Six-Forty by Four-Eighty: The Design of Computational Materials

Removed to preserve anonymity.

CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

Abstract
In this paper we describe the development of Six-Forty by Four-Eighty: an art and design installation composed of 220 interactive lighting tiles. We discuss previous work that address the physicality of computation, our design and fabrication processes, technical implementation, the development of a new technique for data transmission through the body and the piece's exhibition context. By describing the interrelationship between these elements we hope to shed light into the forging of an industrial design practice that straddles the art, design and technology trichotomy.

Keywords
Art, body communication, industrial design, interface design, materials, physical pixel, tangible interface.

ACM Classification Keywords
H.5.2 User Interfaces — Theory and methods.

Introduction
As computers progressively permeate our ecology of physical objects, the interaction language and metaphors that were once relegated to the world of GUIs are now finding themselves highly intertwined with the affordances of physical things. The result is the emergence of a new class of objects that are crafted

through computational tools, carry within them embedded computers, and communicate and behave through with the use of computational metaphors.

Six-Forty by Four-Eighty is an installation piece composed of 220 interactive lighting tiles and was presented at Design Miami/ Basel 2010 in conjunction with Art Basel in Basel, Switzerland. Through its form factor, interaction model and conceptual definitions, this work conveys to viewers a future where computation will leave the confines of computer screens and spread itself onto the world.

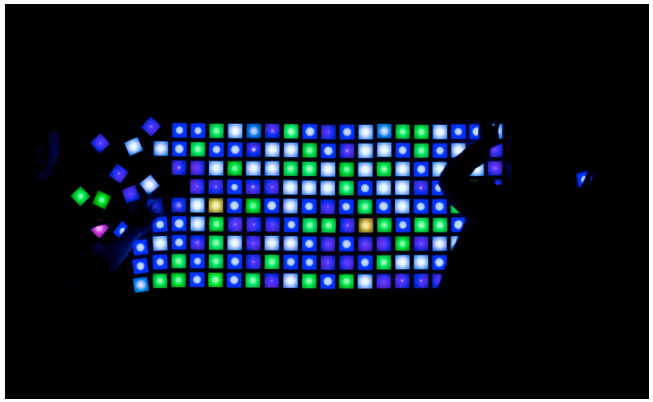

figure 1. Six-Forty by Four-Eighty packed into a grid.

At a conceptual level, Six-Forty by Four-Eighty uses the metaphor of the pixel as the ambassador for computation, and more specifically, references how our tacit understanding of what computers are – and can be – is highly mediated by the prevalence of addressable displays. The pixel-tiles in Six-Forty by Four-Eighty can be packed into a grid as one would traditionally expect and be controlled in unison at the aggregate level, but can also break away from this grid, making the interaction physical and bringing the focus to the particulate level. As users start rearranging and sculpting with this luminous medium, a new interaction model opens up, where it is possible to touch a pixel-tile to change its color and, most interestingly, it becomes possible to physically "copy-and-paste" color from two distinct pixel-tiles by using the user's body as the information conduit. In a future where computation is to become highly tangible, our bodies have to play an intrinsic role in our ecology of computational objects.

Related Work

The drive to turn pixels and computers into tangible and graspable artifacts is far from new and has continuously pervaded the HCI conscious seeking new implementations and rationales as the technology possibilities advance. In this section, we introduce a couple of noteworthy examples.

An early example of this motivation is John Frazer's *Universal Constructor*, which implements a working model of self-organizing interactive environment composed of stackable physical pixels [1]. On a similar vein is Kelly Heaton's *Physical Pixel Project*, which focused on the convergence of physical sculpting and computer animation by developing light orbs and cubes that were networked and responded to touch [2]. More recently, Susanne Seitinger's *Urban Pixels* has brought these ideas to the scale of the city and implemented wireless, solar-powered lighting units that influence how we experience the city as a display [3].

In Six-Forty by Four-Eighty, we have to chosen to focus on two fundamental aspects: (1) that physical pixels can concomitantly operate at global and local scales

depending on the proximity, perspective and level of physical engagement of the user; and (2) that it was crucial for the user's body to play a critical role in how the computation metaphors cross the different levels of perspective taking and engagement.

In order to implement the physical "copy-and-paste" capability, we built upon two different works, namely: the *Personal Area Network* project developed by Thomas Zimmerman, where handshakes were used to transmit data between two users [5]; and Jay Silver's *Drawdio*, where it is possible for people to draw resistive networks with a regular paintbrush and by touching different parts of drawing one can modulate a sound output [4].

Design Principles

Six-Forty by Four-Eighty design principles were elicited from the necessity to create a piece that could straddle the art, design and technology trichotomy chasm, while communicating to our audience the latent possibilities of physical computing. It was important that the piece (1) conveyed a strong conceptual motivation captured in its form factor, aesthetics, and exhibition context; (2) supported a utilitarian functionality that could be easily communicated to visitors and; (3) that the technology implemented could reveal and support the conceptual and functional motivations.

