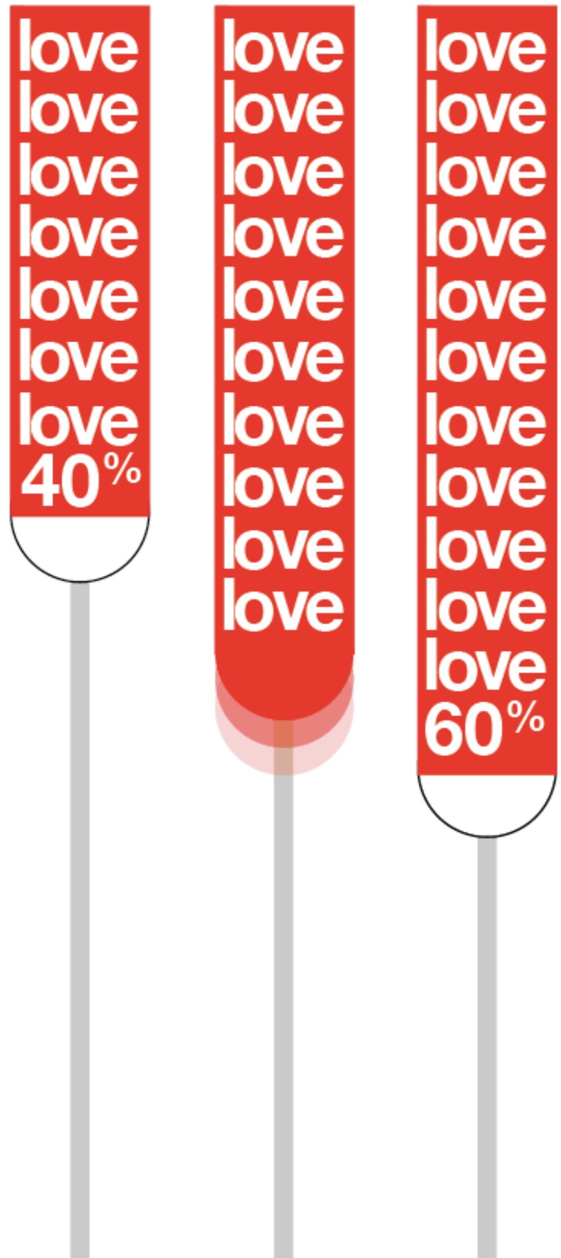
Development of a Tangible Display and Metric for Qualitative Human to Human Electronic Communications



Theodore R Ullrich
Masters Project
Industrial Design Program
College of Architecture
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Spring 2009

Advisors
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Abstract

The goal of this project is to humanize electronic communications between people by creating a device that can tangibly display the emotional quotient of your email inbox.

These days, so many of our daily interpersonal communications are collected (digitally) into our email inboxes. these communications are received from friends, family members, colleagues, teammates, spouses, bandmates, supervisors, etc. Access to this method of communication is now considerably easy, as messages can be sent from desktop, laptop, and mobile email devices. Email, as a communication method alongside face-to-face conversation, phone conversations, text messaging and letter writing, now accounts for a very large percentage of human to human communication.

Yet, despite the computer's ability to report the number of emails in an inbox, the sender, the size, the date, the subject, etc., we are unaware of the more 'human' characteristics of these messages. The messages have been stripped of their human content and emotional nature.

This project takes a critical look at current research and prototypes, past and present, in the fields of Calm Computing, Ubiquitous Computing and Tangible User Interfaces, specifically those that leverage form and shape to communicate digital information. Through a precedent study, recent relevant prototypes and commercial products that use a tangible technology as a display method are discussed. In conjunction with the background research, these prototypes help form a zone of opportunity towards developing a new type of tangible display with unique qualities.

While the majority of the literature emphasizes tangible *inputs*, the focus of this project is on the tangible *display* of information. The aims for the device are to provide:
1) An enhanced understanding and accessibility of digitally conveyed information through using natural modes of human perception and representation.
2) Multiple users to be able to share the 'use' of the device.
3) Perceptibility of the information at both the center and at the periphery of the users' attention.

A Systems Design approach is used as the methods to the design process, which is highly explorative and development based. Physical prototyping and sketching are used as the leading development tools. The development path is recorded and presented in this paper in a journal-like fashion to replay the discoveries and learned pieces of information during development. In this way, the multiple prototypes hold equivalent value and information as the final product.

The final product is a piece of functional tangible technology. It is a percentage gauge of email communications within a user's email inbox that contain a user-defined term. Informal testing and a brief discussion are given at the end to analyze the final result.

Background & Significance

This masters thesis project looks at the future of computing. It aims to question how humans could and should interact with information. I shall probably refer to computers and information and visa versa since, today, they are essentially synonymous and inseparable. Any computing device connected to the internet means almost any information is available to it.

Topics and terms discussed in this paper are Tangible User Interface, Human Computer Interaction, Palpable Computing, Calm Computing, Ubiquitous Computing, and Interaction Design.
These topics shall be introduced one by one in the next paragraphs for those unfamiliar with these areas of technology.

Before jumping in, I would like to describe my personal motivation for making a study in these areas my focus for a Masters of Industrial Design project.

I studied Inventive Design Engineering at Purdue University. This hybrid program combined interdisciplinary engineering with industrial design and introduced me to the basic understanding of how to 'make anything'. Along the way I put emphasis on and received my EIT (Engineer in Training) in Mechanical Engineering. I am fascinated with things that 'work' and are mechanical. Such matters I call physical and analog. I believe that humans are creatures and we are therefore physical and analog.

Equally so, I am fascinated with emerging technology and a digital lifestyle. Having any information you want at your fingertips is empowering. *Digital information* or *digitally conveyed information* is any information about the world that is transmitted digitally, over the internet. While having access to such information is convenient and enabling for humans, I am not convinced that the current methods available to *perceive* digitally conveyed information are appropriate, natural, or intuitive for humans. Nor do they necessarily support human habits of collaboration. More on that later.

Up until now, I have made a case for these two worlds: digital and physical. At the intersection of these two worlds is a complex area ripe for all those capable and interested to take part in shaping the future of human's interaction with computers and information. This location is also an especially appropriate one for an Industrial Designer to study and play, as it involves humans, culture, technology, and products. These are the quintessential ingredients in Industrial Design.

I shall now introduce some key fields of professional technology and design research that are helping shape the future of interactions between humans and computers. This list is not intended to be comprehensive, but instead to introduce multiple angles that are being taken to address opportunities in the complex arena of how humans interact with computers.

After the introduction of the fields, I shall introduce existing prototypes, projects, or products that, as an Industrial Designer, I find relevant and important to demonstrating the strengths and opportunities across the particular fields.

This list is meant to:

1) Emphasize the growing amount of research in this area of design.
2) Disambiguate what lens i am approaching the problem through once I reach my Specific Aims, and
3) To help draw the border around what areas I am treading in outside of Industrial Design. This list assumes the reader has a basic understanding of the realm of Industrial Design.

Interaction Design

I'm starting with describing Interaction Design because it is the field that, in reflection and through the discovery of research, I found myself most strongly aligned with to due to the nature of my fascination and the trajectory of my project.

Interaction Design is a new field, so much so that it overlaps heavily with (and some argue is a subset of) Industrial Design. While Industrial Design concerns itself with a human's interaction with *machines*, Interaction design is mostly concerned with human's interaction with *each other*. (Saffer, 2007). In the end, both Interaction Design and Industrial Design can manifest their solutions in the design of a physical device, but this is not always the case with Interaction Design, where a web interface, environmental design, a robot, or a product workflow or service may be more appropriate. Again, Interaction Design is all about improving the interactions between two or more humans.

Interaction Design is a particularly relevant lens through which to view a human's interaction with information when the information being accessed is coming from another human. This is the case with all electronic communications like email, blogging, verbal conversations, video chats, instant messaging, etc, **which comprise a significant portion of our reasons for using a typical personal computer today.** Keep this fact in mind, as it this it will be referred to again.

As technology products rapidly become more and more complex and the 'platform' on which a product stands could span from digital to physical (as the Apple iPod does), Interaction Design is emphasized (Saffer, 2007).

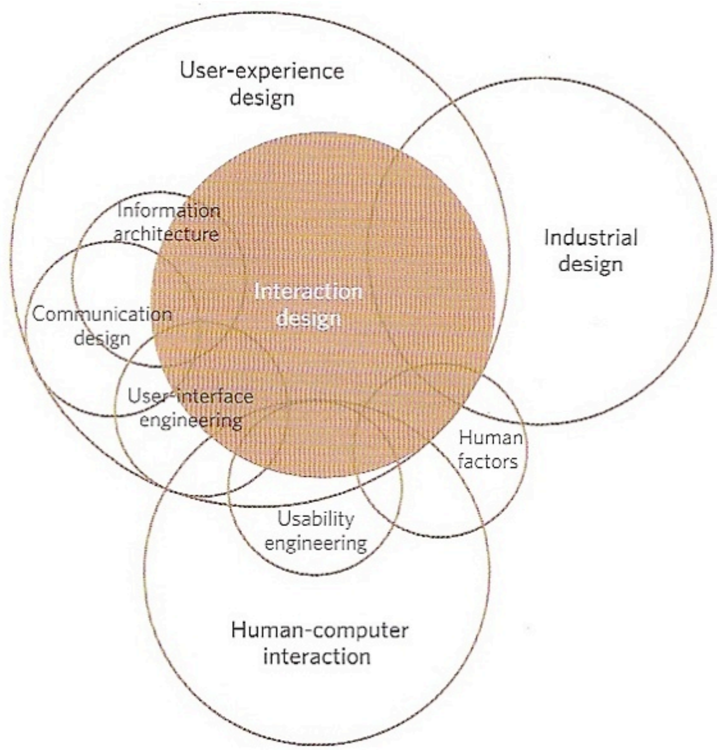


Figure 1. The Span of Interaction Design. Saffer, 2007.

Human-Computer Interaction (HCI)

The next relevant field is Human-Computer Interaction which is closely related to Interaction Design.

Saffer draws a distinction between Industrial Design, Human-Computer Interaction and Interaction Design for us. While Interaction Design is about designing for *human to human communication,* HCI tends to be more quantitative and is strongly focused on how humans interact with *computers*. Broadening the comparison, HCI is about human's interaction with *computers* and Industrial Design is about human's interaction with *machines* (Saffer, 2007). Therefore, an HCI specialist may design a computer's operating system or other matters directly improving the computing experience. While HCI is a noteworthy 'parent' field to many of the other fields being discussed, not a lot of emphasis will be placed on HCI, as it is more relevant for designers trying to improve existing interfaces as opposed to developing new ones.

Ubiquitous Computing

Marc Weiser from coined the term Ubiquitous Computing during his time at California-based technology research lab Xerox PARC. Ubiquitous Computing is a post-desktop model of Human-Computer Interaction in which information processing has been thoroughly integrated into everyday objects and activities. As opposed to the desktop model, in which a single user consciously engages a single device for a specialized purpose, someone "using" Ubiquitous Computing engages many computational devices and systems simultaneously, in the course of ordinary activities, and may not necessarily even be aware that they are doing so.

Ubiquitous Computing is an emerging field in computing research and development. Researchers in Ubiquitous Computing advocate a change to a new method of computing in which access to computational services occurs through a variety of devices at different scales and locations within the environment (Ishii & Ullmer, 1997). Contrast this notion with today's method of using one centralized device, the personal computer. The shift in methods of computing is often referred to as a shift in paradigms, for which we are currently between the 2nd and 3rd.

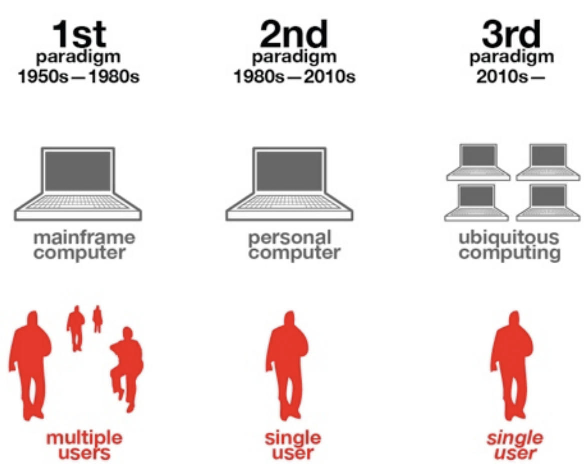


Figure 2. Ubiquitous computing proposed by M. Weiser, A. Key, J. Brown, 1996.

Key Ubiquitous Computing researchers Mark Weiser and Alan Key share the insightful qualification that Ubiquitous Computing is the "third paradigm" of computing (Weiser, 1996). The first paradigm was the mainframe computer, in which multiple people shared one computer (one computer, many people). We are currently in the second paradigm of personal computers, in which one person has one computer (one computer, one person). The third paradigm of ubiquitous computing is anticipated to occur when there are multiple devices for one person (many computers, one person) (Weiser, 1996). The third paradigm is essentially the reverse of the first. This shift is being helped along. According to Weiser and Brown, the internet's characteristic of widespread computing is the mediator which is acting as the transition between the personal computer and ubiquitous computing (1996).

A key aspect (and major hurdle) in the transition towards a ubiquity of computing devices in our environment is the break-down of the Graphical User Interface (GUI) which is used by most second paradigm computing devices. Your personal computer uses a GUI, allowing you to click and drag folders and file icons to manipulate data with a mouse and keyboard. Ubiquitous Computing attempts to progress the status of today's computing *past* the GUI. The vision in the third paradigm is one that acknowledges the natural human environment and objects and seeks to have the computer recede into the background while it foregrounds its functions.

The shift towards ubiquitous computing is not being pushed by technology, but instead by human psychology (Weiser, 1991). The argument can be made that when humans learn something particularly well, they cease to become aware of it. It is therefore our understanding of computer technology that would allow our minds to seek and ultimately accept a paradigm that de-emphasizes computers.

The question of "how can computers disappear into the background?" must eventually be addressed. There are a number of factors that contribute to answer this question. First, ubiquitous computers must know where they are (Weiser, 1991). The self-awareness that comes with knowing one's location allows communication with other devices that are in the proximity. Secondly, ubiquitous computers must each be suited for a set of limited tasks and appropriately manifest themselves in different sizes (Weiser, 1991). With these factors in place, the computing devices can number in the hundreds, all having a silent conversation and individually serving straight-forward tasks. This scenario would ultimately lead to "transparent" computation (Ishii & Ullmer, 1997), representing a significant approach to consolidate the best of analog with the best the digital.

Bill Moggridge's book *Designing Interactions, 2007* lays the groundwork for the emergence of Ubiquitous Computing in a quote from Terry Winograd, one of the field's early developers at Xerox PARC. Terry explains that people do not want to interact with computers, but instead just want to get something done (like write a document, turn off the lights, get the weather report) and "the fact that there's a computer involved in an interaction is instrumental. It's not the purpose; it's the way they get things done" (Moggridge, 2006). Furthermore, Mark Weiser and the team at Xerox PARC were asking how can computers become invisible? How can we interact with our *environments* instead of our *computers*?

Tangible User Interface (TUI)

After introducing Ubiquitous Computing and the Graphical User Interface, naturally the next field of research to discuss is the Tangible User Interface, a term coined by Hiroshi Ishii of MIT. A Tangible User Interface (TUI) is a user interface in which a person interacts with *digital* information through the *physical* environment. Interactive surfaces, graspable objects, and ambient media such as sounds, light, and airflow are all examples. Note that a 'TUI' is a catch-all term for many methods of digital information display and control. Ishii describes the work of his TUI group as giving physical form and tangible representation to information and computation (Moggridge 2007).

Ishii and Ulmer's 2000 paper on Emerging Frameworks for Tangible User Interfaces discusses an important tangible computing model called model-control-representation (physical and digital) or MCRpd (2000). They explain the four key characteristics of the MCRpd which are also in diagram form below.

1) Physical representations are computationally coupled to underlying digital information,
2) Physical representations embody mechanisms for interactive control,
3) Physical representations are perceptually coupled to actively mediated digital representations, and
4) Physical state of tangibles embodies key aspects of the digital state of the system (Ishii and Ulmer, 2000).

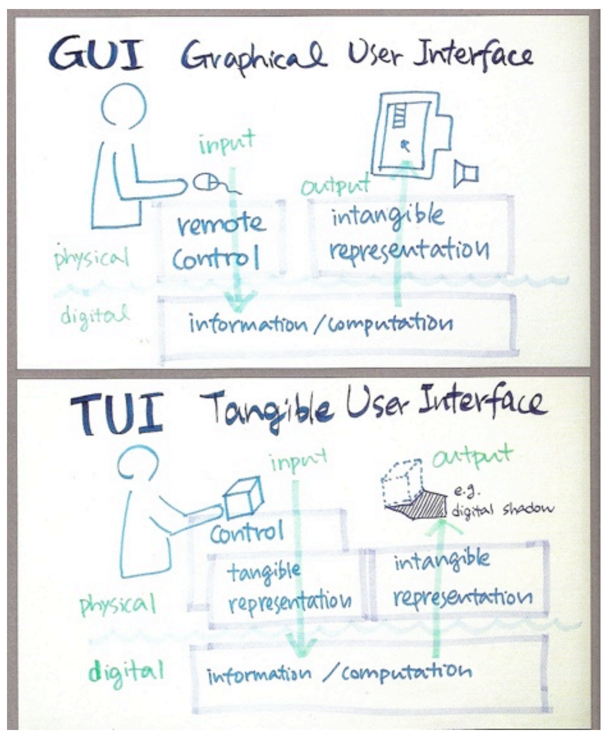


Figure 3. GUI vs TUI. Moggridge, 2007.

