SMART THINGS

Ubiquitous Computing User Experience Design

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OBSERVATION AND IDEATION

Technology is just another part of society, and the markets for new technologies sometimes seem like a convoluted dance of intentions, reactions, and unexpected consequences. Apple Computer sent thousands of unused Lisa computers to a garbage dump in 1989 because they could not sell them (Hall, 1999). In 1994 Nokia sold 50 times as many of their model 2100 handset than they had predicted, which caught them by surprise (Ravasi and Lojacono, 2005).

Because markets are complex and people are unpredictable, it is tempting to say that developers should focus on technology because it is easier to understand. This decision, which may seem like a safe focus on "core competencies," is actually quite risky. It leads to a technology creation approach where engineers first "invent," and marketers look for "applications" for these so-called inventions later. This invent-in-isolation approach defers any inquiry into what people might find valuable and interesting about an invention to a time when there is little ability or will to make big changes to actually meet those needs. The product's success then depends on whether initial assumptions match what people want, what people are willing to accept, what the technology can do, etc. If any of those assumptions is off, and if post-production marketing cannot overcome them, the project risks joining the warehouses full of failed gadgets destined for discount sales, recycling, or the dump. Products made with embedded information processing are particularly vulnerable because they mix novel services, specialized hardware, and new interaction design.

It does not have to be this way. Observation techniques can identify what people are interested in, what technologies they are willing to accept, and the role those technologies can play in their lives. Ideation techniques can define what a technology (or a combination of technologies) does well and how it can satisfy people's needs.

Combined, the two approaches constitute a tactical risk management approach that uses constraints derived from direct observation to generate novel design ideas.

14.1 OBSERVATION

Note: For a broader discussion of user experience research techniques, please see Jones and Marsden (2006) and Kuniavsky (2003).

The novelty of ubicomp technologies and their attendant social changes requires an especially close examination of people's attitudes and desires. Simply watching people is a key way to know what to emphasize when designing technologies for them.

There are many techniques for observing how people experience technology. Many can apply to any technological experience, not just digital products. House keys, scalpels, and forklifts all create user experiences that can be observed. This chapter presents several that are particularly useful for mobile/ubicomp user experience design, but the details matter less than the overall philosophy: the more you watch people, ask them questions, and analyze their behavior, the more attuned you can make the experiences you design to *their* ways of experiencing the world.

14.1.1 A BASIC OBSERVATION METHOD

The simplest observational technique is unstructured extended observation, what Agar (1996) described as being a professional stranger. This is the core of most professional observation techniques. Everyone from anthropologists and journalists to police detectives uses unstructured observation. It is the first step when trying to determine what is really going on in an unfamiliar environment. At its most basic, it can be summarized as "pick a spot, hang out there for a while, watch carefully." Those commands can be formalized into an eight-step process:[1]

1. Define the scope of the observation
2. Pick an audience
3. Observe for an extended period
4. Document observations
5. Interview representatives
6. Organize observations
7. Identify patterns
8. Make recommendations

This technique has become the core of a practice called *design ethnography* (Salvador et al., 1999).[2]

[1]This specific description owes a lot to Beyer and Holtzblatt's contextual inquiry (1998), a highly structured method explicitly created for technology design.

[2]For an excellent introduction to design ethnography methods, see Chapter 5 in Jones and Marsden (2006).

Although any given project will produce many interesting observations, only a small subset of them will directly address the goals of the project. Defining the questions a research program will try to answer is key to making sense of the observations. Answering these questions defines the scope of the research. Is the goal to validate assumptions behind a preferred design or technology solution? Is it to generate ideas for new products? Is it to understand why an existing product is not as successful as had been expected?

14.1.1.2 Pick an Audience

Similarly, describing a product's audience answers many design questions before observation even starts. If, for example, a product is used in a hospital, is it primarily going to be used by doctors, nurses, or support staff? Each group has different responsibilities, different behavior patterns, and different relationships to the wide range of technologies used in hospitals. A product for all three groups would have to cover the entire range of activities at the hospital. Few products have such general utility, so although it would be nice if everyone at the hospital used the product, odds are that it is going to be used by one of the groups significantly more than the others. That group, then, is the primary target audience. It should be the focus of observation. If the product proves successful with one audience, its functionality can be broadened to secondary audiences. But it has to work for *someone* before it can work for everyone.

14.1.1.3 Observe

In field observation, an observer finds a location where she can observe the target audience without significantly interfering with activities. After getting permission[3] to observe the people in that location, the observer watches, trying not to make assumptions about what she is seeing. This is notoriously harder than it sounds. The duration of the observation depends on the complexity of the situation under study, the novelty of the planned intervention, and the familiarity of the observer with the domain under observation. For a researcher from a large corporation, a day's observation of office workers in a similar corporation in the same city may be sufficient. On the other hand, an urban researcher may have to spend several weeks over the course of six months to get even a basic understanding of who does what, where, and why on a farm in a foreign country.

A powerful close observation approach for design is the master/apprentice model (Beyer and Holtzblatt, 1998). An observer acts as an apprentice, treating

What constitutes permission varies greatly with the location. In a public space in the United States, getting permission to watch people is probably not required. In other countries, you may need to ask permission if you are taking photographs. If there is any doubt about the rules for doing research in public spaces, check national laws and ask locals about how they do things. Formal permission in an office could require only a memo from an executive. Obtaining permission to be in a hospital or factory can be quite involved because of liability, privacy, and intellectual property issues.

the person observed as the master craftsman. The observer watches the master do his work and occasionally asks questions. The master describes what he is doing while doing it. This keeps the "master craftsman" focused on details and avoids the generalizations. Retrospective narratives often lead to generalizations from glossing over key details that seem so obvious to the person doing the work that they go unmentioned.

14.1.1.4 Document

In *Blow-Up*, Michelangelo Antonioni's 1966 film, a photographer uncovers a murder by making increasingly larger prints of a photographic negative. Similarly, examining documentation from field observation regularly reveals surprising details.[4] For example, when examining photographs from an observational session at a hospital, a researcher noticed that a doctor was wearing two pagers. Why two pagers? Questions from follow-up interviews revealed an important use of this basic hospital technology. One pager represented each doctor as an individual, and the other represented the doctor's role during the current shift. Thus, when a woman arrived at the hospital in labor, her nurses would call the role pager for "the obstetrician on duty" knowing that some qualified doctor would reply to it. However, if Dr. C's own patient experienced complications, then she would get a page on her personal pager. During shift changes, doctors passed role pagers as a kind of badge that signified the shift of responsibility. At the same time, their personal pagers stayed free from calls that were not directed to them personally.

