Crafting Concrete as a Material for Enhancing Meaningful Interactions

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Abstract. Concrete is a composite material mostly used for the buildings and road surfaces ever since early human history, and which also can be used in contemporary product design as its unique aesthetic properties. In this paper, we present a series of small-scale explorations of concrete crafted as a central material, first utilizing its hygroscopicity interacting as an ephemeral and dynamic display; and secondly eliciting tactile interaction for its unique surface textures. Through hands-on engagement to unveil concrete potential when fabricated with digital technologies, we discuss how this large-scale and ubiquitous material could bring particular and intriguing experiences in our everyday lives, most importantly how can the potential of concrete be framed and described and enhance meaningful concrete reflections within HCI community.

Keywords: Concrete · Craft practice · Digital technologies · Material properties · Material experience · Material-centered interaction design · Human-Computer Interaction

1 Introduction

Concrete is a composite material composed of sand, gravels and water mixed by cement, which hardens over time [21], thus mostly used for the building and road surfaces, which used as an ubiquitous material for a quite long period of time throughout human history. Materialists investigate concrete for a better performance, for example, stronger hygroscopicity and self-repairing capability through material science perspective. Additionally, as its particular aesthetic (e.g., grey color, unique textures, coldness) and craft properties, designers also use concrete to conduct product design concepts [1, 14] and artistic artifacts. Another corpus of designers attempted to mix concrete with extra materials (e.g., silicon, resin, fiber optic) to change its existing properties for various behaviors.

As the robustness and rigidness, concrete is always used for large-scale installations. In architectural space, Wastiels provided "touching material visually" to assess concrete through its visual aspects as a building material [19]; the recent development of materials

M. Kurosu (Ed.): HCI 2017, Part I, LNCS 10271, pp. 634–644, 2017.
DOI: 10.1007/978-3-319-58071-5_48

also promote designers and architecture researchers to define changeable and responsive properties of this materials. Chronos Chromos Concrete fabricated thermodynamic ink with computational technologies as a dynamic display through color change, holding the properties of ordinary state [16]. Marin Philippe presents an experiment based on the design and fabrication of an interactive concrete surface as a smart material [7]. However, for being such a ubiquitous material in our environment, how to utilize its intrinsic properties and characteristics for new form of interaction design is poorly addressed to date. Through a cross-discipline perspective, concrete is still largely unexplored in the domain of HCI community and interaction design.

In the field of HCI, An increasing number of HCI researchers and scholars have to give a further definition of the material at hand, and also need to explore how they can shape new expressions, experiences, characters and functions of design through their unique properties. By blending digital and physical properties into a composite material, future interactions may benefit from materials-centric modes of development and analysis.

2 Craft in Design and HCI

Craft practice has played a considerable role in practice-led design research for the last two decades, especially as the subject and the media for theoretical inquiry [8]. And considerably, craft practice has already recognized as a logic thinking [2] and a dynamic process of learning and understanding through material experience by hands-on engagement in interaction design research.

A corpus of scholars and researchers in HCI have similarly conducted different types of experiments and exploratory design process by using interactive electronics fabricated with materials such as paper [10, 12], wood [15], some other types of textiles [3, 9, 18], and even crafting code as a digital material [4] and plant as a living material [13]. Vasiliki also presents a series of explorations around leather for providing new types of interactive design by blending traditional craft method with contemporary fabrication [17]. Another relevant orientations within this field tend to articulate a perspective of crafting artifacts could reveal particular 'hidden' qualities of the material [11].

With the concrete material as an entry point, several questions need to be further explored, the most important perhaps what roles will concrete play and how concrete gains new values in designing interactive system. We shed light on two strands of problems for further understanding of concrete, exploring its future possibilities within HCI.

- What are the special properties of concrete? How might we describe this material in terms of material character [20]? How can the potential of this material be framed and described?
- By applying craft practice into our design process when fabricated with digital technologies, what kind of interactions will be elicited, and to what extent the interactions will be extended to a broader areas within HCI community?

In this paper, we tend to articulate how concrete will enhance meaningful interactions and what experiences it will bring through its properties when fabricated with digital technologies, how to "allow material properties to guide our design" [22], and what roles it will play in the future interaction design and HCI domains.

