Office for the Vice President of Research Grant Report

Brown University
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Introduction: Designing Humanity Centered Robots

The genesis of the projects featured in this report all began with the first iteration of the course, CSCI 1951C Designing Humanity Centered Robots, which is now in its 5th year. This class, originally co-taught by Ian Gonsher (CS/ENGN) and Professor Michael Littman (CS), was launched in the same year as the Humanity Centered Robotics Initiative, and was intended to provide a pedagogical complement to the research initiatives being envisioned at the time.

The questions that both the Humanity Centered Robotics Initiative and CSCI 1951C Designing Humanity Centered Robots have attempted to address, and that the SEED grant has provided support for, are questions that explore ways in which we might foster an interdisciplinary culture for design research at Brown, in general, and the way design research might be applied to the convergence of technological innovation and human needs through thoughtful design, in particular. The development of this institutional scaffolding has produced more than just the prototypes featured in this report, each of which offers exciting new avenues for further design research. Over the past several years, Brown has developed a robust ecosystem that fosters interdisciplinary innovation in design and technology with the notable additions of the Brown Design Workshop in the School of Engineering, and the Humanity Centered Robotics Initiative in the Computer Science Department. Over the past two years, through the support of this grant, we have cultivated a creative community that brings together teaching and research by building bridges between computer science, engineering, and design. The projects featured here, and supported by the OVPR SEED grant awarded to Ian Gonsher (CS/ENGN) and Stefanie Tellex (CS), are the fruit of those efforts. It is our hope that these projects might be developed further and act as a catalyst for other similar initiatives.

Aside from seeking further funding for the of the projects documented in the following report, we are enthusiastic about the kind of creative culture HCRI and the Brown Design Workshop have become for catalyzing a sui generis approach to design research here at Brown. The hope is that by further developing these creative assets, Brown will be in an even better position to attract talented students and faculty interested in the convergence of these disciplines, and to further draw in resources in the form of grants, corporate research partnerships, and the development and licensing of intellectual property, which will help to continue to support these kinds of initiatives.

The Walkerbot Project

It was in that first iteration of CSCI 1951C Designing Humanity Centered Robots that the idea for a “walkerbot” emerged. Our initial design research throughout the semester led us in directions that suggested the benefits of integrating telepresence into the lives of seniors. Evidence emerged which suggested myriad health benefits if we could find ways to connect seniors to other people as we increased their mobility and autonomy. Social isolation and loneliness, with all their adverse mental and physical health effects, could be addressed through better design. An idea emerged to combine an assistive mobility device – a walker – with the functionality of a telepresence robot, not dissimilar to the Beam robots being used in other areas of research in HCRI. The hope was to give seniors the ability to 'age in place' by connecting them, via telepresence, to friends, family, and caregivers. In addition to increased quality of life, this approach also could make the need for assistive care and live-in caretakers less of a need, thereby dramatically decreasing healthcare costs.

Figure 1 - These are the original prototypes of the "Walkerbot," developed by the student design team from the class.

By adapting a rolling walker to move autonomously, we initially believed that we could replace many of the functions of human caretakers. To this end, we developed and built a drive system that allowed us to test the viability of this approach (figure 1).

Although these initial prototypes were quite limited, they served as important proofs of concept. The initial design research sparked excitement about what could be possible if we could develop projects like these on a grander scale. Along with the invaluable support of Stefanie Telex and her lab, The SEED grant supported the development of this next generation of prototypes, and in doing so, opened new horizons for design research that have far exceeded the original goals of the initial Walkerbot prototypes. As the project developed, we recognized that this approach to telepresence, could be developed much further by integrating user interfaces into common everyday objects and the built environment.

We also discovered is that the autonomous motion we had developed for the walker had some significant limitations, which compromised its use as a walker. It was too heavy, and too difficult to move with all the added hardware. However, the telepresence functionality had promise, even it could not completely replace human caretakers. These insights proved to be an important pivot for the project, leading us in two fruitful directions, which in turn lead us more broadly to the development of a creative process for design research that continues to produce innovative and paradigm shifting research projects.