Documentation typically includes written notes, photos, and video. Notes should be as detailed as necessary to help reconstruct the action later, without impeding the observer taking in as much of what is happening as possible. When forced to choose between observing and documenting, observing always wins. Whenever possible, try to clearly differentiate between the concrete things you can see, and what you believe those things *mean*. The latter almost always indicates the presences of assumptions that may or may not be justified.

Wasson (2000) recommended dividing observations into five categories, mnemonically organized in the order of English vowels:

- Activities. What are people doing?
- Environments. Where is it happening?
- Interactions. How are people doing it?
- Objects. What artifacts are they using?
- Users. Who are they?

[4] Although, hopefully, no murders.

Film language provides a guide for what to visually record:

- Establishing shots record the broad environment in which the action happens.
- One or two people dominating a frame are a medium shot, focusing on how they interact. A medium shot captures details about people, their relationships, and what they are wearing and carrying.
- Close-ups show important details in the story.

The combination of text and visual documentation is a rich source of material for insight into people's relationship with technology and inspiration for new products and services.

14.1.1.5 Interview

Observation describes what happened, but interviews help determine why it happened. Interviewing members of the target audience is necessary to understand how they understand what they are doing with technology and why. People's descriptions of what they do and how they do it are fallible (which is why surveys about preferences and future behavior often do not predict actual future behavior), but personal narratives help explain behavior and technology use.

Interviews can be structured and unstructured. In structured interviews every interview consists of standardized lists of questions. Answers to these questions can be directly compared between interviews. In unstructured interviews, the interviewer asks whatever questions seem appropriate at the time, following discussion threads and examining certain ideas in more detail than others. In practice, nearly every interview combines prewritten and improvised questions (a semi-structured interview). Interviews should also be non-directed, which means that the interviewer should try not to influence the interviewees' responses.

14.1.1.6 Organize

Once all of these data are collected, the researchers and designers need to make sense of it. Organizing observations through coding (the process of assigning short tags to individual observations) is a typical, although somewhat time-consuming, first step in design research.[5] The basic steps in coding are:

- Identify atomic units of observation. Typically single statements in a list of notes, individual photographs, and "interesting" video segments.

[5]Young (2006) documented a similar, but much more detailed, method for analyzing people's descriptions of their behavior and used that analysis to identify their information and navigation needs.

- Create a list of codes. This is often done by going through observations and creating new codes until most observations fit an existing code. Several people can do this and then compare their lists of codes to see if there is general agreement on how to group observations.
- Code all observations, entering observations and codes into a spreadsheet or database.
- Sort to identify clusters of similar observations and extract underlying unifying qualities among them.

This method creates a way to organize observations so that patterns can be identified and documented. Constructing *affinity diagrams* (Beyer and Holtzblatt, 1998) is another popular analysis method. In this method, analysts write individual observations on Post-It notes, organize the notes into clusters, label the clusters, and sequence the clusters to create a model of what has been observed. As the diagrams grow, researchers can find patterns in the proximity and distance of the notes.

14.1.1.7 Identify

Identifying the tools people use and the patterns in which they use them creates insight into the role that new technologies can play in the given context. Someone takes a coffee break at the same time every day. Someone else reads on the phone during the morning train commute. Another person is making a playlist as a gift. And that person's spouse is printing a map of public bathrooms with baby changing tables in midtown Manhattan.

The basic user experience pattern identification method is to cluster data, then examine the clusters for recurrent themes and inspirational edge cases. The first group identifies common behaviors, places, and times where technology can intervene to help make things easier, better, more entertaining, etc. The second group showcases unusual, evocative possibilities that provide rich avenues for exploration.

14.1.1.8 Recommend

> Weeks or months of observations are wasted unless you can mold them into forms that succinctly, yet richly, communicate the salient aspects of your users' lives.
>
> *Jones and Marsden (2006)*

Finally, every observation project needs to provide concrete value for technology development teams through specific recommendations. Because it takes complex social behavior and turns it into a set of design constraints, the process of creating design recommendations cannot be purely objective (Dourish, 2006). However, at its best it presents a grounded analysis that links specific design decisions to actual behavior.

What observers choose to report and how they choose to report it depends on the goals of the project, the company, and (frequently) the observer. Because analysis introduces bias, it is the observer's responsibility to present observations in the clearest way, even if it shows that positions previously advocated for, or hoped for, are wrong.

In one approach, analysts present a range of possible actions, describing possible implications of each one, and let the developers explicitly choose a path. This reflects the fundamental uncertainty of reducing complex attitudes and behaviors to a short list while still providing specific guidance so that the project can move on.

Sidebar: Ethnography vs. Design Ethnography

Despite the confusing name, it is important to distinguish design ethnography from the traditional ethnography practiced by social scientists. Their work emerges from engagement with other ethnographic texts and theories. Traditional ethnography is an intensive process that attempts to paint a deep and rich picture of the lives of a group of people. Ethnographers observe people across contexts (in their homes, at work, at play, etc.) to describe their lives as a whole.

Design ethnography rarely aims so high. Instead it tries to generate insight about the behavior and attitudes of people in specific situations with the goal of creating products and services. Where ethnographers observe to generate theories about entire cultures, design ethnographers conduct fieldwork to develop the next generation of a product. For an elegant discussion of the history and differences between the two kinds of ethnography, see Paay (2008).

14.1.2 SPECIFIC METHODS

This section highlights several observation practices that elaborate on this general approach, but there are many more.

14.1.2.1 Digital Ethnography and Public Photos

Thanks to the rise of social networking Web sites and photo and video sharing services, many people publicly describe and document themselves and their lives in great detail. Using Internet tools to gain insight into people's lives is a significant part of digital ethnography (Masten and Plowman, 2003).[6] In solicited digital ethnography, researchers recruit people to use digital means to describe their life. The methods used can range from asking people to send

[6] This term was widely popularized in the wake of cultural anthropologist Michael Wesch's YouTube video "The Machine is Using Us," created by his Digital Ethnography class at Kansas University in 2007.

Figure 14-1

What was in blu_pineappl3's bag on April 26, 2008? (Photo by blu_pineappl3, licensed under Creative Commons Attribution 2.0, found on Flickr)

e-mail updates to asking them to respond to questions and record their lives using tools such as digital cameras, mobile phones, social networks, wikis, etc. Unsolicited digital ethnography is the analysis of how people describe themselves digitally without being part of a research project. This can include analyzing blogs, videos, photos, and forums to extract an understanding of people's behavior based on how they have documented it.[7]

It is relatively simple to search for photos and videos tagged with specific keywords on Flickr, YouTube, and Photobucket. These provide a rich source of documentation of people's lives, and how they use technologies.

