The Tangible Map: Designing the User Interface for a Public Installation

by

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Submitted to the Department of Electrical Engineering and Computer Science
in Partial Fulfillment of the Requirements for the Degree of

Master of Engineering in Electrical Engineering and Computer Science

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2017

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Abstract

The Mobile Experience Lab in the MIT Comparative Media Studies Department is developing the Tangible Map in order to determine the potential of three-dimensional digital displays as a medium of providing information about the physical world. The Tangible Map is a three-dimensional digital map installation in the Atlas Service Center that aims to provide an interactive and personalized experience with the MIT campus. The Tangible Map will provide users the opportunity to both search for specific facts about the campus as well as learn new and surprising insights about their own community. Through a sequence of development, design reviews, and user testing, the Tangible Map investigates the capabilities of providing information through various access points in a public installation, and the Mobile Experience Lab aspires to better inform and unite the greater community at MIT.

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Acknowledgments

This thesis would not have been possible without the help and support of many people. First, I thank my parents for supporting both my academic and personal endeavors in countless, innumerable ways. Thanks to the Tangible Map team throughout the 2016-2017 academic year for all the brainstorming sessions and critical discussions on the purpose and methodologies of developing such a novel public installation for our community. Special thanks to Will Walker, who led the team and whose enthusiasm for design and craft provided an endless source of ideas and lessons throughout the development of the project. And most of all, thanks to Federico Casalegno for his patience, support, and guidance during every stage of developing and installing the Tangible Map and throughout the process of writing this thesis.

Chapter 1

Introduction

With the global push for expansion of technology, humans have changed the way that we communicate and connect with the world around us. With striking improvements in the structures of software systems as well as data storage systems, there is a constantly increasing amount of data being gathered from the environment. However, we are still struggling to find an effective and natural method of accessing and interacting with this data.

With this pressing need, there have been increasing interest and production of Tangible User Interfaces (TUIs). TUIs have become an accepted means for translating digital information into human-readable interfaces while raising user engagement in the field of human-computer interaction [1, 2]. This recognition suggests that a TUI could be successful as a public interactive digital installation. By offering a three-dimensional representation of a space, a display can invite touch-based interactions with structures in the space as well as convey characteristics and meaning derived from data sources in the environment for each structure. We can further observe multi-mode interactions and provide a variety of entry points into quickly grasping and

Figure 1-1. The Tangible Map allows access to building data by touching the sculptural interface.

understanding data by allowing a range of tactile input opportunities in the display. Through the Tangible Map (Fig. 1-1), we have explored and analyzed various forms of providing information in a public space through such an apparatus. More specifically, this project has investigated the value of tangible interactions, data visualizations, and a corresponding chat bot.

1.1 The Project

The MIT Mobile Experience Lab has been working on the design and construction of the Atlas Service Center, a center intended to bring together an array of services for the MIT community in a single location [3]. The Tangible Map is a public interactive digital installation for the Atlas Service Center. The target audience for both the Atlas Service Center and the Tangible Map is comprised of users exploring the university for the first time and a student body that needs access to a wide range of data on campus services. The Tangible Map presents the university campus as a relevant space for investigation and exploration. This interactive tactile/digital display consists of a three-dimensional representation of the relevant data space and multiple entry points for accessing further details about the campus. This system is meant to aptly guide the navigation between the physical space depicted on a map and the underlying data latent in the cognitive space.

User-centered design principles drove the development of both the hardware and software components of the Tangible Map. With this focus, we implemented a procedure to quickly iterate and test a variety of displays and interactions, incorporating only the most natural and compelling elements into the final installation.

1.2 The Tangible Map

1.2.1 Physical Layout

The Tangible Map consists of a two television displays overlaid with a single touch screen. A physical representation of the campus then sits on top of this touch screen; the models of the campus buildings are constructed through a 3D-printer and held in place through puzzle configurations at the base of the buildings as well as an overlaying fitted platform. Each model also contains two conductive rods through them so that a touch on these conductive rods translates to a touch on the touch screen. The touch screen, models, and the platform have clear coloring so that users are able to see the television display screens underneath.

There were design investigations into features of the 3D-printed buildings. One investigation involved the conductive rods that are placed inside the buildings. In order to best facilitate connection between the users and the touch screen, the team experimented with an assortment of materials for the conductive rods as well as various distances between the two rods. Another chief investigation examined how to make the coloring of the buildings clear. There were ideas and experimentations (to varying degrees) of using different materials for the 3D-printer and for digitally changing the display from the screens. The most successful result from these attempts came from using a mostly clear material and dying this material in order to balance and equalize the color.

