, sensors and actuators, many ordinary objects can be enhanced into “smart” ones using various approaches. These environmental objects such as smart furniture (Tokuda et al (13)), smart rooms (Edward (2)), smart homes (Si el al (8)), and smart buildings (Snoonian (9)) are generally defined as "smart surroundings", and they support our lives and activities in the real world.

The main targets of most research have been "immovable" places that have been installed and fixed at one site. Needless to say, buildings, homes, offices, and rooms are inherently immovable.

In our daily lives, however, we sometimes hold special temporal events such as festivals, camps, and outdoor ceremonies in public spaces in the open air (Fig. 1). To organize these, we have to pack furniture and devices, transport them outside, and arrange them in appropriate positions.

Fig. 1. Temporary Space and Movable Surroundings

Until now, it has been too difficult to adopt contemporary ubiquitous computing technologies and construct interactive surroundings for such temporal activities at open-air events. Event organizers seem to need new-style “smart” objects at the same time that will make their events more enjoyable and minimize their task of making arrangements in advance. For example, numerous physical objects and electronic devices are set up on the spot at rock music festivals. However, since these physical objects and electronic devices are inherently separate, organizers’ advance arrangements involve too much hard work. Many technicians from many fields have to take individual charge of their part of these arrangements.

Ubiquitous computing technologies can contribute to combining all physical objects and electronic devices together, and to develop “smarter” interactive objects that can be used to create new events that are more fantastic than ever before.

We therefore began this research to design and develop universal modular units called "I/O-CRATEs", which are box-shaped units embedded with microcomputers, sensors, actuators, and batteries. The two basic requirements in our challenge were:

(1) Easy-to-Assemble (on the spot):

To design intelligent units, that were physically easy-to-assemble, and electrically easy-to-connect.

(2) Easy-to-Disassemble (for portability):

To design portable (by ship, cargo container, car, or hand) units that could be disassembled and packed into a container.

This research was primarily focused on box-shaped materials like crates that enabled users to create various spatial objects such as furniture, floors, walls, and playful topographies by connecting and assembling them. Physical size was an especially important factor in our design. Through trial-and-error processes, we determined to adopt ordinary "beer cases" and enhance them into smarter versions for our first prototype (Fig. 2). Beer cases are lightweight and the exact scale to adopt as a piece of furniture. Since beer cases can be assembled both vertically and horizontally, one can be a chair, two can be a table, and three can even be a bar counter (Fig. 3). Furthermore, they can be used to make playful topographies like mountains and hills (Fig. 4). We found that beer cases were easy-to-transport in most circumstances.

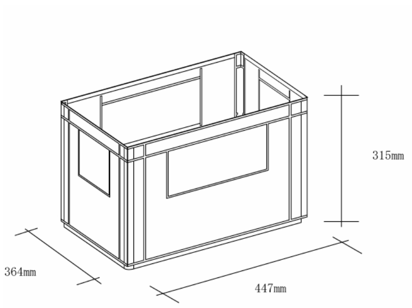


Fig. 2. Beer case module

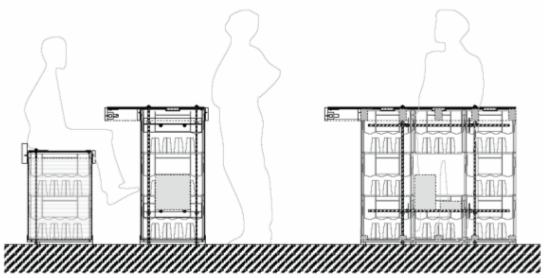


Fig. 3. Relationship of scale between humans and units

Fig. 4. Playful topography like small hill

Our next design challenge was to enhance these cheap cases into smart objects with embedded sensors, computers, and actuators. We created two hundred "I/O-CRATEs" embedded with eight electronic modules as our first prototype. Every case had eight modules, such as sensors, computers, actuators, and batteries that could be electrically connected wirelessly. The only requirement was for users to assemble and connect the “I/O-CRATEs” in physical configurations for what they wished to do.