For example, the Flickr "what's in your bag" photo pool[8] contains thousands of pictures of what people carry with them every day (Figure 14-1). The metadata around the items, the photographers' other images, and the images taken by their friends give insight about their lives (see Sidebar: Image Search Tips).

[7] A particularly eye-opening example is Sharpe and Earle (2003), who analyzed the comments on a Web site where prostitutes' customers rated their service providers.

[8] http://www.flickr.com/groups/whats_in_your_bag/pool/.

[9] Thanks to Elizabeth S. Goodman for this technique.

Sidebar: Image Search Tips

People rarely use the same terms that designers use to describe what they have photographed. Until image indexing technologies understand the content of images, the tags associated with an image will be those put there by the photographer. Choosing keywords to get at the right kinds of images is more of an art than a science, but several approaches can help uncover interesting photos:

- Search from the perspective of the photographer. For example, searching for specific brand names ("Nokia," "Sony," etc.) can generate results when category names ("mobile phone") cannot. When searching for pictures of older women, search for "mom", "mum," or "mama," rather than "older woman."[9]
- Examine the photo pools (in Flickr terminology) or photo groups that an appropriate photo belongs to in order to find more photos of a similar type.
- Note what other tags or descriptive words photographers use and search for those.

The downside of this technique is that unless solicited or followed up on, the images come without context. The photographers present themselves and their world in a specific way, to a specific imagined audience. They do not show their whole life, just the parts they think their audience will appreciate. Often, it is difficult to know the exact relationship between the people, objects, and technology in the photos. (However, since most of these sites have ways of contacting the person who posted a photo, it is possible to ask them to explain it over e-mail). Further, the technique is limited to people who have access to the Internet, can use photo/video-sharing sites, and are interested in doing so.

However, as an observation method that can be done without leaving your office, looking at photographs online is hard to beat.

14.1.2.2 Diary Studies

Reporting on a single, recent behavior, or getting a first-time impression of a proposed solution is useful, but it does not represent how people actually live with technology. Relationships with a technology — or with the lack of one — change over days, weeks, and months. Something that seems trivial on first inspection, like a map that can automatically detect the current location, may become indispensable. Conversely, something that seems valuable on first glance (such as getting text messages whenever friends update their Facebook status, for example) can become tedious or uninteresting with repeated exposure.

As ubiquitous computing devices are largely novel, it is difficult for researchers and for potential users to predict the long-term value of any given technology. An idea that sounds uninteresting as a concept may be embraced when actually experienced (the Nintendo Wii's popularity with senior citizens, for example). On the other hand, descriptions of the Segway scooter sounded exciting and futuristic, but the actual adoption rate was quite low.

Diary studies are a solicited method for getting insight into long-term use. The general technique consists of regularly prompting a group of volunteers to describe their experiences. Diary studies can either examine people's use of technology (say, a new phone) or their experience with a problem that the technology is trying to solve (for example, managing caloric intake while eating out).

A common diary study method gives participants a simple questionnaire to fill out on a regular basis. The questions can be about people's attitudes toward a task they do, a technology they use, or a log of their behavior. Participants can complete diary entries daily or weekly, prompted by an e-mail or text message, or a specific event can trigger them. Researchers can ask participants to take photographs and videos, and save artifacts, in addition to filling out questionnaires. The technique is very flexible.

For example, Colbert (2008) described a diary study where participants documented plans they made to meet in a specific location with others. The participants were encouraged to fill out a questionnaire soon after they made plans with someone else. Such structured diary studies are typically easier for participants to fill out than unstructured ones, although they provide less opportunity for unexpected information and need to be worded to not lead the participants to answer one way versus another. Yet another variant is experience sampling,[10] in which participants answer questions whenever given a specific signal. Traditional experience sampling is conducted using a pager to signal that it is time to fill out a paper form, but such research can be now be conducted using forms sent as e-mail messages to mobile phones or through instant messaging.

Diary studies can also involve in-person interviews where the participant can review individual entries with a researcher and provide context and background. A typical sequence of these can be:

- An initial interview, where the researcher explains the structure and purpose of the project and gets background on the research participant.
- An in-process interview, where the participant and researcher discuss specific diary entries and adjust the process as necessary.
- A concluding interview, where the two review the project and the results. If the research is investigating the technology, this is an opportunity to get the perceptions of the participants about the technology, how those perceptions changed, and how they compare to actual behavior.

14.1.2.3 Design Probes

> The core of the probes approach is to give people (possible future users) tools to document, reflect on and express their thoughts on environments and actions.
>
> *Hulkko et al. (2004)*

The design probe is a relatively new technique to help designers understand people's experience and to inspire new design approaches. Like a diary study, probes give people devices or activities to perform and document their experience over extended periods. Unlike a diary study, the technique encourages unexpected, poetic, and interpretive responses to highlight or exaggerate attitudes or behaviors that people would otherwise not document.

Cultural probes (Gaver et al., 1999) are used to help designers form interpretive responses to people's lives without observing them directly like a diary study would. These probes consist of packs of evocative materials. The packs can include cameras, workbooks with exercises for participants to use when

[10]Csikszentmihalyi and Larson (1987) originally developed experience sampling (or ESM) for social research in the 1970s. Design ethnographers adopted it in the 1990s and 2000s. See Consolvo and Walker (2003) for a ubiquitous computing-specific interpretation.

exploring ideas, colored pencils and markers, online social networks, etc. These are coupled with open-ended activities that can be delivered as postcards (Roibás and Johnson, 2008) or mobile phone messages (Hulkko et al., 2004). These activities can be straightforward documentation exercises or they can be deliberately ambiguous tasks that force participants to think about their lives in unfamiliar terms. Participant responses, which may be just as ambiguous as the questions, then force the analysts to rethink their own expectations.

Thus, Roibás and Johnson (2008), in a study for a phone company, asked participants to photograph things or events they would like to photograph with their phone and then to draw a map of their house, marking on it where they like to be alone and where they like to meet people. To understand what participants wanted in house cleaning technology, Wyche (2004) asked participants to write a help wanted ad describing the skills they would want in a cleaning person. To understand how technology communicates intimacy, Vetere et al. (2005) asked couples to keep scrapbooks documenting their communications, noting emotion and completing evocative phrases ("I misunderstand my partner when…"), which were delivered as stickers.

Technology probes (Hutchinson et al., 2003) try to understand people's relationships to technologies by using partially functional, sometimes whimsical devices to explore people's relationships with and attitudes to certain kinds of technologies. For example, one project proposed installing a robot to weed small gardens and send photos of flowers and plants to the garden owner.[11] How would different kinds of gardeners react to that? The goal is not to evaluate the desirability of robotic weeding technology — it is unlikely to exist for domestic use for many years — but to understand a gardener's relationship to the idea of automation. Most gardeners are comfortable with taking phone calls in their garden and participating in online garden forums, but what are the limits of technologies in relationship to home gardening? A probe that sits outside of expected uses of technologies in gardens creates a point of discussion for identifying what the expected uses are.