Interactions are facilitated on the map through touch on the buildings, a designated information panel portion (located in the upper left corner) of the screen, as well as through a running application on an iPad Pro. The iPad is fixed next to the television displays and provides the search feature as well as an access point for visualizations (Fig. 1-2).

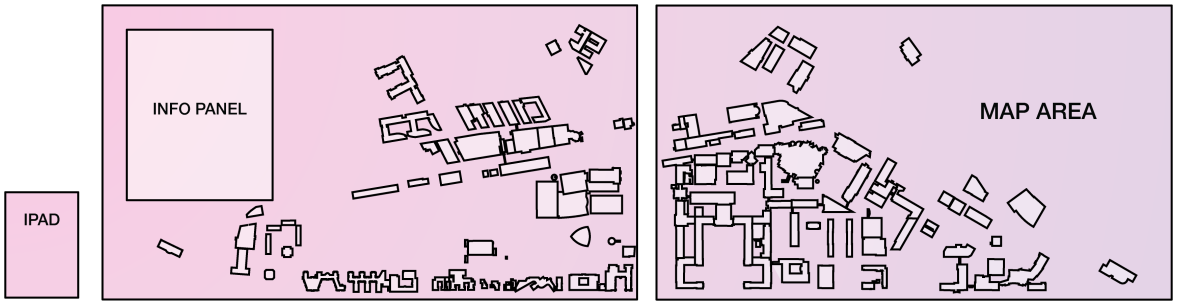

Figure 1-2. The content layout on the map displays.

For the official public installation, an aluminum casing surrounds the completed construction. This aluminum casing both protects the hardware from being mishandled by users as well as moderates the temperature of the electrical components.

1.2.2 Software Layout

The software for the Tangible Map is built using JavaScript and Swift. It is built upon the JavaScript development framework Node.js and the database program MongoDB.

The system's database contains comprehensive information about the departments, buildings, faculty, and classes at MIT, polled regularly from API endpoints serviced by the institution. We have also incorporated further information from other MIT-affiliated organizations into the Tangible Map in the form of data visualizations. There has been development in two types of data visualizations: static visualizations and dynamic visualizations.

When a user interacts with the Tangible Map or new content is displayed in the information panels, animations accompany the responses and transitions so that the user's attention will be drawn to the campus. These animations have been designed and iterated upon with the intent to make the experience of interacting with the Tangible Map a more involving and personal one.

1.3 Thesis Contributions

The contributions from this thesis cover both development on the Tangible Map installation and analysis of various user interactions with a public tactile/digital display. More specifically, the contributions are as follows:

1. Design of a user case study for analyzing efficacy and intuitiveness of a public digital interactive display.
2. Evaluation of results from user case studies in order to understand the optimal approach for presenting and streamlining information to users in a public space (through tangible interactions and data visualizations).
3. Backend software development for achieving the functionality of core features in the Tangible Map (e.g. showing directions between buildings and creating new data visualizations).
4. Frontend software development (based on results from the user case studies) of the user interface from Version 1 to Version 2 as well as from Version 2 to Version 3 (the final form of the installation).

With the public and permanent installation of the Tangible Map, this research has aspired to contribute both experimental as well as robust and reliable advancements to this project.

Chapter 2

Related Work

2.1 Tangible Tabletops

The Tangible Map is far from being the first experiment in terms of tangible tabletops. Architales was a project that consisted of an interactive table, designed for shared story engagement involving conversational public or transitional spaces. This interactive and tangible tabletop found success with incorporating physical/digital co-design principles; the success of this project suggests that these design practices could also prove to be successful for applications in other contexts as well [4].

The T4 design was another research into the design of tangible tabletops. This project further investigated the development of transparent and translucent tangible objects that would sit on top of digital display tabletops. There were limited interactions between the objects and the screens: the screen display could illuminate through the objects and the screens could register touches from the objects (which required more precise touch interactions with the screens) [5].

The Tangible Map builds off these design concepts from prior research to build a tabletop topped with tangible objects. The Tangible Map endeavors beyond these projects to allow for less restricted user interactions and to access current data harvested from the environment.

2.2 Public Installations

Tangible interfaces have been explored and established in many different forms as public installations, which are typically formally evaluated during the installation period. Researchers

have generally found that the support of the display owners and the clarity of the project's specifications are key to the success of an installation [6, 7].

