To be published as a CHI'01 short paper (April 2001, Seattle, WA)

Strata/ICC: Physical Models as Computational Interfaces

Brygg Ullmer, Elizabeth Kim*, Axel Kilian†, Steve Gray, and Hiroshi Ishii**
MIT Media Lab
Tangible Media Group*, Aesthetics and Computing Group†
20 Ames St., E15-445
Cambridge, MA 02139 USA
+1 617 253 4121
{ullmer, eliskim, akilian, gray, ishii}@media.mit.edu

ABSTRACT

We present Strata/ICC: a computationally-augmented physical model of a 54-story skyscraper that serves as an interactive display of electricity consumption, water consumption, network utilization, and other kinds of infrastructure. Our approach pushes information visualizations into the physical world, with a vision of transforming large-scale physical models into new kinds of interaction workspaces.

Keywords: tangible interfaces, physical models, information visualization, ambient displays

INTRODUCTION

Physical models of buildings, historical artifacts, molecules, and other structures have long played important roles in architecture, museums, science and industry, and beyond. These models are important both as physical representations and communications mediums, enabling people to view and interact both with the models and each other. In the computing world, information visualization tools have begun to serve related ends, emerging as important vehicles for understanding complex, dynamic systems such as astronomical simulations, financial models, and the human genome.

Some links between information visualization and physical models have emerged in recent years. Stereo lithography and related techniques are now used to fabricate inert physical models of molecules and other structures. Embedded lamps and video projectors have been used to "bring to life" traditional physical models and mimic boards in museums and control rooms. However, information visualization has remained largely confined to graphical screen- and VR-based mediums, while electronically-augmented physical models have remained limited both in function and frequency of use.

In this paper, we present Strata/ICC: a computationally-augmented physical model of a 54-story skyscraper that serves as an interactive display of electricity consumption, water consumption, network utilization, and other kinds of infrastructure that normally remain invisible to human eyes. Strata/ICC employs new approaches for using physical models as interactive displays. We believe this work begins to suggest paths toward using physical models as computational interfaces in a wide variety of application domains.

Figures 1a,b: Strata/ICC model; token and time-wheel controls

DESIGN GOALS

Strata/ICC was designed and realized as an interactive installation for an exhibition of tangible interfaces in the NTT InterCommunication Center (ICC), an art/technology museum. Strata/ICC was designed as a representation of the building hosting this exhibit: a 54 story Tokyo skyscraper.

The Strata/ICC installation had several design goals. Several tangible interfaces have used building "phicons" (physical icons) as representations of architectural buildings (e.g., [1]). In these cases, a general purpose graphical surface has served as the central workspace, with the building phicons used as data elements and controls within this space. In contrast, Strata/ICC sought to transform the physical building model itself into a kind of interaction "workspace," with other physical tokens and tools used within this model.

A second design goal related to physical scale. Most tangible interfaces have centered around systems of small physical objects. Strata/ICC explored the space of more architectural-scale interfaces to be explored by the hand, eye, and foot – in this case, a two-meter-tall physical model. We hoped this larger scale might strengthen collocated collaboration; suggest new interface techniques; and in general deliver a qualitatively different experience than the same content on a screen or small object.

A third design goal involved the choice of display mediums. Our target "task," both for gallery visitors and prospectively for a building atrium or control room context, was to give users a sense of the building-wide consumption and utilization of resources such as power, water, and network bandwidth. Instead of the high-resolution graphics favored by most information visualization techniques, we sought to use a low-resolution approach sharing common ground with "ambient displays." [2] While not a replacement for detail-oriented screen displays, this seemed a promising medium for communicating the "big picture" of building activity.

PHYSICAL STRUCTURE AND INTERACTION

Strata/ICC was constructed of 54 layers of transparent acrylic. Each layer was cut in the form of a building floor, and etched with high-level features (e.g., stairwells and theatres). Every tenth floor was frosted, as a cue for "reading" the structure. Each active layer was embedded with a networked microcontroller and eight white LEDs; large base-level floors were embedded with several of these units. These allowed floors to edge-light (glow) with variable intensity. Illumination could also shift around or between floors with variable speed and intensity.

Interaction was mediated by five physical tokens and a "time wheel" mounted in the model at the location of the building's main entrance. Each token was associated with information about the activity of a kind of building infrastructure over a 24 hour period (ideally, the last 24 hours). Two tokens were bound to actual floor-by-floor data describing the building's hourly water and electricity consumption. Three other tokens were bound to simulated temperature and network activity data.