So why are Tangible User Interfaces so significant to how humans interact with computers and digital information? As can be seen in the diagram, the TUI is the antithesis of the GUI (Graphical User Interface) introduced in the prior section. Unlike the GUI, a Tangible User Interface “augments the real physical world by coupling digital information to everyday physical objects and environments”(1997). Since Tangible User Interfaces often involve multiple objects found in a human’s natural home or work environment, Tangible User Interfaces are a significant subset (if not the manifestation of) Ubiquitous Computing.

Even electronic products themselves often have text-based displays to tell you what they mean. There is a large contrast between these objects and the real world which is full of more self-evident mechanical things like scissors, wine bottles, and bottle openers. (Moggridge 2007).

Therefore, while the future of Ubiquitous Computing promises to dissolve the centralized computing model into multiple devices within our environment, Tangible Computing adds a clearer vision that these devices will be used and operated in the same we use everyday objects and environments: with all our humanly senses.

A refreshing and relevant quote comes from Moggridge's *Designing Interactions* book, from Hiroshi Ishii, on the subject of the merging the two fields of digital and physical:

“At the seashore, between the land of atoms and the sea of bits, we must reconcile our dual citizenships in the physical and digital worlds. Our windows to the digital world have been confined to flat rectangular screens and pixels — “painted bits.” But while our visual senses are steeped in the sea of digital information, our bodies remain in the physical world. “
- Hiroshi Ishii

Admittedly, though, there are some difficulties to note in the development of TUIs for testing. According to Ishii, one of the limitations of current technology in physical prototypes is that we cannot easily change a shape, color, or form dynamically (Moggridge 2007). Instead, we usually couple illusionary representations of the information like video projections or sounds. So an important feature of Tangible User Interfaces are to give physical form to digital information so that you can have multiple (natural) methods of control over it, *allowing a better understanding, interaction experience, and helping many people work in a collaborative environment simultaneously*. (Moggridge 2007).

Diving in a bit deeper, after being introduced to the realm of tangible computing, there exists some measurements for the ‘success’ of the designing tangible devices. In his paper on taxonomies for tangible interfaces, Fishkin identifies the use of *metaphor* and *embodiment* as the two key axes of a taxonomy space (2004). The higher a TUI example can place on the two axes, the more ‘tangible’ it is (not necessarily better or worse).

Along the metaphor axis, Fishkin identifies two groups of metaphors: those that appeal to the shape of an object (nouns), and those that appeal to the motion of an object (verbs). In other words, whether the metaphor embodies a noun and/or a verb (2004). The more that either type of metaphor is used (or both), the higher the TUI reaches on the metaphor axis.

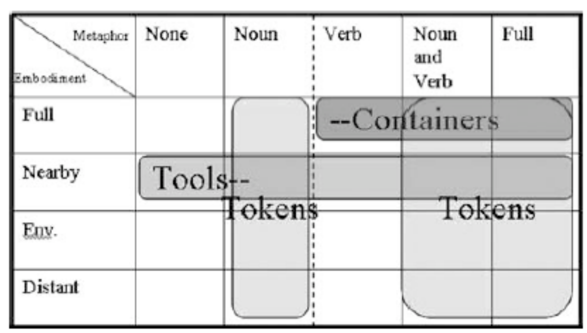


Figure 4, Tangibility Matrix. Fishkin, 2004.

Fishkin identifies that when a tangible interface is not used to display the result of *user* input (but rather the *computer* provides the input signal), the experience is termed “Calm Computing” (2004). Wellner et al.’s famous live wire example called “Dangling String” in which a hanging wire’s movement represented the movement of network traffic is an instance of Calm Computing (2004).

Figure 5. Dangling String. Weiser and Brown, 1995

Calm Computing

The small realm of Calm Computing was perhaps one of the most simple yet informing areas of this development project.

Calm Computing are designs that “encalm and inform humans”, two things that do not often work together in a world of cellphone rings, TV, radio, and email chimes. (Weiser, 1996). In the words of Weiser and Brown, the output of the Dangling String, “is so beautifully integrated with human information processing that one does not even need to be looking at it or near it to take advantage of its peripheral clues” (1995).

Like real-life objects, calm technology engages our attention from both the center and the periphery and can move back and forth between the two (Weiser 1996). This explains one of the positive factors to Tangible User Interfaces, and represents a factor to be capitalized on. While it may seem like a backwards approach, appropriate placement of information within our attention range (moving it from the center to the periphery) may be just the answer to information overload.

Admittedly, the authors’ understanding of calm computing is, “still incomplete and perhaps even a bit confused” (Weiser, 1995). Part of this may relate to the assumption that this representational model of information is calming. On hectic days with heavy network traffic, a whirring wire in the office may be anything but calming. In any case, the physical representation of digital information is observable from across the room and has the opportunity to be ignored, at our periphery, or at our center of attention, by multiple people. Perhaps the calming factor is created by a message that is continuously and visible in terms we understand. The case of being overwhelmed often occurs with a sudden discovery of information (as in a factory worker having to dig through a computer system to find the state of the system horribly wrong).

Palpable Computing

Jumping back to Ubiquitous Computing and Tangible User Interfaces, we step one layer even deeper to Palpable Computing.

A researcher at the University of Åarhus in Denmark, Morten Kyng, coined the term Palpable Computing to refer to a Ubiquitous Computing technology that is Tangible (Palpable Computing, 2008). Palpable computing denotes “a new kind of ambient computing which is concerned with the ... challenges in complex and dynamic ambient computing environments (Andersen, Bardram, Christensen, Corry, Greenwood, Hansen, Schmid, 2005). Kyng, along with more than a hundred European researchers embarked in the EU funded PalCom project, which has developed a software architecture and a hardware toolkit (Palpable Computing, 2008). For Kyng and the PalCom project, the major application for Palpable Computing is in large-scale events, accidents, and emergency response when you need to monitor what many technologies are doing instead of making it invisible, as is the tendency in ubiquitous computing (Palpable Computing, 2008).

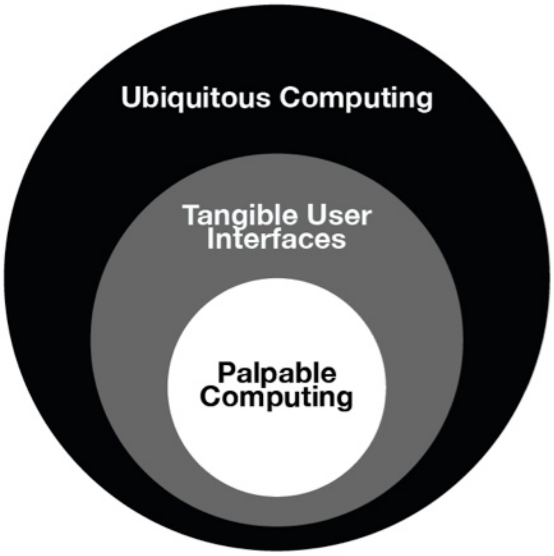


Figure 6. Comparing Ubiquitous Computing Fields. Ullrich 2008

Palpable Computing complements and extends the tenets of ambient computing by focusing on the user experience through control, understandability, de-construction of systems and variable visibility of underlying computational process particularly in object technology.

The relevance of having 'touch-only' technology will become apparent soon enough once the project aims are described. In the meantime, the following is a list of synonyms of Palpable and Tangible to disambiguate terms. Although these terms have dictionary definitions, pioneers in the fields of Ubiquitous Computing (Mark Weiser), Tangible User Interfaces (Hiroshi Ishii), and Palpable Computing (Morten Kyng) have used the words in their own coined terms. The coined terms use the words in specific ways which may not directly match the dictionary definitions. As a good researcher, I have acknowledged these coined terms so that my research remains consistent to existing research. Nevertheless:

HAPTIC - of or related to the sense of touch

PALPABLE - capable of being handled/ touched, easily perceived; obvious

PHYSICAL - pertaining to material things

TACTILE - perceptible to the sense of touch, proceeding from, or pertaining to sense of touch

TANGIBLE - discernible by touch; palpable Capable of being treated as fact/real/ concrete

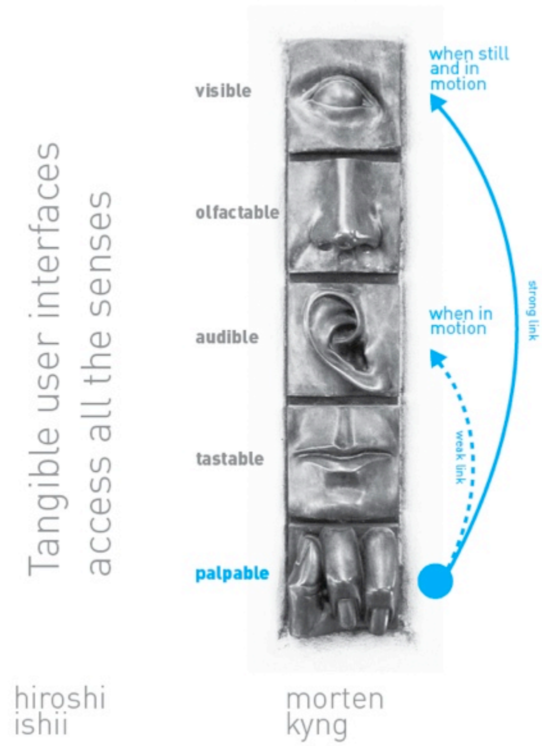


Figure 7. Comparing the sense. Ullrich 2008.

Relevant Existing Prototypes, Projects, or Products

The Stock Orb is an ambient computing device that uses a Tangible User Interface technology to display live, continuous information about the stock market or a number of other user-configured parameters. The Stock Orb works right out of the box with absolutely no configuration necessary, using a colored light and a micro-controller receiving signals from a cellular pager network every 15 minutes. Users the device plug into a power outlet to track the Down Jones Industrial Average or other information. Configurable through a website, the Orb can also be configured to display:

S&P 500
NASDAQ Composite
My Stock
Personal Portfolio
Business metrics
Weather Forecast
Golfing conditions
Sailing conditions
Commute traffic congestions
Pollen count
Google news alerts
Energy pricing

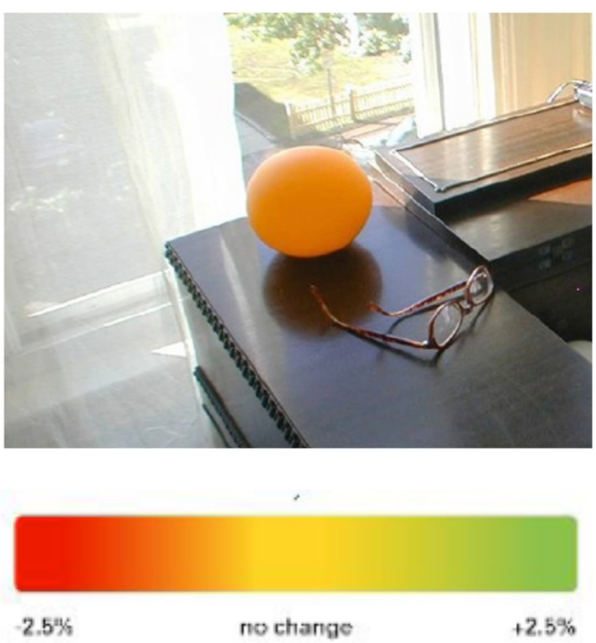


Figure 8, Ambient Devices, Inc. 2004.

The Stock Orb is an example of a tangible technology that uses light to continuously display a single piece of digitally conveyed information. It is also a Calm technology, in that the device can operate at the center or periphery of the user's attention. The Orb's information is also perceptible by multiple users at once, an advantage of a Tangible User Interface.

A similarly compelling product by the same company embeds the prediction of precipitation into the handle of an umbrella. With a simple flashing light, the umbrella reminds its users to bring it with them. What is fascinating here is the ability of everyday objects embedded with tangible technology to request or recommend their own use.

One researcher who is leveraging the advantages of Palpable Computing is Oren Horev, a graduate of the Interaction Design Institute Ivrea (IDII) in Ivrea, Italy (2001-2005).

A brief background on the IDII: during its early days, it was graced with some of the world's leading design researchers serving as academic advisors including John Maeda, John Thackara, Bill Verplank, and Bill Moggridge. These instructors are now operating at Domus Academy and the Copenhagen Institute of Interaction Design, as the IDII has dissolved.

Oren Horev's masters thesis work, entitled "Talking to the Hand" explored new opportunities in shape-shifting technologies that could be used to display information tangibly, or more specifically, palpably. His project prototypes can be seen on the right.

Oren's work is highly tangible, highly 'touchable' (palpable) and mostly focused on output display more-so than input, setting it apart from others. One of the inherent benefits of physical objects identified by Oren is that they hold meaningful affordances. In his masters thesis paper, Oren describes these meaningful affordances with the help of Thomas Reid's direct realism theory. This theory claims that a real object is not an image that is projected on the brain in the form of sensations and then processed as a form of perception, but *instead* hold in themselves, external to the brain, direct meaning available for perception (2005). Unlike most symbolic information systems like language, icons, and signage, *physical* objects require no ‘decoding’ by the brain because we deeply understand their physical state and form. We are reminded of Donald Norman, who provided it as a foundation lesson in his book The Design of Everyday Things.

Oren’s research work was based around a three-part thematic framework, as follows:
1) How can the affordances available within shape-changes communicate specific qualities about an object?
2) How can shape-change leverage our ‘habituality’ in perceptions that overlap our senses such as visual and tactile feedback?
3) How can shape-change bring our interactions with digital devices a peripheral dimension? (2005).

I found these issues are very relevant to my thesis. One of the key lessons to be learned from Oren’s form-making explorations was the importance of an obvious *reference point for the objects*. It is this reference point that the current physical state of the object is continually referenced and measured, thereby conveying meaning. The same idea applies to a temperature gauge which is always referencing a min and a max amount.

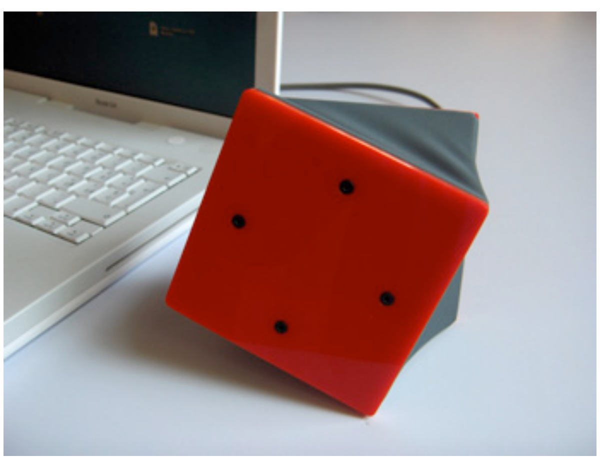


Figure 9. InSync Prototype. Oren Horev, 2005.

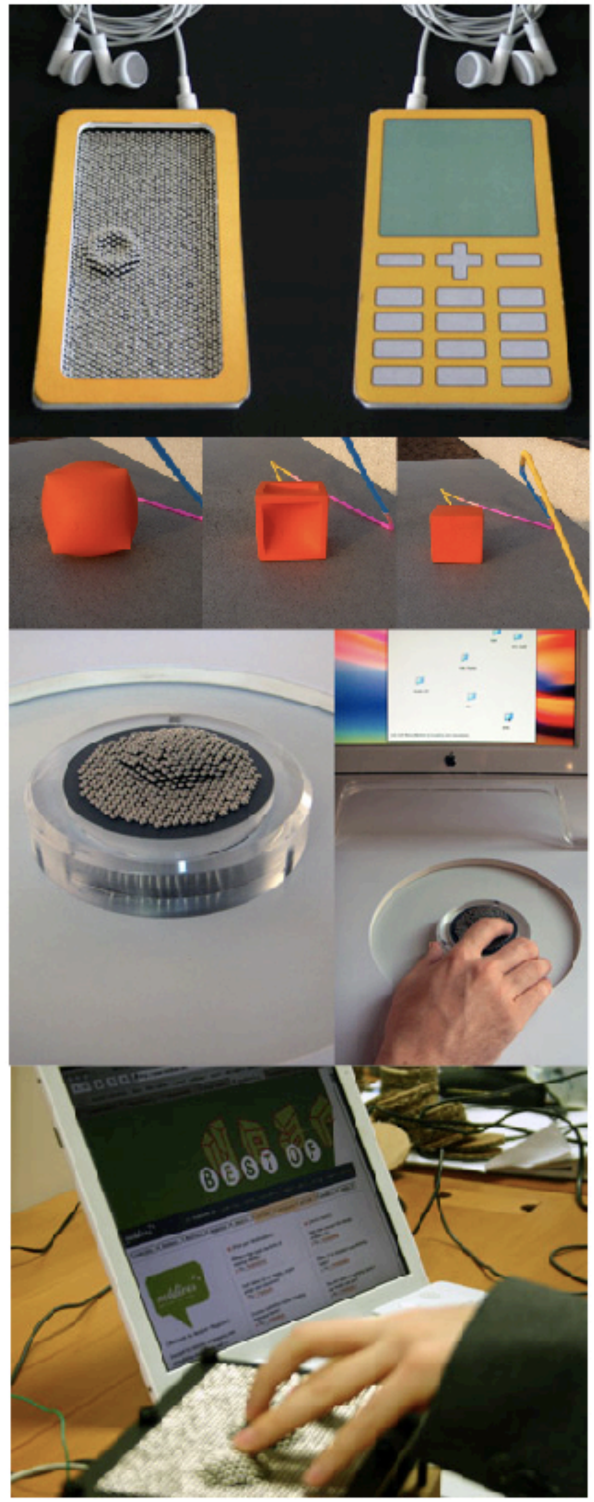


Figure 10. Info Terrain 1, Info Terrain 2 , InSync, Tactophone, Morphing cube. Oren Horev, 2001-2005.

