Currently, a new interactive movement is beginning to take place in architecture whereby we are seeing increased desire to create space that has the ability to dynamically interact with users. A number of emerging technologies and insights are being made in paralleling fields that will have a vast influence on future spatial interactivity. This paper looks at a number of contemporary projects and themes in user interface design that are shaping and contributing to the future of tangible interactive architecture.
1 Introduction

The fields of interactive media design and tangible interactive architecture are converging and will become even more entwined in the upcoming decades. Many of the same themes are being examined and tested in both fields and we are beginning to see how individual advancements in each field could beneficially influence the other. Currently, the pace of design experimentation and fabrication in interactive media is much more accelerated than in physical architecture and this means that there have been more projects to experiment with and learn from. Through many of the user interface (UI) projects I have worked on and are currently developing, I have noticed a number of trends in interactive media and user experience design that can profoundly impact robotic and built architecture projects.

Currently, a number of very interesting trends and advancements in UI design should be examined and applied to the creation of interactive built environments; among these, the most notable advancements being made in the organization (both graphically and through data relationships) and control of user interfaces. While it is important to understand that themes in each field may be similar, advancements in a particular area such as in the organization of information usually need to go through a type of translation to continue to make sense in another field or at a different scale. For example, the meta-data relationships between personalized content in a television UI could influence the organization of architectural elements that make up a dynamic transformational interactive space (i.e. how data from sensors could be organized for a specific type of personalized reaction). However, some advancement in UI design can be seen as having a more direct translation into architecture. For example, the gestural language currently being developed for the Apple iPhone, Microsoft Surface Table, Emotiv Headset and other UIs could be directly ported to the control of architecture environments right now.

As the fields of user interface design and interactive architecture converges we will begin to see a new type of hybridized digital/physical space. The lines between interactive digital UIs and interactive architecture are becoming increasingly blurred. New design standards and usability practices for current interface design coupled with new means of controlling interfaces has the potential to offer much to the field of architecture. Other paralleling technologies that rely on digital information but rooted in more tangible application such as meta-morphic robotics, evolutionary robotics and nanotechnology also have the ability to learn from UI design and in turn exponentially affect the interactive relationships users can have with space. More specifically these insights and new technologies can physically and intelligently empower architecture to be more adaptable, responsive and interactive.

2 Current Trends in Interface Design

A number of interesting trends can be seen in many of the new UI projects in our office as these projects incorporate an increased desire to create user-friendly, customizable and immersive interactive experiences for users. This does not mean stepping away from creating useful task based predictable experiences but instead means layering a new set of criteria on top of what we have thought of historically as good design, good usability and good user experience. Many of the current projects we are developing are designed with increased emphasis on using real-time data in personalized, reconfigurable and adaptable user interfaces. As more applications and software become available on-line, the amount of data that is created and available by specific users is growing exponentially. This in turn means that we have an increasing need to develop new methods for visualizing and accessing information and new technology to create a more seamless user experience. A number of projects outlined in this paper currently demonstrate some of this new spatial thinking and are very useful in understanding how new relationships are being developed between information in interfaces and users controlling or interacting with these interfaces.

Real-time customization is being applied to an increasing number of new UI projects and creates a unique experience as it allows users to dynamically manipulate the organization of information without needing to refresh a specific page (giving a user an uninterrupted experience). New technologies, specifically advancements in software and language
FIGURE 1. (Top Row) Facebook User Profile Page, User Moving Modules in Real-Time
FIGURES 2, 3. (Second Row) Digg Labs, Arc
FIGURES 4, 5. (Fourth Row) Digg Labs, Stack
FIGURE 6. (Fifth Row, Left 2 Images) Current State, Power Consumption Control for the iPhone, Real-Time Spatial Diagrams
FIGURES 7. (Fifth Row, Right 3 Images) Current State, Power Consumption Control for the iPhone, Real-Time Updatable Controls
FIGURES 8, 9. (Bottom Row) Photosynth Image Collage Using a Three-Dimensional Model Geometry
(Flash, Silverlight, AJAX, etc.) being used to create and run these interfaces, allows for this on-the-fly customization. Facebook uses a simple modular drag and drop interface that allows for users to create and view different applications and reorganize them in real-time on their page (Figure 1). The interface itself begins to imply having a spatial nature as modules can be lifted over (press, hold and drag) other modules and placed between modules inside of a predefined structural logic. Since individual modules are embedded with a consistent data structure the organization of the entire system can be choreographed by an overall logic.