However, users had to consider two aspects of “I/O-CRATE” in this creation process. The first was the physical aspect in creating appropriate shapes such as chairs, tables, desks, counters, walls, and floors. Physical shapes strongly affect natural human behaviors such as standing, sitting, walking, and lying. The second was the electronic aspect in forming a total (wireless) electronic circuit that generated computer-human interactions. By sensing neighboring conditions, “I/O-CRATEs” could autonomously control light and sound, and change the ambience of the location.

Users have to consider “spatial interactions" because of that from the viewpoint of both the physical setting and the electrical system. We studied several design patterns to make this process more creative. Although it is possible to have infinite variations in interactive space with “I/O-CRATEs”, our design patterns may serve as useful guidelines for future applications.

The advantage of this system is its simultaneous pursuit of both simplicity and multifunctionality. Being similar to the famous “LEGO MIND STORM”, users can create an almost infinite variety of temporal interactive spaces at open-air events. However, unlike MINDSTORM for small robots, our kit was to create social and public places based on the scale of a human body. We had to consider appropriate settings for hosts and guests, good communications and comfort, and stability and flexibility in the space. Therefore, we held a one-night special event as our first experiment to both demonstrate the prototype system and observe users’ activities in this one case. This paper describes our first experiment in a public space as well as our development of the smart cases.

The sections of this paper have been structured to make each point independently. After presenting the "I/O-CRATE" in Section 2, this paper continues with describing design studies in Section 3. We cover our experiment in Section 4 and finally discuss the advantages of using "I/O-CRATE" in Section 5. Section 6 describes past work related to our research and Section 7 draws conclusions from our current endeavors and outlines future work.

2. OVERVIEW

The main points we focused on in designing "I/O-CRATE" are discussed below.

2.1 Scale, Size and Weight

Users have to transport multiple "I/O-CRATEs" by ship, cargo container, car, or by hand. A beer case, which is 364 mm× 447 mm× 315 mm, is a very suitable module, which is also lightweight (approx. 2 kg). We considered it to be the perfect material for both assembly and disassembly. Conceptually, they can be treated in three ways- "transport" (from one spot to another by cargo container), "transfer" (from the cargo container to the exact spot by hand), and "transform" (changing the layout at the spot). Figure 5 illustrates this concept.

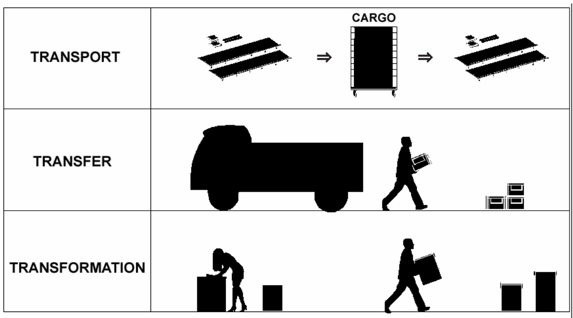


Fig. 5. Three ways to treat units

2.2 Sensor, Microcomputer, Actuator, and Battery

Every case is embedded with eight modules of sensors, actuators, a microcomputer, and a battery. Table 1 summarizes all the electronic modules embedded into every "I/O-CRATE". We adopted "PIC16F88" as the core microcomputer. All sensors and actuators were electrically connected to a PIC microcomputer inside the case (Fig.6). In addition, each case had a 9800-bps wireless connection. We adopted the "R80" wireless transducer (Fig.7), which enables microcomputers to send and receive digital data at a distance of about 20 m, without the need for wired cables. We can connect several separate computers electronically by tuning in to the same frequency channels. The "R80" offers 80 frequency channels ranging from 309.025 to 311.000 MHz.

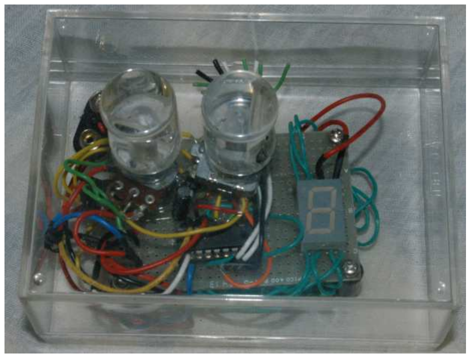


Fig.6. Electronic modules embedded into a case

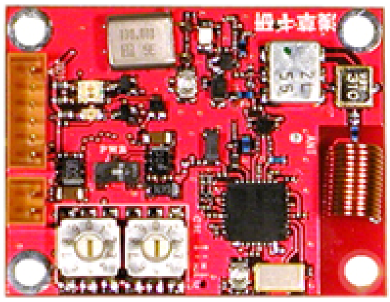


Fig.7. Wireless component "R80"

