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Crafting Meaning in Matter: an aesthetic approach to networked device design

Thesis

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by

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Abstract of the Thesis

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In networked communication devices, values of speed, consumption and infrastructural independence are evident in their design to be carried anywhere and receive information from seemingly everywhere. Primarily using optical screens as the output mechanism, these devices largely neglect the emotive quality of texture as a dynamic communication medium. As an alternative, an opportunity exists to create devices that encourage personal interpretation and reflective thought of networked information through texturally rich abstract representations. These concepts have been explored and developed through three projects: *Physical DOM*, *Digital Sandbox* and *Gravitable*.

Introduction

The increased presence of portable communication devices and the availability of information on the World Wide Web make it easier than ever to learn and share human knowledge across a developed infrastructure. However, the speed and quantity of information delivered through popular Internet channels like email, RSS feeds and the World Wide Web can often be too overwhelming for thoughtful consideration. As an artistic and critical design intervention, I propose a genre of *crafted, networked, informational artifacts* (*CNIAs*) that represent information through an aesthetic approach of hand-made natural materials and abstract representations. This approach draws upon the intricacies and imperfections of craft materials and processes to present information in a different context than the majority of mass-manufactured devices. By using sensuously rich materials, human craftsmanship and abstract tangible representations, information consumption can be shifted to encourage personal interpretation, contemplation and reflection.

In pursuit of these ideas I have developed three projects that make use of rich materiality in the communication of information: Physical DOM[1], *Digital Sandbox* and *Gravitable*. *Physical DOM* blurs the boundary between the physical world and cyberspace by manipulating the appearance of a web page in real time according to measurements from a light-sensitive sensor. *Digital Sandbox* directs attention to the feel of materials and creates opportunities for haptic experience of information and tactile communication. *Gravitable* draws upon technological and material aspects of the two prior projects to display information in an abstract form that provokes personal interpretation and contemplation. These projects are not intended to be prototypes for a new wave of furniture gadgetry. Instead, they

[1]DOM, pronounced "dom", refers to the Document Object Model that is used to render web pages

are unique artistic expressions of communication devices designed to encourage critical engagement with information.

This thesis is organized into four chapters that progressively explore ways that objects inform everyday life. Chapter one investigates how humans relate to objects, how objects evoke emotions, and how objects are used to perform thought. Chapter two considers concepts of communication theory and the ability of computers to manage and create information at high levels of abstraction. The third chapter draws upon the first two to propose the creation of *crafted, networked, information artifacts* to share information as well as provoke reflection and contemplation. Finally, chapter four describes *Physical DOM*, *Digital Sandbox* and *Gravitable* in full detail.

As an interdisciplinary effort, this thesis is primarily situated within the emerging field of Interaction Design, but draws upon Industrial Design, Human Computer Interaction (HCI) and Media Arts. Within this interdisciplinary setting, this thesis contributes an approach to networked device interaction that emphasizes the aesthetic use of sensuous materials to present information in ways that encourage personal interpretation and reflective thought.

Chapter 1

Meaning in Matter and Motion

It began with a cloth rabbit–a simple puppet with rosy cheeks, little white feet and satin trim that came together at the corners to form the perfect combination of thickness, slickness and softness. Being so pleasurable to touch, I eventually rubbed the corners of the fabric bare. Even after the smoothness of the satin was abraded, the pleasure of feeling the cool fabric between my index finger and thumb remained. Like many other textures, I can conjure its feeling in my hand and remember its simple pleasure. I may have outgrown my rabbit, but my craving for tactile stimulation has in no way decreased. Not a single pair of my shoes have ever retired with aglets[1] in tact; all have been rubbed and pried apart by relentless picking. I do not know the impetus for this action, but as I watch my grandfather patiently sit and diligently use his thumbnail to trace his cuticles, I know that I am not alone in my sensitivity to texture.

Psychologist Sherry Turkle calls things like my rabbit and shoe aglets *evocative objects* [63]. As a companion to significant life experience, evocative objects fuse emotional experience and intellectual reflection, serving as powerful icons that create and reinforce personal values. This occurs through the object's material excitation of the senses, whether it is the smell of a bottle of perfume, the texture of leather, the sound of a music box, or an image caught on film. Special objects, such as heirlooms, act as tokens of memory that evoke the connection of ephemeral moments of the past to physical properties of the present. As a subset of *objects*, *artifacts* are objects that have been modified by humans in form or function to contain cultural value.

[1] the plastic tips at the end of shoelaces

From the Latin roots *arte* and *factum*, artifacts are “something made using art”–where “art” is used to refer to creative human expression. The earliest artifacts of *Homo faber* (“Man the maker”) must have come directly from natural materials able to be manipulated under human strength. As material processes have developed, the meaning of *manufacture* no longer refers to manual handiwork but to the mechanized production of things. Human strength is no longer the limiting factor in the manipulation of matter, and as a result the materials of objects have changed along with the ways that humans relate to the materiality of objects. Mass-produced artifacts have become so uniform that surface color is often the only variable of materiality. Consequently, material worth is based upon cultural value as well as functional performance. Depending upon the context, artifacts may be valued for either their perfect uniformity or unique originality. Ultimately, the potential of an object to provoke thought is not limited by its method of production, but is found within its ability to serve as an icon of significant memory. Regardless of the way an object becomes evocative, Turkle succinctly states: “we think with the objects we love; we love the objects we think with” [63].

Materiality: Exciting the Senses Through Matter

Weight, texture, sheen and density are some terms that describe physical matter and characteristics of material. Materiality as a concept is rooted in the latin *materia* meaning ’matter or substance’ and goes back to the Greek word *hyle* meaning ’wood’–specifically to the kind of wood used by carpenters [9]. Psychologists Alan Costall and Ole Dreier trace the intellectual inquiry of *materialism* back to the Greek philosophy of Democritus. In his theory of atoms, Democritus limited knowledge of the material to their ability to be sensed; to deal with metaphysical issues such as the mind and soul Democritus included smooth and round 'soul atoms' in his theory [9]. Contention over metaphysical separation of the real and the imaginary continued in mechanical and material philosophy during the 17th and 18th centuries. Within an approximately 200-year period, René Descartes theorized his separation of mind and body and Wolfgang von Kempelen and Vaucanson built automatons in order to resolve the separation and to understand physiology. Continuing their historical analysis of materialism into the 19th century, Costall and Dreier cite the dialect between Karl Marx and Friedrich Engels as the next major development. The theory of Marx and Engels, *historical materialism*, rejected mechanical materialism in favor of an approach that considered materiality on several ontological levels, including layers of physical, social, political, cultural and aesthetic phenomena. Specifically related to the inquiry of this chapter, the aesthetics layer deals with the complex sensori-emotional qualities of objects.

For humans, the ability to perceive the world through sensory input goes beyond survival to include stimulation of emotional responses and intellectual inquiries. Memories, the essence of an evocative object, are a recollection of the sites, sounds, tastes, smells and textures that were sensed at a moment in the past. And the act of remembering, or evoking, draws upon the senses to reconstruct an experience from the past. Among the senses, smell is a powerful trigger of memory. American author Diane Ackerman poetically describes the sensation in *A Natural History of the Senses*: "Smells detonate softly in our memory like poignant land mines, hidden under the weedy mass of many years and experiences. Hit a tripwire of smell, and memories explode all at once. A complex vision leaps out of the undergrowth" [1]. Taste is a personal and intimate sensation that often changes over one's life, as indicated by taste's metaphorical use in fashion. Hearing serves as a powerful sense of ambient information, sharpening mental focus at the sound of danger or change of tempo. Touch, embedded within the body's largest organ, communicates the most primal sensations of pleasure and pain to the body. Vision extends to the distant horizon and gathers all kinds of environmental and social information, from distant lightning to a subtle body language. Together, these five senses orient humans within their environment and transfer the physical world to cognitive processes.

Perhaps because seventy percent of the human body's sense receptors are in the eye or perhaps because language is so strongly visual in its metaphors, the look of things receive prominent status among the senses in Western culture [1]. Appearance of materials indicate quality and lead to conclusions about weight based upon past interactions with similar looking materials. Visual congruence can be helpful, but it can also be deceiving. Optical illusions are one indicator of the brain's power to make sense of confusing imagery. When vision fails to convince, touch is usually the next sense to be employed. Stumbling through a darkened roomed, vision is augmented through touch by reaching out with hands and probing with feet. Vision may reveal two things to be alike, but touch and hearing can reveal one as solid and the other as hollow.

Among the senses, vision and hearing are the the primary sense used for communicaiton, however touch is developing as a powerful communication tool as well. The textural Braille writing system has existed since 1821 and recently tongue-mounted stimulators have become available to aid the visually impaired [13]. According to psychologists of touch, Morton Heller and William Schiff, the perceived dominance of vision and audition is a development that has only recently replaced touch as the dominant sense, which many still regard it as the ultimate probe to prove the existence of an object [30]. When it comes to measuring minute changes in thickness and slight vibrations touch outperforms all other senses, even vision [36]. Regardless of any perceived dominance, all senses function in different and often-overlapping capacities that coalesce to create a concept of an object's materiality or use as an icon.

Using Matter to Perform Thought

Objects do more than simply excite the senses. They can also represent cultural significance, meaning and provoke thought. Art historian Herbert Read believes that aesthetic creations of form are necessary to formulate a new idea and views Paleolithic cave art as the emergence of humans' first ideas through drawing [51]. For Read, cave markings serve as representations of concepts that existed in the imagination of the creator, allowing the subject of inquiry to be considered despite its absence. Cognitive scientist Donald Norman calls objects that help project abstract ideas onto a physical context *cognitive artifacts*. Norman separates cognitive artifacts into two categories: experiential and reflective. *Experiential* artifacts augment the experience of the world by providing additional information that may otherwise be hidden or obscured, while *reflective* artifacts allow humans to concentrate on the artificial world being represented [43]. People use cognitive artifacts every day at all levels of formality from presentational diagrams to impromptu hand gestures. While studying early child development, Jean Piaget theorized that the quality of object manipulation is a key identifier of stages within human cognitive development. Piaget's studies, along with more anecdotal observations from others in academia [21] [63], reveal that the manipulation of objects is central to the way humans learn, think and manage their environment.

Objects can be meaningful on many levels. Some simply serve as signifiers while others are fully mobilized in the construction of meaning. Concepts of agency and performance are emerging in social science theories[2] as important aspects of experience. Andrew Pickering, a sociologist and historian of science, characterizes this as a shift away from an epistemological *representational idiom* to an ontological *performative idiom* concerned with "doing things in the world through an interplay of human and material agency" [45]. Through this shift, Pickering argues that the concept of *knowing* should be expanded to include context along with cognition, thus emphasizing the role of material agency in the actions humans perform. The attribution of agency to non-humans is seen in Donna Haraway's work within Science and Technology Studies: "All that is unhuman is not un-kind, outside kinship, outside the orders of signification, excluded from trading in signs and wonders" [28]. Drawing upon Haraways' work on agency, sociotechnical scholars Finn Olesen and Randi Markussen conclude: "Gradually, with, for example, the replacement of hand-written books by mass-produced, printed type volumes in the renaissance, and with the hermeneutic-humanist interest of modernity in trying to grasp the meanings hidden in our texts, there has come to be a culturally accepted separation between the *materiality* of the written word and its *meaning*. A separation between things and signs" [44]. The consideration of objects' agency, in addition to their capacity to represent, opens up new avenues of relationship between humans and objects.