Beyond the maintenance of the installation, displays with tangible interactions served well as a novel way to better access and immerse users in the available digital data and the physical experience of interacting with this data [7, 8]. Both the intentional visual design with clear cues and the animated graphical patterns used to convey information were crucial in building these positive interactions with these public installations [6, 8].

From the very start of the research and development process of the Tangible Map, the ownership and maintenance during different stages of the installation have been planned so that the project will consistently have the support and publicity required for its success. The following sections will further detail the considerations that were placed into the design of the user interface in order to foster positive interactions with the Tangible Map as a public installation.

Chapter 3

Concept and Design

3.1 The Atlas Service Center

Throughout the past few years, MIT has endeavored to make the campus experience more welcoming to all members of its community. For this purpose, MIT launched Atlas in September 2013. Atlas serves as an effective and efficient online platform, providing access to campus information, administrative systems, tools, and resources all in a single location. MIT has since then designed and started development of the Atlas Service Center, a physical space that will complement the systems, services, and resources available through Atlas [3].

In early 2015, the Mobile Experience Lab joined the planning process of the Atlas Service Center to explore and understand how space and technology can work together to enable the best possible experience for visitors to the Atlas Service Center. This partnership cumulated in the design and implementation of the Tangible Map.

The Tangible Map was designed to be an installation in the Atlas Service Center that provides an interactive and informative experience with the MIT campus. Users would be able to search for facts about buildings, departments, and faculty throughout the university as well as discover current events that are open to the general public. Furthermore, the Mobile Experience Lab strived to collaborate with various organizations affiliated with MIT in order to gather and present insightful data visualizations across the campus, such as the environmental footprints or data usage of the community. Through the initial designs of these features, the Tangible Map aimed to best facilitate interactions between humans and a three-dimensional digital map.

3.2 Audience

As mentioned previously, our audience consists of both members of the MIT community who are interested in accessing specific information about their daily environment as well as visitors unfamiliar with the campus who are looking to explore their surroundings. We have identified that most (if not all) of the users of the Tangible Map will have never encountered a similar installation in the past. With this novelty factor, users have shown interest in being able to explore the map and having an organic experience in understanding their surroundings. While users have shown most significant interest in this explorative aspect of the map, users more familiar with the university campus have expressed interest in more specific, targeted data inquiries from the Tangible Map as well.

3.3 Design Goals

The primary design goal of this project was the enhancement of accessibility and understanding of data through the use of spatial information. In parallel to this objective, we have also pursued an intuitive user interface design that carefully considers the user as well as the range and depth of interactions that the user can handle. As a novel installation, we evaluated a high risk of the modes of interaction becoming too unfamiliar for the user to process. While we aimed to incorporate the most recognizable forms of interaction, some unexpected considerations presented themselves throughout the design iterations of the Tangible Map; for example, one such consideration was how much information should be displayed at any given time.

Finally, because the Tangible Map is a public exhibit built for many first-time visitors to MIT, the aesthetics of this installation could not be compromised.

Chapter 4

Evaluation Metrics

4.1 Design, Development, and Review

From the very beginning of the research and development process for the Tangible Map, the Mobile Experience Lab has conducted studies through mockups, various prototyping kits, and guidance from professional researchers in design in order to determine the interfaces and interactions that would be most intuitive to users. With each round of feedback, we iterated on the design of the system, developing new interactions in order to fix weak components of the previous design as well as integrating the successful features from the previous design. After the concept was completed (detailing both the interface and the allowed interaction trees), we developed this new design. Concurrently, we also moved towards establishing the final structure of the hardware setup for the installation. With the development of this next iteration finished, we start the process again, conducting a review of the interfaces and interactions of the system.

At the start of the project, we conducted more design reviews with researchers as the mockups and prototypes were less functional but easier to iterate more quickly upon. As the Tangible Map began to take its final form, we conducted more user studies in order to analyze the performance of the interface with its targeted audience in its official location of installation.

4.2 User Study

The user study was comprised of interviews conducted at the Tangible Map in order to understand how easily accessible different features of the Tangible Map are and how users

interact with different entry points into the Tangible Map. While there were previous rounds of user studies with earlier iterations of the project, this thesis will detail the final two rounds of user studies and redesign for the Tangible Map, which occurred during my time working on this project. These two rounds of user testing are discussed as both resulted in significant redesigns of the user interface.