2.3 Software Processing

To enable PIC microcomputers to process any I/O signals, we adopt "ECA rules" as basic software principles (Terada, 2003 and Terada, 2004). "ECA" means "Event", "Conditions", and "Actions". "Event" means a timer or other triggers to start processing one event. "Conditions" mean parameters that the microcomputer obtains from the sensors. "Actions" mean parameters that the microcomputer outputs to the actuators. By writing all ECA rules in programming language, "PIC-C" into PIC microcomputers, "I/O-CRATE" obtains unique performance and interacts with human actions. Figure 8 lists the basic mechanisms. Examples of interactions are described in Section 3.2.

Table 1 Electronic Components

	TYPE	MODULE	USE
A	Sensor	Cds Sensor	Sensing light
B	Actuator	Fullcolor LED	Actuating colorful light
C	Actuator	Speaker	Making sound
D	Sensor	Microphone	Sensing sound
E	Sensor	Camera	Capturing image and color
F	Micro Computer	PIC16F88	Processing
G	Battery	9V Self Battery	Providing current

Event	Conditions	Actions
the timer == 20	Sensor.1 == 0 Sensor.2 > 20 Sensor.3 == 30 Sensor.4 <40	Actuator.1 = 1 Actuator.2 = 0

Fig. 8. Principles of software descriptions based on ECA-rules.

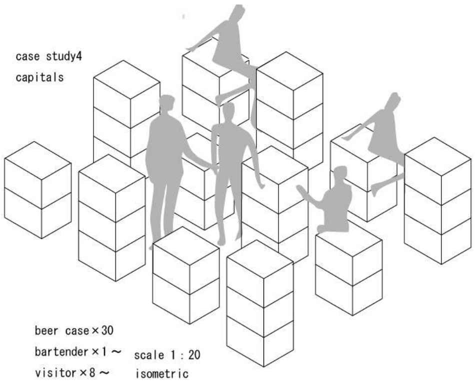


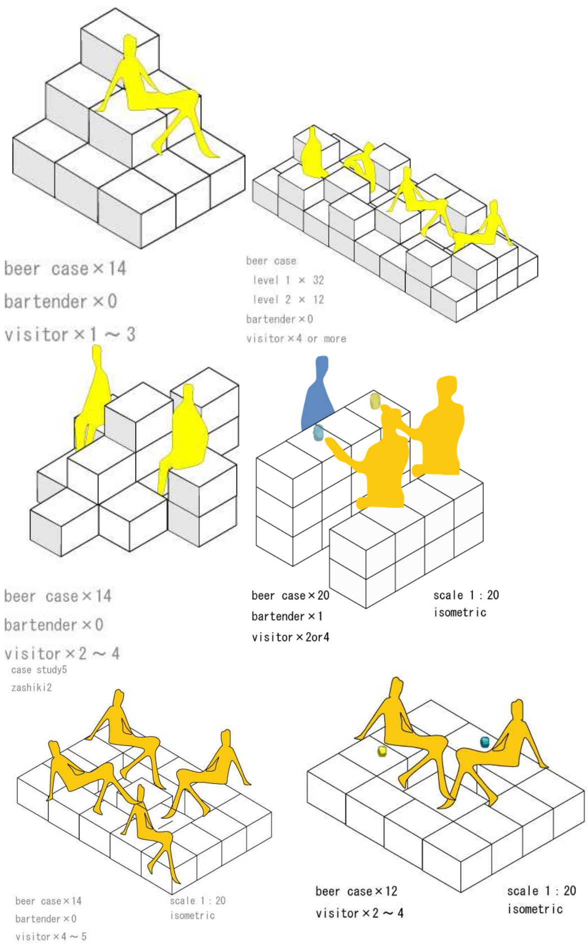
Fig. 9. Various types of spatial arrangements (Illustrations)