The interaction between human and material agency can be observed in the human activity of sport, where humans compete against each other, often mediated by an object as simple as a ball. However, balls are not the prototypical spherical objects that they seem to be. Variances in material weight, thickness and shape contribute to a ball's material agency, which denies completely predictable motion despite the intentional manipulation.

As a specific example, the interplay between a baseball pitcher and the baseball

[2] Actor Network Theory and Activity Theory among others

is a highly developed performative practice rich with nuance. The pitching of a baseball requires rigorous training of technique in order to gracefully, forcefully and accurately control the body in execution of a pitch. These moves include embodied knowledge to perform a variety of pitches (fastball, sinker, slider, curve, knuckle, change up, etc.) that cannot be entirely represented in two or three dimensional forms. In order to throw a specific pitch, knowledge must extend beyond any representation to include the executed performance of the pitch. To learn a pitch the pitcher must observe the motions of a master and then practice. Michael Polanyi, a philosopher and polymath, calls the kind of knowing that cannot be put into words "tacit knowing" [46]. Since tacit knowing denies representation, the student must learn from the master through a process of indwelling: "the performer co-ordinates his moves by dwelling in them as parts of his body, while the watcher tries to correlate these moves by seeking to dwell in them from the outside" [46]. In addition to the performed movements of the pitcher, the baseball is a vital part of the action. The stitched rawhide ball is loaded with material information. Raised stitches serve as grips for control of the ball and the surface of the leather reveals a vital history of use. It is even possible for a pitcher to discern a smaller than average ball and use this to his advantage. As part of the performance the pitcher hides the ball in his glove and cycles through grips to contemplate the next pitch. However, despite any pitcher's best execution, the material properties of the ball are always a factor in the outcome.

Spritual Meaning in Objects

Beyond surface appearance and agency, some cultures attribute additional characteristics to objects, such as spirituality. The Monotheist tradition of Western society attributes spiritual qualities to relatively few sacred objects (the Eucharist in Catholicism for example), however several Eastern religions attribute sentient spirits to all objects. This view leads to a rich, reverent view of objects where even the movement of a stone has consequences. As part of the Shinto religion, beliefs in animism have certainly contributed to the high degree of care evident in the craftsmanship of Japanese wooden and clay artifacts. Because objects are considered as distinct spiritual entities in Shintoism, relationships form between owner and object. The Japanese term that describes this special relationship, *Aichaku*, translates to "love-fit" and describes the symbiotic love that exists for the object's essence rather than for its utility [38]. Similar beliefs are evident in the traditions of Native Americans, whose belief in animal spirits are similar to the animism of Shintoism. The Native American view of history as a continuous cycle rather than a linear progression inspires their stewardship of the environment and care for natural resources [39]. Shinto and Native American belief systems, and their response to the environment, stand in stark contrast to a Western culture of dominating nature.

A Confluence of Matter and Meaning: Kircher's Sunflower Clock

During the period of the European Renaissance in the 16th and 17th centuries material qualities were the topic of much philosophical inquiry. Descartes was formulating his hypothesis of the duality between mind and matter, and von Kempelen and Vaucanson built automata during this period. In practice, metaphysical beliefs were being replaced by scientific inquiry in pursuit of an objective understanding of the world. However, as formal academic disciplines had not yet been established, much of science, art and belief were still intertwined. Among the thinkers and tinkerers of the Renaissance is a man who holds an ambiguous place in history, marked by his use of curious materials to explore ideas of art, science and religion.

Educated as a Jesuit scholar, Athanasius Kircher (1601-1680) had broad academic interests, ranging from Egyptology to medicine, that were widely published and recognized in his day. Today, however, Kircher is often overlooked because his work defies simple categorization as either art or science, success or failure. At face value, Kircher's spectacular apparatuses were presented as some of the most advanced scientific tools of the day, however upon inspection their utility was not always scientifically genuine in terms of a direct representation of cause and effect. For this reason, Kircher was often recorded as more of a trickster than savant. Mark Wadell, a historian of Kircher, proposes that instead of tricks Kircher's inventions and presentations may have been more about provoking thought than presenting objective truths [65]. Kircher's Sunflower Clock was one such object.

Kircher's sunflower-powered clock was claimed to follow the sun from sunrise to sunset, regardless of a clear path between the sunflower and the sun. Contemporary scholars of Kircher such as Claude Fabri de Peiresc, Pierre Gassendi, and René Descartes were all interested in and skeptical of the clock's purported power. Through the lens of Peiresc's special attention to Kircher, science historians Thomas Hankins and Robert Silverman challengingly recount the story of the clock in *Instruments and the Imagination*, asking "what was the purpose of these clocks, and what was the purpose of similar instruments of the seventeenth century" [26]? Hankins and Silverman propose that Kircher was working within a paradigm of natural philosophy that was neither scholastic or mechanical, but magnetic. At the time, magnetism was an occult force only understood for its effects rather that its cause. Kircher, fully aware of his devices' artifices, built his devices as rhetorical analogies to nature rather than instruments of science. Thus the magnetic sunflower clock–essentially a compass–used the occult force of magnetism to demonstrate properties of nature. In this light, Hankins and Silverman conclude that Kircher's devices were simply instruments of demonstration, patronage and education.

However, Wadell reaches a different conclusion about Kircher's work that speaks to the value of Kircher's works as tools for thought:

> "Athanasius Kircher was in fact a gifted and extraordinarily subtle natural philosopher who encouraged his audiences to consider the most difficult parts of the world for themselves and, more importantly, provided them with the tools, and the autonomy, to do so" [65].

In analysis of Kircher's *Mundus subterraneus*, a speculative book about the content of Earth's core, Wadell sees Kircher's text and images as operating between divisions of "spiritual/temporal, contemplative/active, knowing/doing". Likewise, the sunflower clock can be viewed as a pseudoscientific spectacle designed to engage the spectator in personal contemplation of nature and its forces. Discussing Ross Ashby's cybernetic self-equalizing homeostat, Pickering makes a claim that could equally well apply to Kircher's sunflower clock, calling the homeostat "a true philosophical object, a thing to think with, a simple but beautiful material model of the processes of material, social and cultural extension in science. . . " [45]. Though it may have cost him his scientific reputation, Athanasius Kircher's controversial, sensually exciting artifacts grappled with concepts of learning, performance and spirituality in ways that continue to capture the imagination of inquisitive minds[3].

[3] Kircher's tradition is carried on by the "Athanasius Kircher Society". http://www.kirchersociety.org

Summary

More than matter, the materiality of objects excite human senses to bridge cognition and perception. Materiality, representational form and performed-use all contribute to the power of objects to be strongly emotive and effect humans' understanding of nature. Industrial designer and sustainability advocate, Ezio Manzini envisions a future composed of a "garden of objects. . . objects that endure and have lives of their own, objects that perform services and require care". This vision "demands a new esthetics that attributes worth to materials and products that in some way are able to embody vestiges of their earlier existences". As humans continue to shape their environment and mediate their interactions, the roles of objects and their materiality deserve thoughtful consideration.

Chapter 2

Meaning in Information

One paradox of information is that it can simultaneously provide answers and create questions. Depending upon abundance and quality, information can be empowering or crippling. Of course, quality of information is a notion that is highly subjective and culturally situated. Its interrogation leads to hard-to-answer questions of knowledge, value and truth. Chapter one dealt with the materiality of objects and their ability to stimulate the senses, embody meaning, aid in the performance of thought and evoke emotion. This chapter takes a look at similar properties of information, specifically questioning the capacity of digital systems to store and communicate information, knowledge and wisdom.

Communication Theory

In 1948 Claude Shannon revolutionized the communication of information through his mathematical work at Bell Labs. His theory made it possible to faithfully communicate information despite interference. In analog systems, such as speech, a message can become unintelligible if unwanted noise is added to it. In this case there is no way to successfully communicate the message, except to resend it. Using discrete signals, Shannon's communication theory [59] makes it possible to perfectly transmit messages despite additional noise without resending the signal. This was a major historical development in digital communication that makes possible today's extensive communication networks of electronic devices.

Shannon's separation of meaning from message is of particular interest to this discussion. Prior to mediated communication, meaningful information within a message resided in its ability to share an idea. However, in electrically mediated messages the content of a signal is inconsequential as long as it is faithfully transmitted. As historian Theodore Roszak points out, this changed the meaning of information:

> "In the past, the word has always denoted a sensible statement that conveyed a recognizable, verbal meaning, usually what we would call a fact. But now, Shannon gave the word a special technical definition that divorced it from its common-sense usage. In his theory, information is no longer connected with the semantic content of statements" [53].

The smallest of Shannon's discrete communication units is the binary digit or "bit". This simple on/off representation is the paradigm on which all mainstream computer systems operate. As part of a long historical trajectory that includes the automata of von Kempelen and Vaucanson, as well as computational innovations from Alan Turing, John von Neumann and Norbert Wiener, Shannon's communication theory contributed to the emergence of artificial intelligence as a field of study [62]. In seeking methods to produce machine intelligence through digitally codified behavior, the field of artificial intelligence has raised many fascinating questions about human psychology and the extent to which it can be reproduced.

Data, Information, Knowledge and Wisdom

In order to investigate the computational mediation of human ideas, Human Computer Interaction, Computer Supported Cooperative Work and Knowledge Management have emerged as field of research. Developing in the last decade of the 20th century, Knowledge Management (KM) is a new field primarily driven by the desire of corporations to utilize computer networking in consolidating employees' knowledge [4]. Knowledge management separates itself from information management by paying attention to personal interpretation of information in addition to information's factual basis. Both of these fields are largely made possible by Shannon's communication theory and use digital communication processes to store, aggregate and deliver information in aid of human cognition at increasing levels of abstraction. This extended building up of cognitive abstraction in the formulation of knowledge management as a field is reminiscent of an excerpt from a T.S. Eliot poem written in 1934:

> *Where is the Life we have lost in living?*
> *Where is the wisdom we have lost in knowledge?*
> *Where is the knowledge we have lost in information?* [16]

Mindful of Eliot's poem [8], a complex discussion of data, information, knowledge and wisdom has emerged within KM that raises questions about just how far information can be abstracted. Within KM, the data, information, knowledge, wisdom (DIKW) hierarchy is a pervasively used and debated model in understanding the transition from observation to understanding. The original description of the popular hierarchy places each concept in a pyramid, with data as the base upon which successive layers build up toward wisdom.