14.2 IDEATION

Technologies are created, not discovered. Nor is innovation just identifying unmet needs in a target audience's life. Despite the popular rhetoric about "discovering" needs, some needs do not exist until a product creates them. For example, people likely did not buy white carpets before vacuum cleaners created the opportunity for the emergence of a new desire (Cowan, 1983).

Design changes technologies and it changes people. Every new product design does two things: it extends the capabilities of devices and it shifts

[11] Thanks to Elizabeth S. Goodman for this example.

people's expectations for what is possible and valuable. Designs based solely on observations carry with them the assumption that the future will look a lot like the past, which is only partly true. The past is important, but backward-facing design rarely succeeds in creating long-term change and provides little information about replicating unexpected successes or avoiding unexpected failures.

To alter expectations of what is possible and desirable requires understanding why certain design choices were made. To justify choices requires defining a design space, exploring it thoroughly, and documenting the exploration. Ideation is a way to develop and test design hypotheses about technologies and people in a controlled way.

For example, the "Vision of the Future" project by Philips Design in 1995 (Baxter et al., 1998) generated 300 different product use scenarios, extensively prototyped 60, and created short films for each showing how Philips envisioned people using them. None of the prototypes became products, but the process defined the Philips approach to consumer product design for more than a decade.

Of course "generating new ideas" and "exploring a design space" are easier said than done. Fortunately, creativity is not magic, especially in user experience design. There are many effective idea generation methods, ranging from brainstorming and mood boards to decks of specialized cards[12] and innovation games. Several emerging techniques useful to ubicomp user experience design come from outside of the standard industrial design and creativity and problem-solving[13] toolkits. These next techniques are adapted from a variety of fields and represent the rich variety of approaches for generating and documenting many design ideas in a short period.

14.2.1 EXTRAPOLATION

Extrapolating current trends is a popular scenario planning[14] method. Scenario planning typically selects issues from four classes — political, economic, social and technological[15] — to see how changes in any of them affect a company or a product line, creating new challenges or opportunities. Similarly, extrapolating from identified trends generates new design ideas and insights.

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[12] IDEO's Method Cards (ISBN 0954413210) are probably the best known, but the practice goes back to at least Eno and Schmidt (1975).

[13] See Michalko (2006) or de Bono (1999) for many more examples of general approaches to creative problem solving.

[14] See Schwartz (1996), Pillkahn (2008), and Wilson and Ralston (2006) for more detailed descriptions of scenario planning.

[15] Often collectively referred to as PEST, presumably to be swatted with SWOT — strength, weakness, opportunity, threat — analysis.

14.2.1.1 Extrapolation Across Demographic Groups

Differences in income, employment, location, and age are broad indicators of differences in relationships to technology. By imagining what would happen if a technology designed by one demographic was adopted by another, it is possible to generate ideas about how that technology can be useful in unexpected places and how it would have to change to be valuable to new markets.

For example, someone who grows up as a digital native (Prensky, 2001), sharing personal information on the Internet with friends, schoolmates, and strangers, might have a different attitude about sharing personal information as an adult. As this person moves into the working world, expectations for self-presentation through digital devices in a business context may be quite different from previous generations' expectations when compared to the expectations of someone who did not grow up sharing on a social network. What does this mean for how the digital native would use other technological devices? What does it mean for the non-native in a workplace of natives? Each of these questions can generate a response in the form of a product or service design, or many designs.

Virtually any relevant demographic data[16] can be used as a starting point for ideation based on demographic extrapolation. For example, a survey (PriceGrabber.com, 2009) reported that 53% of North American respondents who own Web-enabled phones said they bought their first one in the previous two years. These statistics point out that most people who can access the Internet through their phones have only been aware of it, or had the capability, for two years at most.

What will happen after these people have been knowingly using Web-enabled phones for five years? Many European countries reached these levels several years before the United States. How is this reflected in their attitude toward devices? Can that be mapped to American users?

14.2.1.2 Extrapolation Between Domains

> Colorful, affordable, available at malls and simple to operate, beepers are hip accouterments among the young. Marketers say people 35 or younger account for up to 80% of retail pager sales, a booming business that barely existed before 1991.
>
> *David Dishneau*, LA Times, *June 30, 1994*

Mapping documented behavior with one technology to another is another source of design idea creation.

Such forecasting by analogy requires finding a well-documented technology or behavior, then imagining replacing the technology or behavior with an analogous, hypothetical one and working through the differences and similarities. For example, as mobile phones grew in popularity, manufacturers

[16] Pilkahn (2008) has a good list of public sources in Appendix I.

could have looked at pagers as a model of who would buy them, when, why, and how they would use them. Even a simplistic model ("mobile phone adoption will be exactly like pager adoption") could have been sufficient to generate a range of design directions for phones and phone services. For example, colorful Motorola pagers became a fashion hit in the early 1990s, but it took until the late 1990s for Nokia to introduce their first mobile phone in a choice of colors.[17] That delay could have been intentional, or it is possible that Nokia's designers did not look at the pattern of pager adoption (first as niche tool, then as consumer electronic, then as fashion item) and project that mobile phones would quickly become fashion objects.

Today, we might compare house media servers to other home appliances and extrapolate based on the adoption and use of those devices. Home media servers share certain characteristics with automatic espresso machines, DVD storage racks, garage door openers, trash compactors, water purifiers, and closet organizers. What can be learned about media server design by examining people's attitudes toward those devices and how each of those devices is used?

14.2.1.3 Extrapolation by Orders of Magnitude

A digital device that is expensive and rare today is likely to be cheaper and more common at some point in the foreseeable future. Extrapolating from current use leads to insights about device adoption. One simple way to generate ideas about how a technology could be used is to multiply its prevalence by one or two orders of magnitude or to divide its price by similar amounts.

In other words, multiply the prevalence of any given technology by ten, or pretend it costs one tenth as much. How would that affect how people use it? What if there were ten times as many glowing screens in every room as there are today? A hundred? This was the question that led Appliance Studio to the development of RoomWizard (Chapter 11).

What if a relatively expensive technology today, such as bright digital video projectors, was 10% the price it is today? What if it was 1%?

14.2.2 NEW IDEATION TOOLS

Traditional ideation methods either rely on a single person told to make up "a bunch of ideas," on small groups formed for one-day brainstorming sessions, or on consultants hired to do the same. Although any method can lead to innovative ideas, all the traditional methods have significant limitations. The following techniques use collective distributed labor and the talents of an entire team to create unexpected and inexpensive sources of inspiration that come from a wide group of people.