Several lighting mappings were used for these tokens. For example, the electricity and water tokens were coupled to rotating lighting patterns, analogous to an electricity meter's rotation. Higher consumption mapped to faster rotations and brighter intensities, and vice versa. Other mappings included fades of whole floors from light to dark, and light pulses that moved vertically through the tower.

The time wheel's 360° of rotation were coupled to the day's 24 hours. When a token was placed into a receptacle in the time wheel's center, a line of light underneath the translucent time wheel was illuminated, indicating the selected time. Simultaneously, the building layers shifted their illumination to display the token's associated data. When the wheel was rotated, the building layers again shifted illumination to reflect the corresponding data in time and space.

IMPLEMENTATION

Given the gallery context, a compelling integration of aesthetic and technical factors was a high priority. Another focus was the development of new fabrication techniques which might allow Strata/ICC's approach to be rapidly applied to other content domains. Half of the four-month project was spent using 3D illustration software to develop more than twenty major designs iterations, resulting in a visual catalog of more than 600 sketches. Functioning screen-based and quarter-scale physical prototypes were also implemented en route to the final design.

Laser cutter fabrication was central to the project, allowing the structure's 600 pounds of acrylic to be cut by a single person within two days. The cutter's bed size was 32"x18", so lower building floors were cut as arrays of interlocking tiles (also easing shipping and on-site manipulation). Circuit boards were also lased out of acrylic, allowing rapid design iteration, customization of the boards on a layer-by-layer basis, and the seamlessness of transparent circuitry in a transparent tower. As another technical feature, the four aluminum columns structurally supporting the tower were also used to pass power, ground, and RS485 A/B lines to the thirty networked nodes throughout the tower (due to time constraints, some floors were left unlit).

Strata/ICC was successfully installed in the gallery, and experienced by the exhibition's 5500 visitors.

DISCUSSION AND FUTURE WORK

Just as information visualization is eased when the information has a "native" visual form, architectural buildings lend themselves well to representation by both traditional and computationally-mediated physical models. We chose the ICC's home building as a subject both for its relevance and conceptual accessibility to gallery visitors, and as a feasible first target for our efforts. We have also prototyped and continue to develop similar interfaces to more abstract information in the distributed networking and biotechnology domains, which have been met with enthusiasm from experts in these fields.

One challenge with ambient displays lies in establishing clear mappings between displays and underlying content. By embedding lamps within the floor of a specific building model, and controlling these with causal, hands-on physical manipulation, Strata/ICC made progress in this area.

However, visitors noted that while it was easy to make relative comparisons – e.g., one floor's lighting being brighter or moving more quickly than another – absolute judgements about intensity levels were difficult. Several visitors suggested that shifts in color (e.g., red to blue), rather than intensity, might make for a more legible display.

While Strata/ICC was interactive, the interaction mechanisms were limited, and weakly integrated with the building model. Several of our exploratory designs involved direct physical interaction with the individual building floors. These designs involved representing building floors in a more logical/functional fashion, rather than as series of literal floor maps. In response, our continuing work is focusing more on logically-structured interaction spaces.

ACKNOWLEDGMENTS

Many people have assisted this work, including James Patten, Paul Yarin, Rehmi Post, Matt Reynolds, Jay Lee, Phil Frei, Ben Piper, John Underkoffler, Joanna Bersowska, Saul Griffith, Golan Levin, Ali Mazalek, Tim McNerney, Joe Pompei, Kelly Heaton, and Suzanne Beavers. Special thanks to Rob Poor for his PIC PWM implementation. Special thanks onsite to Shoji Itoh, Koichi Kido, Tetsushi Nonaka, Haruo Noma, Chie Arai, Lisa Lieberson, and many others, and to the Tokyo Opera City building management for building data. Profs. Neil Gershenfeld, Joe Jacobson, and Joe Paradiso lead a fabrication class that partially motivated our approach. We thank NTT ICC, IBM, Steelcase, Intel, and the TTT consortium for financial support.

REFERENCES

1. Ishii, H., and Ullmer, B. Tangible Bits: Towards Seamless Interfaces between People, Bits, and Atoms. In *Proceedings of CHI'97*, pp. 234-241.
2. Wisneski, C., Ishii, H., et al. Ambient Displays: Turning Architectural Space into an Interface between People and Digital Information. In *Proceedings of CoBuild'98*, pp. 22-32.