In order to test some of these features, we developed the concept of “situated robots.” These robots are both situated and situational. Situated in the sense that they “hide in plain sight”, as furniture and other similar objects might, situated within the built environment. We explored questions that an architect, for example, might be interested in; questions of spatiality and human scale.

But these robots are also situational, in that they afford the user with the conditions for new kinds of interactions within, and beyond their local position. Rather than carry a device on your body, such as a smartphone, we could integrate new features into the furniture, objects, and spaces always already around us. Situated robotics allows us to think about the user interface in a way where we could almost make it completely disappear, or at least disappear when it is not being used.

A demo of the Walkerbot autonomous motion test can be viewed here: https://vimeo.com/357082176

The Telewalker

Despite our initial disappointment with regard to the constraints autonomous motion placed on the movement of the user, we eventually realized that a simpler solution could address our goals in a more effective way.

There is a surprising dearth of options for mounts that connect assistive mobility devices with users via a tablet computer or smart phone. Many users, especially the elderly, find it challenging to see and use these kinds of devices, especially when they are already encumbered by the use of a walker. Our solution was to mount a tablet directly onto the walker, so that users could easily connect with others, and adjust it to their comfort and preferences.

We realized that the problem we were trying to address wasn’t one of mobility, which the walker already addressed well. It was one of connection and relationships to other people, and by creating a hands-free interface onto an object that users were already familiar with and understood well, we could make a bigger leap towards our goals of achieving improvements in mental and physical health outcomes.

We also added a front facing camera and projector, which further enhanced users' ability to make an image larger, more immersive, while also bringing the proximity of others into spaces adjacent to the user. In this way, friends, family, and caregivers could be brought closer to the user, whether they were physically in the same space, or interacting through video conferencing software. In addition to these features, this approach also gave the users a heads-up display and connection to the internet.

Figure 2 – Final prototype of augmented walker, with tablet mount, front facing projector, and rear and front facing cameras.

TBO the Tablebot – Robot as furniture, Situated Robots

What will the universal remote control of the future look like?

Will it be an object that is a conspicuous feature of the built environment, like a TV or a computer, or more like a smart speaker? Or, will it take the form of one of the ubiquitous rectangles that we carry in our pockets or that are set on our tables and desks?

What if these kinds of interfaces could hide in plain sight as the furniture around us, to be called upon when needed, and then to fade back into the built environment? This was one of the initial questions we posed that led to the development of Tbo.

Tbo is a “Situated Robot” in the sense that it is both situated and situational. Situated in the sense that it hides in plain sight as furniture, situated within the built environment. But unlike most furniture, it is mobile, too. Tbo helped us explore UX/UI questions that an architect, for example, might be interested in; questions of spatiality and human scale.

But Tbo is also situational, in that it affords the user the conditions for adaptive interactions. We were interested in creating a design model that allowed the user interface to disappear. This approach allowed us to move beyond some of the limitations we had encountered with the Walkerbot, and led us to the development of robots that not only blended more seamlessly within the built environment (i.e. ubiquitous computers) but also provided a more immersive telepresence experience than most other telepresence robots, which are little more than “Skype on a stick.”

Tbo is a proof of concept prototype that provided insights into four areas:

Situated Robotics: Tbo “hides in plain sight” as part of the furniture and built environment. Most of the time, Tbo is a table, which like other tables fits inconspicuously into the environment around it.

Mobility: Unlike most furniture, Tbo can navigate around its environment using SLAM mapping. Tbo can reposition itself in relation to the user and environment, both locally and at a distance (i.e. telepresnece). For example, it can find a wall, position itself in relation to that wall to project a full scale, standing image of a remote user, all without the need for a screen.