3 Prototypes

We built these two prototypes to illustrate how utilizing concrete properties can shape new meaningful interactions. And each prototype demonstrated a different concrete-based interaction design. There is a detailed explanation of what the properties are, how this property can be associated with people's everyday life, what the prototype does, and how it was crafted. Each prototype is developed as open-ended to encourage more and further exploration.

3.1 Water Shadow

As we know concrete will change its color naturally when meeting with water, and the parts that meet water will change to a darker color than the peripheral parts immediately, which makes it appear various images without any other external components. Especially, the temporary image will disappear following the evaporation of water.

What are we inspired from the 'ephemeral shadow'? What if this properties encounter with human behaviors such as Hand Shadow Games, which is playing when exposure to a strong light environment? And what if people can still play this game without a limiting environment? What kind of different experiences it will bring into everyday lives? If so, what are the differences between the Hand Shadow Games and the Water Shadow? On the other hand, besides the game itself, what it will bring when focusing on the certain material concrete, what kind of new definition or meaning can be framed around concrete in our daily life within HCI community?

Fabrication Process
We conducted a Water Shadow system, which could display a dynamic but ephemeral image according to the hand shadows. We used PO 42.5 cement, which is easy and cheap to achieve from online shops, and then crafted the concrete according to the normal cement-water proportion (3.5:1) within laboratory level. We made a 17 * 25 * 0.8 cm container for crafting the concrete slab. And we would achieve an ideal slab with 5–8 h setting time and the 20 °C room temperature (Fig. 1).

To achieve a better hydrophil effect, we drilled holes into an array at the back of the slab, from where for guiding the water. Then, fixing the transparent pipes onto each hole.

Hygroscopicity Test
With repeating experiments to test concrete hygroscopicity and permeability, we solved the problems around water amount and the needed appearing or vanishing time, and finally found an ideal way to display water traces you needed. Through test, the time for appearing is only 1.5–3 s, the vanishing time will be 1 min–2 min because of the limitation of temperature and ventilation.

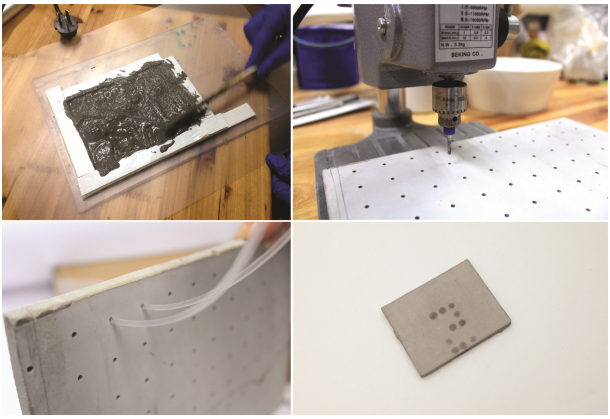

Fig. 1. Water Shadow: craft a concrete slab (top left); drill holes on the back of the concrete slab (top right); guide the water through pipes (bottom left); conduct an hygroscopicity test on a small concrete slab (bottom right)

Water Shadow (Fig. 2) contained no extra coloring matter, which is different with Chronos Chromos Concrete [16], but can also make dynamic changes through on or off the water.

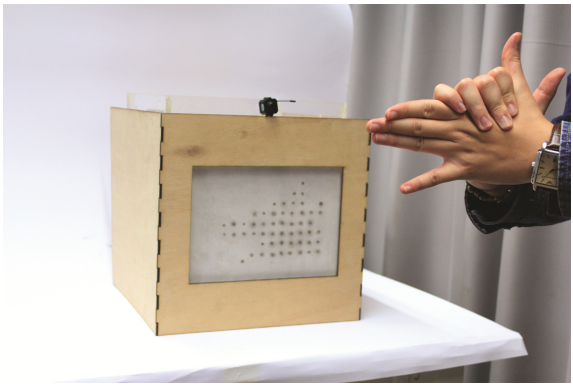

Fig. 2. Water Shadow

Technical Design

As the system described (Fig. 3), water goes down through pipes from the water tank on the top to the holes back the concrete slab, and stops when the steering engines cut the current by straining the ropes tying on the pipes, and on the contrary, loose the ropes to keep water flow.