Another Masters thesis project, this time from Jack Schulze, a student in the Masters of Interaction Design at the Royal College of Art in London. Schulze explored ways to anthropomorphize a toy with the digital presence of an Instant Messenger buddy in physical space. His product, named Availabot, collapses when its pre-programmed AOL Instant Messenger buddy is away, and stands up when the buddy is present. Since the project is a toy, it is easy to overlook the significance in it as a Tangible User Interface and Interaction Design between two humans.

Figure 11. Availabot. Schulze & Webb, 2005.

The final example is a design concept from Plus Minus, which gives physical volume to a USB storage drive. This move towards a tangible display of digital information is an example of the intuitive advantages of Calm Computing. No beeps, flashing lights, or buzzers are needed to communicate when the drive is ‘empty’ or ‘full’.

Figure 12. Flash Bag concept. Plus Minus

Opportunities & Specific Aims

Preface

By now, I’ve provided a background look into the multiple design and technology fields that are helping shape the future of a human’s interactions with computers and digitally conveyed information. I’ve also discussed some relevant products and prototypes related to these fields through the lens of an Industrial Designer. I will now move into the specifics guiding this project.

This is not a standard research project in that the goal of this project was not necessarily to answer any large question from the start (although multiple sub-questions did arise throughout the process). Instead, it was my intent for this project to be *explorative* and *development-based,* bounded by specific fields of interest and curiosity, especially Ubiquitous Computing, Calm Computing and Tangible User Interfaces. This means that, from the start, the designer is responsible for mapping a course to follow, but allows questions and his or her own material developments to guide the project towards reaching and uncovering new design opportunities. New questions and refined trajectories are formed along the way as the purpose of the project becomes clearer. But the end product is not what is most important, but instead the entire ‘path’ is taken as the project.

In a development project, how do you measure success? Success in this case is measured on how far the designer comes to covering and understanding the map set out for his or herself from the start. These are the goals. The ‘map’ is basically a designed method of research, describing the scope and paths through a development project. What makes this an Industrial Design project are the methods used as an approach to development. The methods used were those of Industrial Design and Interaction Design.

More on the methods in the Methods section.

Now onto the specifics of this project. The goal of this project is to progress the fields of Ubiquitous Computing and Calm Computing by using Tangible User Interfaces by design to develop an artifact that displays digital information in a physical way. The ending point will be to create a functional prototype.

My hypothesis or belief is that if we use physical displays for certain pieces of digitally conveyed information, then we can allow:

1) An enhanced understanding and accessibility of digitally conveyed information through using natural modes of human perception and representation.
2) Multiple users to be able to share the 'use' of the device.
3) Perceptibility of the information at both the center and at the periphery of the users' attention.

I use the term *certain* pieces of digitally conveyed information, because I am aware that not all information would be appropriately displayed in a physical way. Part of the development process is to discover what pieces of digitally conveyed information *are* appropriate and could benefit from physical representation.

Narrowing the Focus & Drawing Distinctions

Using the background research and existing prototypes, projects and products previously introduces, I shall now draw distinctions and give justification for the focus of this project. I shall also point out some opportunities across the fields that are used to inform the development project.

Regarding Ishii & Ulmer's work, Ishii and Ullmer define no narrowness to the human senses used with Tangible User Interfaces. While prototypes classified as TUIs include ones that primarily use ambient lights and sounds as their main method of conveying information, I am taking a narrower view by placing a high value on the sense of *touch* and the use of *form* to convey meaning. This is closer to the stance of Palpable Computing.

Furthermore, while Ishii & Ulmer's intent was to interface with 'everyday physical objects and environments', this project keeps open the possibility of creating a *new* physical object or environment. Limiting the outcomes to be only existing objects would put this project closer to the realm of Human-Computer Interaction, since the only work left to do would be to develop the connection between a coffee cup (for example) and a computer system. In this case, I am taking the stance of an Industrial Designer or Interaction Designer interested in developing a *new* device. Despite this difference, I share with Ishii and Ullmer an intent towards an enhanced understanding of digital information.

Overwhelmingly, the literature and current prototypes within the TUI realm are heavily or entirely *input*-oriented. Very few discuss Tangible User Interface prototypes which either provide both tangible input and output or solely *output* (display). Even within the examples given in the paper on Emerging Frameworks for Tangible User Interfaces, tangibility is only considered as an input method while the output or change-of-state stays in the digital realm. Examples of the Urban Planning and Design Tool "Urp" which uses physical model buildings and bridges, and the on-line media content organizing project "mediaBlocks" which uses physical blocks to manipulate lists of video, images, and other content, among most others use tangibility solely as an input strategy.

Within the examples stated in Fishkin's paper, which are four TUI examples, "The Great Dome", "Sketchpad", "ToonTown", and "Photocube", all systems involve a physical input device while the output change/result remains in the digital space. In other words, none of the Tangible User Interfaces seem to effectively address the sole issue of tangible output (display), but instead favor input. This was a red-flag of opportunity for me.

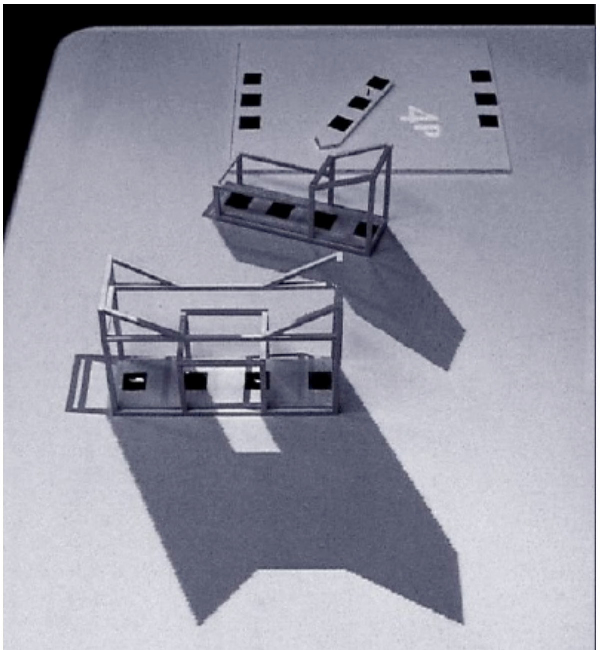


Figure 13. Urban Planning Design Tool, *Urp.* Ishii

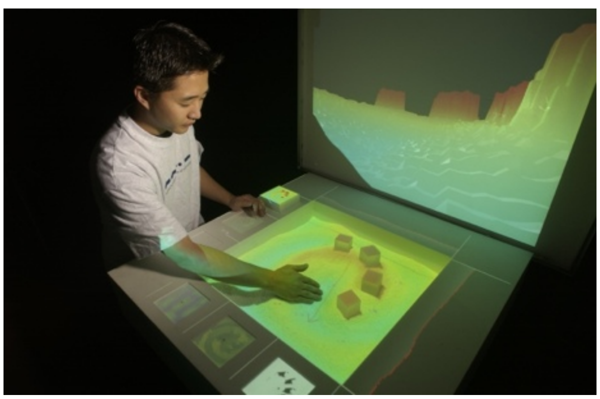


Figure 14. Sandscape. Ishii

The prototypes and products shown earlier were all chosen as examples that focused on tangible output (display). While the stock orb focuses solely on the tangible output of information, it relies on colored light to convey information. Therefore, the slice of 'tangibility' used by this product and with the work of many other existing research prototypes is the reliance on the sense of vision. We go back to the main research topic and consider what if form is emphasized over light or sound?

As a contemporary masters project to this one, Oren Horev's hypothesis in Talking to The Hand is, "on the relevancy of habituality as a concept to shape-change behavior, that a design acting physically within its environment (changing its shape through the course of an interaction within this environment can provoke a better understanding of the purpose of that interaction and situations along its course.

While highly inventive, most of Horev's prototypes are brilliantly simple means of generating a physical display for a set of "operation modes or statuses through shape changes" (2005).

The driving force behind Horev's research was developing a catalog of display taxonomies and methods, not necessarily defining the message to be displayed. When it came time to application, most of Horev's prototypes were grounded in electronic or personal-computer components and parameters such as hard disk data capacity, adaptive next-generation computer mice, and the activity of data transfer (as in the Dangling String example from Wellnar et al).

This masters project attempts to build on Oren's physical prototyping towards expanding the nature of the message being displayed beyond the realm of local personal computer parameters. Using the internet, weather forecasts, bank balances, train schedules, and other quotidian information and communications can expand the potential use of these types of displays. Two other examples of tangible technology displays worth mentioning use palpability to display information. They are the Availabot from Schulze & Web, a toy that can be linked to show the online availability of a buddy on an Instant Messaging program, and the other Flash Bag, which gives Oren Horev-esque physical display of the capacity remaining in a memory stick.

Below is a graph of these three projects with the strength of the physical metaphor on the x-axis (low to high) and the source of information on the y-axis, (on your local computer or pulled from the internet).

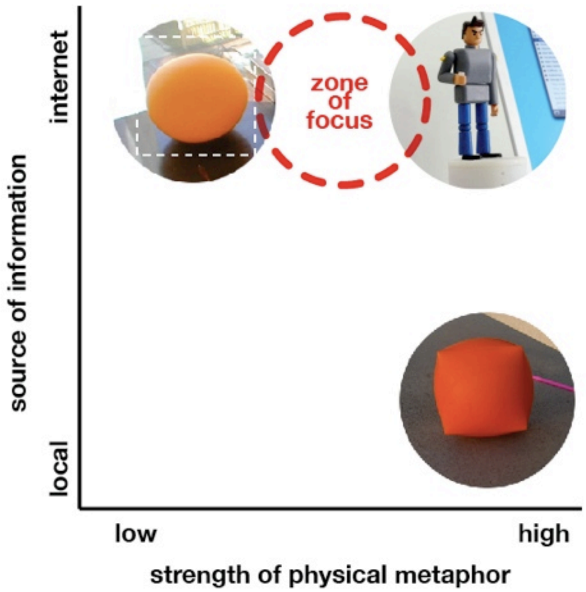


Figure 15. Comparing Precedents. Ullrich, 2009.

Figure 16, Ambient Devices, Inc. 2004.

One of Oren Horev's prototypes is positioned on the bottom right, since it displays local information about your computer (the remaining hard drive space on your desktop computer) with an intuitive volumetric form. The strength of the metaphor is very strong, but the "source" of the information it is displaying is not far from you.

Both the Availabot and the Ambient Orb display information from the internet, but the Availabot has a very literal form: it is a model a specific person, so the meaning of it is also fairly intuitive. The trade-off of this specificity in form is that it limits the customizability of what the device is displaying. Given the male figure on the toy, It would be hard to imagine this device representing the online presence of a female friend, for example.

On the other hand, the Ambient Orb uses a more ambiguous colored light to communicate information. The creators have used this to their advantage, allowing the user to define which parameters they would like the device to represent, as seen below.

While this level of user-input allows flexibility in the information being displayed by each device, the weakness of the required metaphor means that the meaning of the display has to be learned (and re-learned) by each user or group of users. So a device set to display the Traffic conditions on the nearest highway would not have an intuitive meaning to a group of first time users, or a user who owns their own Ambient Orb but has it set to, say, the Pollen Count.

Going back to the graph, I have 'zone of focus' that describes an area of opportunity. This area of opportunity is between the Availabot and the Ambient Orb, in that it is a physical manifestation of information pulled from the internet, but attempts to strike an appropriate balance between *specificity* of form and *flexibility* of user definition.

To review, the major points of emphasis in this project are:

1) Strike an appropriate balance between specificity of form and user customization of the information being displayed.
2) Usable by multiple users at once.

3) Focus on a *tangible display* instead of input.

These points of emphasis map on to the goals defined earlier:

1) An enhanced understanding and accessibility of digitally conveyed information through using natural modes of human perception and representation.
2) Multiple users to be able to share the 'use' of the device.
3) Perceptibility of the information at both the center and at the periphery of the users' attention.

To wrap-up the Specific Aims, I wish return to the paradigm shifts of computing as proposed by Weiser, Key, and Brown. While their Ubiquitous Computing model predicted a *single* user to be surrounded by multiple computing devices in the 3rd paradigm, I propose a different expectation. Instead, I propose the ability and expectation for *multiple users* to 'use' multiple computing devices. I hope to advocate for this type of thinking with this project.

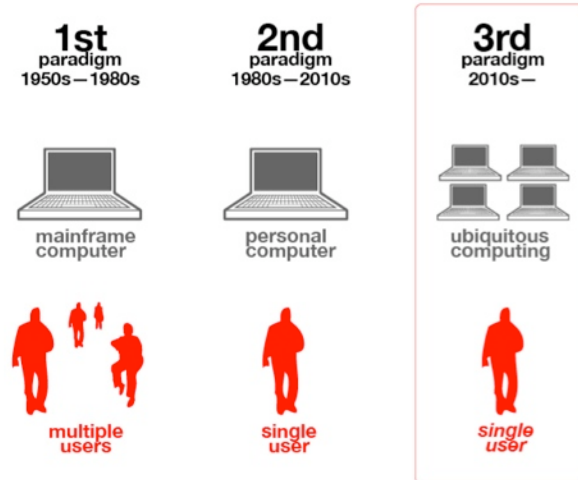


Figure 17. Computing Paradigms. Proposed by M. Weiser, A. Key, J. Brown, 1996.

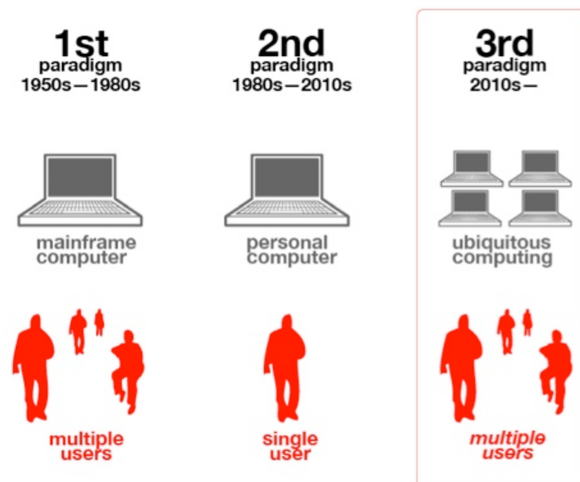


Figure 18. Computing Paradigms. Proposed by Ullrich, 2008.

Methods

In the previous section, three operational objectives were identified which give action-oriented terms to the *goals* of the project:

1) Strike an appropriate balance between specificity of form and user customization of the information being displayed.
2) Usable by multiple users at once.
3) Focus on a *tangible display* instead of input.

Using a design methods framework created by Saffer, author of *Designing for Interaction*, the design method employed in this development project was a hybrid approach between 'Systems Design' and 'Genius Design'.

TABLE 2.1 Four Approaches to Design

Approach	*Overview*	*Users*	*Designer*
User-Centered Design	Focuses on user needs and goals	Guide the design	Translates user needs and goals
Activity-Centered Design	Focuses on the tasks and activities that need to be accomplished	Perform the activities	Creates tools for actions
Systems Design	Focuses on the components of a system	Set the goals of the system	Makes sure all the parts of the system are in place
Genius Design	Relies on the skill and wisdom of designers used to make products	Source of validation	Is the source of inspiration

Figure 19. Interaction Design Methods. Saffer 2007.

First, a bit on Systems Design. Where User-Centered design positions the user at the center, Systems Design positions a set of entities (people and devices) that act upon each other in the center of priority (Saffer 2007). Users are not as important as the whole context of use.

Systems Design projects can be broken down to 8 key characteristics. I will reference this list later as a check-list of components on my final design, but for now the list is given: Goal, Environment, Sensors, Disturbances, Comparator, Actuator, Feedback, and Controls (Saffer 2007).

'Genius Design', a term coined by Saffer, assumes that the designer knows best and does not consider user input or testing until the very end of the process. Strangely enough, Saffer admits that this is how most interaction design is done today, due to shortcomings in time and funding. Apple used Genius Design with the iPod, which succeeded, but they also used it with the Newton PDA, which.

Genius Design also seems to be the fastest and most flexible of the methods allowing the designer to focus where they see appropriate and innovate more freely (Saffer 2007).

An important note that applies to *all* the methods, Dan Saffer writes, is the importance of using ideation and building prototypes towards solutions. The built prototypes do not represent the solution, but instead one possible solution in a set of many others (Saffer 2007). Prototyping was to be used heavily throughout the development process, and have direct feedback from their successes, failures, and feasibility guide the project.

Taking everything into account, the proposed high-level methods employed were:

1) Conduct case studies of physical products that display digital information towards categorization under my taxonomy.
2) Study impacts of morphology for technology applications towards understanding of the digital information.
3) Design with prototypes, towards understanding the value of physicality of artifacts. Perform tests for effectiveness with users and collect data.

Development Process

Preface

The following section chronicles the development of this project. It reads as a sort of journal in roughly chronological order, recording my thoughts, learned pieces of information, and other changes gathered along the way. When viewed in concert with the physical prototypes, this is my development process. The majority of the information is pulled directly from an actual journal kept during the project.

While some design research projects may place less emphasis on the work leading up to the final product, the entire path is informative and valuable in this case, and therefore the inclusion of key developments seemed appropriate to include in this document. It is also my hope that someone else in the middle of a similar research project could find value in reading these developments. Let's get started.

Creating a Map

August, 2009

The first step was to create an Operational Framework. This would describe in simple terms what my aims were.