Fig. 10. Various types of spatial arrangements (Snapshot)

3. DESIGN STUDIES, SIMULATIONS AND PATTERNS

3.1 Human behaviors and physical setting

The “I/O-CRATEs” enabled us to construct basic furniture such as a chair, a table, and a bar-counter. Furthermore, a composite spatial layout could have been created from multiple “I/O-CRATEs” (Fig. 9). The “I/O-CRATEs” enabled us to build a slight artificial land form consisting of a wall, a floor, a bench, and a tower, all continuously joint together (Fig. 10). We investigated the relationships between human behaviors and physical setting and the relationships between the number of cases and number of people who could gather together. Figure 9 and 10 outline our design arrangements and simulations.



3.2 Human actions and interactive surroundings

By combining several components, we could create a total electronic circuit. It could achieve various “interactive surroundings”. It was not necessary to use all the sensors and actuators in one case. According to its position and necessary role, one “I/O-CRATE” could be applied to only one function. For instance, one case could be applied as a light sensing crate or as an LED lighting crate. The simplest examples are a Cds Module (A) that could be applied to sense human behaviors (detecting whether standing or sitting) and a microcomputer module (F) that could switch to an LED module (B). Figure 11 has a block diagram of these.

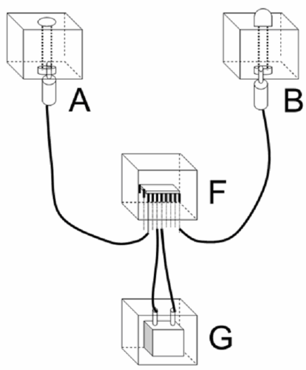


Fig. 11. Simple electronic circuits

Note that the light sensor (Cds module) could be applied to multiple purposes according to its "spatial context". When a person sits on a crate, a light sensor attached to it can detect such behavior (motion), because his or her body casts a shadow. Although the light sensor can only actually sense "light", that input signal is interpreted to mean the existence or the non-existence of an object (a person in this case). Figure 12 illustrates this mechanism. The same can be said for the other sensing modules. The meaning of data that electrical sensors detect depends on their "spatial contexts".

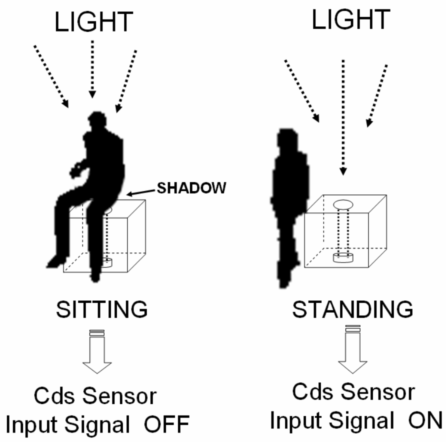


Fig. 12. Detecting whether standing or sitting with Cds module

Therefore, users have to consider both physical and electronic aspects at the same time in the design process to attain achievable interactions between people and their environment. We have assumed that the "chair" senses whether a person is sitting or not, the "table" senses whether objects are on it or not, and the "wall" senses whether a person is leaning against it or not.

As described in Table.1, an "I/O-CRATE" has three sensing modules, a Cds, a microphone, and a camera. Their possible roles are listed in Table 2.

Table 2 Sensing parameters and interpretations.

Module	Sensing parameters	Interpretation
Cds	Light	Existence or non-existence of objects
Micro-Phone	Sound	Detecting sudden motions
Camera	Image and color	Storing RGB colors

4. EXPERIMENT

This section reports our practical experiment. We organized a bar spot for one night and observed users' interactions and behaviors to evaluate our units.

4.1 Site and Setting

There is an old pier at Hakodate in Japan and our one-night-bar project took place in that famous historical setting (Fig. 13). Two hundred "I/O-CRATEs" were constructed on an artificial landform that fit the site. We have built one bar-counter, twenty chairs, seven tables, and walls and floors (Figs. 14 and 15). It took 15 people about one hour to set up all the furniture and surroundings.