Many KM texts use the model, but it is open to a wide degree of interpretation. For instance, the "data" term was not included in system scientist Russell Ackoff's original model, but the concept of "understanding" was included [2]; another early KM pioneer, Milan Zeleny included the concept of "enlightenment" at the top of his model [68]. In 2007 Jennifer Rowley published an extensive literature survey of the hierarchy and her cumulative definitions are listed below [54]:

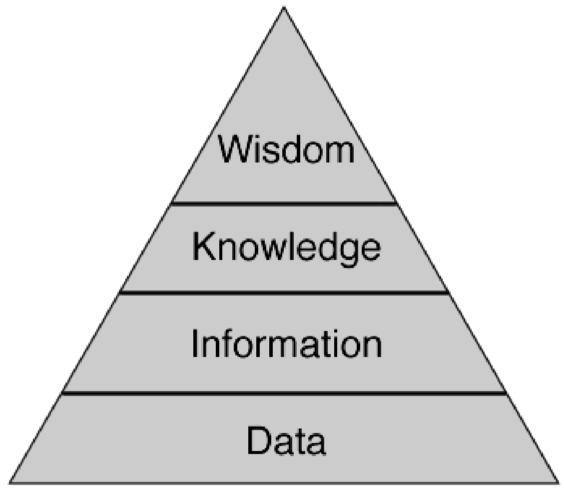

Figure 2.1: Traditional DIKW pyramid

Data

- 'Data items are an elementary and recorded description of things, events, activities and transactions.'
- 'Data has no meaning or value because it is without context and interpretation'
- 'Data are discrete, objective facts or observations, which are unorganized and unprocessed, and do not convey any specific meaning.'

Information

- 'Information is formatted data (and) can be defined as a representation of reality'
- 'Information is data which adds value to the understanding of a subject'
- 'Information is data that have been shaped into a form that is meaningful and useful to human beings'
- 'Information is data that have been organized so that they have meaning and value to the recipient'
- 'Information is data processed for a purpose'
- 'Information is data that have been given meaning by way of context'
- 'Information is an aggregation of data that makes decision making easier'
- 'Information is data that is endowed with meaning, relevance and purpose'

Knowledge

- ’Knowledge is an intrinsically ambiguous and equivocal term’
- ’There is still no consensus on the nature of knowledge, except that it is based on perception that can provide a rational justification for it’
- ’Knowledge is the combination of data and information, to which is added expert opinion, skills, and experience, to result in a valuable asset which can be used to aid decision making’
- ’Knowledge is data and/or information that have been organized and processed to convey understanding, experience, accumulated learning, and expertise as they apply to a current problem or activity’
- ’Knowledge builds on information that is extracted from data ... While data is a property of things, knowledge is a property of people that predisposes them to act in a particular way’

Wisdom

- ’Wisdom is the highest level of abstraction, with vision foresight and the ability to see beyond the horizon’
- ’Wisdom is the ability to act critically or practically in any given situation. It is based on ethical judgement related to an individual’s belief system’

From Rowley’s survey, it can be concluded that most professionals in KM agree on a similar definition of data, however agreement on definitions of information and knowledge are less clear. According to the various definitions, information is considered to be meaningful, valuable, representational and contextual. The definition of knowledge is more abstract, but generally considered slightly more than a summation of information that requires aggregation and reflection. Finally, wisdom is even more nebulously defined and draws on ethics, values, and the ability to form inferences and plans of action based upon non-associated sets of knowledge.

Rowley finds it particularly interesting that the concepts at the pinnacle of the pyramid are the least discussed among the literature. Considering the value that Western culture places on objective analysis, this is not a surprising finding. The accumulation, application, and description of wisdom is an abstract process that defies objective observation. As a result, some DIKW models eliminate the inclusion of wisdom altogether. In Ackoff's original description, the DIKW pyramid is useful in expressing the idea that each term contributes to its predecessor, i.e. wisdom is composed of knowledge, information and data–knowledge is composed of information and data–and information is grounded in data. Beyond this most simple interpretation the schema can be problematic in its representation of information abstraction.

Jonathan Hey, a PhD candidate at the Berkely Institute of Design, has made astute observations about the various representations of the hierarchy and their metaphors. Hey's analysis considerably broadens the conceptual narrative, though he admittedly shies away from the analysis of wisdom. Hey describes the colloquial metaphorical uses of *data* as a minable resource ("data mining"), something that appears in streams ("streams of information"), that is capable of drowning its observer ("drowning in information"), and something that can explode ("information explosion") [31]. Focusing on the aggregation and disintegration of data and information, Hey proposes that information has become a product in itself. This interpretation eventually leads Hey to the conclusion that knowledge may be increasingly "crystallized" and embedded into smaller packages as part of an evolution of the uid metaphor. Though Hey seems to stretch the metaphor too far in his application of novel technology, his assertion that information has been transformed from a resource to a product is resonant with the research expansion of information management to knowledge management. Considering the transition of computer use from numerical calculator to its modern position as a mediator of complex arrangements of information, questioning the role of computation in the DIKW model becomes increasingly relevant.

In order to confront some of the conceptual challenges of the pyramidal representation, additions and complete changes of the DIKW hierarchy have been presented. Chaffey and Wood (in Rowley's literature review) include one-way arrows that symbolize a move up the hierarchy as an increase in "value" and a move down the hierarchy as a descent toward a lower level of "meaning". Like other hierarchies, Chaffey and Wood do not include wisdom in their pyramid. Awad and Ghaziri (also in Rowley's literature review) include wisdom in their hierarchy and add two-way arrows between non-programmable/non-algorithmic and programmable/algorithmic at the top and bottom of the pyramid, respectively. These arrows are problematic in their representation of programmability as a continuum when in practice programs will either succeed or fail. Thus, Awad and Ghaziri's model does not account for the point of breakdown between the programmability of data and the non-programmability of wisdom.

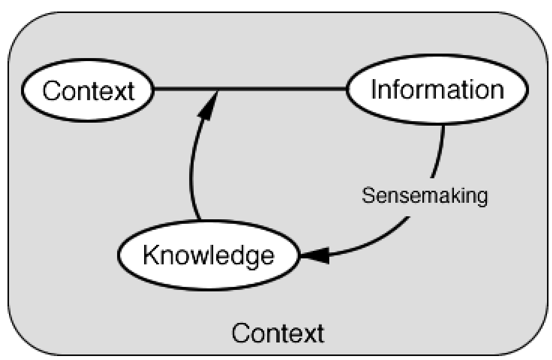

Figure 2.2: DIKW feedback loop

There are other DIKW interpretations surveyed by Rowley, but two representations that are neither pyramidal or linear offer fresh perspectives on the concept. One of the challenges in the traditional DIKW hierarchy is that the causal structure does not account for iterative interpretation through any levels of abstraction. Shawn Callahan, a professional in KM, offers a revision in Figure 2.2

that escapes a linear structure by using a first-order feedback loop [7]. This is an interesting adjustment to the concept because of its reliance on context and additional requirement of *sensemaking*. The contextual parameter is important because data, information and knowledge are highly situated with regard to personal background experience. A simple interpretation of Callahan's feedback process is that once a person has made sense of information, the person may use their new understanding to insert new knowledge back into the system. This may be considered as a process of reflection-in-action as described by the philosopher Donald Schön [56]. Despite the useful interpretation of the hierarchy represented in Figure 2.2, its representation as a system diagram should not be interpreted too literally. The emergence of higher levels of informational abstract are processes that are not as simple as feeding one parameter to the next stage. However, when considered as a constantly occurring process, the feedback model offers a description of the performative nature of the transition between data, information, knowledge and wisdom. By removing wisdom from the data, information, knowledge process, the problematic discontinuities of other primarily causal representations (the algorithmic to non-algorithmic concept in Awad and Ghaziri) are addressed in a more thorough manner.

A final model places the DIKW hierarchy within a historical context. By placing the historical timelines of data processing, information management, and knowledge management along the "yield" axis, Figure 2.3 contextualizes the historically changing role of data, information and knowledge in the 20th century [48]. Additionally, the non-linearity of the graph acknowledges the emergent properties of higher degrees of abstraction inherent in the DIKW hierarchy; as an agent approaches/achieves/creates wisdom, the *yield* increases from an emergent process that is not attributed to further *learning/experience*. Instead, the combination of knowledge by an intelligent agent leads to higher yields.

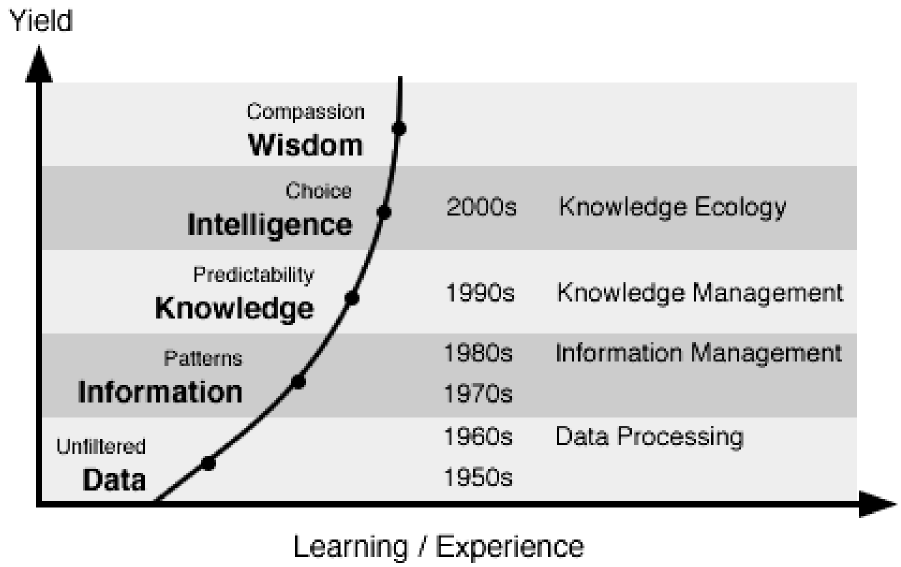

Figure 2.3: Non-linear DIKW timeline

Summary

Overall, the DIKW model prompts similar difficult questions of human and machine agency that artificial intelligence has grappled with since its emergence as a field. These questions currently have no definitive answers but are necessary to ask as the horizon of digital information expands. As seen in chapter one, objects and their materiality are capable of evoking strong emotions and contributing to thought. Likewise, the use of digital communication and computer networks have increasingly provided access to information in the aid of human thought throughout the 20th century as technology has matured. The field of Knowledge Management seeks to harness these technological advances to codify and share human knowledge with the hope that intelligent and wise human decisions will emerge. The degree to which machines can store knowledge and wisdom remains to be seen, however its difficulty to be diagrammed as evidenced by the problems of the DIKW concept is indicative of the unique ability of humans to find meaning at the highest levels of abstraction.

Outside of a Knowledge Management initiative, humans living within the most technologically advanced cultures are viewing and sharing more information than ever. Through technological advancements like the Internet the challenge of collecting information in pursuit of knowledge has become simultaneously easier and more challenging. Increased access to information through better search methods and more storage provide greater search results, however large quantities of information can be difficult to humanly process. This difficulty arises because humans, unlike machines, are specifically interested in assigning value to information that goes beyond semantic meaning. Value, like truth, wisdom and beauty, is subject to personal, cultural and contextual interpretation that denies representation. This leads to the question: how can physical representations impart value to digitally communicated information?