[17]With the Nokia 252, introduced in the fall of 1997 in the United States (Nokia, 1997).

14.2.2.1 Crowdsourcing

People are creative and like interesting challenges. Many of them spend days in cubicles or at home out of necessity. Crowdsourcing (Howe, 2006) uses their available time, Net connectivity, and collective ingenuity to perform work that only people can perform. Using Amazon's Mechanical Turk, a generalized platform for crowdsourcing work in exchange for small amounts of money per task, an ideation technique could work like this:[18]

1. Invite people to generate ideas using a fixed set of criteria.
2. Generate hundreds or thousands of ideas.
3. Invite other people to evaluate the quality of the ideas generated by the people in the first group. Use multiple people to evaluate each idea (or set of ideas) and average the results.
4. Use the highest rated ideas as seeds for further ideation in-house.

Because Mechanical Turk costs so little per task, it is possible to generate hundreds or thousands of ideas on a given topic for relatively little money. But the challenge is to generate good ideas. As Krieger (2009) documented, unrestricted public ideation can lead to chaos. His project to generate ideas using Mechanical Turk for technologies "to promote healthy eating"[19] was built on a significant amount of research into what had caused other crowdsourced projects to fail. Villarroel and Tucci (2009) determined that most people participating in Mechanical Turk were doing it equally for fun and money. Thus, effective crowdsourced ideation requires balancing fun and money, while maintaining structure and effective evaluation mechanisms.

[18] Amazon's Mechanical Turk is a general crowdsourcing platform, but crowdsourcing models also exist for specific design processes. For graphic design, for example, there are (as of spring 2010) companies like 99designs and crowdSPRING; Quirky is a crowdsourced product development platform and Kickstarter is a crowdsourced funding company. By the time you read this, entire crowdsourced product development economies may have sprung up based on tools that get participants to generate, evaluate, design, fund, manufacture, market, sell, and buy products. Or not. It could just be a fad.

[19] This was a sample question to evaluate a system that crowdsourced new ideas based on a core of existing ideas.

14.2.2.2 Bodystorming

Acting out scenarios can suggest opportunities or reveal problems that would not be obvious when "brainstorming" in a studio, office, or lab. In shopping malls, urban streets, parks, schoolrooms, etc., designers can observe people directly, create prototype responses, and talk to prospective audience members to gauge their reactions to the ideas. Placing developers bodily into situations where the products of their work will be used lets everyone use all their senses to understand the context for which they are developing.

14.2.3 OBSERVATION AND IDEATION AS RISK MANAGEMENT

> It is one thing to recognise that an innovation progresses by means of decisions, some of which are occasionally implicit; it is another to maintain, as we have started to do, that these decisions are made in the middle of uncertainties amongst which it is practically impossible for a sure case to be guaranteed. Such is the paradox which should never be forgotten.
>
> *Akrich et al. (2002)*

Observation and ideation both take a lot of time and designer resource. So why do them? They are done to minimize the impact of unintended consequences. As risk management strategies, they reduce the chances of outright failure. In making decisions, the goal is to create design processes that are resilient but not rigid, and that can adjust quickly to changing market circumstances and unexpected behaviors.

This key justification for knowing as much as possible about your audience or exploring as much of the design space as the budget allows is not to generate that genius Apple-beating design. Nothing substitutes for the skill and intuition of the development and design teams. But even the best development team is imperfect. We are human; our intuitions and even our systematic logic are fallible in the face of factors outside our knowledge or control. To make a financial analogy, the point is to make bets based on a fundamental analysis of the audience through observation and to create a hedge against the unexpected with a diversified portfolio of ideas. To do neither is to be at the mercy of unintended consequences.

CHAPTER 15

SIMULATION AND SKETCHING

There is a moment in nearly every project when someone asks, "Wait, *what* are we making, again?" That moment may be scary for the project lead ("Wait, you don't know?"), but the discussion that can follow is actually productive. It is in situations of insufficient communication and product definition that team members have no doubts about what they are making. It is just that everyone is making something different.

Repeatedly examining and refining the whole team's understanding of the experience goals and methods to achieve them builds a shared definition of the project. As the team describes the experience they are creating — what their project will do, and how — they generate a common vision that goes beyond a functional specification to include how the project will accomplish its goals, what those goals are, and why they were chosen.

Achieving such vision requires progressively focusing the team on the details of the experience, starting with abstract strategic goals and ending with small design details. For example, button color rarely matters early in the process, but button appearance, which contributes to forming a cohesive device identity, can become critical later. It is tempting for nearly everyone (engineers, designers, managers, marketers) to jump into designing specific details. Those concrete decisions produce artifacts (visual mockups, circuit diagrams, models, etc.) that give the impression of progress toward completion. Unfortunately, such detail-first experience design rarely produces the results that the design team expects. Details take a long time to work out, and designs have intellectual momentum that makes it difficult to envision a different solution later. It is easy to get all the details perfect and have made the wrong thing, or the right thing for the wrong audience.

Few organizations can afford to produce more than a couple of detailed, working ubicomp device or environment prototypes before the economic realities of engineering and manufacturing force them to start developing the final product. This expense encourages development teams to make working prototypes of conservative concepts for fear of wasting precious resources on things that will not function, but sidesteps the core questions of whether the functionality is even appropriate or presented correctly. Thus, the design team ends up making final design decisions based on a handful of conservative explorations, which were based on untested assumptions.

This combination of attitudes leads to a pathological situation where companies ship products that are simultaneously both conservative and half-baked, virtually guaranteeing either failure or unrepeatable success. When they fail, the company may not understand whether the technology was wrong, badly implemented, or that it did not go far enough. When these products succeed, the company may not know why either, because the functionality was not rigorously defined. As Buxton (2007) said, it is not just a question of getting the design right (developing/designing/engineering well), but getting the right design (developing the right thing).

The way out of this dilemma — of overly effortful prototypes that actually exclude exciting ideas from implementation — is to aim for "just enough" prototyping. By simulating functionality *wisely* rather than *exactly*, the design team can explore key ideas and get a rich understanding of what is being done, and just as important, why, without having to spend energy and money making working devices. Chapter 14 described how to use observation and ideation to shape a design space around people's behavior and explore potential solutions within it. This chapter focuses on methods for further mapping the defined design space. Simulation uses ideas from theater and film to focus on the effect a technology induces in its audiences, whereas sketching uses lightweight methods to rapidly create designs and technology prototypes.

15.1 SIMULATION

Simulation corresponds to a short-circuit of reality and to its reduplication by signs.