The structures of the interviews were consistent across both rounds of user testing. The interviewees were first asked to find specific information about the campus using their own resources (e.g. their cell phones) and then asked to discover this same information through the Tangible Map. This information reveals how the Tangible Map compares as a tool for uncovering information about the campus. We used a think-aloud protocol. After these targeted tasks, we gave the interviewees time to explore features of the Tangible Map on their own accord. Finally, we inquired in a free-form structure as to what they liked, what they didn't liked, and which tasks they had difficulty completing. Throughout the interviews, the moderator would also describe any incomplete parts of the product at the current iteration if a misunderstanding arose and observed the responses of the participant.

In both the first and second user studies, the interviews were conducted and recorded through a moderator. The marked difference between the two user studies is that in the second user study, we added an online survey, part of which was completed before the interview and the rest completed after the interview. The purpose of this survey was to give more time to the interviewees to be thoughtful about their responses, especially for the free-form questions regarding the Tangible Map. The results and takeaways from these user studies will be discussed in the following section.

Chapter 5

Managing Content and Interactions

The objective of this research was to understand the most effective way to display and maintain digital information in a public space. Put another way, this objective asks what is the optimal strategy used to manage content and interactions with a public installation. The Tangible Map encompasses much content through the form of information about buildings, departments, and faculty, the datasets provided through partnerships with organizations on campus, and a Twitter feed following official MIT Twitter accounts. With such comprehensive and eclectic information, the greatest challenge was building the pathways for users to access this core substance contained within the Tangible Map. There are three access points into the project: touch on buildings; the information panel on the screens; and the iPad. The user studies elucidated both more intuitive interfaces of these access points as well as the most compelling connections between these access points and the underlying content of the campus. This thesis will detail the development for data visualizations and the information panel as the design of these two features demonstrate the key takeaways from our research: the development of data visualizations delves into the presentation of latent spatial data as well as a means of keeping a public installation current, and the development of the information panel delves into the optimal touch points, breadth, and depth for allowed interactions on a public installation.

5.1 Data Visualizations

MIT maintains many facilities and organizations that administer a wide assortment of data about the university campus. For example, the List Visual Arts Center manages information about

public art installations on campus, and Facilities Information System manages the information about the history of each building at MIT as well as information on the location of every emergency phone on campus. However, few in the MIT community are aware of the availability of such data, and even fewer have the knowledge in how to access this information. With initial conception of the project, the Mobile Experience Lab speculated that the Tangible Map would present a great opportunity for better publicity as both groups in our target audience have expressed interest in learning such information about the campus. This conjecture was further confirmed by the relevant facilities and organizations showing consistent excitement and positive responses towards the idea of incorporating their data into the Tangible Map for the community to see.

There has been development in two types of data visualizations: static visualizations and dynamic visualizations. Both types of visualizations convey information related to either a set of buildings or a set of coordinates across the campus, and each location point is designed to correspond to a section of a color mapping. The information panel then displays a description of the visualization and a map key, which describes the color mapping for the given visualization.

The static visualizations allow each location point to contain a single unchanging numerical value. However, all the location points in a visualization must unanimously either have such a value or leave this value empty. The color mapping is assigned depending on this presence or absence of associated values. For visualizations with associated values (such as the visualizations for bike racks and how many racks are at each location), the color mapping assigns lighter hues to lower values and darker hues to higher values. For visualizations without associated values (such as the visualizations for public art installations across the campus), the

color mapping assigns lighter hues to the more westward locations and assigns darker hues to the more eastward locations.

In contrast, the dynamic visualizations were meant to allow each location point to store a numerical value as well as the history of how this value has changed over time. A prototype for this type of visualization was built early this past Fall to demonstrate the Wi-Fi usage across different buildings over a period of twenty-four hours, and the database of the Tangible Map system has the means for primitively storing the dataset of dynamic visualizations. However, the dynamic visualization has not been added into the final product of the public installation as it lacks the form of a refined feature. Furthermore, there has been insufficient user testing regarding the interface and interactions required for dynamic visualizations.