Telepresence: In addition to its ability to move about the space, the user can “beam into” these kinds of objects, providing an affordance for connections between distant locations and people. Projection onto nearby walls and surfaces both replaces the need for a screen as well as creating a more immersive experience. By incorporating cameras and a projector, Tbo reshapes the spatial experience of the user by creating “portals” to other, non-contiguous spaces.

Virtual Assistant/Artificial Intelligence: Tablebot is also an integrated virtual assistant platform (using the Watson API) which could be developed further into a whole family of smart, connected objects. Unlike Amazon Alexa or the Facebook Portal, which are spatially fixed, Tablebot is mobile and situated within its environment in ways that expand its functionality considerably.

[A demo of TBO can be viewed here: https://vimeo.com/225230975](https://vimeo.com/225230975)

Figure 3 – Final prototype of Tbo the tablebot

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The Stanchion Computer

Three questions emerged from the development of these prototypes that we were interested in exploring further:

1) What other strategies might we develop for designing interfaces that hide in plain sight? What new strategies could we develop for ubiquitous computing?

2) How might we radically simplify the user interface, perhaps developing design modalities that went beyond the “rectangle in your pocket” or “Skype on a stick?” How might we radically rethink the norms of laptop and desktop computer interfaces?

3) How might we develop an inexpensive public computer? How might these computers delimit space and assist in wayfinding?

Figure 4 – Stanchion computer with projector and mouseless keyboard

The mouse and keyboard are so common that they are taken for granted as one of the basic conventions of modern personal computers. Our goal was to explore a radically different configuration for human-machine interfaces, while building upon the conventions so familiar to most people.

The Stanchion Computer is a low cost, public computing platform. It not only explores a radically new configuration for the screen and mouse, which is eliminated in favor of a mouseless keyboard and wall projection, it also employs a standing configuration, and is battery powered, so it can be situated in nearly any environment. The elimination of horizontal surfaces, such as table tops or desks allows for myriad applications that go well beyond conventional interfaces.

Like the velvet rope that is linked together with stanchions, a stanchion computer can also delimit space. Although public wayfinding was our initial user scenario, we envision many design applications and research directions that this kind of human-machine interface can be applied to.

The Mouseless Keyboard

Our design research for the Stanchion Computer began with the development of the mouseless keyboard itself. Our prototype plugs into any USB port, just as any other keyboard or mouse might. It offers an unconventional user experience, while respecting the conventions that most people are used to, making for an easy and comfortable user experience.

Since Douglas Engelbart's famous demo in 1968 - the so-called "Mother of All Demos" – the keyboard, mouse, screen triad has been a fixed convention in interface design. To this day, most desktop computers on the market use a combination of a mouse and a keyboard as part of their basic interface. We have combined these interfaces by placing a keyboard on the top of a joystick. This allows the user to rock the keyboard around a pivot to select items that are displayed on a screen or projected onto a wall. The left and right buttons work the way any mouse does, but the red button allows the user to toggle between "mouse mode" and "keyboard mode."

The Mouseless Keyboard is patent pending with support from Industry Engagement and Commercial Venturing (IECV)

Figure 5 – Final prototype of the mouseless keyboard

A demo of the Mouseless Keyboard can be viewed here: https://vimeo.com/354634689

Experiments in Blended Augmented Reality: Oppositional Force Feedback

In addition to our primary focus of research, which emerged from our interest in situated devices, we developed several proof of concept prototypes in order to explore other areas that seemed ripe for further design research. One such project, which developed out of the Designing Humanity Centered Robotics course, explored the question of how to create a blended augmented reality user experience. This blended experience needed to have affordances for haptic interactions with objects, allowing the user to use their hands to manipulate a device, as well as a way to give force feedback to create the illusion of a physical object in virtual reality. We developed a strategy we called "oppositional force feedback." While oppositional force feedback is somewhat limited in its applications – e.g. pliers, scissors, tongs, etc - we believe it could open the door to many other applications.