Jean Baudrillard, Simulacra and Simulation, *1981*

Simulation is a kind of drama. Media creates a sensation of *realness* so that the audience can suspend their disbelief long enough to provide authentic reactions to the unfamiliar things they are seeing and hearing. Simulation takes place in the world at large, not just on a screen. In fact, simulating ubiquitous computing user experience design has much in common with theater.[1] In this theater of design, devices are props, environments are stages, users are actors, and user experiences have internal narratives.

This section describes a handful of techniques that are particularly appropriate for ubicomp user experience design, but the history of drama (in theater, film, role playing, etc.) still holds many valuable ideas that are not covered here.

[1] Laurel (1993) first described computers as a kind of theater with the screen as the stage and the monitor bezel as its proscenium arch.

15.1.1 SCENARIOS AND STORYBOARDS

Scenarios are mini scripts that describe situations where a product is used. Storyboards, first used in film, visualize a narrative. These two techniques work together to simulate key moments in the use of a product, help the team understand the nuances of the product experience, and communicate key aspects to people outside the group.

Scenarios can take virtually any format that tells a story about a product and people. As mentioned in Chapter 14, the "Vision of the Future" design exploration by Philips (Baxter et al, 1998) generated 300 future product scenarios to help the designers understand the capabilities of the technologies and people's needs. Each scenario described a situation where a new product could be of benefit. Philips used five parameters (a variation on the familiar set of who, what, where, and when interrogatives) to describe each scenario:

- People
- Time
- Space
- Objects
- Circumstances

With each of these parameters defined, the scenarios tell a short story about people (characters,[2] borrowing from theater), environments (sets), situations (plots), and how products (props) introduced into that situation change people's experience. The resulting description is like a use case or user story in software development, but more detailed, evocative, and focused on the value of the experience to people.[3] As in drama, one product can be the subject of multiple scenarios, the same people can experience different situations, and the same situation can be played out with different products or people. For one single product, a team can write scenarios that describe, for example, an ideal everyday use situation, a first use scenario, and an edge-case (someone who uses the product ten times as heavily as an everyday user). The point is to tell detailed stories about a specific user experience and to use the process of creating the scenario as an opportunity to better understand the details of the experience and to share that understanding among the team.[4]

The user experience design practice created the term persona (Cooper, 1999) to describe an extensive fictitious profile of a person for whom a product or experience could be useful or interesting. From the perspective of scenario creation, personas are the characters in the mini drama described by experience scenarios.

See Chapter 2 of Cohn (2004) for a good comparative discussion of use cases, user stories, and scenarios.

See the section on bodystorming in Chapter 14. It is an effective technique for understanding people's experience in a way that is very scenario-like and can be a good input in a scenario creation process.

Figure 15-1

A user experience storyboard. (Image © Rob Enslin, licensed under Creative Commons Attribution 2.0, found on Flickr)

Once a scenario is written, it can be turned into a storyboard (Figure 15-1). Traditional film storyboards are drawings of camera shots. These shots are pinned to a corkboard (so they can be replaced or re-sequenced), or laid out in a sequential series of drawings (like a comic book). Each drawing illustrates a key element of the shot or scene, along with directions about how the actors should move or what the camera should do. For example, a single action movie storyboard drawing can show a car careening around a bend to the left with camera directions that indicate that the camera pans to the right to show another car in hot pursuit. The next drawing can show the inside of the first car, with the second car visible through the rear window and indicate a slow zoom onto the face of the first car's driver.

User experience storyboards describe stages in a technology interaction. Unlike a film, however, user experiences can have multiple outcomes based on the users' choices. Thus, a single product or environment can have multiple storyboards describing possible experiences or interactions. Storyboards are particularly valuable in helping people (developers, stakeholders, etc.) imagine the various scales of a multiscale interaction (Chapter 12). Imagine a person controlling a giant interactive wall installation by dancing. A storyboard can show the perspectives of the dancer, a close-up audience member, and a far-away viewer. The dancer's perspective will make it clear that everybody — because of the scale of the architecture — gets a different vantage point. It also makes clear that the value of the designer is in choreographing those different vantage points and giving the dancer a platform to work from.[5]

Although traditional film and user experience storyboards are hand drawn,[6] it is not necessary in user experience design. Storyboards can include clip art, photos found on sharing sites, staged photos, or computer illustrations. Since there are multiple possible paths through ubiquitous computing interactions, storyboards are often delivered interactively in a presentation that demonstrates how different decisions lead to different experiences (Jones and Marsden, 2006).

15.1.2 RAPID VIDEO PROTOTYPES

> Film or video enables one to build the ultimate demo out of pure "unobtanium." Gone are hardware limitations and computer artifacts. Everything works perfectly […]. [This is] both the advantage and curse of video prototyping. Will you end up with a prototype of a system that can be built, or only a slick piece of propaganda?
>
> *Bruce Tognazzini (1994)*

User experience designers have long used film and video to envision how future technologies could work since the earliest days of industrial design and filmmaking: the Bauhaus design school made a film showing all of their technology prototypes in 1926[7] and the Frigidaire film *Design for Dreaming* (Figure 15-2) made in 1956 envisions a future where all domestic chores have been designed away through automation. Apple Computer produced *Knowledge Navigator* in 1987 to help then CEO John Scully evoke the future of networked computing to a group of educators (Dubberly, 2007). Sun Microsystems used *Starfire*, created

[5] Thanks to Elizabeth S. Goodman for this example.
[6] See Holtzblatt et al. (2005) Chapter 12 for a detailed description of one method for creating storyboards for user experience design.
[7] Humboldt GMBH, "Wie wohnen wir gesund und wirtschaftlich. IV. Teil: Neues Wohnen. Haus Professor Gropius, Dessau" (How we live in a healthy and economic way. Part IV: New Living. The House of Professor Gropius, Dessau), 9 min., 5 sec., Bauhaus-Archiv Berlin, 1926.

Figure 15-2
Still from Design for Dreaming, *a 1956 concept film © Frigidaire. (Public domain film available on the Internet Archive)*

between 1992 and 1994, as a genuine prototype, rather than as an exercise in evocative corporate science fiction. They wanted it to "be a video prototype of a real proposed system, capturing enough detail of the interaction methodology to display the concepts. The software interface had to be capable of reaching maturity within ten years" (Tognazzini, 1994).

The practice of creating conceptual technology videos as marketing and design exercises continues today. In 2008, Adaptive Path created a vision of a future Web browser called Aurora for the Mozilla Foundation[8] (Figure 15-3). In 2009, Adobe, Microsoft, and Nokia all created videos exploring how computing could affect a variety of fields (productivity, health, manufacturing, banking, retail) in five to ten years (Adobe, 2009; Microsoft, 2009; Nokia, 2009).