Fig. 13. Site of old pier

Fig. 14. Setting we created with "I/O-CRATEs"

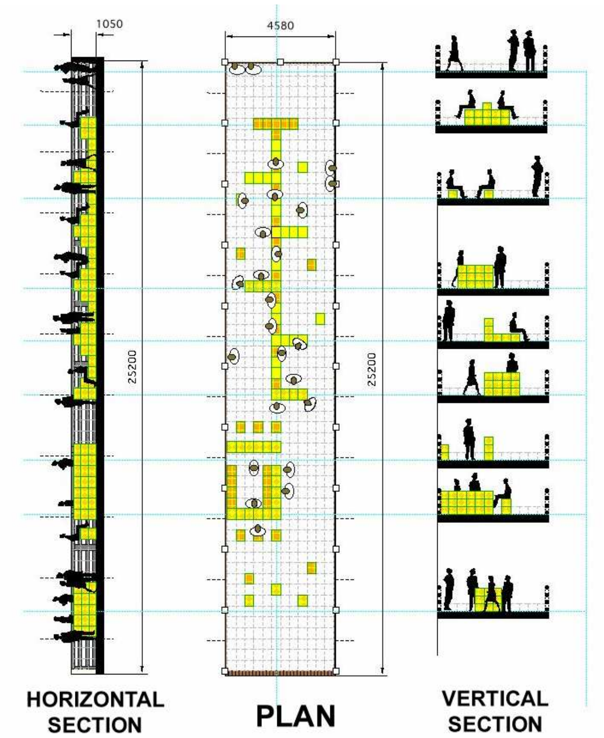


Fig. 15. Plan and horizontal and vertical sections of event space

4.2 Interactive Applications

We implemented two types of interactive applications in this experiment. The first was called a "cocktail color transmitter (*4.2.1*)" and the second was called "cocktail flowers (*4.2.2*)".

4.2.1 Cocktail Color Transmitter

The "cocktail color transmitter" was composed of a camera module and a full-color LED module. A small camera module on the bar-counter sensed the colors of drinks the bartender had prepared. Through computers, a full-color LED reflects its color over the whole table with the lighting module. Guests who are sitting some distance from the bar-counter can also recognize what services the bartender is offering and the sorts of prepared drinks (Figs. 16 and 17).

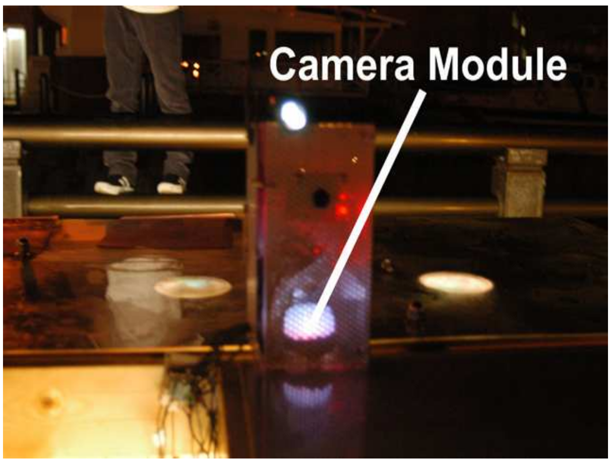


Fig. 16. Camera module

Fig. 17. Full-color LEDs on table

4.2.2 Cocktail Flowers

The "cocktail flowers" was composed of a Cds module and a full-color LED module. Sensors embedded in all guests' tables sensed the existence of cocktail glasses and lit them up. When a guest lifted a glass to take drink, the light turned off. Thus, flickers of light represented "repetitive actions" by guests. Colorful cocktails themselves flickered to light up the hall, just like flowers blooming in a real garden (Figs 18 and 19). Figure 20 shows this interaction mechanism.