This design research took the form of two prototypes. The first used mechanical feedback, employing resistance from a servo motor integrated into a set of pliers. In our user scenario, the user can interact with physical objects such as bolts, as well as in virtual environments, which still give the user the sensation that there is an object present when no physical object is physically there.

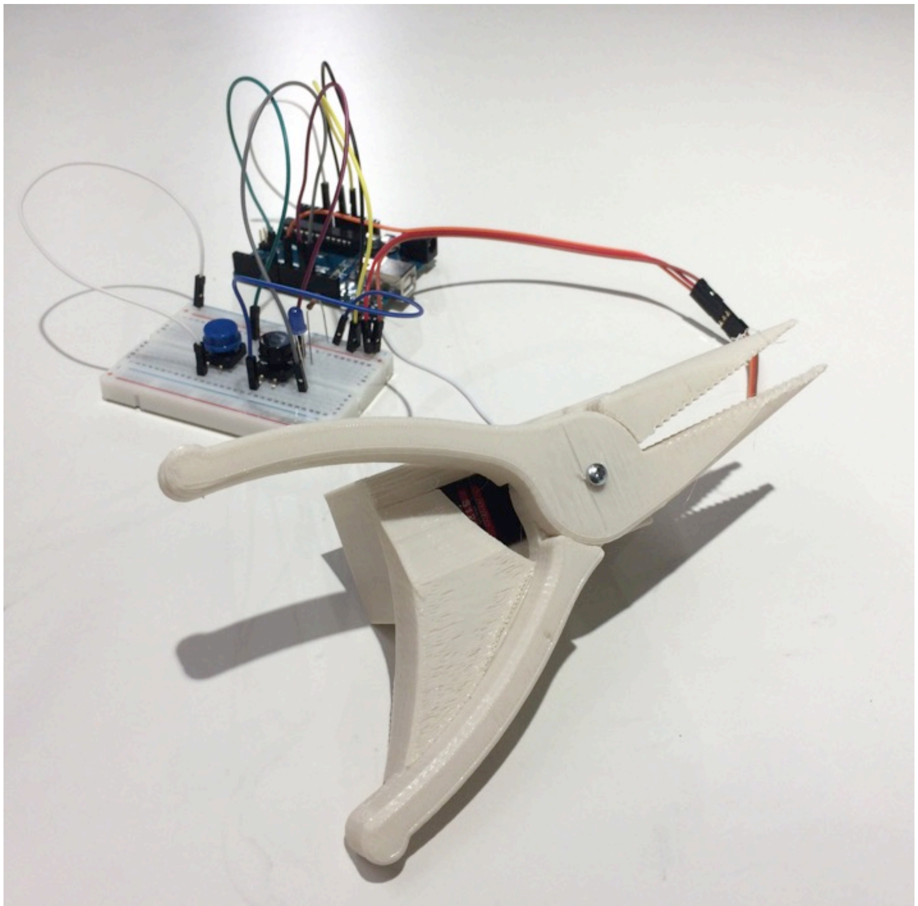


Figure 6 – Blended augmented reality plier prototype, using force feedback.

The second prototype uses magnetic force feedback to give the user the sensation of an object that exists only virtually. This approach has the advantage of being able to regulate the amount of feedback, based on the application of current to the magnet.

[A demo of oppositional force feedback can be viewed here: https://vimeo.com/354464898](https://vimeo.com/354464898)

High Speed Multidirectional 3D Printing

Rapid prototyping isn't rapid. It can take hours to 3D print objects. This proof of concept demonstrates the viability of an approach to 3D printing that can reduce print times significantly, which we call High Speed Multidirectional 3D printing.