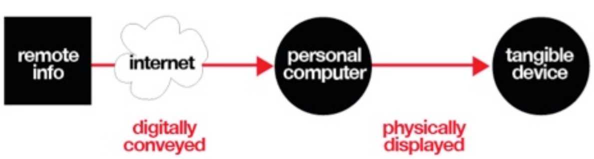


Figure 20, Operational Framework. Ullrich 2008.

Using a personal computer as a standard piece of hardware to act as a mediator, the tangible device physically displays remote information from the internet.

While a decision had been made to lead with form development and delay the selection of the message to represent, some early understandings of the types of messages to be made needed to be created to help inform drawings and prototypes.

Starting with the Remote Information, I developed a list of digital information that one might want to access. This list was categorized under 4 categories of increasing complexity: Binary (two positions), Static Variable, Dynamic Variable, and Abstract Variable.

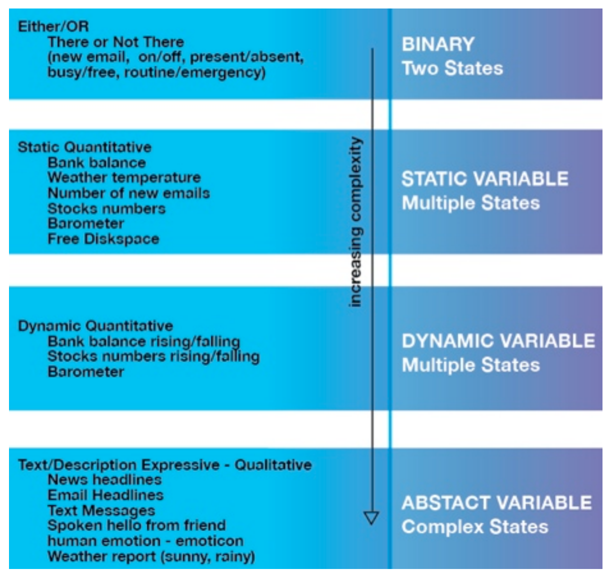


Figure 21. Types of Digital Information. Ullrich 2008.

After making this list, an important observation arose that while all variable scenarios can be binary, not all binary scenarios can be variable. For example, the temperature of a weather forecast (which is a variable piece of information, like 70°) could simplified into a binary report of “hot” or “cold”. On the other hand, the binary notification of “an emergency” or “no new emergency” could not be divided into more states. This observation served to be valuable once the translation to physical devices was made.

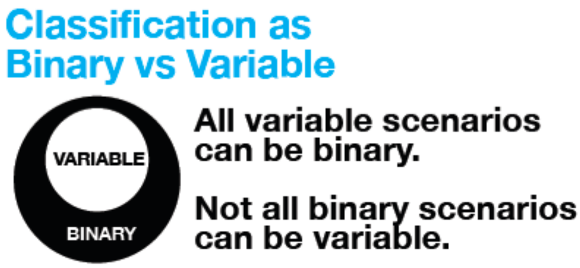


Figure 22. Binary vs Variable. Ullrich, 2008.

Next came the task of generating a taxonomy of physical forms and actions that could be used to display these pieces of digital information. It soon became clear that I was developing a *translation taxonomy*: a method of translating a piece of information into a physical form. Based on limitations of technical skills to build a dedicated piece of hardware that could do the necessary computing, I decided the translation would be accomplished with the use of a personal computer, thereby becoming the 'brain'. The device would be connected to the computer.

The most logical way to do create a digital to physical translation scheme was to use the categorizations of Binary, Static Variable, Dynamic Variable, and Abstract Variable as a conceptual bridge.

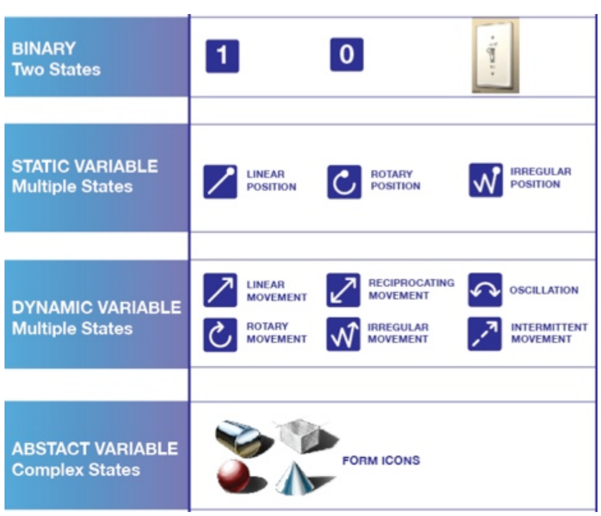


Figure 23. Physical Taxonomy. Ullrich 2008.

Using a set of diagrammatical icons, the physical equivalents of the taxonomy was created. Binary had two states, like a light switch. Static Variable had multiple static positions like a temperature gauge. Dynamic Variable had to include all types of motion including rotation, vibration and oscillation, as Dynamic Variables (like a falling stock market) suggests motion. Finally, Abstract Variables were given the form of complex shapes like cone, cube, sphere or other coded languages like semaphore or sign language. Like language, these physical methods of communication are learned codes.

With the urge to move into prototyping swiftly, a list of possible methods of implementation was also generated. This list included a Stepper Motor, Nitinol Wire, and a Vibrating Motor. In asking " what type of motion are each of these items good for?", a comparison list was made incorporating the previous diagrammatical icons.

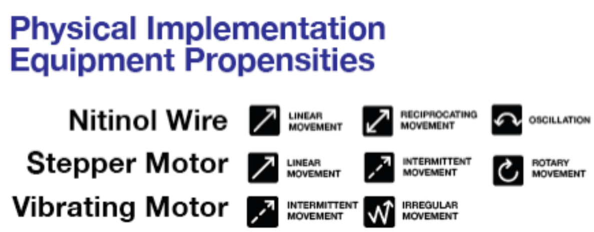


Figure 24. Physical Equipment Propensities. Ullrich 2008.

The final step in creating the map was to try my hand at creating some prototypes. Using Saffer's recommendation to prototype early, ideas were recorded in order to get a sense of what methods of physical display might be feasible. For the purpose of completing the map, sketches were used to explore simple physical forms that could shift, move, etc. and potentially hold some meaning.

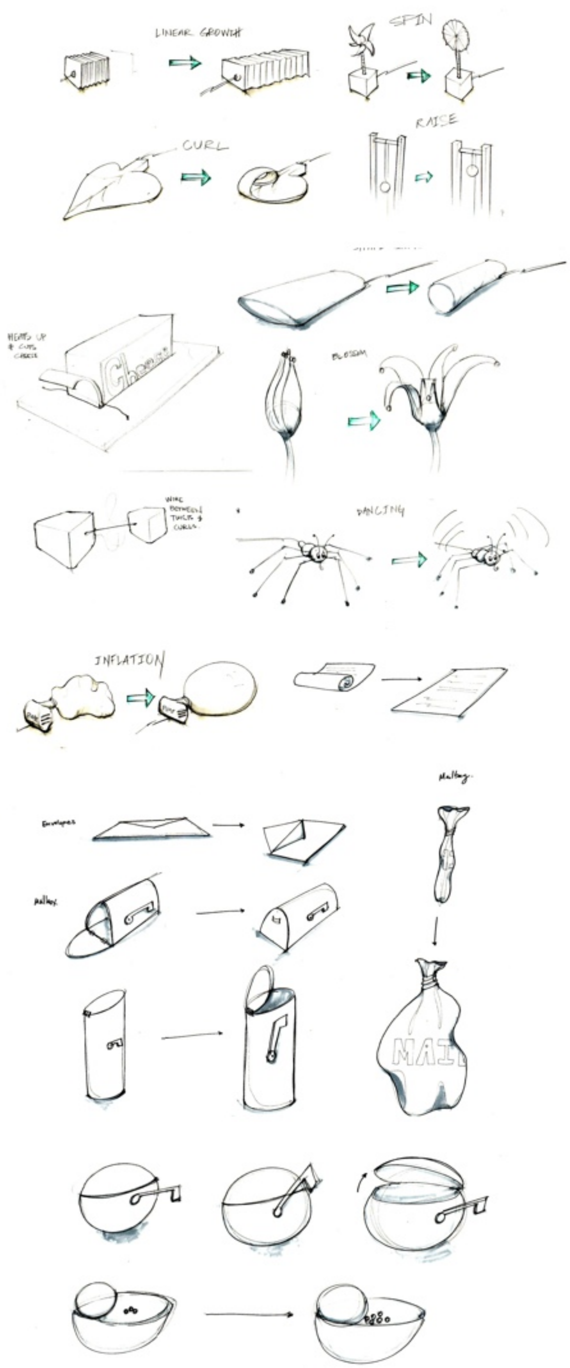


Figure 25, Form exploration sketches. Ullrich 2008.

Individual sections of understanding following the Operational Framework were made. Now, a summed map was created. (see next page) This would serve as my initial understanding of the field and chart possible trajectories on where I would go and what I would hope to learn. This was a rather instinctual move from design education, to visually map out everything i knew, what i needed to find out, where I think I might be heading, so that, once ‘in the thick of it’, I had a scaffold to place pieces of collected information and make sense of it. Alongside conducting an initial literature review, the Research and Development Plan was created.

Building off the Operational Framework, this Research and Development Plan was to help answer my two primary research questions:

WHAT: What is the stimulus? What is the range of electronically communicated messages? What type of information is ripe for physical display? Is it about communicating a change of state, alert, inform, getting attention, etc.?

HOW: How will the digital message be physically represented? What is the range of possibilities for physical representation? How can I design a recognizable form of the response?

The Research and Development Plan was also to inform secondary research questions, or ones that seemed less important and therefore could be asked later or simply answered by myself from the start:

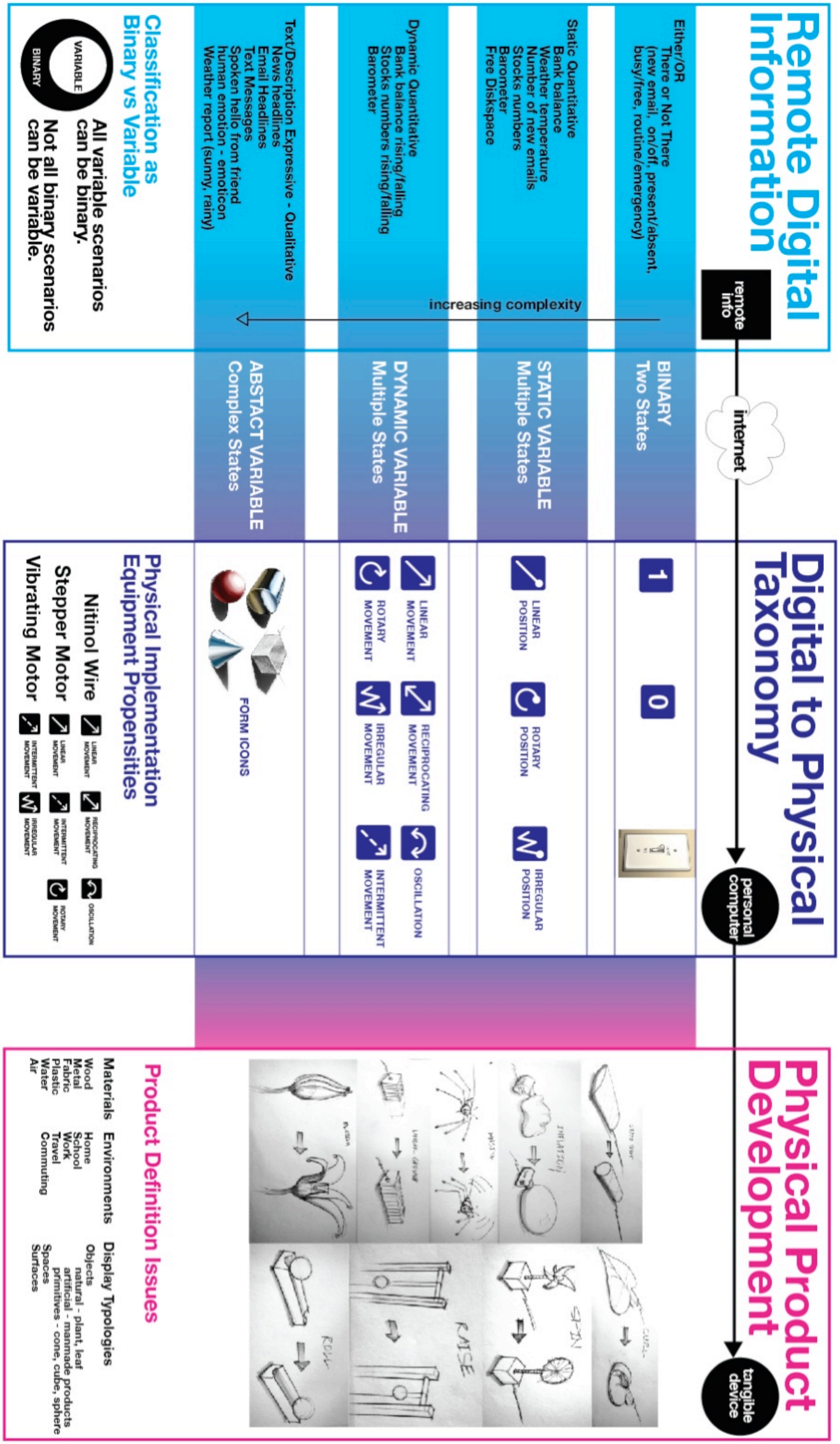
WHO: Who are the target users?

WHEN: How often are these messages being communicated?

WHERE: What is the most appropriate environments for usage of such a device?

Next Page:
Figure 26, Paths to Translation. Ullrich 2008.

Paths to Translation



Developing a Platform
September, 2009

Based on the typology organizations, there is a possibility of developing a palpable display that allows the user to assign the piece of digital information it is displaying, or the 'message'. This message would still have to be limited to a single message at a time. In this way, I could create a platform for palpable display of one or more pieces of information. The idea of a platform is not new. Modern personal computer operating systems, video game consoles, and cell phones like the iPhone are platforms.

Allowing the user to customize the message to be displayed allows the product to be both successful in *concept* and in *product*. The Availabot is something that is successful in *concept*, but has a small value as a *product* due to its 'hard-coded' application of displaying the presence of a particular online chat buddy. To be a successful *product*, it should allow more opportunity for use to a greater audience. This is only possible if we 'back the concept up' and widen its application to, for instance, the presence of anything online. Then, the Availabot would serve a greater audience and range of applications.

As a consequence of allowing for more flexible use, the physical form or metaphor must be watered down and made more vague and unspecific. In the case of the Availabot, if the device allowed the user to signify the arrival of a package at home, it may have to take the form of flag for example, instead of a particular human. Keeping the form of the human when the message it represents is the signal that your package has arrived might confuse the user. Of course, this limits the specificity of the design of the final object.

To strike a comfortable compromise, the deign should remain general enough to allow multiple messages to be displayed, but specific enough so that the message is effectively conveyed. They key is completely understanding the typology family I am representing and exploit that to the fullest potential in the form.

The Spark of Collaboration
October, 2009

I have began collaboration with Tom Morgan, of the PIXI Lab at Georgia Tech's Graphics Visualization Unit (GVU) (http://www.cc.gatech.edu/pixi/). PIXI Lab's intent is to explore the boundaries between interaction and infrastructure. Tom's work in prototyping and research is very similar to mine. He has been using the Arduino hardware as a platform for creating ambient network monitoring for the home, similar to Weiser's LiveWire project.

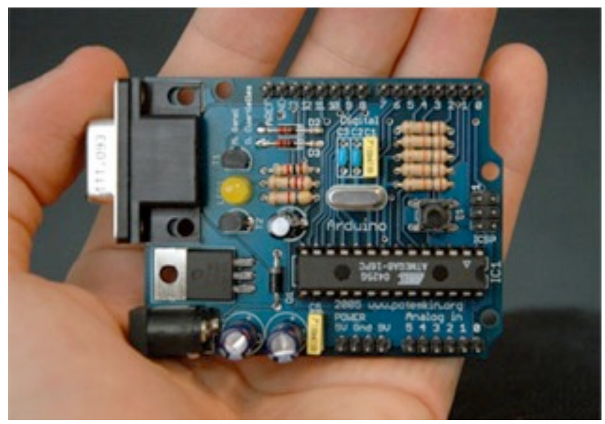


Figure 27. Arduino. Photo by Nicholas Zambetti. http://arduino.cc

Before meeting Tom, he had developed computer code, using the Ruby coding framework, to perform two functions:
- Listen for an instant messenger ping.
- Listen for the computer to pass a certain threshold of bandwidth speed while downloading a file via an internet browser.

Once the system found either of these cases to be true, the system was the programmed to trigger a blue LED light in the Arduino hardware. After meeting and discussing more potential applications, Tom wrote the code to listen for the presence of a new Email from a specific domain, and perform the same task with the Arduino. In essence, he was developing code for an Arduino that could be swapped-out at any moment. He was developing the code needed for a platform.

My task in asking Tom to collaborate was for my physical prototypes to replace his blue LED in creating a more meaningful, accessible, and tangible display platform.

Author's note: *Tom provided the base code for what I needed to accomplish. I adapted it to my needs throughout the project. At the end, about 50% of the final Ruby code (email_v3.rb) was created by him in the original file. Thanks to Tom Morgan for all your help.*

Tangible to Palpable

November, 2009

While continuing research and honing the specificity of this project, I decided to focus the area of tangibility (all senses) to emphasize palpability (the sense of touch). The reasoning in doing so is two-fold:

1) Incorporating Oren Horev's work in developing physical metaphors also provides the ability for increased meaning past the use of just colored light, which most current tangible user interface displays seem to rely on. If we are attempting to truly fuse the digital space with object around us, we should attempt to display information using pre-established methods, very few of which use light as an information conveyance method. For example, the limping of a leaf does not use light, only form and shape.
2) The ability for an object to communicate information in a palpable way allows it to exist in our attention's periphery even more so than a flashing light or beeping sound. The concept of Calm Computing may actually be achievable if all Tangible User Interface displays are palpable.