Chapter 3

Designing Critical Devices for an Information Age

Chapter one explained ways that humans form emotional attachments to objects and use them as tools for thought and performance. Chapter two dealt with how computers contribute to information and higher levels of cognitive abstraction. This chapter brings these concepts together in the creation of artifacts that excite the senses and communicate information. The first section of this chapter establishes why this genre is necessary and socially relevant. Section two introduces *crafted, networked, informational artifacts* as a vision for designing informational devices that facilitate meaning beyond semantics. To conclude, section three reviews existing design strategies that apply to this genre of artifact.

Global Communication

Designers and engineers are more responsible than ever for making products that meet the challenges of sustaining a human and environmental ecology. Among products, communication devices are increasing in ubiquity every year throughout the entire world. For this reason, communication devices deserve special attention as artifacts that must fit into human ecology. Through the application of appropriate technology communication devices may be designed to fit their environment, communicate networked information and afford a sensuous experience in the computer-mediated world.

In the 1960s Marshall McLuhan considered the cultural effects of technology spanning history from the printing press to the television. McLuhan argued that the newest electronic technologies of his day, television and radio, were shifting cultural exchange from print media to aural media and that this shift was creating a "global village" [41]. McLuhan hypothesized that humankind would form a common "tribal base" composed of shared knowledge. Today, McLuhan's concept of a global village is a reality in many ways; economies and cultural phenomena of the world's nations are inextricably tied together. Mark Poster calls this the "Information Empire" and its residents "networked digital information humachines" [49]. These agents, a mix of humans and machines, are capable of creating agglomerations of power or serving as points of resistance to centralized power. Poster's argument is strictly political, however his description of the relationship between humans and information can raise questions regarding the design of communication devices, such as: What will be the differences in devices that lead to centralized power versus decentralized power? What kinds of devices will inspire action as opposed to complacency? How can devices encourage reflective thought rather than unreflective consumption?

Computational communication devices (cellular phones, laptops, PDAs, etc.) are so ubiquitous in developed countries that they are considered an essential part of modern life, yet many parts of the world are far from this level of ubiquity. In order to bridge the so-called *digital divide* in a socially responsible way, technological infrastructures and devices need to be designed using a mulit-disciplinary approach to sociological and environmental issues.

In rural areas of the world the screen/keyboard interface of traditional computational devices is simply not functional for use that is out-of-doors, off the power grid and that requires more versatility than a screen can provide [22]. Most computational devices demand a user's undivided attention and the use of two hands to operate. This interaction paradigm has dominated the human-computer relationship since it was first hacked together from a manual typewriter and cathode ray tube, and as a result the functional capacity of computation has remained severely limited. In order to broaden the horizon of computational devices, new contexts and modes of use must be considered. Computer and social scientist, Paul Dourish, makes a strong case for using embodied interaction to extend computation to cultural artifacts by "capitalizing on the contextual factors of presence, location, and activity. . . to unify computational experience and physical experience, and to apply the experiences and skills of those who understand our relationship with the physical environment–architects, designers, artists, and others–to the design of computation and interaction" [12]. Embodied interaction and contextual use of computers open many avenues of exploration for creators of computational devices. Technologists Bell and Kaye remind designers that spaces "function not as sites for technologists' or technological in(ter)vention, but as sites where meaning is produced. . . These spaces are the places where we dwell" [5]. The current trend in design of computational devices largely disregards concerns of context, embodiment and production of meaning in favor of upgrades to dysfunctional devices.

In contrast to underdeveloped interactions perpetuated by the technology industry, a culture of do-it-yourself electronics has been steadily growing as micro-controllers, sensors and actuators become more available and affordable. New publications such as *ReadyMade*, *Make: Technology on your Time* and *Craft: Make Cool Stuff* and web sites like *instructables.com* and *opencircuits.com* cater to this audience by providing instructions for creating and modifying electronic devices. At MIT's Center for Bits and Atoms Neil Gershenfeld's course entitled *How to Make (Almost) Anything* resulted a new vision for personal fabrication, where desktop printers are replaced by desktop fabricators capable of printing three-dimensional parts to be assembled into make custom devices. Throughout the course Gershenfeld made many discoveries about the desire of students from different departments to solve problems in a physical dimension. These students were driven by a self-discovery process that was contagious among the class participants. This process of self-discovery and self-actualization is also a key experience of the open source software movement [42]. Gershenfeld witenessed a blurring of disciplinary boundaries "between artist and engineer, architect and builder, designer and developer, bringing together not just what they do but how they think" [22].

Radio, television and the Internet have cntributed to a global village by sharing a set of cultural ideas and images. Additionally, these communication tools impart subtle ideologies through their hardware that do not give full value to the human user's context. In response, designers must begin to investigate how to use communication resources to embrace embodied modes of computing that are relevant within the context of a variety of cultures. This approach will require new interdisciplinary strategies to rethink designer's roles in making and using tools in an ecologically sustainable and socially responsible manner.

Crafted, Networked, Informational Artifacts

So far this thesis has set out an argument of the importance of objects in performing thought and the potential of computational devices to augment interactions with networked information through contextualized and embodied interaction. In order to engage these concepts I am proposing an aesthetic approach to communication devices called *crafted, networked, informational artifacts* (*CNIAs*). *Crafted* and *artifact* describe the nature by which the devices are created–individually crafted by a human being, the way fine pieces of carpentry and musical instruments are created. As such, these are not merely objects, but artifactual pieces of culture. *Networked* conveys the degree to which the artifact relies on an electronic network to display dynamically changing content. The medium of the network–telegraph, telephone, modem, Ethernet, etc.–is unimportant as long as it conveys information. Finally, communication of *information* from the device to humans is the primary role of *CNIAs*.

Examples

Though a new concept, *CNIAs* have existed since information was first shared across great distance. The large semaphore towers of France must be the first instance of a *CNIA*. These structures were erected on the highest peaks of a countryside to communicate a visual language based upon a combination of flag design and position. In semaphore, messages are communicated by an operator moving flags manually or through the control of large mechanical arms, a process that requires careful observation and physical exertion in order to faithfully relay the message. With the invention of electric telegraphy the wooden and brass Morse code keys and speaker may be the next historical example of a *CNIA*. Like semaphore, the reception and transmission of Morse code is a highly embodied skill that requires careful listening and manual dexterity. As telephony replaced telegraphy, communication instruments became standardized and easier to use without esoteric knowledge. By the time earliest forms of sharing digital communication developed, interfaces were entirely standardized in the form of screens and keyboards.

One of the earliest shifts away from the screen/keyboad paradigm came in 1991 when Mark Weiser wrote his vision for the future of computing in the 21st century [66]. In his description of *ubiquitous computing*, computers fade into the periphery as embedded support systems to store and recall information. This description was expanded in 1996 with the help of John Seely Brown. Together they described a theory of *calm technology* where information elegantly moves back and forth between the center of attention and the periphery [67]. Calm technologies broaden human's range of attention, conveying information in a pleasant, subliminal manner. Drawing upon the ability of indoor office windows to allow peripheral monitoring of office activities, calm technology offers rich and subtle information [67]. Included in Weiser's vision is a description of Natalie Jermijenko's *Dangling String* project at Xerox PARC. In this project a dangling string oscillated at different frequencies to convey traffic over the office network. Weiser's vision of ubiquitous computing and calm technology is still taking shape, however the ubiquity of computing has occurred more through mobile handheld devices rather than through his vision of contextually embedded systems.

Concepts of ubiquitous computing now include wearable computing, locative media and sensor networks among others. Adam Greenfield thoroughly surveyed this territory in 2006 and coined the term *everyware* to describe the burgeoning field of ubiquitous computing:

> "In everyware, the garment, the room and the street become sites of processing and mediation. Household objects from shower stalls to coffee pots are reimagined as places where facts about the world can be gathered, considered, and acted upon. And all the familiar rituals of daily life . . . are remade as an intricate dance of information about ourselves, the state of the external world, and the options available to us at any given moment" [24].

If ubiquitous computing continues in the form of everyware, then serious design considerations that go beyond perfunctory implementation of human factors and usability must be made about the value of devices in everyday life. These are described in the following sections as they related to the creation of *crafted, networked, information artifacts*.

Tangible Computing

Inspired by Weiser's vision and scientific instruments in museum collections, Hiroshii Ishii began to apply physical form to information in order to "bridge the gaps between cyberspace and the physical environment, as well as the foreground and background of human activities" [34]. In tangible computing, users can interact with information through a "Tangible User Interface" (TUI) rather than the standardized Graphical User Interface (GUI). The three goals of *tangible bits* are to create interactive surfaces, to couple bits and atoms (digital information and graspable objects), and to create ambient media. Ishii's concept was developed as interest in Augmented Reality was growing in response to a backlash against Virtual Reality's lack of physical weightiness. Tangible computing uses *phicons* (physical icons) to manipulate digital information. These physical handles serve as the critical interface between physical space and cyberspace.

This description of Tangible User Interfaces is the paradigmatic basis for *crafted, networked, informational artifacts*, however the execution of design through aesthetics and materials is a critical point of difference in motivation. Though inspired by wooden and brass instruments, early projects created in Ishii's lab like *metaDesk*, *transBOARD* and *ambientROOM*[1] favor a material aesthetic of projected imagery, plastic and otherwise industrialized materials. This aesthetic approach is not explicitly stated and does not detract from the work, however it tends to convey a quality of novelty rather than intrinsic worth. An outstanding exception to this is *inTouch*, a networked device for haptic communication that includes fine craft as part of the design considerations [6]. As computational objects continue to grow in ubiquity, this consideration for craft will preserve a connection to nature in an increasingly artificial environment. Just as the beautiful complexity of nature

[1] A full list of projects from the MIT Tangible Media Lab can be found online at http://tangible.media.mit.edu/projects/

calms and inspires, so too can the devices that we spend so much time using.

Affordance

Most things that humans encounter in the world can be used in different ways. For example, trees provide shade and a way to climb to a higher viewpoint. The physical properties of an object determines its efficacy for achieving certain tasks. The psychologist J. Gibson coined the term "affordance" in order to discuss these characteristics of an object [23] and Donald Norman subsequently incorporated this notion into his studies of cognitive science within the field of HCI. Gibson originally defined the term to describe the possible actions that could be performed by an actor and an object in an environment regardless of the actor's prior knowledge. Norman's use of the term is more subjective and includes consideration for the actor's perception of what can be performed with the object, based upon cultural context and prior knowledge [60]. In design, Norman's use of the term serves as a design tool to provide a user-centered perspective for determining the ability of an object to achieve a certain task. Thinking about the affordance of an artifact is a powerful way to design for a performative culture concerned with doing things with information in addition to consuming it.

Affordances are important to design into a device, but a key challenge to the design of calm technologies is to keep the interface sufficiently abstract and at the periphery of awareness. Backlit and projected screens are difficult to use in this way because of their natural intensity within the setting of a dim room. For this reason, the primary interface mechanisms of *crafted, networked, informational artifacts* are spatial, rather than projected. Dimensionality provides another layer of interaction that draws attention to materiality and taps into an emotional response to form. Additionally, crafted organic forms use draw upon human natural ability to selectively attend to the environment. Furthermore, organic materials, forms, and the inevitable imperfections in craft allow people to subjectively interpret information as they would interpet clouds or knots in trees. Weiser and Seely Brown were concerned that designing for affordance would eliminate the ability of a device to fade into the periphery, however the aesthetic approach of *crafted, networked, informational artifacts* is aimed at affording ambiguous interpretation and selective interaction.