Fig. 18. Lighting-up cocktails

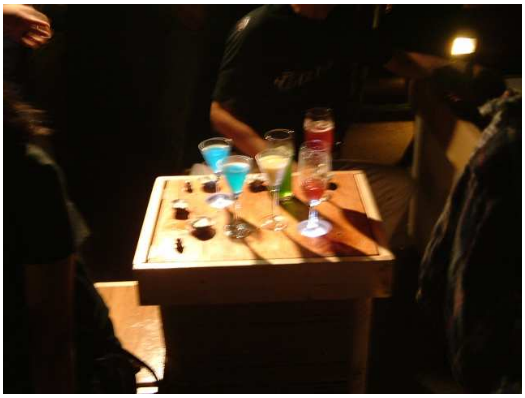


Fig. 19. Cocktails on table

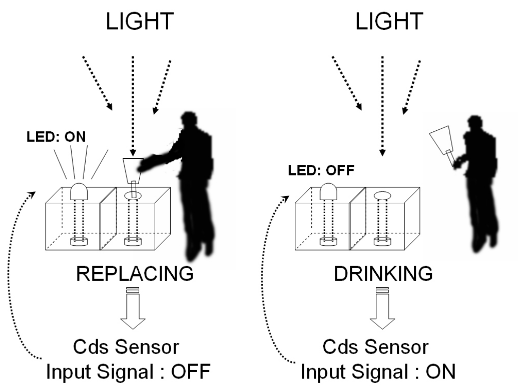


Fig. 20. Interaction mechanism

4.3 Observations

Our temporal interactive surroundings created a fantastic atmosphere on the pier. Interactive applications (described in Subsections 3.2.1 and 3.2.2) played a curious role as "attractors" in the space for the first hour. However, the situation changed over the course of time. Guests transferred units by themselves and arranged their places proactively. They created their original chairs and tables in uncrowded corners with several "I/O-CRATE" boxes. Furthermore, they constructed original interactive furniture.

This is one of the important advantages of these proposed smart objects. Since "I/O-CRATEs" are so easy to use and have a simple mechanism, not only the hosts of an event but also their guests can participate in arranging the space with them.

4.4 Movie and additional descriptions

A movie and slideshows of our experiment are at:

http://htanaka.sfc.keio.ac.jp/bar/movie.html
(MOVIE)
and

http://htanaka.sfc.keio.ac.jp/bar/
(SLIDESHOW)

5. DISCUSSION

One object such as a piece of furniture affords a user "behaviors", a combination of several objects affords several users "communication", and the total layout of all objects affords all users a flow and "activities" all over the site (introduced in appendix). The range of interactive designs can be understood as being on these three levels (Figure 21).

To create "design patterns" to apply "I/O-CRATEs" to several events is an important ongoing work. Our policy of design is to develop smart objects that will encourage users to consider how they can be applied, how they can be combined, and how they can be customized. The main candidates in this proposal were event organizers, architects, and ordinary people. We are going to prepare a "guideline manual" for this system by collaborating with these designers.

	Small scale	Middle scale	Large scale
Object	Furniture (one object with several connected crates boxes)	Combination of several pieces of furniture	A Place
Target	One person	Several peoplepersons	All hosts and guests
Interac tion	"Behavior"	"Communicati on"	"Activity"

Figure 21. Three levels of interactive design with "I/O-CRATEs".

6. RELATED WORK

There is so much work related to our trial. "u-Texture: Self-Organizable Universal Panels" (Kohtake et al(4)) involves very smart objects that can recognize assembled shapes and autonomously extract appropriate context-aware applications corresponding to them. "Connectable" (Tandler el al (12)) can be used as a public display by attaching several displays. Compared to this research, the weakness of "I/O-CRATEs" is that the crate itself does not have "context-aware" functions. The applications for "I/O-CRATEs" depend on users' designs and configurations. Users themselves have to observe and understand "contexts", and plan spatial arrangements.

Our perspective is similar to McCullough's statement (McCullough(6)). Far from "context-aware" computing, our crates rely on users' design skills and abilities. McCullough claimed his standpoint should philosophically be called "context-centered situated design".

There are several works on small intelligent toys-Wyeth et al(14), Gorbet et al(3) and Resnick et al(7). We consider that "I/O-CRATE" is one of the practice media like "LEGO MINDSTORM". Another related work is the "BOX. Open System for Connected People"(1), which is a kit of small smart boxes. A collection of modular, wireless, tangible boxes has been created to connect them to structures developed through the BOX model and speculate with different platforms for communication and information exchange. The system architecture and point of view are similar to ours. However, "BOX. Open System for Connected People" is a tool for interior design and is smaller than "I/O-CRATE". In addition, their boxes are impossible to assemble and physically connect. Our "I/O-CRATEs" can be turned into various kinds of furniture such as racks, chairs, tables, stools, counters, walls, and floors. We also assumed original concepts of "transportability" and "open-air conditions".