Around this time, I realized that if the information being displayed fits into the category of digital information stemming from an object that already exists in physical space (i.e., a hard drive), the digital information would most likely be layered on top or integrated into the existing object. Or, if like the Availabot, the information being displayed originates at a distance or only exists in digital space, a new physical form is needed for display.

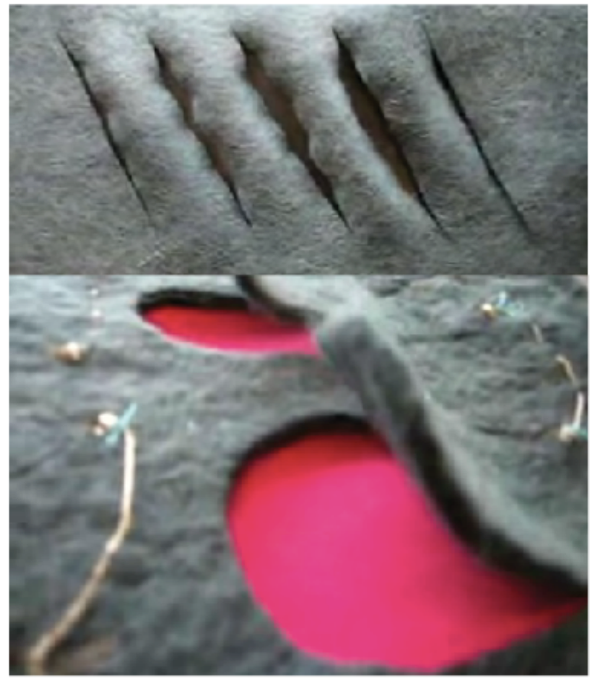


Figure 28. Nitinol prototypes in felt. XSLabs, 2007.

Figure 29 Nitinol prototypes tissue. Ullrich, 2008.

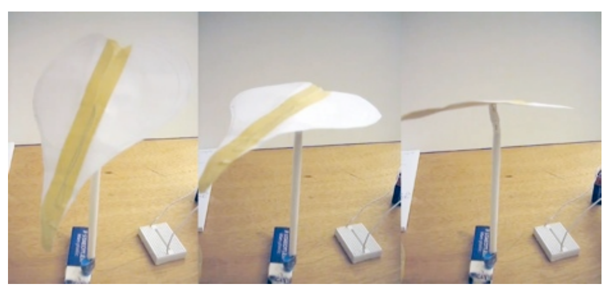


Figure 30. Nitinol prototypes paper. Ullrich, 2008.

Figure 31, Nitinol prototypes tissue, Ullrich, 2008.

One of the prototyping instruments used during this transition was nitinol wire. With such a simple instrument like nitinol wire, the presence (binary) and amount (variable) of information is directly transduced to electronic current, and as a result, physical state. It is a very simple physical actuator and valuable to prototyping. Given the proper amount of control over the current feeding into the nitinol wire, it could serve as an effective method of a variable display. With more power, the more the display would flex.

A reference to the recent BMW GINA project helped ground the concept of shape-shifting in a physical example. The GINA automobile is comprised of a stretchable surface material over top of a rigid, flexible frame. The frame is reposition-able, creating a form that can morph into different shapes. These shapes could potentially provide a platform for symbolic meaning.

Figure 32. BMW GINA. 2008.

Upon further research, Peter Pearce has created a helpful a catalog of forms that outlines the way a stretched surface and rigid form could be configured.

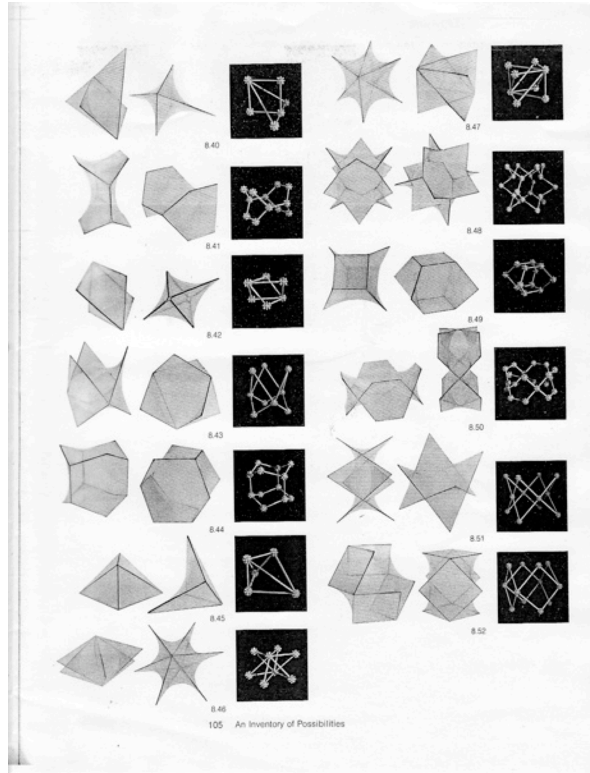


Figure 33. Stretched material with rigid frames. Peter Pearce 1978.

I used the ideas of the BMW Gina along with the structural schemes proposed in Peter Pearce's prototypes to develop my own set of forms that can be repositionable with a flexible skin and rigid frame. Given the proper mechanics inside, this could provide a robust method of creating a shape-shifting display.

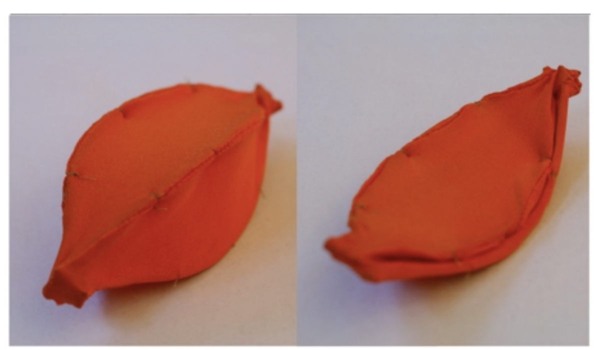


Figure 34. Stretched material/rigid frame prototypes. Ullrich 2008.

Considering Scales

December, 2009

What have we lost now that nearly all electronic communication devices are 'personal'? The personal computer, the personal cell phone, the personal music device are all examples. I believe that Ubiquitous Computing devices have the ability to actually help build community instead of separate it. The reason is that devices can and will be shared by many. An example is of a device that can help build community instead of separate it is the single household or office telephone, which creates a shared communication experience among many.

The question of scale begs certain other questions. How many people could this device serve? What is the required scale of this display? How will others be able to understand the meaning of the display if in public? Should understanding of the device be required to be learned, as in learning how to read an analog clock? Or should it be obvious from the start as an unlearned code?

A public display, if expected to be functional, requires its coded information to be understood by most. It also required a relatively low 'density' of information to be displayed at a time to reduce confusion. As in the example of the simple wall clock, or the StockOrb, the idea is that these displays are for multiple people, not just one. The personal computer displays information at a scale and format for one person at a time.

While there is an emphasis in creating a device to be used by many people, due to physical constraints in prototyping, the extreme end of *large* scale public displays will not be considered. At the same time, to avoid repeating the problems with the current personal desktop, the *small* scale will also not be considered. The Zone of Focus will be somewhere in between.

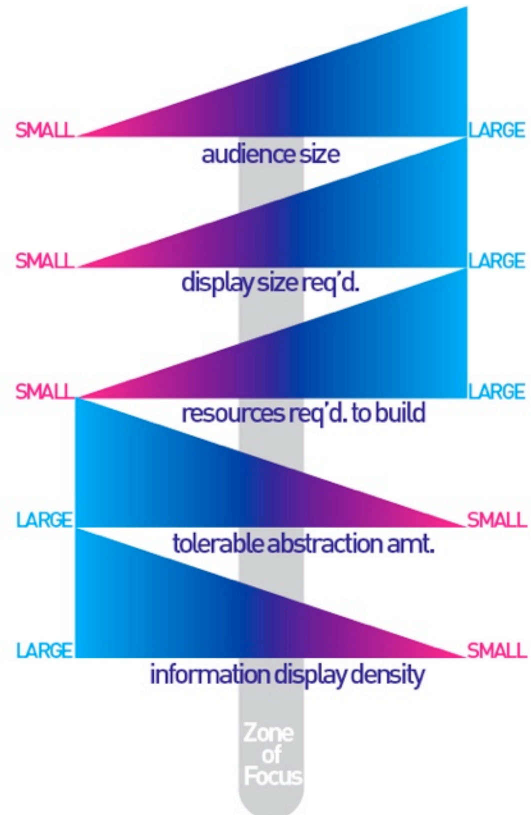


Figure 35. Zone of Focus. Ullrich 2008.

This marked a period of heavy prototyping. Tests were also made with vibrational motors in different scenarios. The vibrating effect would likely be a *binary* movement if implement, since it really only provided an on and off case effectively.

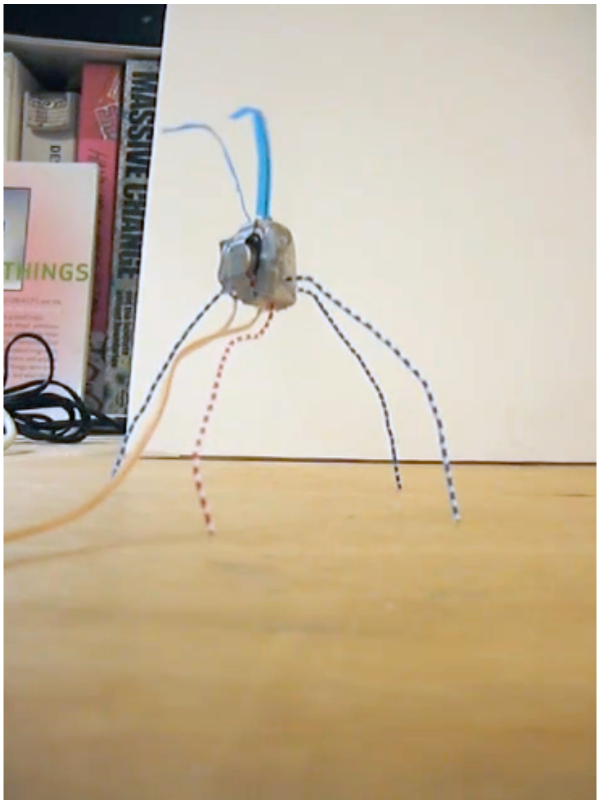


Figure 36. Vibrating bug. Ullrich 2008.

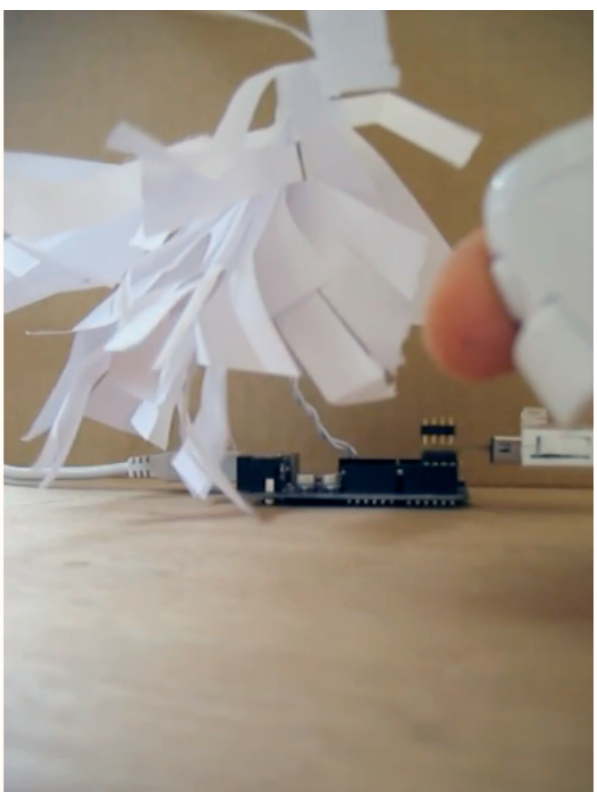


Figure 37. Vibrating plant. Ullrich 2008.


Figure 38. Vibrating Membrane. Ullrich 2008.

Scalable prototypes using the stepper motor were also made. An interesting ability of these objects is to show a sort of ‘history’ in their use, as their positions could be charted throughout the day. The precise control in positions using the stepper motor allowed for a more robust display of variable information.


Figure 39. Vertical Scaling 1. Ullrich 2008.

Figure 40. Vertical Scaling 2. Ullrich 2008.

Figure 41. Table-top scaling. Ullrich, 2009.

Opportunities Arise in Email
January, 2009

At this point, one of the major roadblocks in the way holding-up development was: *What piece of digital information am I displaying?* While this is an important question, I resisted answering it at first. I did not want such an explicit question limiting exploration for fear of missing a simple solution. Instead, the intent was to arrive at an appropriate connection after developing a few prototypes. After sufficient prototypes had been made, the narrowing of the digital information (the 'message') had to be made before moving farther.

Up until this time, i had been mimicking the 'trigger' of the devices with a Nintendo Wii chuck controller I had wired to the Arduino.

I turned to the existing code I had, the Ruby files created by Tom Morgan. We had discussed using the idea of using a device to display email in the past, and shortly thereafter he had supplied me with a working file that searched for only NEW emails in an email account. With some Google searches, I found I had a number of other searchable parameters to deal with. With the alteration of a few lines of code, the Ruby script could search an IMAP Email account for the total number of emails:
. in the inbox
. since a specific date
. from "yahoo.com" or "hotmail.com" etc.
. from "yahoo.com" AND from a specific date
. with "scott" in the FROM field, etc.
. with "scott" in the TO field, etc.
. larger than __mb
. smaller than __mb
. sent on a specific day
. sent after a specific day
. sent before a specific day
. have "Thanks" in the subject, etc.
. have "Thanks" in the body, etc.
. that are unanswered

With these capabilities in mind, an email survey was composed to gather the preferences of individuals who were asked to imagine they owned a tangible device. The survey question was as follows:

---

hello.

can i ask you to imagine something,
then reply to me with an answer?

there is a small object, sitting on your work desk. it can display information about your **email account**, without you having to look at your computer. it is a holiday gift from your nerdy friend. yes, that one.

what information would you hope this object could display? place an 'x' between the ( )s. you have up to 3 choices.

( ). the number of unread emails
( ). an email from a specific domain (for ex., any email from @obama.gov)
( ). an email from a specific person
( ). you have an email with photos attached
( ). you have an email with a large file attached (> __ mb)
( ). you have an email that is marked as 'urgent'

( ). choose.your.own.adventure: ___________________

With 41 unique respondents providing 104 responses, a general understanding of people's preferences when it came to such a device were understood.

	41 respondents, given a max. of 3 choices each.
Choice of notification parameter	Number of Responses
the number of unread emails	30
an email from a specific person	25
you have an email that is marked as 'urgent'	18
an email from a specific domain (for ex., any email from @obama.gov)	11
you have an email with a large file attached (> __ mb)	2
you have an email with photos attached	1
additional requests (see additional comments)	17
TOTAL	104

The top-two categories were for the device to report the number of unread emails as well as emails from a specific person. Unpopular display capabilities were to know if an attachment of a particular size or kind was received. These statements more or less confirmed assumptions I had made on the preferred uses of such a device, while the interesting bits came from the open-ended responses. Some of these are as follows:

Open-ended response 1:
"I don't really care about email as my phone tells me when and who email is from, and I don't have to be in the same room as my desk to get it. what I want to know is information I can't get from some other device. therein lies the interest and challenge of your thesis..."

Open-ended response 2:
"Between my laptop and phone, I don't need another email tool. I would, on the other hand be interested in that thing doing something creative with the information in my email database. can it be "love" gadget? throughout the day it'll tell me how many smiley's i've received. how many times the word "thanks" occurs in my inbox... kinda, stress reliever object?"

Open-ended response 3:
"Email related to a specific context (work, thesis, video games - or even Fun vs boring) currently probably definable by a text string, but computers are getting better at id'ing overall context and that's what I really want"

There was a good portion of respondents that requested the physical device to tell them something that their computer could not. Additionally, most of the respondents were not interested in the identity or real content of the message, but instead hinting at more human, emotional aspects of the message, like how it makes them feel or of relating to a specific context.

An article from a friend helped shed light on the opportunity of moving forward with Email as the trigger. In an article from the CS Monitor, 3 major problems were identified in the medium of email:

1) E-mail lacks cues like facial expression and tone of voice. That makes it difficult for recipients to decode meaning well.

2) The prospect of instantaneous communication creates an urgency that pressures emailers to think and write quickly, which can lead to carelessness.
3) The inability to develop personal rapport over e-mail makes relationships fragile in the face of conflict (2006).

In more simple terms, *e-mail cannot adequately convey emotion*. Also, e-mail lacks body language, tone of voice, and other cues - making it difficult to interpret emotion. “A typical e-mail has this feature of seeming like face-to-face communication,” Professor Nicholas Epley of the University of Chicago says. “It's informal and it's rapid, so you assume you're getting the same paralinguistic cues you get from spoken communication.”(2006).

Clearly, there was an opportunity to infuse some “emotional intelligence” into this electronic communication method. The article wraps up by comparing the success of communications in email versus phone.