Designing for Contemplation and Reflection

The primary goal of a *crafted, networked, informational artifact* is to encourage the user to become a participant by experiencing information in new ways that lead to personal interpretation, contemplation and reflection. In order to achieve this reaction, creators of *CNIAs* must draw upon a mix of disciplines to create devices that are functional and compelling. This interdisciplinary approach has been taken up by the field of Critical Computing to explore issues of meaningful computer interaction.

The paradigmatic conflict between current informational devices and *CNIAs* is an issue of speed and efficiency, where the former encourage superficial, speedy consumption of facts (stock prices, traffic conditions, weather, etc.), and the latter present patterns of information for contemplation that hopefully lead to questions like: "what may be behind the stock trends" or "how are traffic and weather related"[2]. Perhaps personal contemplation of the correlations among gas prices, traffic and weather may arise. This kind of contemplation is central to the role of a *CNIA*. In discussing the aesthetic application of contemplation within interactive art, Lone Koefoed Hansen cites Kant's notion of the sublime work of art, which allows the viewer to "improve her consciousness of both the object, the world and

[2]Studies have shown that patterns of weekly commuting can influence weather patterns. See http://www.sciencedaily.com/releases/1998/08/980814070429.htm

the relation between the two" [27]. Through contemplation viewers can explore associations that go beyond the object's physical properties to reach a new understanding.

Because contemplation is typically considered a passive activity of still thought and observation the concept must be extended to describe an interactive situation. Hansen calls this "interactive contemplation" and describes it as an oscillation between immersion and reflection that arises from visual perception and haptic contact with an artifact's tactile properties; this occurs between periods of flow where the user is interacting with the devices and periods of still contemplation. Interactive contemplation allows users to perform with the information in a way that is relevant to a contemporary audience that draws upon eclectic sources to continuously reform identity and culture [47].

The reflective role during contemplation has been extensively considered by the HCI community. Among this community, Phoebe Senger et al. has described an emerging *reflective design* practice asking, "How can we help users be reflective about the role of technology in their lives?" [57]. This approach to design was party inspired by Phil Agre's development of a Critical Technical Practice (CTP) in the field Artificial Intelligence. CTP seeks to challenge unreflective participation in the "tried-and-true practices" of culture [3]. Like Agre, Senger et al. seek to reveal awareness of the covert forces that subtly shape identity and standardize practice by extending reflection to include device users in addition to their designers [57]. Similarly motivated, Tony Dunne has developed the concept of Critical Design to explore the role of electronic objects in everyday life:

> "Hertzian Tales expores the way critical responses to the ideological nature of design can inform the development of aesthetic possiblities for electronic products. It focuses on the role they play in shaping our experience of inhabiting the "electrosphere", looking beyond the

> quality of our relationship with objects themselves to the aesthetics of the social, psychological, and cultural experiences they mediate.” [14]

In order to design meaningful artifacts in an age of information, critical reflection of this kind is an absolute necessity. As digital information is embedded in more places by more unidentified authors it becomes increasingly important to reflectively discern a message’s value. Furthermore, discernment must extend to the consideration of the ways in which we receive information and the values embodied by our devices. The shiny surface of Apple’s iPhone distracts consumers from its non-upgradable hardware and designed-in obsolescence. *CNIAs* approach environmental issues by being honest about their material lifespan and dependence upon ecology.

A reflective design philosophy is good, but a method of practice is necessary to turn *crafted, networked, informational artifacts* into a reality. Theory can be put into practice by approaching the artifact as a tool for performing information. In order to act as a provocative object *CNIAs* must be addressed from a sculptural perspective that is not normally applied to informational devices, which rely on glitter for most of their appeal. As an approach to critical design Soren Pold considers aesthetics as more than the wrapping of a product. Pold sees the use of aesthetics as an opportunity for critical reflection upon how representation is related to material and cultural context [47]. From Pold’s point of view, a Leonardo da Vinci painting is as much a pictorial representation as it is a reflection on linear perspective: “aesthetics is useful as a way to generate reflection both as a way of producing artefacts, as a way of perceiving them, and as a way of thinking about them” [47]. Aesthetic sensitivity is imperative as computational tools spread into new cultural contexts so that aesthetic interpretations and representations can be built in tandem with computation, facilitating interaction with information on personal terms.

One suggested approach of designing to allow for reflection comes from Lars Hallnäs and Johan Redström, who combine Weiser's vision of calm technology with inspiration from time-based performance media like music, dance, theatre, film and poetry to propose a genre of *slow technology*. This approach fuses the temporal qualities of artistic expression with the design and engineering values of efficiency to present opportunities for reflection. Instead of collapsing time to achieve a task, slow technology impregnates the process to create time for meaningful presence of mind. Similar to other design concepts, slow technology is a call to more carefully consider aesthetics in technology as a way to reflect on its use in everyday life [25].

When a performance perspective is adopted, participants are able to think "feelingly about the artifacts around them and engage in the situation in reflection or perception in action" [35]. Reflection-in-action has been described by psychologist Donald Schön as the practice of thinking while doing. Reflection-in-action is a process that occurs when one is adjusting performance while doing, such as improvisational jazz musicians adjusting their play in response to their band [56]. This kind of action involves the constant refinement of the performer's actions. Another example from Schön described the reflection-in-action involved during the "groove" of a baseball pitcher. Music and sport are both playful activities that drive performers to constantly refine their skill. Play can be casual and informal or it can be the mechanism for achieving the highest form of art that elicits contemplation. Unfortunately, the opposite is true of computational devices that provide speed, mobility and embrace a "don't make me think" attitude. Unwitting consumers find meaning in the status symbols of electronics rather than in their usefulness. Herbert Read reflects:

> "A people whose occupations are mechanical, whose leisure is spent in motor cars and cinemas, whose ideal is speed and whose god

> is money cannot discover points of contact with the arts whose existence presupposes life lived in a more leisurely and contemplative fashion." [50]

In order to create thought-provoking informational devices it is essential to included playful modes of interaction that foster artful performance. First described by Johan Huizinga in *Homo Ludens*, play is a significant aspect of culture that predates all other cultural developments [33]. It is a fundamental way in which all animals communicate meaning. Gestures of play communicate the spectrum of emotions from affection to anger and are used to communicate among any age group. Not only do humans play with each other, but people also play with ideas. By manipulating and playing with representational artifacts, humans can effectively consider ideas and enact imaginary scenarios on a manageable scale. Lego™ blocks and Lincoln Logs™ are examples of toys and cognitive artifacts that embrace innate desire to play, while at the same time enhance motor skills and teach a knowledge of mechanics.

Play is clearly a required aspect of design for creating an object that people are passionate about using. It is the aspect of design that goes beyond the ergonomics and makes something fun to experience. Play can probe deep and lead to questions that would not normally be asked in a serious setting. Because computational devices have traditionally been designed as a platform for work, it has not been until recently that creating computational devices for play has been considered. Drawing upon Huizinga, this is exactly what Bill Gaver has done in *Designing for Homo Ludens* [18]. He describes computational devices that "invite relationship", are "quietly suggestive", demand "suspension of disbelief" and go beyond pleasure and "mere entertainment" to raise issues and questions and instead of providing answers. As a methodology, Gaver offers a handful of suggestions for designing for *Homo ludens*. First, Gaver suggests that scientific approaches to design should be complemented by more subjective, personal experiences. Second, designs should be made with open-ended appropriation in mind, allowing people to construct their own narratives of use and to feel a sense of ownership. Gaver sees two ways to achieve this: a) create 'suggestive media' - playful tools that allow people to create and communicate freely and b) employ ambiguity as a resource for design. Ambiguity is used to encourage *speculation*, *interpretation*, *assessment*, *disruption*, *imagination* and *questioning* [19]–all critical components all common to meaning-making, reflection and play. Designing devices to display information in ways that are aesthetically engaging and open to interpretation will empower users to actively engage in the process of making meaning for themselves [58] [40]. In order to enable this response, Gaver urges designers to become provocateurs that "incorporate intrigue and delight at all levels of design, from the aesthetics of form and interaction, to functionality, to conceptual implications at psychological, social and cultural levels" [18].

As evidenced by the many overlapping aesthetic design approaches within HCI and allied fields, there is a clear call to incorporate more aesthetic consideration into the design of computational artifacts. The goal of creating better contextualized and embodied devices is to allow users to become participants in their interaction with information. The many benefits of computational technology are such that they will continue to be assimilated into more facets of everyday life. Without aesthetic intervention this could lead to a de-humanized, industrialized environment. Worse yet, this consumption-based computational paradigm could spread with devices and erode a global diversity of aesthetic beauty that should be celebrated. Hand-crafted artifacts can serve as both the most primitive relics of civilization and as the most distinct icons of modern culture. Tony Dunne states the objective of *crafted, networked, informational artifacts* well:

"We need to operate between art and industry, work and play, and usefulness and beauty. We need to shape interaction design practices to be more in tune with the craft emphasis, professional judgment, and critical orientation" [14]

Chapter 4

Projects in *Crafted, Networked, Informational Artifacts*

Looking at communication paradigms throughout history such as semaphore, telegraphy, telephony and the Internet, a trend to reduce their size and barriers of esoteric knowledge can be observed. Today, wireless communication has abstracted the operator from the network infrastructure so much that expertise and physical exertion have been all but removed. Coincidental to communication advancements, advancement in material science have changed the nature of communication devices from pieces of hand-made craft to industrially manufactured products. The affordance of plastic to be molded and sealed along with the invention of precise industrial mechanization has led to the design of devices that are inaccessible to end-user repair and modification by hand. In response to these issues and as a matter of personal practice and aesthetics discussed in chapter three, the following projects are presented as critical design interventions of networked communication devices and serve as prototypical examples of *crafted, networked, informational artifacts*.