Art

Conceptually, Six-Forty by Four-Eighty examines the materiality of computation and a future where computers will leave the confines of screens and keyboards to become an integral part of the physical world. Since pixels and their graphical user interfaces are the way that most people understand what computers are, we have chosen to render pixels as independent, physical objects. This created an experience where visitors could touch and metaphorically break computation into pieces, acting as co-creators able to re-sculpt the work, and provided a gateway to discuss the larger conceptual idea.

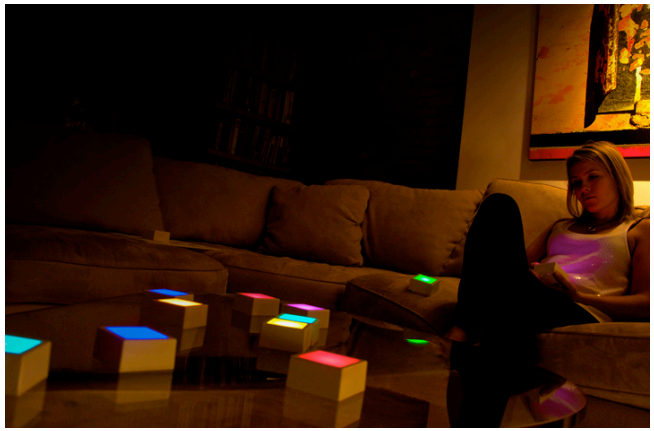

figure 2. Pixel-tiles as a lighting system in the home.

Design

Functionally, Six-Forty by Four-Eighty can also be deployed in the home, doubling as a modular, interactive lighting system that supports a high degree of customization. This functional design role portrays a scenario where lighting becomes a personal experience, which one can physically interact with to create different ambience, moods and living environments.

Technology

Technically, it was important to back the conceptual and functional aspects of the piece with a technology that brought people into the 'computing' experience and where their physical presence played a role in the

behavior and interaction of the pixel-tiles. In order to achieve this, we developed and implemented a new technique where people's bodies are used as a conduit for serial data, literally acting as a wire for pixel-tiles to transfer information from one to another and allowing people to become an integral part of the computation and communication process. When touching a pixel-tile with one hand for a short period of time, its starts pulsing – to indicate its transmission state – and starts transmitting its color through the person's hand. By keeping the first hand in place and touching other pixel-tiles, the color is transferred from one pixel-tile to another, creating a form of physical 'copy-and-paste'.

Interaction Model

Six-Forty by Four-Eighty's only form of output is the light produced by an RGB LED housed inside of the case, while user input happens through touch and an infrared remote control. This simple system allows people to interact with it in four different ways: (1)The pixel-tiles are magnetic and can be rearranged on a ferrous surface; (2) Touching a pixel-tile makes it cycle through a color palette; (3) Touching a pixel-tile and holding, while using your other hand to touch other pixel-tiles, 'copy-and-pastes' color from one pixel-tile to another; (4) The remote control allows users to control a pixel-tile's animation by changing the speed and sharpness in which they pulse a certain color. Additionally, it allows users to switch between a warm or a cool color palette.

In order to bring together these distinct interaction modalities into a cohesive interaction experience, the affordances are broken down into micro and macro behaviors and the light quality is designed under the constraints of a physical model, which furthers the understanding of these pixel-tiles as a physical material.

Micro Behavior: "The Particulate Level"
At the micro scale, the pixel-tiles are designed to be interacted with in exclusively physical ways. First, a person needs to be within arm reach of the tiles, becoming surrounded by the installation and losing the sense of scale and behavior of the global arrangement. From this standpoint, the tiles can grabbed and moved around into different arrangements and by touching their screen it is possible to make their color change. Finally, by sequentially touching two pixel-tiles at the same time, it is possible to physically copy-and-paste their colors from one to another. At this micro scale, the pixel-tiles act as an interactive particulate and their behavior is highly supported by the physical model imbued in the light pattern.

Macro Behavior: "The Aggregate Level"
When a user steps back from the micro level taking a more macro perspective of the installation, the physicality melts away. The three-dimensionality of the cases disappears into darkness and all one sees are floating squares of light animating in unison. The macro behavior requires users to control the installation as a whole through an infrared remote control. The pixel-tiles acting together foster the emergence of behaviors that cannot be perceived when one is standing up close. Additionally, the directionality of the IR beam preserves the sense of direct control but shifts its scope from operating onto a single pixel-tile to acting upon the computational substrate as a whole.

Physical Model
Conceptually, Six-Forty by Four-Eighty is about computation and physicality. Its form references the rectangular field of color most people associate with the pixel and its behavior evokes materiality.The outstanding material property constructed by the embedded firmware, in our case, was the color of the light emanating from the pixel-tile and the ways this color changed in response to touch. Because ordinary material properties tend to be instantaneously evident and consistent, care was taken to make the properties constructed by the computation similarly responsive and consistent. For example, clock rates were chosen to ensure the light did not flicker at all and that the system responded quickly to touch. The software was structured asynchronously to maintain responsiveness.

In addition, the constructed properties were designed to be as similar as possible to the properties of ordinary materials. Specifically, when a touch is detected, the light's brightness changes according to an exponential decay model, which was based on the behavior of incandescent light bulbs and the human retina, but also simulates the experience of elastically deforming a soft object with applied pressure.