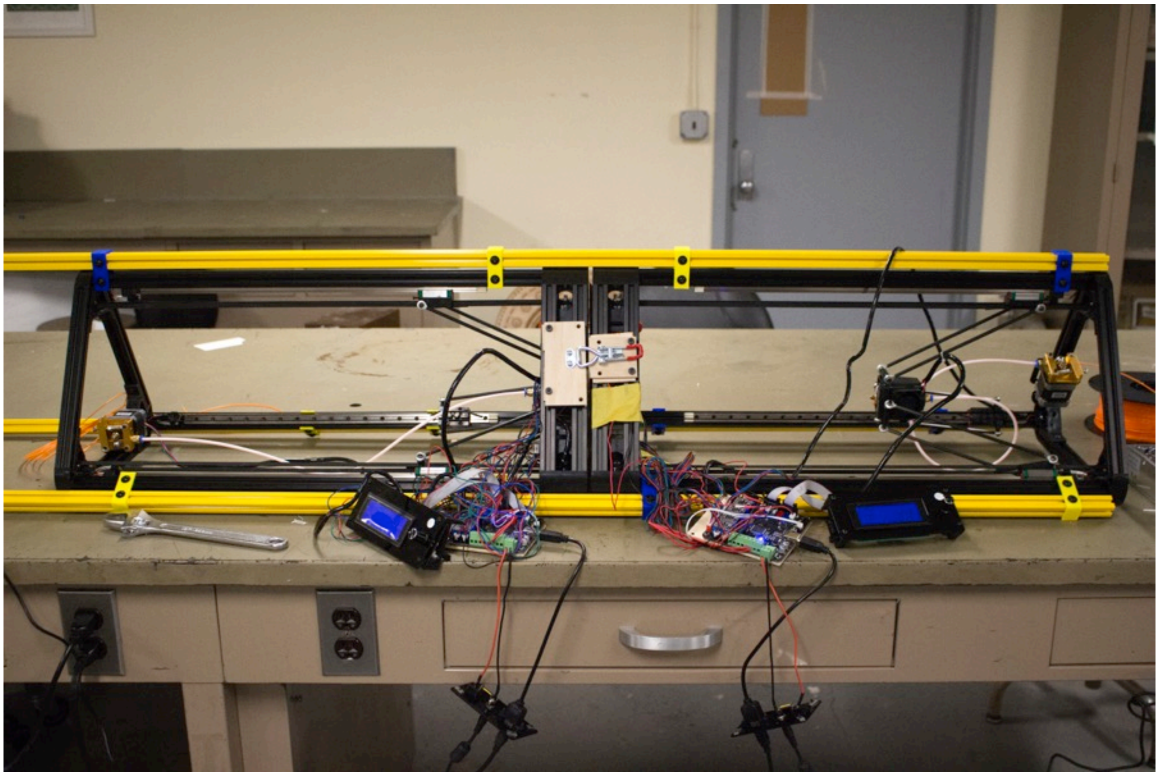


Figure 7 – High Speed Multidirectional 3D Printer Prototype

The initial impetus for this project was the NSF grant proposal "Synchronizing Virtual and Physical Models for Industrial Shape Design" (currently under review), which was developed in collaboration between Ian Gonsher (ENGN) and Gabriel Taubin (ENGN). Within the initial version of this grant, we proposed several strategies for radically reducing print times. We explored many strategies, including: low resolution high speed printing employing an adapted extruder; "voxel printing" that used a combination of an array of control surfaces to create forms that could be vacuumed formed, resulting in almost instantaneous prints; a strategy that used software to divide the part so that it could be printed on multiple machines and reassembled; and an approach that used a combination of lasercutting and stacking to achieve a lower resolution, but higher speed print. We also explored the possibility of combining some or all of these strategies in order to minimize print time. But the approach we thought had the most potential was what evolved into what we now call High Speed Multidirectional 3D Printing.

By printing outward, rather than upward, we can reduce print times dramatically. In order to do so, we needed to overcome the technical challenge of printing against gravity. This prototyped demonstrates that these technical challenges can be addressed. Our prototype prints horizontally, in opposing directions, cutting print time in half. Future iterations could feature multiple extruders, reducing print time to a fraction of what it currently is..