In order to allow for future additions to the Tangible Map so that the product remains relevant to its community, we further developed a rendering engine that streamlines the process for adding new data visualizations. With this engine, new datasets can be added into the database quickly through the upload of a CSV file. For the development of this feature, the table structure inside of the database was changed. The previous structure had tables corresponding to each dataset, and the model for each table was specific to the visualization. This made the calls and displays very specific for each visualization. The new structure has a super-table containing all of the data visualizations, formatting the objects of all infographics into a more generalized model. Given the scale of this project, the management of the objects inside the super-table performs satisfactorily, without losing performance with requests for all of the objects of a specific infographic. This new table structure allowed for the refactoring so that the calls and displays for visualizations are uniform; this uniformity makes the user interactions with data visualizations more intuitive as users are able to more accurately predict the expected responses

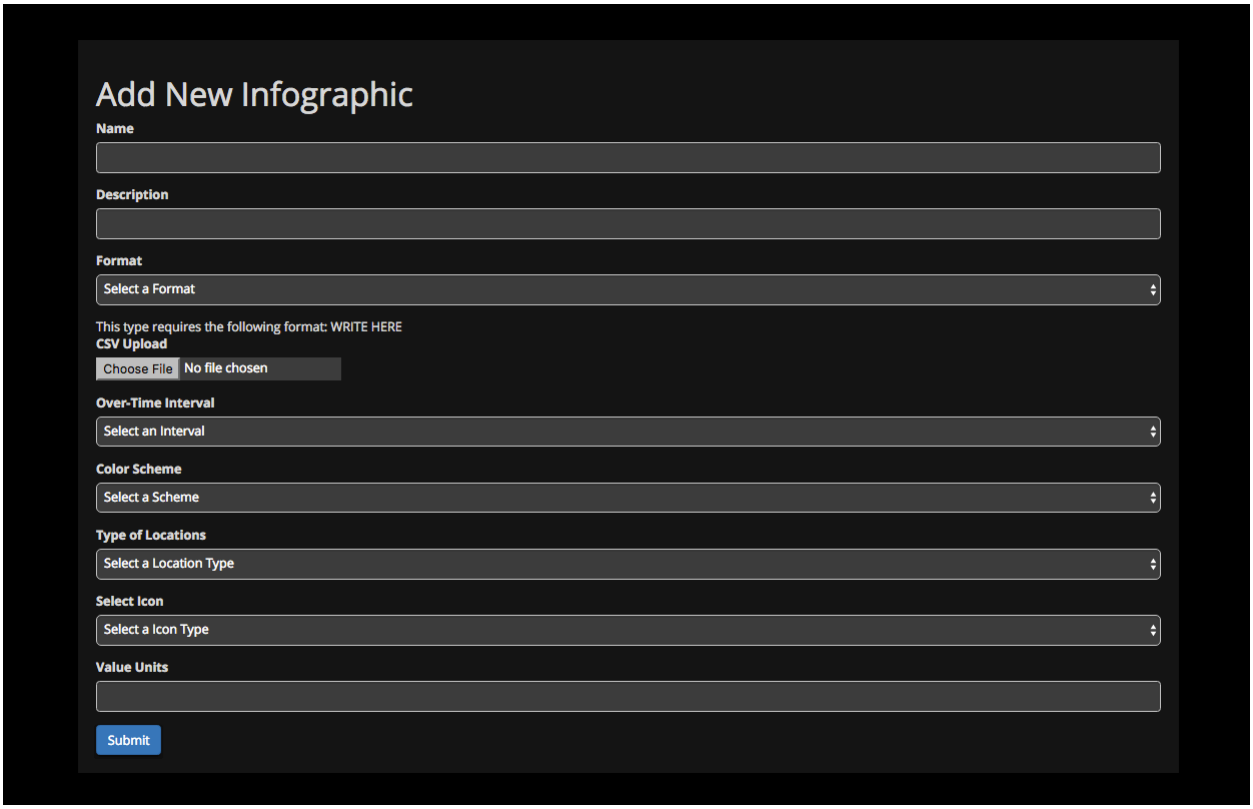

Figure 5-1. The restricted form for adding new infographics.

from accessing data visualizations. The moderators of the Tangible Map foster the process for creating or updating a data visualization through the rendering engine. The moderators are given restricted access to a form, which asks for the name and details of the infographic as well as the correctly formatted CSV file containing the collection of objects for the infographic (Fig. 5-1). Upon submission of this form, the dataset is added or updated within the database, and the Tangible Map makes this visualization available automatically. The homepage of the information panel dynamically queries the available visualizations and offers selection of these visualizations through icons.

5.2 Information Panel

While there were previous rounds of user studies with earlier iterations of the project, this thesis details the final two rounds of user studies and redesign for the Tangible Map. There were a total of eight participants across these two explorative user studies. The first four participants were a part of the first round of interviews. After receiving their feedback, we iterated on the design of the Tangible Map. The last four participants were a part of our second round of interviews that occurred after this redesign. We investigate the best presentation of digital data through a variety of interactions through examinations of participants' responses.