New technologies, specifically relating to language and software are allowing for the creation of new ways of visualizing real-time data. For example, over the past four years users have been using Digg to quickly understand the breadth and popularity of various types of content (mostly blog) across the internet. In the past year, Digg has created a new way to visualize this real-time popularity index in a more spatial way with the creation of Digg Labs (Figures 2, 3, 4 and 5). Both Facebook and Digg Labs serve as interesting models for interpreting real-time networked data. In both cases, a standardized set of data was created and associated with the parts that make up the system and this standardization allows for this information to be choreographed in a spatial way. As physical architecture and digital interface merge together it will become necessary to create a common language or consistent set of meta-data and means for both digital and physical parts to be able to communicate with each other.

New methods for visualizing more tangible concepts in real-time are also taking root. These new interfaces are beginning to blur the lines between controlling space through physical tangible objects and through an interface. Current State allows users the ability to portability control energy consumption. Through specific hardware upgrades applied to existing products (in their home or office) users can directly visualize and manipulate the power consumption of smart devices in their environment (Figures 6 and 7). This project is especially interesting as it allows users to visualize energy and control energy consumption through more spatial life-like controls (digital switches and dimmers) and gesture. This software runs on an iPhone and to make real-time adjustments to their physical space, a user would physically need to touch the phone (similar gesture to real life). Right now this UI manages a pragmatic data set but in the future it is easy to image the interface becoming more three-dimensional and users having the ability to manipulate smart walls, objects or furniture to optimize to a particular activity. One could also imagine that multiple types
of applications, through standardized data sets would have the ability to communicate with one another so that a change in one system could affect and update all of the other systems (i.e. a predetermined hierarchy of information could dictate that efficiencies in temperature control could affect the range by which a user could manipulate the physical size of a particular room).

This heightened level of realism in the interface and emphasis on organizing information in a more spatial manner can also be seen in a number of different interfaces that have recently been developed to enhance the organization of data. Photosynth, developed by Microsoft Live Labs, allows a user the ability to stitch together images into a three-dimensional environment using visual graphical data and image meta-data (Figures 8 and 9). This software automates the act of combining images in collage in a more spatial way allowing users to be able to visualize environments in a way that is more akin to real-life. This software also allows users the ability to seamlessly navigate through images within the same experience. This software begins to describe how it is possible to easily navigate more three-dimensional digital environments to understand complex tangible data sets.

This heightened level of realism in the interface and emphasis on organizing information in a more spatial manner can also be seen in a number of different interfaces that have recently been developed to enhance the organization of data. Photosynth, developed by Microsoft Live Labs, allows a user the ability to stitch together images into a three-dimensional environment using visual graphical data and image meta-data (Figures 8 and 9). This software automates the act of combining images in collage in a more spatial way allowing users to be able to visualize environments in a way that is more akin to real-life. This software also allows users the ability to seamlessly navigate through images within the same experience. This software begins to describe how it is possible to easily navigate more three-dimensional digital environments to understand complex tangible data sets.

Finally, we can also begin to see how digital UIs and physical environments can be more integrated when looking at the Microsoft Surface table. Microsoft, using different design agencies including Schematic, has designed a multitude of various software applications that mimic and enhance real-time physical activities. These interfaces are beginning to blur the lines between physical activity and digital interface as technological advancements within the table allow for gesture to interact with data in real-time. Increased emphasis is being placed on the creation of space, shadows create a depth of field inside the interface, further enhancing the connection between digital/tangible objects and control. Technology in the table allows for physical devices and objects to be able to communicate with software inside the table. For example, users can order food and drinks through an interface and pay by placing a credit card on the table and dragging their ordered items onto the card (Figures 10 and 11). All of these applications put emphasis on spatially organizing information in a way that mimics tangible objects and scenarios we are familiar with. The music application shows cover art imagery for music CDs in their original physical size. Users can interact with on-screen graphics and can share and play music through the table. Users also have the ability to place an mp3 player onto the table and wirelessly transfer and purchase music by dragging songs onto their players (Figure 13). Using gesture users can turn albums over to view album contents and information similar to the way they would in physical space. The Virtual Concierge Application allows for users to choreograph a route through real space using real-time data (Figure 14).