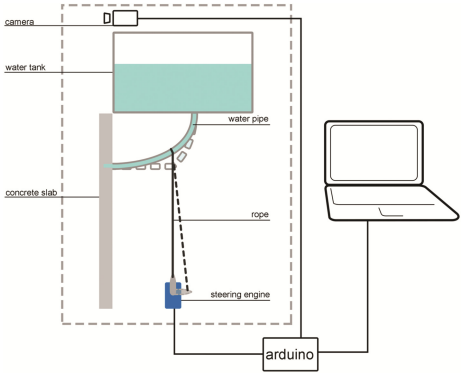

Fig. 3. Technical structure of Water Shadow system

The camera was used for capturing the image of human hands. PC would process the image to a pixel image and then transport the data to the micro controller to actuate the corresponding location of water shadow system. The effects would show within 5 s.

3.2 Live Cube

Concrete is a composite material composed of sand, gravels and water mixed by cement, which leading to unique surface textures. What would happen if we touch the different textures? What if these textures can make a sound, or make different frequencies of vibration? If we give the unique personality to such a material as

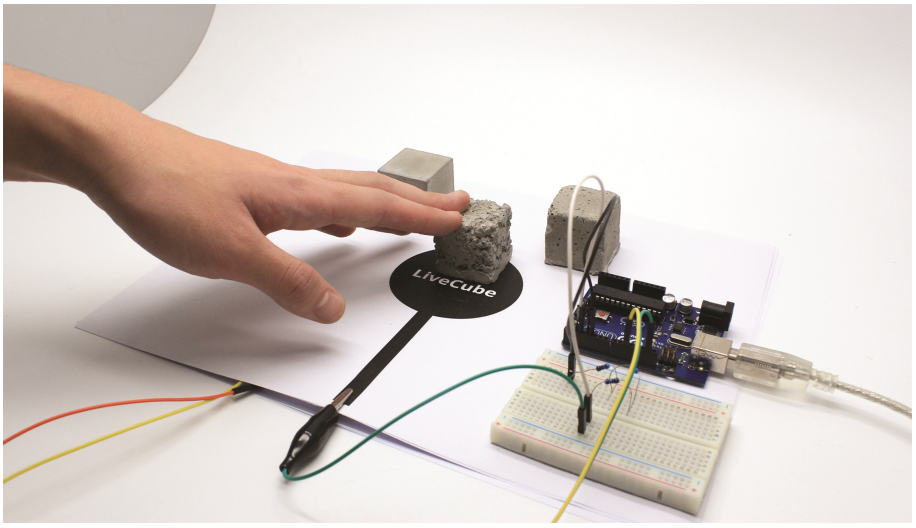

Fig. 4. Live Cube elicits dynamic vibration and tone through 'touching' behaviors, controlled by an Arduino platform

concrete, what will it bring to people's emotion or experiences? How can concrete character be framed in this prototype? (Fig. 4).

We used PO 42.5 cement to craft three samples through three different ingredient's proportion in silicon mould. To underline the surface textures, we crafted concrete into simple cubic shape with sample #1 only with cement and water; sample #2 with cement, water and fine yellow sand; and sample #3 with cement, water, rough gravels, yellow sand, and black sand stones (Fig. 5).

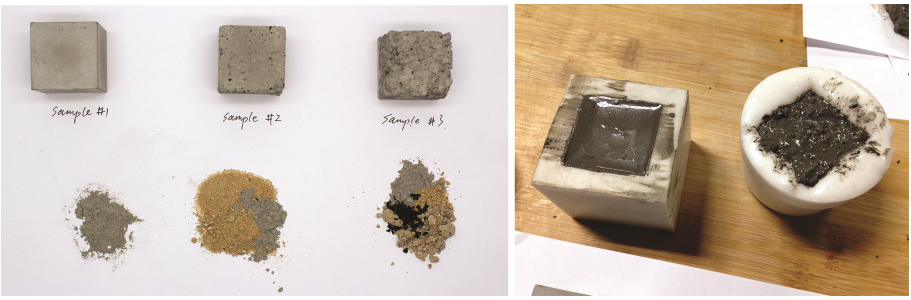

Fig. 5. Three samples with three different ingredient's proportion; craft the concrete in silicon mould

In this system, a camera is conducted to catch each different surface textures, and processing the picture to a black-and-white image (Fig. 6). By embedding with the vibration sensor and buzzer, three different concrete cube could shape three different personality once been touched.