Process and Technology

Six-Forty by Four-Eighty is composed of 220 pixel-tiles, which are 3"x3"x1.5" boxes injection molded from ABS/Polycarbonate white polymer and covered by a special light diffuser and ITO (indium tin oxide) glass composite. Each pixel-tile is outfitted with a lithium polymer rechargeable battery, rare earth magnets so it can be attached to ferrous surfaces and a custom designed circuit board responsible for its interactive behavior and functionality.

The diffuser-ITO composite was created by layering a flashed opal diffuser glass, an optical adhesive, and a Pilkington TEC 15 conductive glass, which is a glass infused with ITO while molten. The edges of the composite were covered with a conductive copper vinyl that was connected to our sensing and data transmission circuits.

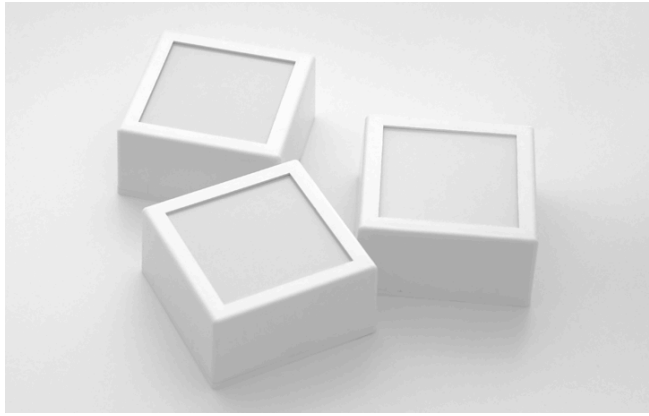

figure 3. Pixel-tiles injection molded cases with diffuser-ITO composite.

Hardware
Six-Forty by Four-Eighty's technical innovation is the ability of a pixel-tile to transmit its color state to other tiles through the human-body. To accomplish this, we use a diffuser-ITO composite as an electrode for capacitive touch sensing, data transmission (TX) and reception (RX), providing users with a minimal and simple interface that can handle multiple functionalities. An AVR microcontroller cycles between the three different modes alternating between sensing and data receiving when a touch is not being detected and sensing and transmission when touch is detected. The

most challenging aspect of this design was to ensure consistent UART data reception that was free of noise and unaffected by the circuit's large stray capacitance. This required the use of a two-step analog amplifier, buffering and a common ground between the pixel-tiles shared through a steel back plate and spring-loaded pin located at the bottom of all cases. The capacitive sensor was implemented through loading mode, where the charge and discharge frequency is controlled through firmware, allowing us to easily calibrate its sensitivity.

The global interaction was trivially implemented by using an infrared receiver at an interrupt port, which allowed people to control and modulate several pixel-tiles at a time.

Installation

Six-Forty by Four-Eighty was commissioned as a new work by Design Miami/ Basel to be featured at their yearly design fair in Basel, Switzerland. The attendance of this type of fair is comprised primarily of art collectors, dealers, critics, artists and designers, who are not particularly familiar with technological artifacts that operate outside of the consumer electronics industry. Moreover, work shown in this environment is rarely meant to be touched or interacted with, on the contrary, touching is highly discouraged.

From our observations, visitors' initial impression was to approach the piece and observe it, completely unaware of its interactive possibilities. After observing others interact with the piece or being instructed to do so, a visceral connection with the tiles started to develop. First, visitors tried to grasp the full extent of its functionality, gaining control of its behavior and color. Similarly to how we observe and physically explore a new material we've never encountered before. After this exploration stage was overcome, then the piece became a tool for co-creation, and visitors used it to create their own designs and arrangements, continuously transitioning between the micro and macro interaction levels.

Conclusion and Future Work

As with any design work, the possibilities for improvement and directions for future work are seemingly endless. At a first instance, the ability to locate the physical position of the pixel-tiles in space would allow for video display and a whole new range of interactions. Additionally, new materials and form factors (shape and size of the pixel-tiles) would open new interaction spaces and use scenarios.

References

[1] Frazer, J. (1995) *An Evolutionary Architecture*. Architectural Association Publications.

[2] Heaton, K. (2000). *Physical Pixel*. MIT Media Lab Thesis.

[3] Seitinger, S., Perry, D. S., and Mitchell, W. J. (2009) *Urban pixels: painting the city with light*. In Proc. of the 27th international Conference on Human Factors in Computing Systems. CHI '09. ACM, New York, NY, 839-848.

[4] Silver, J. S. (2009) *Nature as interface: MacGyver'ing and Martha-Stewart'ing interactivity with trees, pencils, grandpa, even the kitchen sink*. In Proc. of the Seventh ACM Conference on Creativity and Cognition (Berkeley, California, USA, October 26 - 30, 2009). C&C '09. ACM, New York, NY, 483-484.

[5] Zimmerman, Thomas. (1995) *Personal Area Networks (PAN): Near-Field Intra-Body Communication*. MIT Media Lab Thesis.