These high-quality cinematic future visions take many people months to produce. Each communicates a compelling vision to employees, to industry analysts, to the press, and to the public at large. Many have influenced the industry as a whole. Unfortunately, very few organizations have the resources to produce such high-quality films.

For those with shallower pockets, shorter time lines, and more of an interest in exploring a set of ideas (as part of a design process, or as a research tool to gather end user input), there is another effective way to use

[8]http://adaptivepath.com/aurora/.

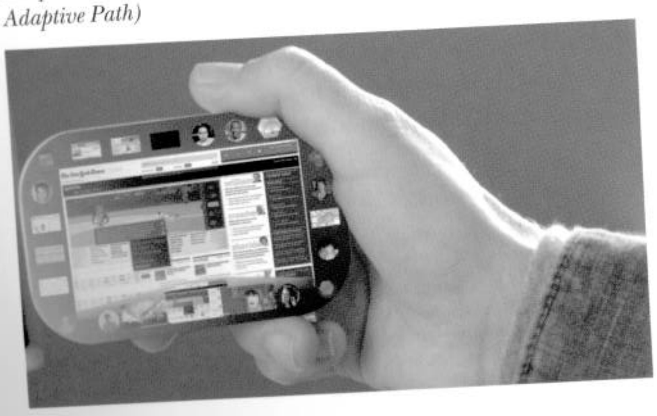

Figure 15-3
Still from a concept video prototype for the Aurora next generation browser by Adaptive Path. (Courtesy of Adaptive Path)

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video simulations. Using consumer-grade video hardware, teams can create rapid video prototypes in hours or days, for very little money, and with very few people.[9] Unlike the fully realized visions described above, video can be used like throwaway paper sketches in an idea generation process. A rapid video prototype is a quick exploration of user experience ideas that intentionally ignores technical details in favor of concretizing and communicating the experience. The value of making videos lies as much in the process as in the actual finished videos. Creating a video forces the team to work through the details of the experience so that the simulation is believable. One group of Kingston University students even called their set of design videos "As If By Magic."[10]

Here is a rough outline of how to create one of these videos:

1. Get a digital video camera and editing software. Nearly every new computer ships with editing software.
2. Write a basic script for your video. A typical video will be about two minutes long and feature about twenty shots divided into a simple three-act narrative:[11]
    - The problem. A handful of shots describe a problem. For example, in the days before widespread GPS wayfinding devices, a rapid video prototype for a phone-based mapping product could have told a story about finding a building in Tokyo. It starts like this. A tourist holding a business card walks up to a neighborhood map outside the train station. She tries to compare the address on the card to the map and scratches her head in puzzlement.
    - The technological experience. A handful of shots describe how the proposed design addresses the problem. In the Tokyo example, the lost tourist then takes a picture of the address using her phone's camera and e-mails it to the proposed mapping service. Seconds later, an e-mail arrives with a map of the area with the address highlighted.
    - The resolution. This is the result of using the proposed design to change the situation. The Tokyo visitor compares her phone map to the train station map, has an "aha!" moment, and walks confidently away. The last shot shows the visitor arriving at the destination and throwing the business card away[12].

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[9] Digital consumer video is probably the most widespread form of everyday ubiquitous computing, so there is also an amusingly recursive aspect to making ubicomp concept videos using everyday ubicomp.
[10] Sadly, the Web site for this project is gone, but a search for "As If By Magic Kingston" on YouTube brings up a handful of the videos.
[11] Classic Hollywood three-act screenplays have three parts: the setup, the confrontation, and the resolution. What is described here is essentially the same thing, compressed into a handful of shots.
[12] Even this may be more narrative than what is necessary to explore the interaction between the lost tourist and the maps by e-mail service. All that may be required is the second act.

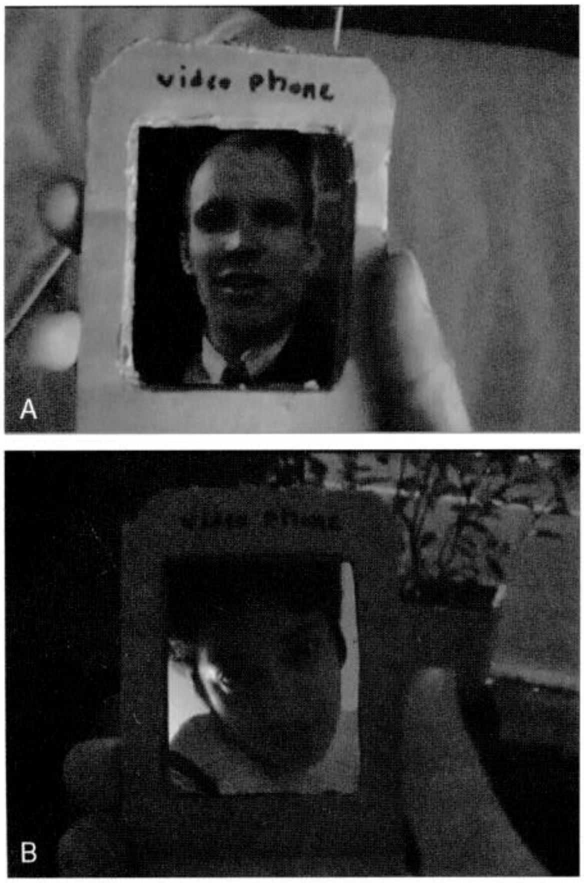

Figure 15-4

(A and B) Stills from a concept video showing a video phone prototype made of cardboard. (© 2004 Søren Pors and Aparna Rao, used with permission)

3. Make the props. These can be existing products that stand in for new technologies, partially functional prototypes, or completely faked mockups. For example, a tablet PC running an Adobe Flash interface can stand in for a dedicated control panel. An old phone with a color printout taped to the screen can simulate a new phone. Søren Pors and Aparna Rao simulated a smart phone video karaoke application using nothing but a bent piece of cardboard with a hole cut in it (Figure 15-4A and B). Howard et al. (2002) said "Props can literally be any artefact." Like good improvisational actors, they used what was close to hand. A wristwatch, coats, and various kinds of sports equipment served as wearable devices, pens became styluses, and a chunk of balsa wood and a cardboard pizza box turned into handheld and tablet devices.

4. Add special effects. A jump cut between two shots can replace a complex technological change in state. One second the world is one way; the next moment it is changed. More complex effects add more realism. Pors and Rao used a close-up of the cardboard phone as a backdrop and put a rectangle of a singing person to simulate the screen.