Physical DOM

Web pages have changed dramatically since they first began populating the World Wide Web as simple hyperlinked text documents in the early 1990s. Within twenty years web pages have become rich audio-visual experiences that feature streaming video, interactive games, live chatting and social networking. Despite these surface-level advancements, the interaction paradigm is still primarily

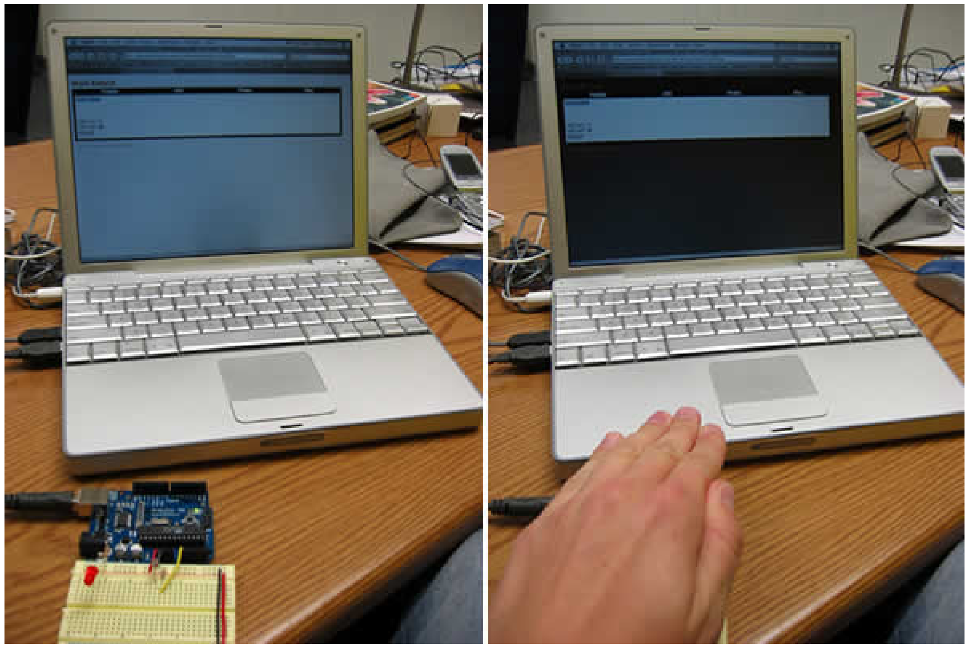

Figure 4.1: Demonstration of *Physical DOM*

limited to the use of the screen, keyboard and mouse to navigate content that is in no way contextualized to the viewer's environment. *Physical DOM* (Document Object Model) challenges this paradigm by blurring the line between physical space and cyberspace. Using a micro-controller, physical sensor and web server, *Physical DOM* is a distributed system that updates visual properties of a web page in real time according to readings from the sensor.

The example in Figure 4.1 shows the background color of a web page changing in relationship to the measurement of light by a photoresistor. When the sensor is covered the background color of the web page dims in a corresponding manner. This is achieved by sending the measurement of the light sensor to a database on a remote server at short intervals. Using Asynchronous Javascript and XML (AJAX) the display of the Document Object Model of the page is updated without any need to refresh the entire page in the browser. As a result the appearance of the page changes dynamically to reflect the physical environment of the sensor without the direct manipulation of any code or input device once set up.

In this example, the mapping of light intensity to the HTML body background color is a simple translation that could be used to convey the time of day at the web page owner's current environment. Abstractions like changing the size or color of the text based upon the sensor's readings, could offer alternative meanings. As a sample scenario, white text could that only becomes viewable at night when the background color becomes dark could be used to indicate the author's desire for the page to be read only at night. The mapping of *Physical DOM* can be as literal or metaphorical as desired, a feature that status messages of social networking sites and chat tools do not currently afford. *Physical DOM* fits into the paradigm of *CNIAs* by using manual, embodied, or environmentally situated input (depending upon the type of sensor) to provide an environmental context for information consumption.

Digital Sandbox

Digital Sandbox is the result of an exploration into the use of tactile media to experience digital information. Part art, furniture and computation, it is an ambiguous object that does not entirely fit a specific category of thing. *Digital Sandbox* provides an experience that is not explicitly about information or communication, but presents the opportunity to have a sensuous haptic experience with possibility of interpersonal communication through a non-traditional medium.

Measuring 24″ wide, 6″ tall and 32″ in length, *Digital Sandbox* is a contoured wooden box filled with sand in which participants reach to manipulate an internal feedback system of fans. The box is displayed at stomach level so participants can see the interior of the box and reach into it comfortably. Openings exist at each end of the box that are large enough to insert a hand but

Figure 4.2: Mary and Marisa with *Digital Sandbox*

small enough to discourage inserting the entire arm. Patterned perforations typical of a speaker cover surround the opening and indicate that the object is somehow mediated, however no other clues of interaction are provided. While reaching inside *Digital Sandbox* participants feel a smooth cavity that contains a half-inch layer of sand at the bottom, as well as a gentle, nearly indistinguishable flow of air. Participants are left to explore the materiality of the sand through its natural affordances of being pushed, sifted through the fingers and otherwise felt. As participants move the sand within the box small fans react to blow the sand against the movement. The dimensions of the box are such that only one end may be explored by any one participant at a time, however two participants can simultaneously interact with the box from opposite ends.

During simultaneous use participants may notice drafts of wind that are not due to their own action. These unexpected drafts occur because the fans (four in all - one in each corner) are wired in such a way that input on one end effects output on both ends. Once discovered by the participant, these airstreams may be modulated by moving sand to appropriate locations. When two participants simultaneously interact with *Digital Sandbox* an opportunity for haptic communication is created through the mediated control of the fans. Together, two participants can effect wind speeds that are twice as great as they can effect alone. This is a subtle layer of interaction that can only be achieved through a mindful attention to the experience, however it carries with it the capacity to communicate on the level of a handshake or hug.

As previously discussed, the intrinsic and aesthetic properties of an artifact's material greatly influence the way it is perceived. In order to successfully engage a viewer in active participation, materials must say "touch me". Tactility is first investigated by the eyes, which identify contours and surface properties that aid in the decision of whether an object is safe or dangerous, pleasurable or revolting.

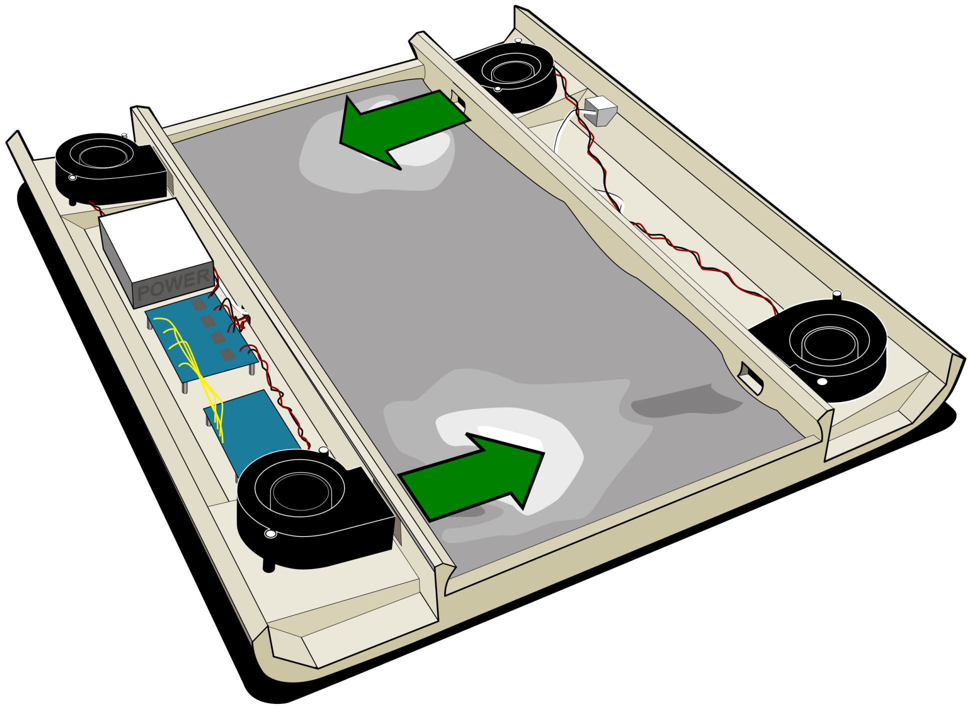

Figure 4.3: *Digital Sandbox* interaction scheme

For this reason *Digital Sandbox* was designed with rounded corners throughout the form to be inviting to touch. To achieve this form *Digital Sandbox* was constructed from laminated layers of high-quality birch plywood. This approach made the contours easy to construct, and the visual pattern of the layers subtly reinforces the idea of reaching inside of the box. Though this approach was labor intensive, requiring approximately 60 hours of hand labor, the form and materiality achieved a level of aesthetic refinement that significantly contributed to the device's overall effect.

To facilitate function, the inside of the box is divided into 3 channels through the length of the box. Interactivity in the central channel is supported by peripheral channels where fans and control circuitry are located. Squirrel-cage-blower type fans are located the ends of each peripheral channel and blow air into the central channel through small holes. Airflow is controlled based upon pressure sensors mounted underneath the sand platform in the central channel. These sensors are read and translated to a pulse width modulated control signal for the fans by an Arduino microcontroller.

Sand is a suitable material for this interaction in many ways: it is patternable, mobile, a medium of construction and destruction, can be considered soft or abrasive, and it symbolizes the passage of time. Additionally, the actual matter of sand has parallels information. All digital information is stored in memory as many bits that convey the information when properly aggregated. Similarly, sand is a composite mass of many granules. Most poignant of all, modern computer processors are made of silicon, the same elemental material as sand. In *Digital Sandbox* sand serves a metaphor for information, as well as a medium of communication. Participants are able to directly manipulate "physical bits" and to send these bits to a participant located at the other end. Regarding materiality, sand tends to evoke strong emotional reactions, possibly recalling pleasurable memories of the beach or a childhood sandbox. For many, the rough texture of sand is displeasing and perceived as dirty. These emotional responses largely contribute to the interactive experience of the participant. The unavoidable and intentional reaction to materiality as part of an informative interaction is a core ideal of *crafted, networked, informational artifacts*. Communication in *Digital Sandbox* is localized to be exchanged within the box, but there is no reason that sensor information could not be sent over the Internet to drive another *Digital Sandbox* at a remote location. This approach has been taken by the *InTouch* project at the MIT media lab. This networked haptic interface facilitates interpersonal communication by sensing and actuating a set of rollers that are simultaneously mirrored at each end of the network, allowing participants to feel and control the same haptic experience [6]. Similar to *Digital Sandbox*, *InTouch* uses the rich tactile quality of wood to make the interface compelling. Projects such as *Digital Sandbox* and *InTouch* add a depth of sensuous experience through materials that challenge the comparatively less stimulating materiality of most mass-manufactured communication devices. This is the critical design and aesthetic goal of *crafted, networked, informational artifacts*.