This project, the Apple iPhone and a number of other emerging technologies allow for new means to control information and objects in space. Current advancements in the integration of these control methods with user interfaces can be used in tangible interactive architecture immediately.

### 3 New Means to Interact

New technology is allowing users new means to control and interact with digital information directly. These new technologies can be broken down into three different categories: Touch and Multi-touch, Gesture and Cognitive Control. In the future, it will be possible to empower architecture with the ubiquitous computation necessary to allow space and objects to interact with us using the technology and gestural language that is currently being developed for these systems. To date, all of these technologies are in their infancy as far as being applied to or used within architecture. As we experiment with these technologies and the types of relationships that are possible we are gaining valuable insights into what each of these systems is good at. All of this new knowledge will help us design better, smarter and more responsive environments.

The Microsoft Surface table (Figure 15), iPhone (Figure 16), and the Reactable (Figure 17) are all more advanced multi-touch hardware technologies that build upon many of the ideas pioneered by Jeff Han at ITP. This technology is significant to architecture because in many cases the gestures used to control the interface are the most similar to gestures that...
would be used to replicate these activities in real space with tangible objects. In addition to being more lifelike, these types of controls have greatly enhanced and extended activities by allowing users the ability to drill down into large amounts of data; thus understanding data through visual scalar moves. Much of the current gestural language to control these types of interfaces continues to be developed by various interactive media agencies, including Variate Labs and Schematic, worldwide. Multi-touch systems are best applied to direct proximity interaction between users and objects that make up systems.

The Peyote gesture control system is one of a number of different types of gesture based control systems that are currently being developed to control interfaces. This technology is significant to architecture in that it allows a user the ability to directly control and interact with objects in an environment from a distance using cameras and infra-red technology (Figures 18 and 19). Currently the amount of control is based on the resolution of input information, this means that while it is possible to control interfaces without devices, devices augmented with accelerometers and other sensor input hardware allow for more precise control. Gesture based systems are much better at manipulating larger quantities of data or objects over a large visual field and currently lend themselves well to the control of interfaces relating to television and large scale display. These systems also allow for the interface to become more spatially integrated into three-dimensional architecture as the sensor recognition system or systems can be placed around a user. Both touch and gesture systems would be extremely good methods for directly controlling objects in space.

The Emotiv headset is setting a new precedent for how interfaces can be integrated with user input. Users wearing a headset have the ability to wirelessly control objects through expression, emotion and cognitive data interpretation registered in a users brain activity (Figures 20, 21). The amount of resolution and granularity that this product is capable of providing for interaction with architecture is largely unknown. Currently, based on videos circulating the internet and some personal physical exposure to the product it is clear that right now immediate applications for controlling space through cognitive data will like be through ambient control. This headset could easily augment interactive experiences and real-time data could directly affect and control a UI or environment. For example, your mood state could drive the meta-data relationships in a user interface to show you only particular images from your Flickr account or directly affect the physical geometry of the user’s seat as they read a book. The possibilities of what this technology can be used for is only beginning to be explored.
4 The Future of Architecture

As the fields of user interface design and interactive architecture converge it is possible to understand how certain advancements in UI design can be applied to architecture at many levels. New control technologies in combination with current trends in user experience and interface design show that digital information and physical space are becoming more entwined. Digital information and interactivity is becoming more lifelike and tangible. Many new interfaces are becoming more three-dimensional as space is being used to aid in the user experience of navigating an increased variety and quantity of content. As objects in space become increasingly empowered with computational intelligence, sensor receiving input (hardware) and computational logic (software and information), users will have the ability to interact with architecture.

I am currently developing a number of interactive architecture projects that look at building architecture out of hundreds of thousands of interactive robotic parts. The scale of objects in these systems becomes increasing important (Figure 22). In much the same way that meta-data is the key granular component that allows for complex systems to be arranged in user interfaces so too is there the need to create a consistent means for robotic parts to be able to communicate with one another to build interactive structures (Figure 23). Using new control technologies it is also possible to enhance our relationship with our environment as we are able to manipulate and control space through direct and ambient means (Figure 24).

Ubiquitous computation is becoming increasingly integrated into the objects and structures that make up our environments, based on current trends, this will only increase in the future. This means that in the near future (this year!), we will have the ability to control architecture with our thoughts. It is up to architects and designers to familiarize themselves with existing technology and design advancements currently being made in interactive media to begin developing and advancing the new relationships that we will create in interactive architecture.

5 References