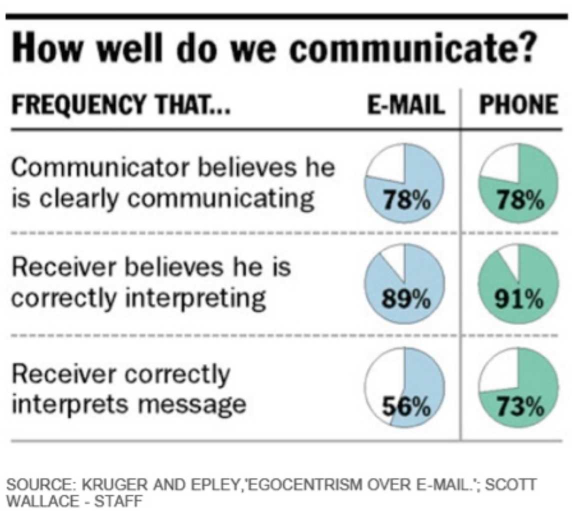


Figure 42. How well do we Communicate. CS Monitor 2006.

While it was not my intent to try to lift the level of communication effectiveness of email to that of phone conversations with a designed device, I thought it was interesting to note the amount of importance the article placed on the tangible and emotive (in other words *human*) aspects of a successful communication system.

A quick prototype was made, taking the existing methods of conveying emotion through email, emoticons, into a literal 3D dimension. This one prototype could pivot the smile to show different emotions.

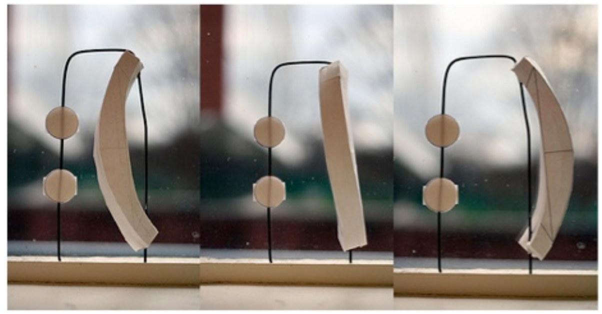


Figure 43. Emoticons prototype. Ullrich 2009.

Consulting with an Expert

February, 2009

A classmate, Cleon Stanley, and myself conducted an informal video conference with Interaction Designer Carla Diana on February 10, 2009. Carla is a former Georgia Tech Industrial Design instructor and is now (at the time of writing this paper) a Senior Interaction Designer at Smart Design in New York City.

After speaking with Carla, the focus of the project developed from just ‘using email’. to a broader view of ‘what do you want to know from people’? In this way, the emphasis was not so much on *email*, but instead looking at human communications and using email as the *method of conveyance*, or the portal through which the device operates. We decided that email was a particularly good choice because of its ubiquity and the multiple ways to access it — via cell phones, computers, and other mobile devices.

The missing link uncovered after talking with Carla is the aspect of *emotion* in the design process. According to Interaction Designer Dan Saffer, “in analytical thinking, emotion is seen as an impediment to logic and making the right choices. In design, products without an emotional component are lifeless and do not connect with people." (2007).

So perhaps I can use email as a method to convey what people want to tell each other, and use a tangible display to share that information. This made me think of topics like love, happiness, thinking, touching, etc. This value begged the question "what value can't be displayed by a computer, in a human way?", or in the context of this project, "**how do i effectively represent the emotional state of my email inbox**?"

This could be accomplishable with the Ruby code, to search for a specific word which means a lot to someone, emotionally. At this point, sharper goals formed:

1) I am Designing Interactions of a 'smart' object.
2) I'm using email as a means of conveying a message to a device.
3) The device will improve/change the users experience of typical human communications through computer systems.
4) The device will hunt email(s) for keywords in email messages, creating a volumetric/ form change as its main display method(tangible).

Narrowing the Metaphor

March, 2009

With the digital message narrowed, it was time to return to finalizing the physical form. While the 'tube' form was still fresh in my mind, I wanted to play with other forms. For this, I devised a scenario:

A device that represents a person or idea, would actually *contain* a photo of that person or that object. When an email is received containing that keyword, the photo or object is *hidden* from view by a closing action of the device, thus the digital presence has *replaced* the physical one. Only by responding to the email is the physical one revealed. In other words, the system would 'activate', or *hide* the physical representation when an email is present which contains a the written word anywhere in the email until it is answered.

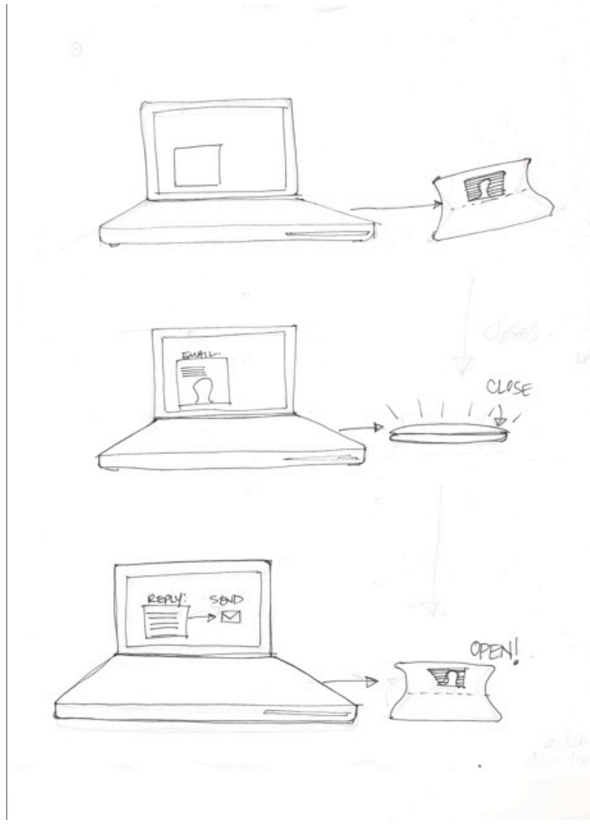


Figure 44. Sketch of device to hide and show physical objects or photos. Ullrich 2009.

The expected experience would be to create an awareness factor of how the digital world is replacing/supplementing the physical world. Only by tending to, for example, the email from a loved one, would their physical instantiation on your desk be seen again.

I tested multiple symbols and metaphors for the device with sketches, only to find they are perhaps too limiting from the start. In this prototype, the user is allowed to participate in the process, and the device could integrate into each user's unique life. Since the user completes the design by using their existing objects, more meaning is brought to the device and the interaction.
While there were some drawbacks to this prototype (discussed in the next section), there were some lessons learned and

confirmed. Limiting the user's input from the start creates a narrow experience and an overly-prescribed device, like the Availabot. Therefore, the decision was made to move forward with placing more emphasis on *designing the interaction* as well as the *device*.

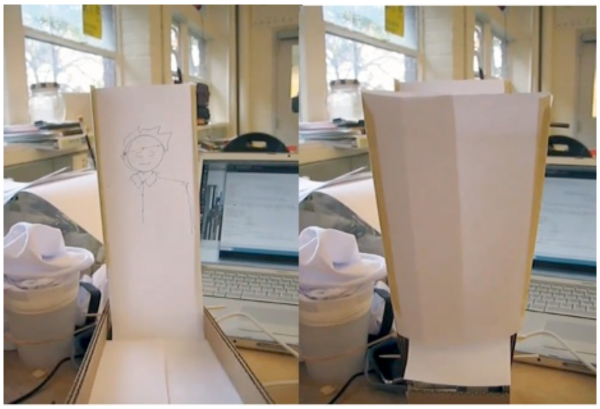


Figure 45. Prototype of device to hide and show photos. Ullrich 2009.

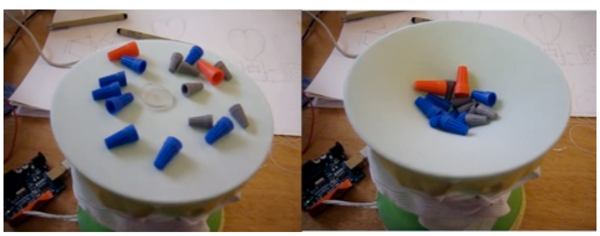


Figure 46. Sketch of device to hide and show physical objects. Ullrich 2009.

Broadening the Metaphor

April, 2009

After some reflection, I found that the scale of the device is very important, and I feel as though I'm losing the ability for the device to be relevant to multiple people. Additionally, the binary open/closed nature of the previous prototype is rather bland.

The variability available in the 'tube' prototype is more informative and adds value to the device. The ability to chart a history over time is also inherent in something with more available physical positions. So, I moved back to having something scale up and down. The good news is that I had built these before.

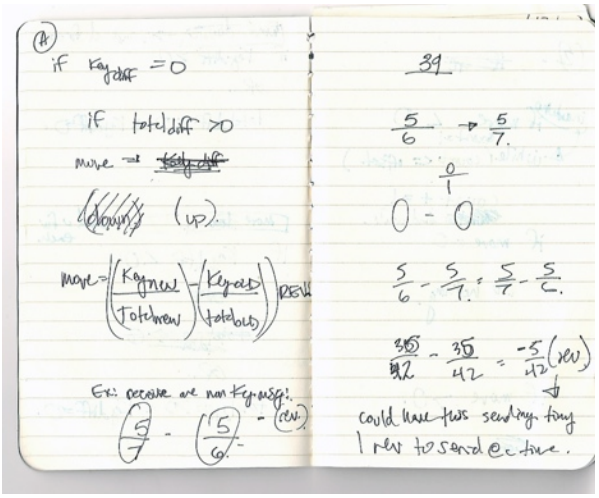
A Refined Goal, Nearing the End

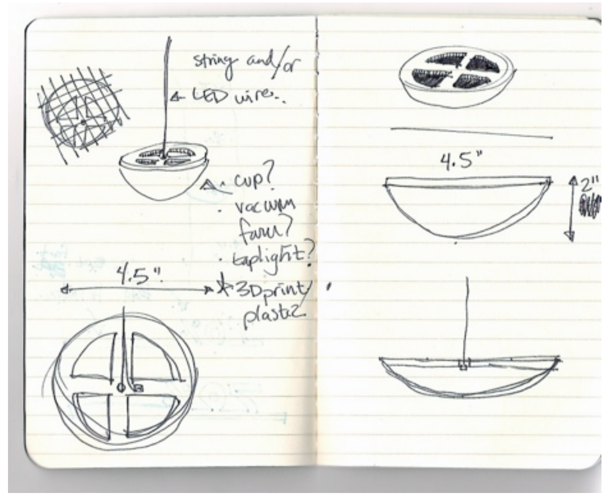
The refined goal is to humanize electronic communications between people by creating a device that can tangibly display the *emotional quotient* of your email inbox.

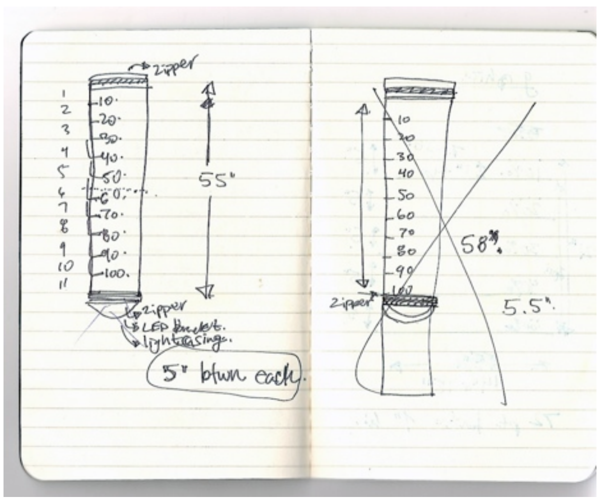
As a justification, so many of our daily interpersonal communications are collected (digitally) into our email inboxes. these communications are received from friends, family members, colleagues, teammates, spouses, bandmates, supervisors, etc. Access to this method of communication is now considerably easy, as messages can be sent from desktop, laptop, and mobile email devices. Email, as a communication method alongside face-to-face conversation, phone conversations, text messaging and letter writing, now accounts for a very large percentage of human to human communication.

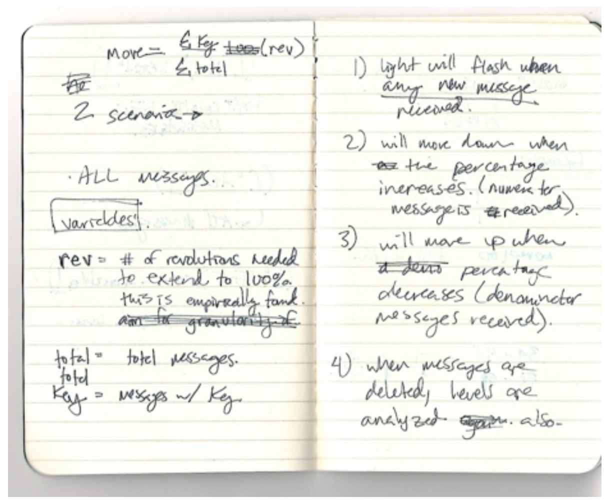
Despite the computer's ability to report the number of emails in an inbox, the sender, the size, the date, and the subject, we are unaware of the more 'human' characteristics of these messages. The messages have been stripped of their human content and emotional nature.

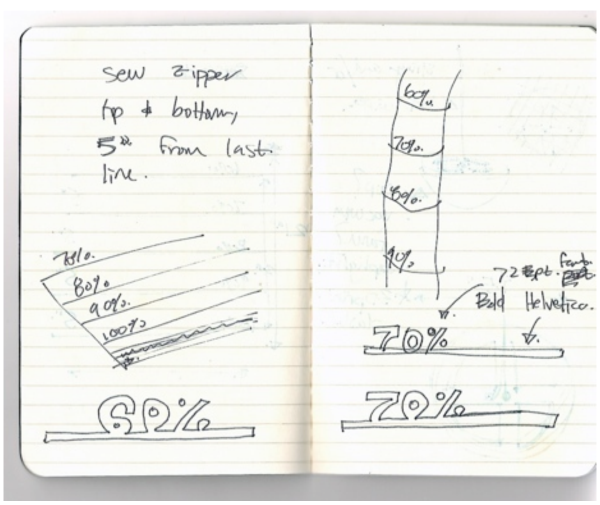
Even with the implementation of emoticons :) :(;) :/, complex human emotions are reduced to a set of two dimensional pixelated punctuation. Imagine if these human emotions could instead be displayed in a more natural, physical way. As physical creatures, we understand physical objects. We can interact with them in more intuitive ways, can share the visibility of them with others, and observe them from a varying range of distances. Their form and color can

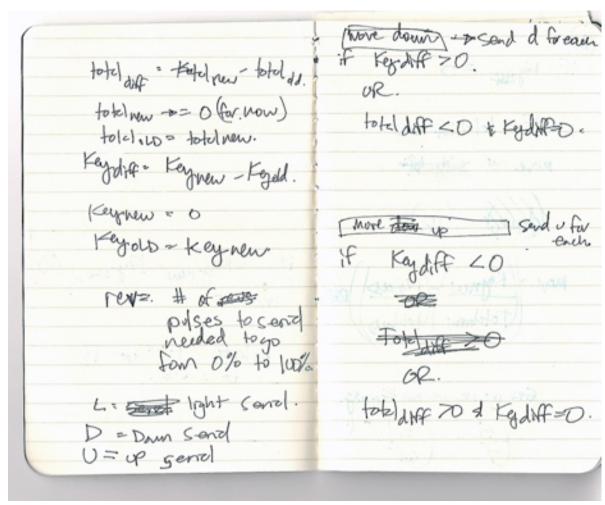












Figures 47-52. Final development sketches and algebra. Ullrich, 2009.

communicate something without the use of words. Imagine an LED display replacing communicating the idea of ‘ripeness’ in the same way we touch, smell, shape, and appearance of a ripe peach. It hardly compares... and how boring!

By letting a user the define terms which they consider to be either emotionally ‘positive’ and ‘negative’, the system becomes tuned to what makes the user ‘happy’ and ‘sad’. the system will then regularly scan the entirety of the messages in an inbox and provide a live, tangible display of the inbox’s emotional state.

Imagine in this scenario that the inbox shared the same interests and dislikes of its user. The expected results are a sort of humanizing effect of the computer system, allowing it to share the same likes and dislikes as you, and reporting this back to you. While acting as an aggregator of communications, this device is both a ‘display’ as well as an ‘entity’ with its own pre-defined triggers. A message from the gas company has a ‘$’ sign in it. The device decreases in volume a bit. A message from a relative signs off with the word ‘love’ . The device grows a bit.

Results

In the end, around 18 distinct prototypes were made, covering the realms of Binary, Static Variable, Dynamic Variable, and Abstract Variable and using the Stepper Motor, Nitinol Wire and the Vibrating Motor. Most of the prototypes were documented with photography and/or video.

Go here to access them: http://www.flickr.com/photos/teddesigns/sets/72157607545991814/

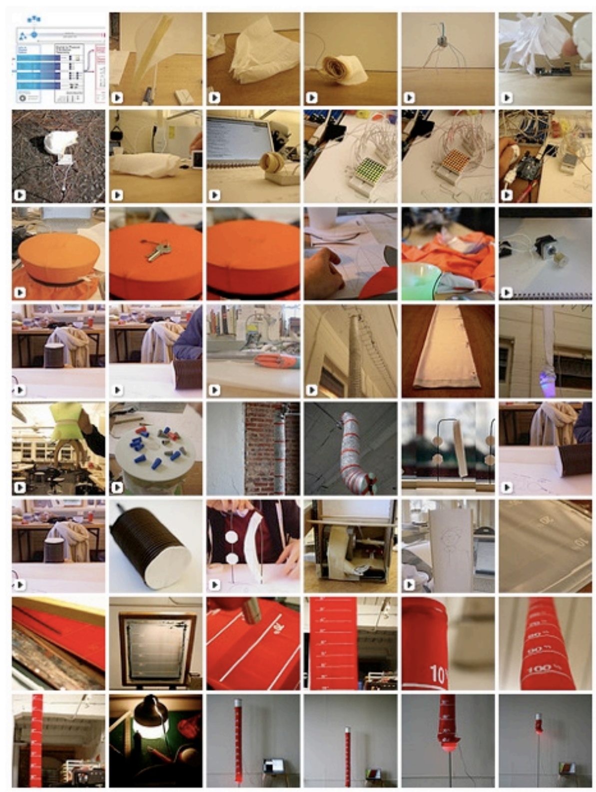


Figure 53. Some of the Prototypes made. Many are videos. Ullrich, 2008-2009.