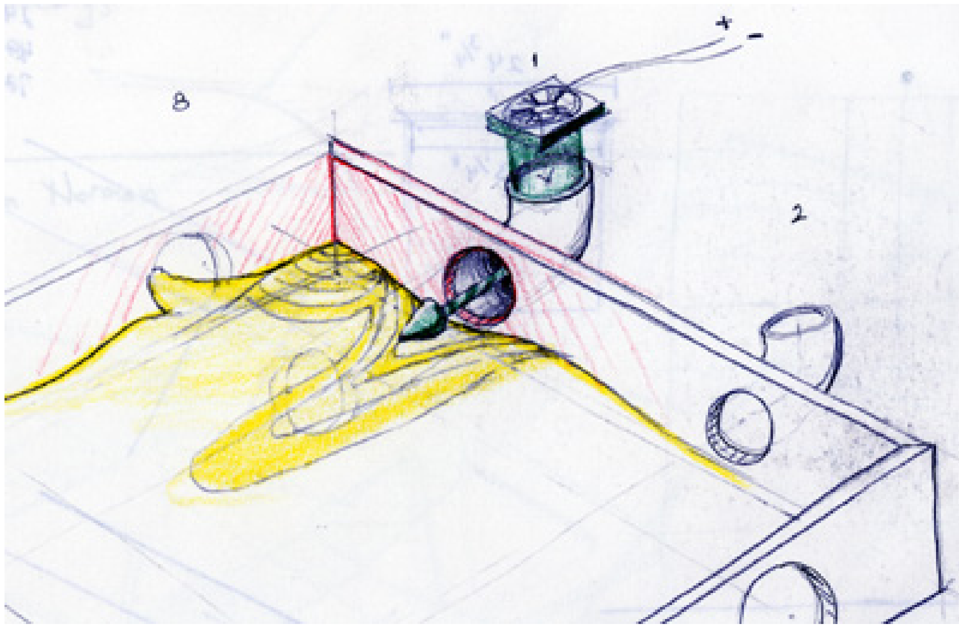

Figure 4.4: Conceptual sketch of *Digital Sandbox*

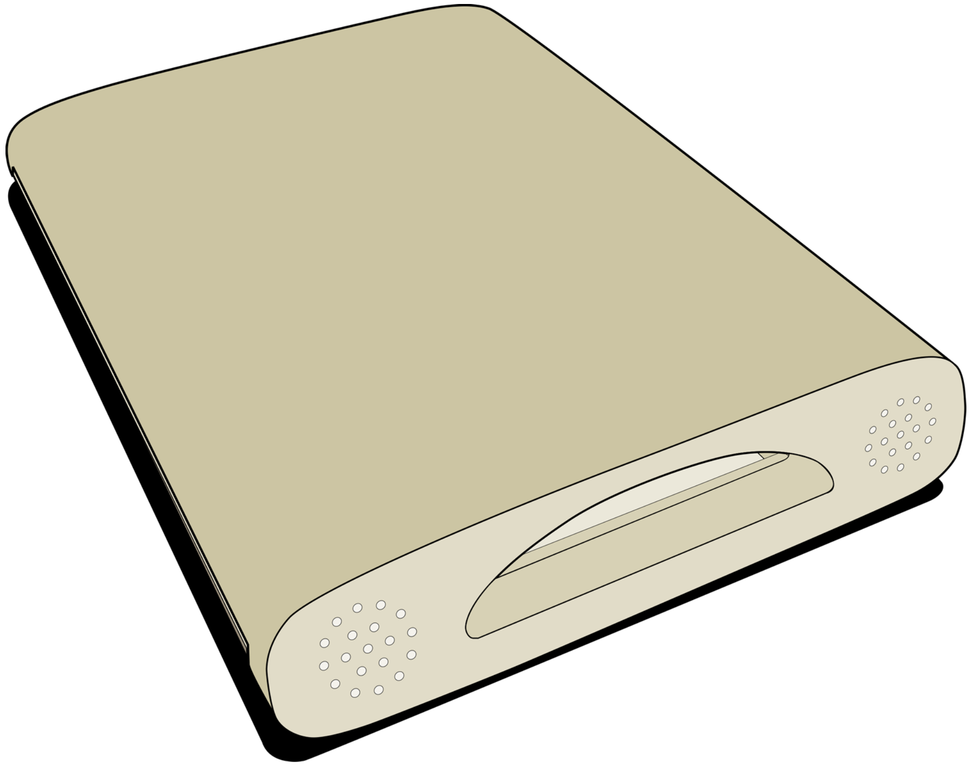

Figure 4.5: External illustration of *Digital Sandbox*

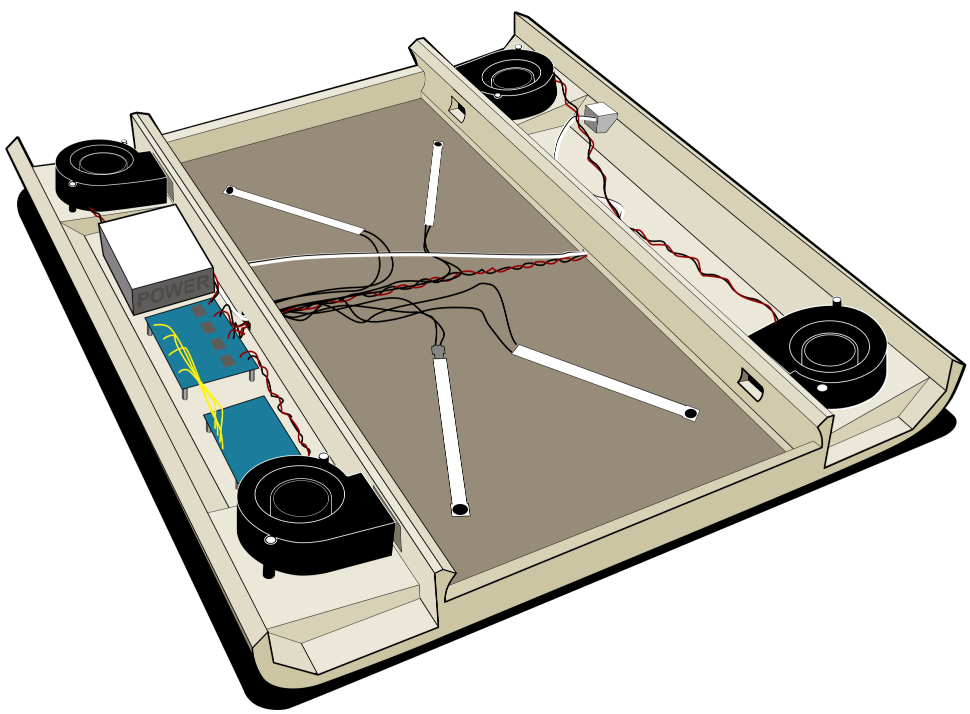

Figure 4.6: Internal illustration of *Digital Sandbox*

Gravitable

Figure 4.7: *Gravitable*

Physical DOM and *Digital Sandbox* both explore non-traditional ways to experience information. *Physical DOM* achieves this by using a physical sensor to add a dimension of environmental context to a web page. *Digital Sandbox* uses participant interaction as part of a feedback loop to create an opportunity for tactile communication. However, each of these projects is only part of a completely developed *CNIA*. Used by a single author, *Physical DOM* does not facilitate two-way communication, and *Digital Sandbox* does not use a network for communication. *Gravitable* brings together properties of these two projects to allow participants to interact with the World Wide Web within a physical context and experience networked information in a visually tactile dimension.

Gravitable is a networked table designed with information, materiality, sculptural composition and interaction in mind. Sitting at the height of a coffee table and measuring 40-inches in diameter, *Gravitable* encourages viewers to sit and spend time with the dynamic device. Below a flush glass pane in the center of a table a shiny steel ball slowly and deliberately traces out patterns in a shallow sand-filled cavity. These patterns are created using information read from the World Wide Web and an algorithm that simulates planetary gravitational attraction. Virtual planetary interactions result in the creation of an ever-changing trajectory for the steel ball that result in the formation of indelible dunes in the table's sand. In order to facilitate interactive participation force sensors are discretely placed around the perimeter of the glass surface that allow the table to sense the presence of objects placed on its surface [55].

Development of *Gravitable*

Like *Digital Sandbox*, the creation of *Gravitable* began with the desire to experience information other than through on-screen representations. In a previous software-based work entitled *Drawn Together* particles are attracted[1] to each other to create a compositionally interesting image. This aesthetic led to the question: how can sources of information be attributed to the particles to generate an informative result? The first answer to this question involved attracting a ball to locations on a surface based upon input from physical icons [34] and networked information. This effect could be actuated by creating dimples in the surface to gravitationally attract the ball or by using electromagnets to magnetically attract a steel ball. Neither of these options seemed feasible, however recalling Bruce

[1] Attraction is based upon an algorithmic representation of Newton's law of universal gravitation:

$$F = G\frac{m_1 m_2}{r^2}$$

The basis of this algorithm is made available online at http://www.shiffman.net/teaching/nature by Daniel Schiffman at the NYU Interactive Telecommunications Program

Shapiro's *Sisyphus* series, it seemed that drawing in sand could produce informative traces through a feasible plotting mechanism.

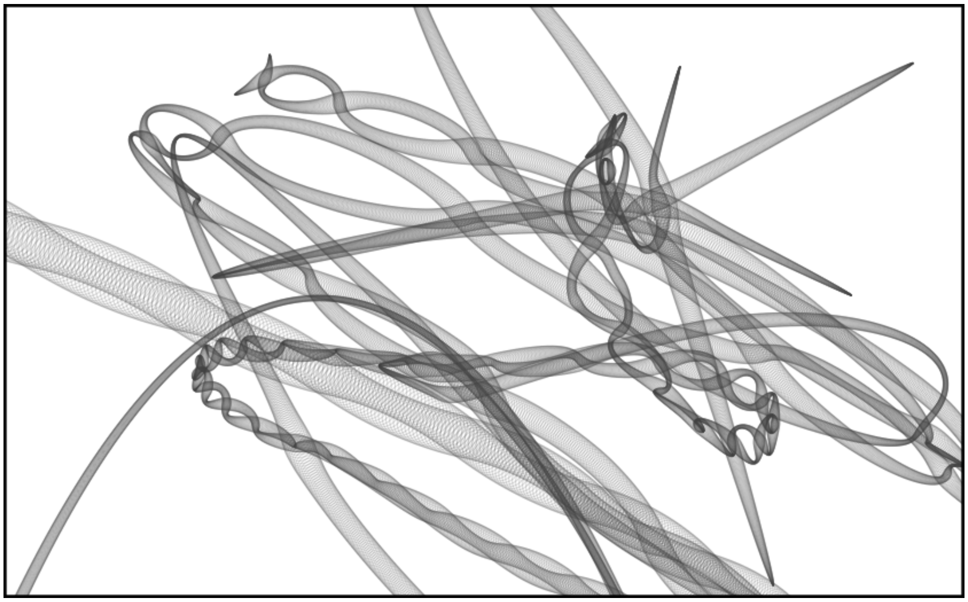

Figure 4.8: Rendering of *Drawn Together*

One of the most significant challenges to creating *Gravitable* was to design the interaction. As a matter of design, *Gravitable* is extensible to display any information available on the web, however as a matter of artistic expression the display should function to communicate a contextually oriented message. Similar clashes of artistic and design purposes have been dealt with by artist/designers such as John Maeda, Tony Dunne, Fiona Raby and Bill Gaver. Together Dunne and Raby have pioneered a genre of product design called "Design Noir", which serves as a medium to fuse "complex narratives with everyday life" [15]. Speaking to the role of design in art, Dunne writes:

> "I believe strongly in the potential of industrial design as applied art, or industrial art, to improve the quality of our relationship to the artificial environment, and in industrial design's potential, at the heart of consumer culture, to be subverted for more socially beneficial ends" [14].

From this point of view, design objects can serve as artistic critiques and interventions of accepted routines in everyday life. John Maeda's algorithmic, computer-based work is also open to interpretation as art or graphic design. In regard to the differences between art and design, Maeda writes, "While great art makes you wonder, great design makes things clear" [38]. However, Bill Gaver's theory, using ambiguity as a resource for design, challenges Maeda's statement by suggesting that design can also be used to pose questions by making things unclear. Ultimately, no hard line exists between art and design and the success of work is left up to the positioning of the content within an appropriate context. For this reason, the following scenarios describe *Gravitable* within two different contexts.