Across both rounds of interviews, participants were positive about and very engaged with the Tangible Map. Participants commended various aspects of the project, extending across the design, animations, and the novelty. The redesigns were mostly focused on the information panel as this was the most interactive component of the user interface, serving as the entry point into the greatest number of different features. The information panel provides access to various content of the Tangible Map at different depths of interactions:

- In-depth information about buildings resulting from tactile interactions with the model buildings.

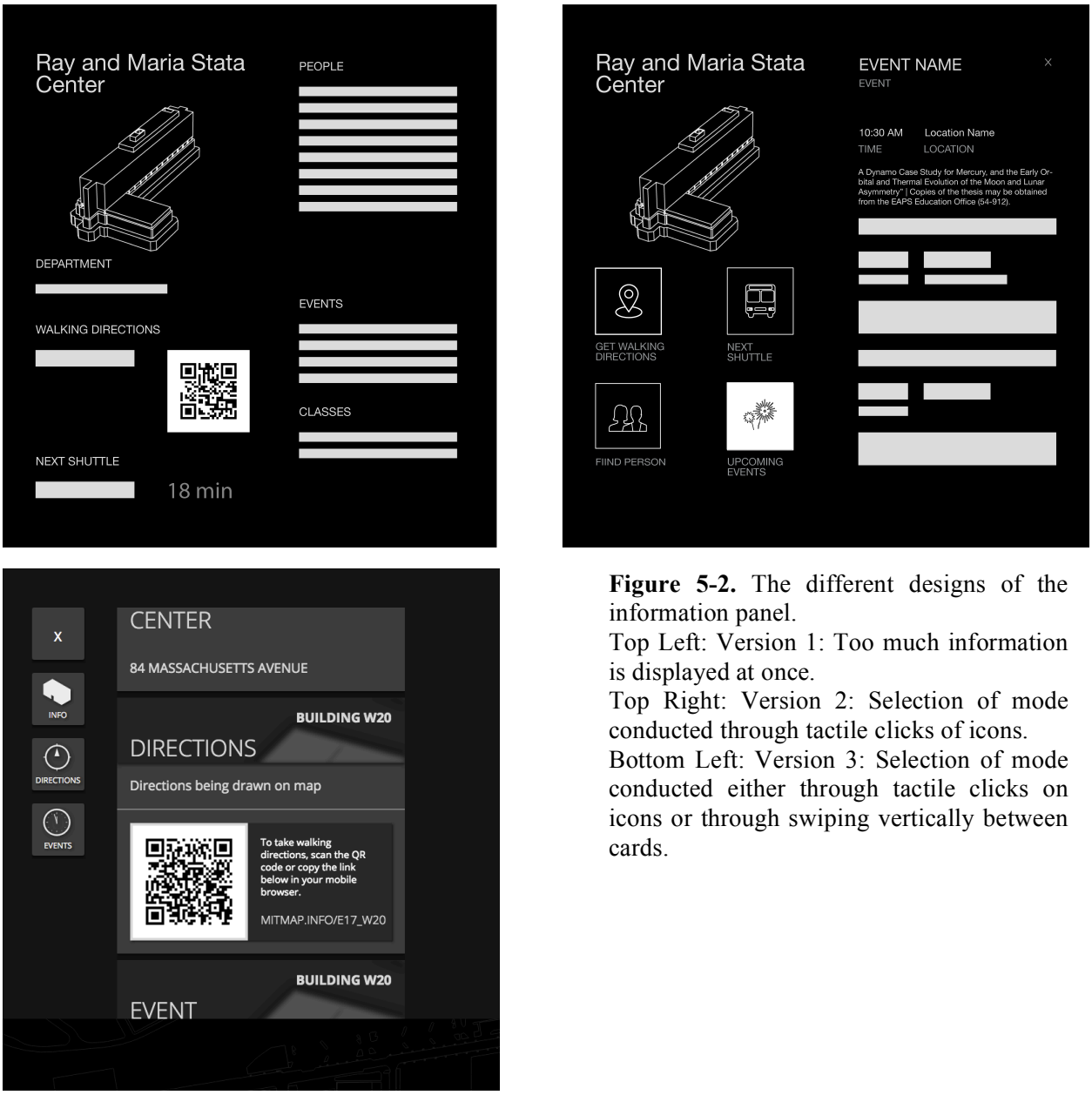

Figure 5-2. The different designs of the information panel.
Top Left: Version 1: Too much information is displayed at once.
Top Right: Version 2: Selection of mode conducted through tactile clicks of icons.
Bottom Left: Version 3: Selection of mode conducted either through tactile clicks on icons or through swiping vertically between cards.