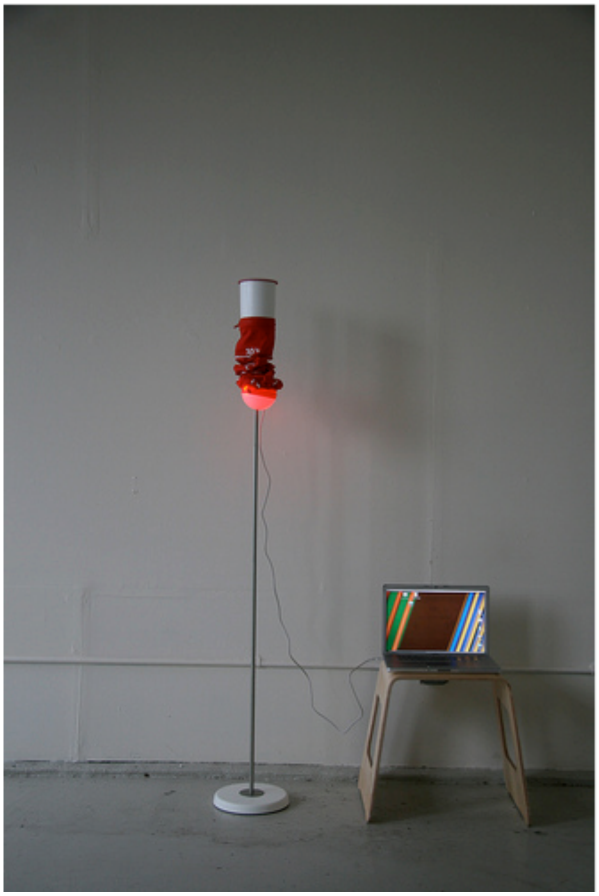


Figure 54. Final Prototype. Ullrich, 2009.

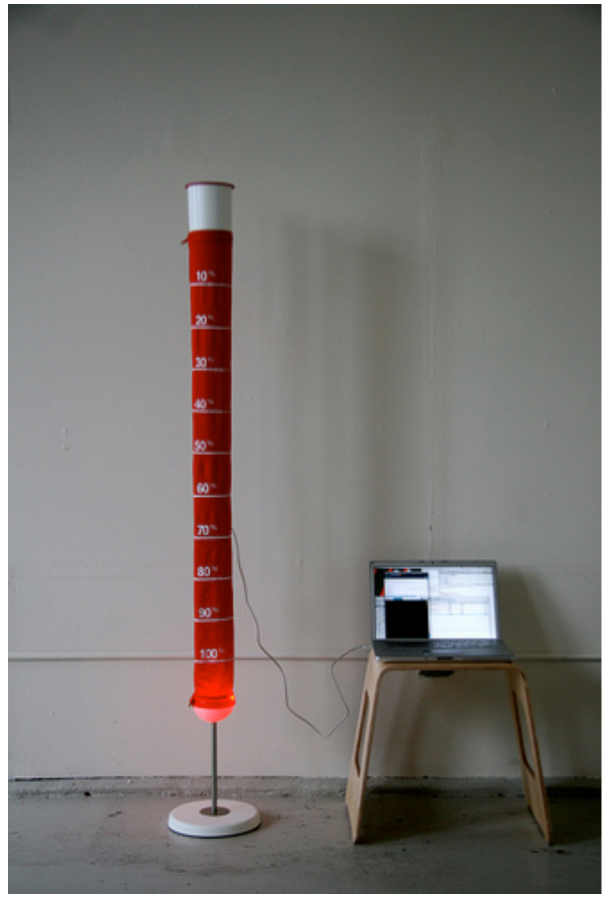


Figure 55. Final Prototype. Ullrich, 2009.

What is it?

The device stands about 5 feet tall. It plugs into your computer via the USB port in order to power the device and transfer data. The body is hand-sewed from red lycra material and hand silk screened with white ink in Akzidenz Grotesk Bold typeface.

The device 'lives' where most people spend their day — near a computer at the office or at home. With the proper length of cord (or with a Bluetooth version of the Arduino which is available), the device can 'live' in a farther range away from the computer.

The device is a piece of tangible technology. It is a percentage gauge of whatever email term the user sets to search their email inbox with. It displays digital information outside the portal of the standard computer, so the user can hide it, move it to the center of their attention, or somewhere in between. This also means that other users can easily observe the position and motion of the device.

The simple color scheme of red and white was chosen to reflect a passionate emotion. Many people associate red with love, and therefor it seemed as an appropriate choice for the final color of the device.

What does it provide?

1) An enhanced understanding and accessibility of digitally conveyed information through using natural modes of human perception and representation.
2) Multiple users to be able to share the 'use' of the device.
3) Perceptibility of the information at both the center and at the periphery of the users' attention.

How does it work?

At launch, the device asks you for your Gmail username and password. It then asks you to enter, in one word, what the contents of the device represent to you. After hitting enter, the device is programmed and goes to work, giving a live display of the percentage of emails containing that word in your inbox. The algebra is relatively simple:

Percentage =
(#Keyword emails / #Total emails)

The script runs continuously, silently checking your email account every 10 seconds and acting accordingly. The script is intelligent in that it knows its current position and knows whether to retract or lengthen itself based on changes in the percentage.

As an added feature, the bottom of the device glows red while increasing in percentage. It does not glow red when decreasing in percentage.

User Scenarios

Three user scenarios are provided in order to demonstrate the use of the device. In these everyday examples, the following use of device is demonstrated by imagined characters. As a whole, the scenarios engage the following goals of the device:

1) An enhanced understanding and accessibility of digitally conveyed information through using natural modes of human perception and representation.
2) Multiple users to be able to share the 'use' of the device.
3) Perceptibility of the information at both the center and at the periphery of the users' attention.

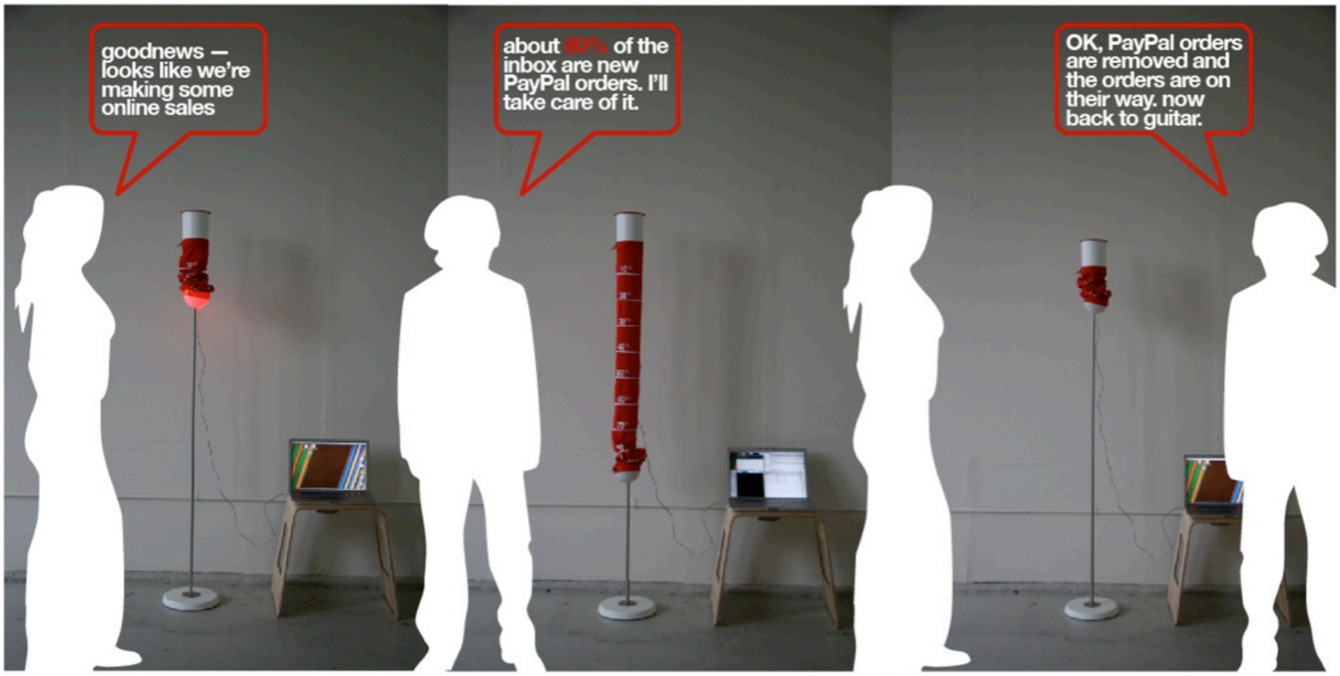
Figure 56. Diagram of Operation. Ullrich, 2009.

Next Page, Figures 57-59. Scenario Diagrams. Ullrich, 2009.

1

john & martha run a side business collecting and selling rare records on eBay.

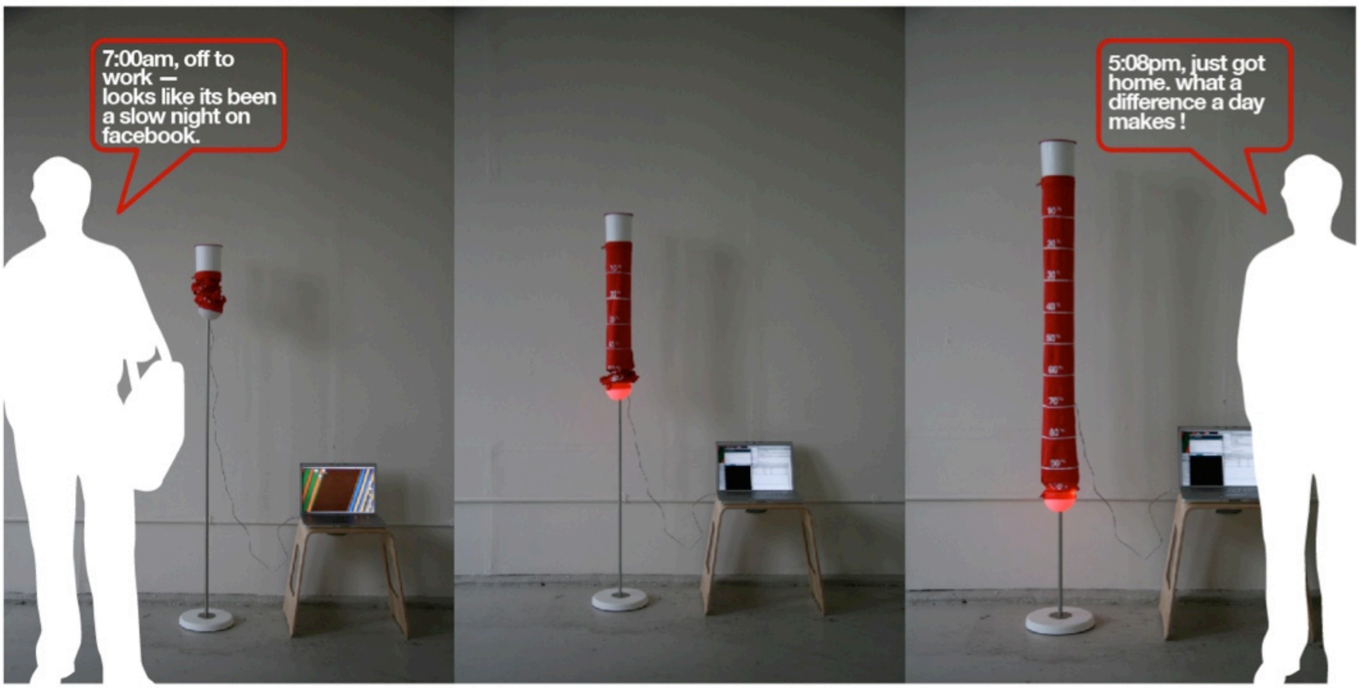
despite providing enough income to pay for his subway fare each week, john would rather spend time making music and drawing than checking to see if they have new orders.



2

matt works at the office all day and rarely has time to check his personal email account

after all the business emails he wades through per day, it is a treat for him to come home and see how many messages he has accumulated from friends and family posting on facebook.



3

paige works at an advertising agency and sometimes works from home so that she can spend time with her 3-year-old child and take care of things around the house.

while she doesn't like to spend her whole day in front of the computer, she likes to keep an eye on any new emails from her company.

Discussion

Validation

Given Saffer's list of 8 characteristic components of a System Design project from his book *Designing for Interactions*, here is the list re-presented in context of the current project to serve as a sort of checklist. (2007). The underlined word is the characteristic from Saffer, while the italicized sentence is how the characteristic is met.

1) Goal — *To provide a metric and display of a key phrase in one person's electronic communications with the world.*
2) Environment — The *system lives in a computer work environment with a lot of information.*
3) Sensors — *A Ruby script checking an email account.*
4) Disturbances — *The detection of a keyword email.*
5) Comparator — *The percentage scale of the device.*
6) Actuator — *The Arduino hardware connected to the stepper motor that responds and changes the size of the gauge.*
7) Feedback — *Light flashes on with any increase. the size of the gauge changes.*
8) Controls — *The user can delete, shape the messages in your inbox to control the gauge. You can also manually control the device via the Arduino Panel.*

Given from Saffer's list of 7 characteristics of a successfully designed interaction, (Trustworthy, Appropriate, Smart, Responsive, Clever, Ludic, and Pleasurable) here are 4 items in that list presented in context of the current project to serve as another sort of checklist (2007). The underlined word is the characteristic from Saffer, while the italicized sentence is how the characteristic is met.

1) Appropriate — T*he user can define what the device means.*
2) Smart — *As the device can continually digest hundreds or thousands of emails within seconds and make simple meaning of it for the user.*
3) Clever and 4) Ludic (playful) — In its purpose and form, the device digests human communications into a physical form for us to keep an eye on.

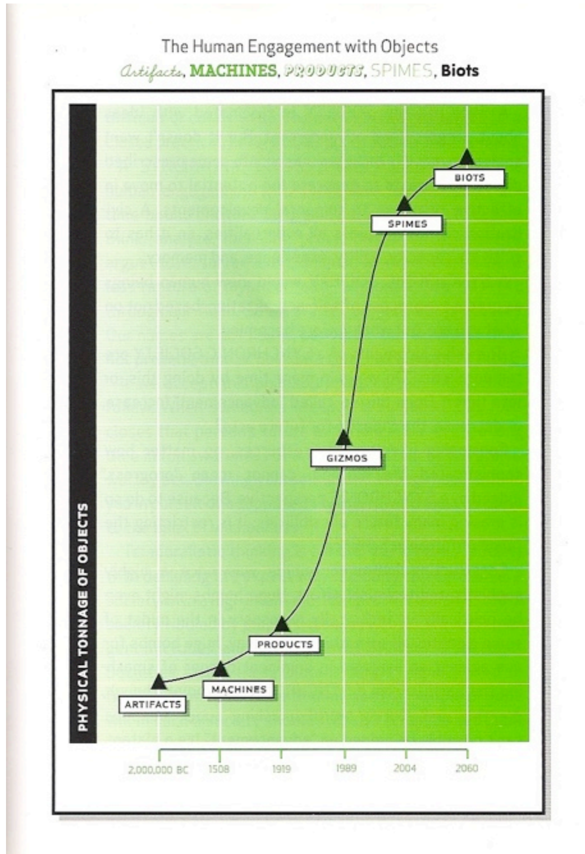


Figure 60. Graph physical objects versus time. Sterling 2005.

In an interesting anecdote, in his book *Shaping* Things *(2005),* Bruce Sterling describes humanity's relationship with 'things'. He describes the path from artifacts to machines to products to the current era of gizmos. Gizmos are inexpensive electronics that do certain tasks. The next era of objects are what he calls 'spimes'. Spimes are objects that have a history of their own and can tell us information about the world. Sterling's description of spimes is very similar to the notion of Ubiquitous Computing (2005).

Sterling emphasizes that in order for the gizmo-spime transition to take place, we need “new, inventive, interactive machineries of representative design” because in a world of spimes, almost everything has a metric and is measurable (2005). To accomplish this transition, we must also revolutionize the interplay between human and object by bringing more attention to objects themselves — asking more from them, as well as engaging with the human body through all its affordances — touch, sight, smell — in all environments (2005). Again, this description is a description of Ubiquitous Computing and of some of the characteristics of the final prototype of this development project. Furthermore, Sterling claims that in the forthcoming world of products that are data collectors and measurers, a world of so called ‘spimes’, designers must design not just for people or products, but for the *technosocial interactions* between them. He adds that this often means designing for the simplification of complex information in order to aid our cognitive loads (2005). All in all, Sterling's views support the efforts of this project.