Scenario One: Personal Information Device

Positioned in the home, *Gravitable* can be used to display personally relevant information in a manner that encourages personal interpretation, contemplation and reflection that is not typically afforded by simply browsing to a web page. For instance, using a single source of information available on the Internet such as atmospheric conditions, the gravitational algorithm of *Gravitable* would create a petaled pattern similar to the Bohr atomic representation of an electron orbiting a nucleus. As the networked information updates the orbital distance would respond accordingly. Sources may come from social networking sites, popular news sites or raw data from NASA. With the source programmed by the user, the resulting patterns are individually meaningful.

As an example of a social networking application several *Gravitables* could be used together to communicate information among friends. In this situation, *Gravitable* serves as a Phatic technology - a system that establishes and maintains the possibility of social interaction [64]. In this scenario the table-top's weight sensitivity is used to communicate presence and availability. Using a shared understanding that an object placed at the center of the table indicates the highest degree of interest in social activity, an interaction among a group of three *Gravitable* owners may occur as follows:

> Having a cancelled class, Sara is at home and looking for something to do. She places her TV remote near the center of her *Gravitable* as she starts to watch television. When Matt comes home for lunch he notices that his *Gravitable* has traced out a pattern that he is not used to seeing–it looks as if Sara is looking for something to do in the middle of the day. Matt calls Sara and finds out that she would love to meet up for lunch. At the end of the day Stuart comes home, notices an unusual pattern, but chooses to ignore it and empties his pockets on the non-sensitive edge of his *Gravitable* before lying down.

In this scenario each of the objects on the table represents an individual agent capable of communicating a degree of social interest. This allows the participant to *generate* information by placing objects on the table and to *interpret* information as it is portrayed in the traces of the sand. Some unique positive affordances of the *Gravitable* in this scenario are the abilities to 1) share status information in a situated manner through the manipulation of household or pocket objects to indicate a degree of social interest, 2) ambiently read the status of others at the micro level[2] and 3) grok[3] the current atmosphere of a social network with a glance at the macro level.

Scenario Two: Gallery Exhibition

The gallery setting presents a different context then the home setting in a couple of different ways. First, by placing *Gravitable* in the home users will either know the affordances of *Gravitable* in advance or have an extended period of time to discover them. Second, in the home *Gravitable* may be personalized to display the owner's specific choice of information. In a gallery setting, viewers must be able to make sense of *Gravitable* very quickly. Additionally, the representative meaning behind the traces should not rely on esoteric information. For this reason the following description presents an appropriate scenario for display of *Gravitable* in a gallery setting.

Gravitable should be placed in a calm setting surrounded by casual seating that encourages viewers to sit down and spend a moment. On a nearby monitor or projected onto the wall is an accompanying description of *Gravitable* in the form of a short paragraph that describes its function and a brief history of the piece. Also nearby are weighty objects available to interactively place on top of the table's sensitive glass surface. As viewers interact with the tabletop the Web-based description changes in real time by changing the content and appearance of the text. In this situation, viewers can quickly observe the relationship between the patterns in the sand and the use of the table's surface as an input device, along with the online representation of interaction with the table.

[2]The differentiation of micro and macro readings are important elements of social visualizations accord to Thomas Erickson's research on chat applications at IBM [17].

[3]*Grok* is a term coined by science fiction writer Robert Heinlein that implies a deep understanding, a oneness of observer and observed.

Placing *Gravitable* Within a Historical Context

Aside from physical context, *Gravitable* fits within a historical context of similar devices. As already mentioned, the inspiration behind *Gravitable* shares common themes with Dunne and Raby's *design noir* products that "exploit the unique and exciting functional and aesthetic potential of electronic technology". Though not a source of original inspiration, Bill Gaver's Drift Table is closely related [20]. Operating within the paradigm of *slow technology*, Gaver's Drift Table was created to challenge the implicit assumption that computationally driven artifacts must behave quickly. The functionality of Drift Table is simple and straightforward: A viewing portal in the center of the table displays a bird's eye view of England that slow drifts in the direction of the load on the table's surface. According to interaction designers Hallnäs and Redström, slow technology is "about exposing technology in a way that encourages people to reflect and think about it" [25]. As a point of contrast with the purpose of Gravitable, Bill Gaver's approach to design is highly oriented toward the field of HCI in its use of field testing and evaluation of user response.

In the field of HCI many projects have been created to display information through *informative art* [32] [10] [29] [61]. In most cases of informative art, popular masterpieces are appropriated and modified to display information. Hallnäs and Redström have developed *informative art* projects that adopt Piet Mondrian's style of painting to convey information by dynamically rendering blocks of primary colors on an LCD monitor [52]. Additional projects from Hallnäs and Redström appropriate Yves Klein's subtle mix of colors to convey time by subtly changing colors on an LCD screen. These projects have their place within the development of creative representations of dynamic information, however their failure to adopt appropriate materials[4] separate them from the aesthetic goal of Gravitable. The

[4] In the case of Mondrian and Klein, a large part of their effort went toward pushing the bound-

Information Percolator from Carnegie Mellon is an example of informative art that conveys information as an original piece of art. This project shares information by strategically releasing bubbles into columns of water-filled tubes, resulting in a matrix of "bubble pixels" capable of displaying information.

In addition to fitting into categories of ubiquitous computing, calm technology, slow technology, informative art, critical design and reflective design (all previously discussed), *Gravitable* also fits into a newly emerging form of Japanese *device art*. According to Machiko Kusahara, media art curator, device art is "a concept for re-examining art-science-technology relationships both from a contemporary and historical perspective in order to foreground a new aspect of media art" [37]. Device art integrates art, design, technology and popular culture in ways that are positive and playful. Kusahara attributes these characteristics to traditional Japanese practices such as the tea ceremony and flower arrangement. One way that device art distinguishes itself from a traditional Western approach is through the role of the artist in the widespread commercialization of their art. In this manner, device art is closely related to the Western fashion industry, with the exception that pieces are required to serve an instrumental purpose. However, as seen in the movement to build sensors and actuators into clothing (wearable computing) these borders are quickly blurring. Designed to be aesthetically pleasing and functional as a communication device, *Gravitable* shares thematic elements with device art.

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aries of their materials and tools. In the case of Mondrian, his use of straight lines and uniform areas of color challenged the inexactitude of paint and brushes. For Klein, his paintings of monochrome color were about presenting colors that were not otherwise manufactured. In each of these cases the affordances of an LCD monitor (straight lines, a defined 16-million-color palette) defeat the original intentions of the artist.

Summary: Personal Reflections on Gravitable

Gravitable is the result of a year-long challenge to create an artifact representative of an interdisciplinary study of art, computation and engineering. Its creation was honed through continual iterations of virtual and physical prototypes, while struggling to balance theory and practice. Because of this approach, *Gravitable* is simultaneously a sculptural expression and a technical tool–a hybrid artifact engaging complex issues of information, materiality and human ecology. The trajectory of Gravitable's creation spans several years of personal training in web publishing, product design, electrical engineering and fabrication. In the last two years these separate practices have been mixed together and shaken with theoretical study. This complex trajectory created intense moments of disorientation and moments of clarity, and as a result themes that were originally part of *Gravitable* were removed and new themes emerged. Specifically, themes of critical and reflective design were not discovered in research until toward the end of Gravitable's development. However, as part of practice these themes had been implicitly experienced as part of the personal reflection involved in the iterative design process [11] [56]. Research on reflective design resonated strongly with concurrent intraspective pursuit of personal purpose and led to the interrogation of ideologies embodied by computational devices through materiality and design. Thus, concepts behind *Gravitable* shifted toward creating a device to be personally meaningful and encourage personal interpretation in addition to displaying information in a creative way. *Critical design* and *ludic engagement* greatly informed these concepts and the interaction design in Gravitable. Finally, Victor Papanek's *Design for the Real World* served as a source of professional inspiration as a designer and supported themes of human ecology found within Gravitable.

Interpretations ranging from technological gadget to kinetic sculpture may be drawn from Gravitable, however the tortuous path of its development reveals a far more complex history than can be represented in its artifactual form. Within a design paradigm, the efficacy of *Gravitable* could be measured through focus groups or user testing, but as an artistic creation the effect of *Gravitable* is left to personal interpretation. Its success should not be measured by what it allows the viewer to draw out from it, but in its ability to allow the users to find their own meanings in it.

Conclusion

Communication devices are among the most pervasive types of ubiquitous computing. These devices increasingly effect daily decisions on personal and global levels based upon their ability to receive and share information through a variety of networked infrastructures. Throughout their development, computers have become increasingly sophisticated at manipulating data to inform human knowledge, however, as a matter of software and hidden electronics, device design has largely ignored the role of external materiality in the communication of meaning. Primarily using the screen, mouse and keyboard as an interface, mass-manufactured devices rarely draw upon the evocative qualities of materials to dynamically communicate information. Through the relatively limited affordances of their interface, these communication devices promote speedy consumption of information via the most concise representations possible.

While these representations have proven successful in communication, they neglect many of the nuances involved in interpersonal communication, especially regarding meaning found in the tacit dimension. In order to communicate in this dimension where ideas cannot be put into words, the use of abstract representations become increasingly important. In this role cognitive artifacts aid in the performance of abstract thought through their properties of form and materiality. More than simply matter, the materiality of an object is an important bridge between perception and cognition. The way objects smell, taste, feel, sound or look effect the way that humans think about them. However, while computers have become advanced in their handling of data, the material interfaces of computational devices have been relatively less developed. As communication devices continue to saturate daily life with dynamic sources of information that approach higher levels of abstraction, material properties of the devices need to be advanced as well.

As an artistic and critical design approach to creating abstract representations in the communication of tacit knowledge, I propose a genre of *crafted, networked, informational artifacts*. This design approach uses craft materials and processes as inspiration and catalyst for interpreting information as a performance of reflection-in-action. By thinking *through* communication devices as materially relevant in addition to their utility, devices can successfully communicate information in ways that go beyond representation and tap into other senses to provoke personal interpretation. This approach has foundations in Mark Weiser's vision of ubiquitous computing and calm technology and has been highly inspired by Ishii's work in tangible computing. Through further research, concepts of critical design, reflective design, slow technology, informative art, ludic design and device art were all drawn upon to color the theoretical development of *CNIAs*.

In practice, I have developed three projects along the with the research process. The first project, *Physical DOM* represents a first attempt at contextualizing the Internet in physical space by changing a web page's appearance based upon input from a physical sensor. Building upon the idea of alternative representations for networked communication, *Digital Sandbox* invites participants to interact with the physical medium of sand to possibly experience tactile communication with a fellow participant through directed manipulation of the sand. Bringing together Internet connectivity and abstract textural representation, *Gravitable* allows users to communicate a context of table use and renders networked information in abstract patterns. As a pattern of development, these *crafted, networked informational artifacts* challenge quick consumption of information through interfaces that encourage playful interaction and personal interpretation. Influenced by a personal process of craft, the materiality of artifacts emerged as an area of aesthetic intervention into the design of communication devices to foster contemplation of information and reflection–skills that are uniquely human and not machine executable. Communication networks will continue to advance technologically, and as they do it is important for artists to continually challenge the network's role in the production of culture.

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