- In-depth information about buildings, faculty, or departments resulting from targeted searches on the iPad.
- Overview details about data visualizations (including name, description, and map key) resulting from selection of a data visualization icon.

5.2.1 User Interface Redesign: Version 1 to Version 2

Given the prominence and magnitude of information available behind each building, the first major challenge we faced was the temptation to show any and all relevant information for an interaction across the available space on the screens. We implemented this approach in Version 1 of our user interface (specifically for the information panel), and we observed negative consequences throughout the first user study. This design caused participants to have difficulties understanding to have difficulties understanding or to completely miss presented information on the information panel. Moreover, the interactions were too loosely tied to the information presented, and participants were unclear about the effects of each interaction and which content would be brought to the displays.

In order to address this issue, Version 2 of the design of the user interface was adjusted to include an additional layer of interactivity to the information panel. Rather than having breadth in the interaction tree of the Tangible Map, we incorporated depth by creating icons to represent and select different modes for each building, such as directions, shuttle timing, building faculty, and events. Version 2 further incorporated more deliberate cues through clearer language of instruction and navigation. This modification entailed revisiting the phrasing for all instructional text as well as the redesign of cons that fostered interactions.

The impact of these revisions in Version 2 was markedly apparent through guided tasks in the second round of interviews. The participants interacted with the Tangible Map with less hesitation and even completed the guided tasks in a substantially shorter amount of time.

5.2.2 User Interface Redesign: Version 2 to Version 3

The most critical limitation in the Tangible Map demonstrated from the second user study was the contrasting ideas of exploration versus guided directions. The study needed to incorporate

guided directions in order to evaluate the interface and functionality of the product. In the interviews, we allowed for an exploration section after the initial guided tasks, but in practice, users would explore the product first and then conduct guided tasks. This contradiction could have been a significant contributing factor to the result that many participants expressed concern for the need of familiarity with the product and campus.

Version 3 of the design of the user interface centered around efforts to make the Tangible Map appear more inviting to users unaccustomed to the product and campus. We increased the size of the mode icons and incorporated swipeable cards (each containing the details of the corresponding mode) into the information panel. We decided to use swipeable cards, as this is a familiar and more engaging interaction, by requiring a swipe, from commonplace tablets and cell phones. These adaptations allowed for more imprecise and attractive interactions with the information panel. The available selections for the visualizations were also moved from the iPad interface to the information panel, leaving the search feature for buildings, faculty, and departments as the only function left in the iPad application. As the data visualizations are designed for users to uncover hidden information latent in their surroundings, this shift concentrates the access points for explorative interactions, aiming to better facilitate exploratory discovery of features of the Tangible Map.

We have been unable to conduct user testing for Version 3 of user interface as of yet, but we intend to in the future. This user study would take the same format as the final user study, consisting of interview, video recording, and online survey. This research is necessary to better understand how Version 3 compares to Version 1 and Version 2 in conveying information in a public space. Given that the depth of the interaction tree has remained the same and the interface now incorporates more engaging forms of common tactile input, we predict that the user

response times will decrease for both interacting with guided tasks as well as discovering novel features.

Across both user studies, even at times when participants struggled to identify a feature, once they were initially exposed to the feature, they quickly learned and adapted comfortably to it. The user studies have demonstrated effective methods of maintaining attention, directing touch and interactions, and making content accessible. A strong connection is built between the physical model and cognitive model of the map through the layout of the interface, the organization of displayed information, and the placement of clear cues, such as instructional text and icons. Beyond these improvements, the Tangible Map has shown to be an attractive installation, as participants were excited to interact with the product and showed enjoyment getting to explore their campus in a brand new way.

Chapter 6

Next Steps

As the Tangible Map has been fully installed into the Atlas Service Center, the focus on the project has transitioned away from development of features. There are two significant pushes at this time: the handoff of moderator responsibilities and conducting research on the final user interface of the project.