Our prototype demonstrates the following:

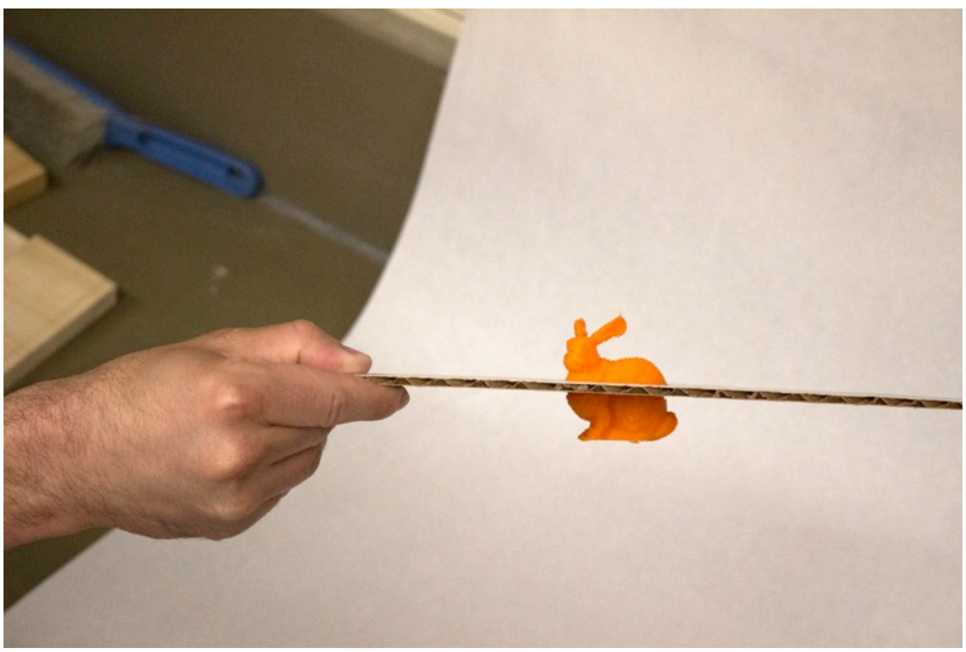
1) That we can print horizontally, rather than vertically, allowing us to print in multiple directions.

2) This is accomplished by developing a surface to print off of. In this version we use cardboard, but future iterations could employ a “kernel,” off of which we can print in all directions.

3) We also developed a technique for better adhesion for printing against gravity by using glue sticks to help adhere the initial print.

It is our belief that this two directional printer, which cuts print time in half, can be scaled up with more print heads to make print times a fraction of what they are now. Instead of waiting hours for a print to complete, you could print an object in minutes or even seconds.

A demo of the High Speed Multidirectional 3D Printer can be viewed here: https://vimeo.com/338516977



The High Speed Multidirectional 3D Printer is patent pending with support from Industry Engagement and Commercial Venturing (IECV).

Future Work

Each of these projects is fertile ground for further development. Documentation of this kind of Design Research can further funding opportunities and contribute to a culture of design on campus. Design Research, of this kind not only provides opportunities for undergrads and faculty to collaborate on design and prototyping through an iterative, critical process, it also provides a path for the University to develop innovations that can impact our community and culture.

The array of projects featured in this report have both pedagogical and research value, and it is our hope that we can continue to build on this model. Through the kind of faculty/student mentorship that makes these projects possible, we are building a robust culture of design on campus. These collaborations between the Brown Design Workshop and the Humanity Centered Robotics Initiative, between Engineering and Computer Science, can advance the development of more intellectual property, more grant opportunities, and more industry partnerships on campus.

Video Demos

Walkerbot motion demo

https://vimeo.com/357082176

Tbo (Tablebot) demo

https://vimeo.com/225230975

Mouseless Keyboard demo

https://vimeo.com/354634689

Oppositional Force Feedback demo

https://vimeo.com/354464898

High Speed Multidirectional 3D Printing demo

https://vimeo.com/338516977

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