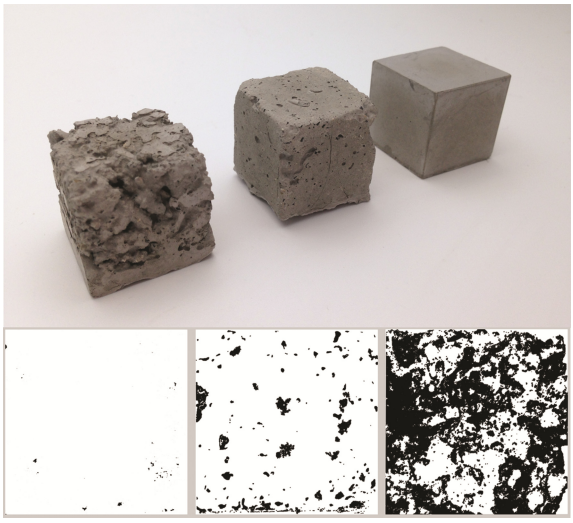

Fig. 6. Live Cube: three samples

Live Cube will give the correspondingly tone and vibration feed back when being touched, through which way makes them like a living human. The smooth one will vibrate strongly and make a smooth but high tone as its unique feedback; on the contrary, the roughest one will act with a weakly vibration and a low, deep tone.

4 User Study

In order to evaluate how are these two prototypes eliciting concrete characters and how they can be framed or described in HCI domain, we conducted a semi-structure interview sessions to gain insight form the participants, also the future applications and possible areas.

4.1 Apparatus

We showed the two different concrete prototypes separately on the table. Water shadow acted as a concrete display controlled by Arduino microcontrollers by applying voltage 220 V. Three different concrete cube were connected with one camera and micro controller and with a PC.

4.2 Participants

The study consisted of 11 participants (4 females) with age range from 21 up to 38 years. The occupation backgrounds ranged from interactive designers, students and animation. In general, 9 participants did not have special experience with concrete before. 3 designers had knowledge of craft method and interactive technologies. The average time spent performing the study was approximately 35 min.

4.3 Procedure

We began each participant with the introduction of a natural concrete sample and its gradients (e.g. cement, sand, gravel) instead of the direct performing and demonstrations of Water Shadow and Live Cube, with questions like: (1) *What are the particular properties of this material in your mind?* (2) *How do you feel this material, physically and emotionally*. In this session, participants were allowed to tinker with this material [5] (e.g. touch, smell, knock). We would like to gain the intrinsic insights in general around the concrete as a material.

Next, we would show the two prototypes separately to the participants, and introduced how the concrete slab display the watermark and how the cubic concrete elicited the personality. Participants were allowed to experience, touch and feel Water Shadow and Live Cube. During this session, we encouraged the participants to talk at length about the aspects of the two prototypes they found interesting and uninteresting, gaining insights into initial interactions and reactions. To extend the usability of these two concepts, we also allowed the participants to describe the potential content design domains, and the ideas for the future applications.

All sessions were video recorded and later transcribed for analysis. Then we analyzed the recorded video and transcripts by using a grounded theory approach [6] in order to reveal how can the potential of concrete be framed and described within HCI community.

5 Findings

5.1 General User Perceptions

In general, most participants consider concrete with the key words like, "*cold*", "*rough*", "*industrialization*", "*large- scale*", "*crack*", "*ambient*", "*lifelessness*". However, during the study participants showed the curiosity, enjoyment and delight to the Water Shadow and Live Cube. P6 stated that the appearance and disappearance of the watermark made him fixate on the concrete slab intently. P2 felt the cubic concrete "*like a cute tiny robot*" which attracted him to touch it more than once. The majority of participants suggested a larger scale system and various forms of information display of Water Shadow, and also more personality and interaction styles for the Live Cube.