The responsibilities of servicing and maintaining the Tangible Map are shifting from the Mobile Experience Lab to the Information, Systems, and Technology department at MIT. This handoff has incorporated switching the server from the virtual machine running at the public installation to a remote machine and ensuring that, with this switch, the server has an up-to-date snapshot of the system's database. Furthermore, the Information, Systems, and Technology department is striving to better institute privacy settings on the server, the web client, and the iPad to protect the product from any unexpected failures or outside attacks. Furthermore, we expect to have a point moderator working inside the Atlas Service Center to handle simple debugging tasks (as most errors are fixed with a refresh of the web client and a re-launch of the iPad application). While these tasks are being conducted through regular meetings, a guidebook and verbal instructions have been also been given for future reference.

The Mobile Experience Lab has yet to conduct a final round of user testing to evaluate the efficiency of Version 3 of the user interface. The user study is likely to take a near identical form to the previous two rounds of user studies, incorporating an in-person interview, a recording of this interview, and an online survey. We expect to see improvements with this

design in the form of quicker and less hesitant interactions with the Tangible Map in accessing both explorative and investigative information about the university campus.

Chapter 7

Conclusion

We have built the Tangible Map as a novel system for addressing the exploration of eclectic spatial information enabled by a tactile/digital public installation. The Tangible Map provides a better sense of scale and immersion for its users through its model spatial representation, strongly connecting the physical space depicted on the map to the data available in the campus environment.

During my initial onboarding into this project, I began working on backend software development for achieving the functionality of core features in the Tangible Map. As these features were completed, we shifted our focus to frontend software development of the user interface, iterating on the design based on results from user case studies. We considered and created a user case study consisting of an interview, video recording, and survey in order to analyze the efficacy and intuitiveness of a public digital interactive display. The results from the user case studies could be evaluated both qualitatively and quantitatively (through response times for specific tasks); as we speculated, these evaluations led to better understanding of the optimal approach for presenting and streamlining information users in a public space. These advancements have progressed the Tangible Map beyond just an experimental prototype to the more robust and reliable form of a public installation it is today.

Through a repeated process of development, design reviews, and user testing, we have identified intuitive and meaningful access points and interaction trees with such a public installation that optimally allows users to discover and comprehend information inherent in the world around them through tangible interactions, data visualizations, and a corresponding chat

bot. Research into this development of the Tangible Map now serves a gateway into the exploration of tangible interactions in a public installation and the idea of giving meaning through these tangible interactions.

Bibliography

[1] Sandy Claes and Andrew Vande Moere. 2015. The Role of Tangible Interaction in Exploring Information on Public Visualization Displays. In Proceedings of the 4th International Symposium on Pervasive Displays (PerDis '15). ACM, New York, NY, USA, 201-207.

[2] Hiroshi Ishii. 2008. Tangible bits: beyond pixels. In Proceedings of the 2nd international conference on Tangible and embedded interaction (TEI '08). ACM, New York, NY, USA, xv-xxv.

[3] "AdminConnect." Atlas Service Center | AdminConnect. N.p., n.d. Web. 03 Dec. 2016.

[4] Ali Mazalek, Claudia Winegarden, Tristan Al-Haddad, Susan J. Robinson, and Chih-Sung Wu. 2009. Architales: physical/digital co-design of an interactive story table. In Proceedings of the 3rd International Conference on Tangible and Embedded Interaction (TEI '09). ACM, New York, NY, USA, 241-248.

[5] Wolfgang Büschel, Ulrike Kister, Mathias Frisch, and Raimund Dachselt. 2014. T4 - transparent and translucent tangibles on tabletops. In Proceedings of the 2014 International Working Conference on Advanced Visual Interfaces (AVI '14). ACM, New York, NY, USA, 81-88.

[6] Jorgos Coenen, Niels Wouters, and Andrew Vande Moere. 2016. Synchronized wayfinding on multiple consecutively situated public displays. In Proceedings of the 5th ACM International Symposium on Pervasive Displays (PerDis '16). ACM, New York, NY, USA, 182-196.

[7] Ivan Elhart, Marc Langheinrich, Nemanja Memarovic, and Elisa Rubegni. 2016. A good balance of costs and benefits: convincing a university administration to support the installation of an interactive multi-application display system on campus. In Proceedings of the 5th ACM International Symposium on Pervasive Displays (PerDis '16). ACM, New York, NY, USA, 197-203.

[8] Julie R. Williamson, Daniel Sundén, and Keith Hamilton. 2016. The lay of the land: techniques for displaying discrete and continuous content on a spherical display. In Proceedings of the 5th ACM International Symposium on Pervasive Displays (PerDis '16). ACM, New York, NY, USA, 38-44.