A Statement of Caution

At one point early in the process, one of my advisors Abir Mullick, raised the question if it would be overwhelming for all objects to have an embedded layer of information. I believe yes. Imagine a scenario: you walk into a room, and every object is telling you something about something else. It could perhaps be overwhelming. The power of communication of palpable computing must be used carefully. M. Kyng believes that health care and emergency industries will use this technology first, due it its ability to be extremely perceptible in a realm of computer monitors. This supports the notion of creating a palpable *platform*, which displays much more fundamental categories, leading towards different applications.
The potential uses for Palpable Computing are diverse, although initially I think the key markets will be in areas, such as emergency response and health care, where there is an urgent need for increasingly more efficient and effective technology,” as Kyng says.

Yet, from the standpoint of this research project, limiting myself to just emergency devices from the beginning might not produce innovation. Instead, I chose not to limit myself and keep it as a possibility to consider later.

Presentation at the 2009 IDSA Southern District Conference

On April 3, 2009, I presented the completed prototype and set of previous works at the IDSA Southern District Conference in New Orleans, as part of a feature focus on 7 students’ graduate design thesis/project work from around the southeast.

My work was well-received. the initial question was, “ok, what does it do?”. I explained that it was a physical gauge showing a frequency percentage of a user-defined word in your email inbox. people were generally curious and had questions about how it worked, what programs were used to code it, what languages it was coded in, and how i got started/interested in this field. many design students felt a connection like “i would like to do this too”. this hinted at an opportunity for low-level tinkering on an expanded user-base scale.

one group wanted to see the device and program run its filter on my spam box. we tried searching for the word ‘eBay’ and the device responded with displaying 30%.

one person could see this as a marketed project in target stores, which was perhaps due to the color scheme i used.

requests: some requests for changes were voiced. one was a question for it to move upwards and grow upwards instead of hanging and expanding downwards. i had faced this decision before, but unfortunately could not work out an appropriate scheme to create a collapsible internal structure rigid enough to allow the scaling to grow upwards.

Figure 61. Presenting at the IDSA Conference, 2009.

Figure 62. Presenting at the IDSA Conference, 2009.

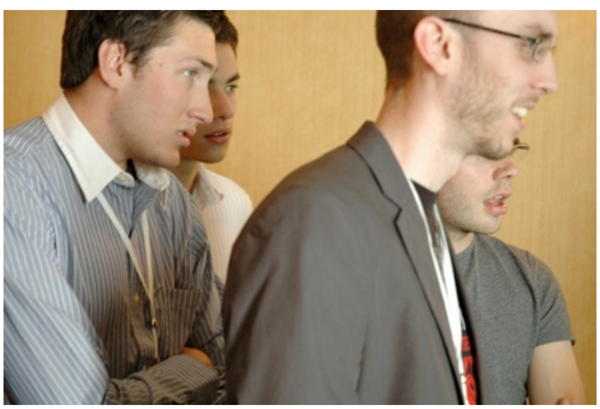


Figure 63. Presenting at the IDSA Conference, 2009.
Reaction of audience to the device demonstration.

Appendices

Survey Prompt

hello.

can i ask you to imagine something,
then reply to me with an answer?

there is a small object, sitting on your work desk. it can display information about your **email account**, without you having to look at your computer. it is a holiday gift from your nerdy friend. yes, that one.

what information would you hope this object could display? place an 'x' between the ( )s. you have up to 3 choices.

( ). the number of unread emails
( ). an email from a specific domain (for ex., any email from @obama.gov)
( ). an email from a specific person
( ). you have an email with photos attached
( ). you have an email with a large file attached (> __ mb)
( ). you have an email that is marked as 'urgent'
( ). choose.your.own.adventure: ____________________

Survey Results

	41 respondents, given a max. of 3 choices each.
Choice of notification parameter	Number of Responses
the number of unread emails	30
an email from a specific person	25
you have an email that is marked as 'urgent'	18
an email from a specific domain (for ex., any email from @obama.gov)	11
you have an email with a large file attached (> __ mb)	2
you have an email with photos attached	1
additional requests (see additional comments)	17
TOTAL	104

Additional comments and requests:

or maybe there are options to how it reacts? based on some settings/software?
don’t really care about email as my phone tells me when and who email is from, and I don’t have to be in the same room as my desk to get it. what I want to know is information I can’t get from some other device. therein lies the interest and challenge of your thesis. then again, you already know this.
i would like to have a notification if someone has replied to a certain email that I recently sent out
a group of determined people rather than just a single person notification, i.e. a notification of professors, or school or family.
email with .ics (calendar request)
something i've neglected, like an email i should have replied to a long time ago
time and current temperature/ weather conditions outside
you have an email from one of your "favorite 5," or "top friends/contacts"
I would also like it if it lit up a bit when a new email came in.
between my laptop and phone, I don't need another email tool. I would, on the other hand be interested in that thing doing something creative with the information in my email database. can it be "love" gadget? throughout the day it'll tell me how many smiley's i've received. how many times the word "thanks" occurs in my inbox... kinda, stress reliever object?
notification of any attachment
showing how close you are to inbox 0
email with any type of attachment, not limited to those w/ photo or large file.
email from a definable group of people (contact list, near friends, work folk)
email related to a specific context (work, thesis, video games - or even Fun vs boring) currently probably definable by a text string, but computers are getting better at id'ing overall context and that's what I really want
An email that has arrived within a specified amount of time , 5 min., 30 minutes, one hour, one day,
an alert saying whether the email is about work or play

maybe the object would glow in a different color or the text would be in a different color depending on which group the email is from or even better, the object would glow a different color depending on the colors within the email or emotion of the title of the email. i.e. the object could glow a bright white if the title read "great to see you" or could be a dull blue/ grey if it read- "sorry" in the title anywhere.
last time you checked your email
knowing when they're going to dump trash.

Ruby File (email_v3.rb)

```
#Ted Ullrich and Tom Morgan Georgia Institute of
Technology 2009. This file is run from the command
line (Terminal application on a Mac) of a computer
to continuously monitor a Google email account and
search for user-defined terms. The corresponding
percentage of all inbox emails containing that term
are coded as a letter and sent to the serial port
for appropriate response from the connected Arduino
and stepper motor.

#!/usr/bin/env ruby

require 'serialport.so' #used for serial
communicatio to the arduino
require "rubygems"
require 'net/imap' #used for connecting to the email
account
require 'highline/import' #used for simplifying text
input/output as well as obfusticating the password

#serial port set up
port_str = "/dev/tty.usbserial-A7005YB4" #HIGHLY
LIKELY TO CHANGE!! this need to be changed on a per
user basis to point to the arduino or it will not
work
baud_rate = 9600
data_bits = 8
stop_bits = 1
parity = SerialPort::NONE
seconds_in_day = 86400
frequency_to_check = 10 #CHANGE THIS TO CHANGE
FREQUENCY OF CHECKING
number_times_to_loop = seconds_in_day /
frequency_to_check

#used for creating a loop, will be implemented in
the future
t = Time.now

servicename = 'Gmail'
service = 'imap.gmail.com'
#end

search_variable = ask('In one word, what do the
contents of the physical device represent to you?:
')
#end

#get the username and password
username = ask("Enter your Gmail username:  " )
password = ask("Enter your Gmail password:  " ) { |
q| q.echo = "*" }

mastercounter = 0
totalold = 1.000 #sets the message counters to zero
keyold = 0.000 #sets the message counters to zero

while (mastercounter < number_times_to_loop)
#log in with username and password with ssl
encryption
imap = Net::IMAP.new(service,'993',true)
imap.login(username, password)
say("Logged in: Checking Mail...\n")

totalnew = 1.000 #sets the message counters to zero
keynew = 0.000 #sets the message counters to zero

imap.select('INBOX')
  #imap.search(["FROM", field, "NOT", "SEEN"]).each
do |message_id|
  #imap.search(["LARGER", 100000]).each do |
message_id|
  #imap.search(["LARGER", 100000]).each do |
message_id|
  #imap.search(["NOT", "SEEN"]).each do |message_id|
  #imap.search(["TEXT", 'Thanks']).each do |
message_id|


 imap.search(["ALL"]).each do |message_id|
        totalnew += 1.000
  end    #end for search  for total messages

   imap.search(["TEXT", search_variable]).each do |
message_id|
   envelope = imap.fetch(message_id, "ENVELOPE")
[0].attr["ENVELOPE"]
    say("#{envelope.from[0].name}: \t
#{envelope.subject} \n")
        keynew += 1.000
  end    #end for search for new messages

quotientnew = (keynew / totalnew)
quotientold = (keyold / totalold)
percentage = quotientnew - quotientold

say(keynew.to_s + " keyword messages found \n")
say(totalnew.to_s + " total messages found \n")

# say(quotientnew.to_s + " quotient new \n\n")
# say(keyold.to_s + " keyold \n")
# say(totalold.to_s + " totalold \n")
# say(quotientold.to_s + " quotient old \n\n")

percentageprint = percentage*100
say("reflecting a " + percentageprint.to_s + "%
change in keyword messages \n")
quotientnewprint = quotientnew*100
say("DISPLAYING " + quotientnewprint.to_s + "% OF
KEYWORD EMAILS IN INBOX\n\n")


sp = SerialPort.new(port_str, baud_rate, data_bits,
stop_bits, parity) #open serial port


if(percentage < 0)
        sp.write('u') #tell the arduino to flip
directions before sending the next value
        percentage = (percentage * -1)
end #end if
if(percentage == 0)
        say("No new messages were found\n\n\n")
end #end if
if(percentage > 0 && percentage < 0.05)
        say("between 0% and 5% change\n\n\n")
        sp.write('a')
end #end if
if(percentage >= 0.05 && percentage < 0.1)
        say("between 5% and 10% change\n\n\n")
        sp.write('b')
end #end if
if(percentage >= 0.10 && percentage <
0.15)
        say("between 10% and 15% change\n\n\n")
        sp.write('c')
end #end if
```

```
if(percentage >= 0.15 && percentage < 0.2)
        say("between 15% and 20% change\n\n\n")
        sp.write('d')
end #end if
if(percentage >= 0.2 && percentage < 0.25)
        say("between 20% and 25% change\n\n\n")
        sp.write('e')
end #end if
if(percentage >= 0.25 && percentage < 0.3)
        say("between 25% and 30% change\n\n\n")
        sp.write('f')
end #end if
if(percentage >=0.3 && percentage < 0.35)
        say("between 30% and 35% change\n\n\n")
        sp.write('g')
end #end if
if(percentage >= 0.35 && percentage < 0.4)
        say("between 35% and 40% change\n\n\n")
        sp.write('h')
end #end if
if(percentage >= 0.4 && percentage < 0.45)
        say("between 40% and 45% change\n\n\n")
        sp.write('i')
end #end if
if(percentage >= 0.45 && percentage < 0.5)
        say("between 45% and 50% change\n\n\n")
        sp.write('j')
end #end if
if(percentage >= 0.5 && percentage < 0.55)
        say("between 50% and 55% change\n\n\n")
        sp.write('k')
end #end if
if(percentage >= 0.55 && percentage < 0.6)
        say("between 55% and 60% change\n\n\n")
        sp.write('l')
end #end if
if(percentage >= 0.6 && percentage < 0.65)
        say("between 60% and 65% change\n\n\n")
        sp.write('m')
end #end if
if(percentage >= 0.65 && percentage < 0.7)
        say("between 65% and 70% change\n\n\n")
        sp.write('n')
end #end if
if(percentage >= 0.7 && percentage < 0.75)
        say("between 70% and 75% change\n\n\n")
        sp.write('o')
end #end if
if(percentage >= 0.75 && percentage < 0.8)
        say("between 75% and 80% change\n\n\n")
        sp.write('p')
end #end if
if(percentage >= 0.8 && percentage < 0.85)
        say("between 80% and 85% change\n\n\n")
        sp.write('q')
end #end if
if(percentage >= 0.85 && percentage < 0.9)
        say("between 85% and 90% change\n\n\n")
        sp.write('r')
end #end if
if(percentage >= 0.9 && percentage < 0.95)
        say("between 90% and 95% change\n\n\n")
        sp.write('s')
end #end if
if(percentage >= 0.95 && percentage <= 1)
        say("between 95% and 100% change")
        sp.write('t')
end #end if


sp.close #close serial port


#update the values
keyold = keynew
totalold = totalnew


 imap.logout() #log out of the email account

mastercounter += 1
sleep(frequency_to_check) #pause and wait for the
next cycle

end#end for while
```

Arduino Sketch (stepper.pde)

```
/* Ted Ullrich Georgia Institute of Technology 2009
 Program to drive a stepper motor in two directions
 Send 'a' thru 't' to send the tube up or down. a is
worth 5%, b is worth 10%, c is worth 15% ... t is
worth 100%
 send 'u' in front of the letter to flip direction
of travel
 */


 // Fading LED values
int value = 0;                              //
variable to keep the actual value
int ledpin = 9;                             // light
connected to digital pin 9
//motor values
int motorPin1 = 2;
int motorPin2 = 3;
int motorPin3 = 4;
int motorPin4 = 5;
int delayTime = 10; // milliseconds between each
step of the motor - don't change
int val = 0;       // variable to store the data
from the serial port - don't change
int count = 1;

int totalrevs = 1600; //number of turns of the motor
axle to go from 0 to 100.
int resolution = 20; //the number of finite
positions available in the hose.

int timer = (totalrevs/resolution); // length of one
knotch in the hose extension, right now set to 5%

int loopqty = 1; //variable to be changed by the
arduino

int godirection = 0; //variable to be changed by the
arduino

void setup() {
  pinMode(motorPin1, OUTPUT);
  pinMode(motorPin2, OUTPUT);
  pinMode(motorPin3, OUTPUT);
  pinMode(motorPin4, OUTPUT);
  Serial.begin(9600);
}

void loop () {
  val = Serial.read();      // read the serial port
 if (val == 97) /*value is a*/ { loopqty = 1 ;}
 if (val == 98) /*value is b*/ { loopqty = 2 ;}
 if (val == 99) /*value is c*/ { loopqty = 3 ;}
 if (val == 100) /*value is d*/ { loopqty = 4 ;}
 if (val == 101) /*value is e*/ { loopqty = 5 ;}
 if (val == 102) /*value is f*/ { loopqty = 6 ;}
 if (val == 103) /*value is g*/ { loopqty = 7 ;}
 if (val == 104) /*value is h*/ { loopqty = 8 ;}
 if (val == 105) /*value is i*/ { loopqty = 9 ;}
 if (val == 106) /*value is j*/ { loopqty = 10 ;}
 if (val == 107) /*value is k*/ { loopqty = 11;}
 if (val == 108) /*value is l*/ { loopqty = 12 ;}
 if (val == 109) /*value is m*/ { loopqty = 13 ;}
 if (val == 110) /*value is n*/ { loopqty = 14 ;}
 if (val == 111) /*value is o*/ { loopqty = 15 ;}
 if (val == 112) /*value is p*/ { loopqty = 16 ;}
 if (val == 113) /*value is q*/ { loopqty = 17 ;}
 if (val == 114) /*value is r*/ { loopqty = 18 ;}
```

```
 if (val == 115) /*value is s*/ { loopqty = 19 ;}
 if (val == 116) /*value is t*/ { loopqty = 20 ;}
  if (val == 117) /* u has been received, flip
directions just for that move*/ { godirection = 1; }


// begin the loop
  if ( val <= 116 && val >= 97 )
  {  /*if a thru t is received*/


  /*move up*/
   if (godirection == 1)
  {
    count = 1;
    while (count <= (loopqty*timer))
    {

      digitalWrite(motorPin1, HIGH);
      digitalWrite(motorPin2, HIGH);
      digitalWrite(motorPin3, LOW);
      digitalWrite(motorPin4, LOW);
      delay(delayTime);
      digitalWrite(motorPin1, HIGH);
      digitalWrite(motorPin2, LOW);
      digitalWrite(motorPin3, LOW);
      digitalWrite(motorPin4, HIGH);
      delay(delayTime);
      digitalWrite(motorPin1, LOW);
      digitalWrite(motorPin2, LOW);
      digitalWrite(motorPin3, HIGH);
      digitalWrite(motorPin4, HIGH);
      delay(delayTime);
      digitalWrite(motorPin1, LOW);
      digitalWrite(motorPin2, HIGH);
      digitalWrite(motorPin3, HIGH);
      digitalWrite(motorPin4, LOW);
      delay(delayTime);

      count += 1;        // Notice this statement
    }
  }
    /*move down, turn on light*/
if (godirection == 0)
  {
  for(value = 0 ; value <= 255; value+=5) // fade in
(from min to max)
  {
    analogWrite(ledpin, value);           // sets
the value (range from 0 to 255)
    delay(30);                            // waits
for 30 milli seconds to see the dimming effect
  }


    count = 1;
    while (count <= (loopqty*timer))
    {
      digitalWrite(motorPin1, HIGH);
      digitalWrite(motorPin2, HIGH);
      digitalWrite(motorPin3, LOW);
      digitalWrite(motorPin4, LOW);
      delay(delayTime);
      digitalWrite(motorPin1, LOW);
      digitalWrite(motorPin2, HIGH);
      digitalWrite(motorPin3, HIGH);
      digitalWrite(motorPin4, LOW);
      delay(delayTime);
      digitalWrite(motorPin1, LOW);
      digitalWrite(motorPin2, LOW);
      digitalWrite(motorPin3, HIGH);
      digitalWrite(motorPin4, HIGH);
      delay(delayTime);
      digitalWrite(motorPin1, HIGH);
      digitalWrite(motorPin2, LOW);
      digitalWrite(motorPin3, LOW);
      digitalWrite(motorPin4, HIGH);
      delay(delayTime);

      count += 1;
    }
```

```
      for(value = 255; value >=0; value-=5)   //
fade out (from max to min)

  {
    analogWrite(ledpin, value);
    delay(30);
  }
  }
 godirection = 0; //reset go direction
  } // close if a thru t is received

  Serial.println(val);
  delay(1000);
} // close the loop
```

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