5.2 Water Shadow

Different patterns of water traces show on the concrete slab within 1–2 s, and disappear in 1–2 min naturally, high temperature or fast wind blowing will accelerate the evaporation of water to promote this process, controlling the time in 2–3 s. P3 said that "*I can't help fixating on the concrete slab tracing the watermarks, it looks so natural*." As the specialness of concrete hygroscopicity, we regard this process as a slow motion, which will increase the focus on the water traces from showing to disappearing not limiting the game itself, which is functioned differently than smart phones and Led-based displays, and the aesthetic properties of concrete could be also reflected through this way. On the other hand, as all the controlling system processed mechanically back off the concrete slab, it will result in increased curiosity, examination and repeating play.

Throughout the study participants were encouraged to envision the possible areas and future applications for the display. A range of possible areas domain emerged: artistic installation; dynamic game playing; architectural environment; weather information; display complex information such as breath and heartbeat.

5.3 Live Cube

Through Live Cube, people could touch concrete's surface, feel their unique textures and various vibration frequencies, and listen their different 'voices'. In this design, each cubic concrete were given a personal identifier, and elicited a particular and joyful emotional experience to the users, which enticed users to touch their surface more than once.

In this prototype, we asked questions like: *If the object were a person, what kind of person would it be? And would it have any personality?* As P4 said: "*the smooth one looks like one beautiful lady with a fine voice*", "*the roughest one seems like a man with*

rugged face" (P3). And we also found participants tended to touch the surface repeatedly to feel the different roughness of each concrete sample without seeing them.

With the discussion around Live Cube, we summarized the possible areas and future applications: toy product design such as 3D cubic puzzle according the surface; intelligent tiny robot.

6 Discussion

6.1 Crafting Concrete as a Material

We crafted concrete through a diversity range of ways to explore and understand what is concrete, what is it made of, and what kinds of particular properties does concrete have. By applying craft practice into our design progress, we succeed to give a new definition through its properties and character, and find a great potential of concrete within HCI community. Meanwhile, the exploration of concrete also makes a significant contribution into craft community.

6.2 Concrete Character

Through the study of two prototypes, participants successfully experienced concrete in a different way, most of them would like to redefine concrete properties and gave a novel definition through the concrete character. Also, they have their personal interests. P4 stated that Water Shadow could express its own information by the hydrophillic properties, which could be connected with the *weather*, or *time*; P10 considered that each cubic concrete of Live Cube had their own personality like a real person, which was so different with his previous concept around concrete, and they could be used as some interactive toys. Concrete crafted as a center material elicits different characters through merging with digital technologies, stimulating impression making and emotional attachment.

6.3 Limitations and Future Work

We conducted a small-scale exploration of concrete within a lab level, one 17 * 25 * 0.8 cm concrete slab and three 4 * 4 * 4 cm cubic concrete, participants could experience this material and also give an evaluation around the concrete characters, also several future applications. However, such interactive prototypes would need more improved; adapting to a larger scale system and high-resolution display for Water Shadow, more different forms for Live Cube. As a future work, various ways of crafting of concrete are pursued, more properties and concrete characters hidden inside concrete need to be explored, as well as different kinds of live dynamic data displays and some other meaningful and intriguing interactions for a diverse range of application areas through these two concrete prototypes.

7 Conclusion

Through exploring these two prototypes, we tend to demonstrate that applying craft practice into our studies is quite useful and appropriate, especially when enhancing concrete interactions within HCI community and interaction design field. In this paper, we articulate concrete crafted as a material, merging with computational technologies, can provide a great potential for providing new types of interactions, and most importantly enhancing meaningful user experiences and reflections. Each prototype illustrates the detailed techniques and methods applied, and find exploring new ways to think and tinker with this ubiquitous medium bring new possibilities into future research. Concrete is, after all, as a massive and ubiquitous material in our environment deserves to have been paid more attention, not limited in its present domain, and also deserves to be explored through various ways within HCI in this digital age.

Acknowledgement. This research was supported by the National Natural Science Foundation of China (No. 51675476 and No. 51175458).

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