7. CONCLUSION

This paper presented the concept of smart transportable surroundings at open-air events using universal modular units called "I/O-CRATEs". We also reported on their design, implementation, simulation, and an experiment. We are interested in social activities in public spaces in the future. The final goal of this research was to support social activities in public spaces, such as festivals, camps, and outdoor ceremonies. We therefore intend to conduct a second experimental event in other spaces.

We are also planning to enhance our kit technologically. We are going to adopt micro-memories that record and memorize all user interactions. The next version of “I/O-Crates” will be able to record and replay activities at one event. Ad-hoc network structures and re-configurability are also our issues.

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REFERENCES

(1) “BOX. Open System for Connected People”: http://projects.interaction-ivrea.it/box/

(2) Edward L (2002)., "Designing a Perceptive Smart Room Interface", UbiComp 2002 Workshop on Collaboration with Interactive Walls and Tables, Gothenberg, Sweden.

(3) Gorbet, M. G., Orth, M., and Ishii, H(1998):. Triangles: tangible interface for manipulation and exploration of digital information topography. Proc. CHI ’98, ACM Press, 1998.

(4) Kohtake N., Ohsawa R., Yonezawa T., Matsukura Y., Iwai M., Takashio K., and Tokuda H.(2005):
“u-Texture: Self-Organizable Universal Panels for Creating Smart Surroundings”. In 7th International Conference Ubicomp 2005: Ubiquitous Computing, pp. 19- 36.

(5) LEGO MINDSTORM:

http://mindstorms.lego.com/

(6) McCullough M.(2005), “Digital Ground: Architecture, Pervasive Computing, and Environmental Knowing”, MIT Press, 2005.

(7) Resnick, M., Behavior construction kits. In Communications of the ACM (1993),36(7):64-71

(8) Si H., Kawahara Y., Morikawa H., and Aoyama T (2005).: "A Stochastic Approach for Creating Context-Aware Services based on Context Histories in Smart Home," In Proceedings of the 3rd International Conference on Pervasive Computing (Pervasive 2005), Exploiting Context Histories in Smart Environments (ECHISE2005), pp. 37- 41, Munich, Germany, May 2005.

(9) Snoonian, D (2003).: Smart buildings. IEEE Spectrum 40 (2003) pp. 18- 23.

(10) Terada, T., Tsukamoto, M., Yoshihisa, T., Kishino, Y., Nishio, S., Hayakawa, K., and Kashitani, A (2003).: A Rule-based I/O Control Device for Ubiquitous Computing, Adjunct Proc. of 15th International Conference on Ubiquitous Computing (UbiComp 2003) Poster Session, pp. 213- 214.

(11) Terada, T., Tsukamoto, M., Hayakawa, K., Yoshihisa, T., Kishino, Y., Nishio, S., and Kashitani (2004),

A.Ubiquitous Chip: a Rule-based I/O Control Device for Ubiquitous Computing, Proc. of Int'l Conf. on Pervasive Computing (Pervasive 2004), pp. 238- 253

(12) Tandler, P., Prante, T., Muller-Tomfelde, C., Streitz, N. A., and Steinmertz, R.(2001): Connectables:

Dynamic coupling of displays for the flexible creation of shared workspaces. In Annual ACM Symposium on User Interface Software and Technology (UIST’01). pp. 11- 20.

(13) Tokuda, H., Takashio, K., Nakazawa, J., Matsumiya (2004), K., Ito, M., and Saito, M.: Sf2: Smart furniture for creating ubiquitous applications. In International Workshop on Cyberspace Technologies and Societies (IWCT2004). pp. 423- 429.

(14) Wyeth, P., and Wyeth, G.(2001): Electronic blocks: Tangible programming elements for preschoolers. Proc. Interact 2001, IFIP (2001).

Appendix.

Temporal transitions of human flows and group dynamics on the pier.