It is important to remember that the process of making these videos is as important as the product. As Mackay et al. (2000) described, the value of video prototyping goes even beyond design exploration. While video prototypes helped developers build software prototypes, they also found that the process of working together to make props, act out stories, and work the camera changed team dynamics. As they wrote, "It is difficult to sit quietly when everyone else is preparing for a new 'take.'"

15.1.3 PAPER PROTOTYPES

> In a paper prototype, the coding effort is always zero.
>
> *Carolyn Snyder,* Paper Prototyping *(2003)*

Paper prototyping uses the oldest, cheapest, most flexible, and most common everyday technology: paper. The entire experience (whether it is a product, a service, or, as described next, an environment) is constructed from paper products (Figure 15-5).

The basics of paper prototyping are quite straightforward:[13]

[13]See Carolyn Snyder's book *Paper Prototyping* (2003) for an in-depth description of how to create paper prototypes and conduct user experience research with them. This section is almost entirely based on that book.

1. Create a prototype that "looks realistic enough to elicit feedback for the issues you're most worried about, but it doesn't need to be any better than that" (Snyder, 2003). The prototype should include paper representations of all the interface elements that might appear in the activity, including error messages.
2. Recruit representatives of the target audience to evaluate the prototype.
3. Conduct usability tests with the representatives using the prototype. In these, a member of the design team uses the paper components to update displays, move elements, and produce error messages while the evaluator tries to perform tasks.

A facilitator guides the evaluator during the process, as in a traditional usability test.

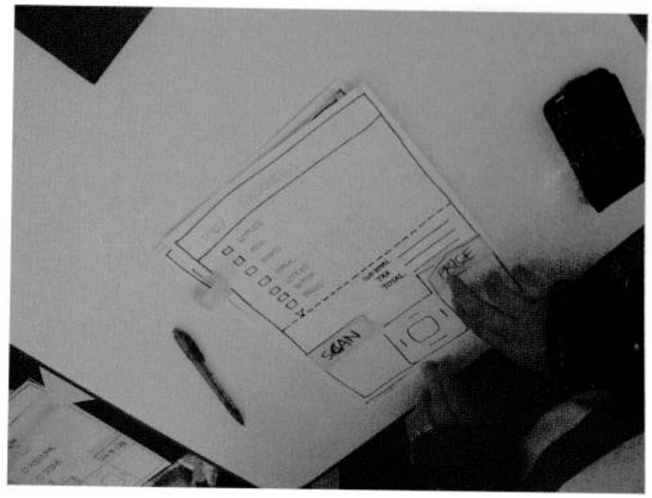

Figure 15-5

Usability testing of a paper prototype of Mobilist, a mobile shared list-taking application. (Photo © Rodolphe Courtier, licensed under Creative Commons Attribution — Share Alike 2.0, found on Flickr)

A paper prototype (Figure 15-6) is a craft project, so the details of its construction depend on the materials available, the experience being prototyped, and the prototyper's skills with scissors, paper, and glue sticks. Any time-saving technique, such as printing out pictures of interface elements instead of drawing them from scratch, is encouraged. One rule of thumb is that it should not take longer than a day to construct the prototype and it is fine — even encouraged — to use whatever materials are available.

A simulation is a kind of fantasy. People have good imaginations and most will willingly treat a thumbtack as a pushbutton. However, the content needs

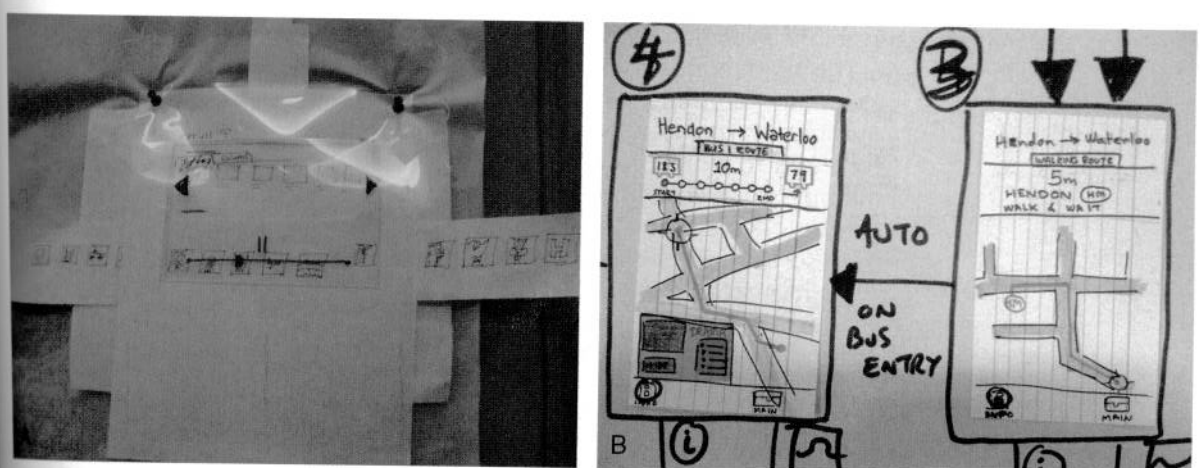

Figure 15-6

(A–C) Paper prototypes. (Photos © Charlene McBride, Andy Bardill, and Samuel Mann; licensed under Creative Commons Attribution 2.0, Attribution — Share Alike 2.0, and Attribution 2.0, respectively, found on Flickr)

(Continued)

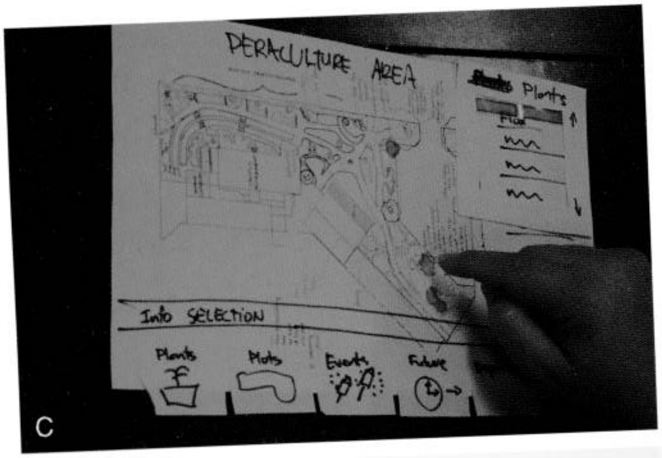

Figure 15-6—Cont'd

to be detailed and meaningful to preserve the fantasy. As Snyder (2003) said, "If your users are accountants and you're testing a financial application, the numbers had better make sense."

This approach can be used to both explore design ideas and answer specific questions. Snyder (2003) described a desk phone paper prototyping project (see Sidebar: An Example of Preparing, Making, Testing, and Analyzing a Paper Prototype) that did both.

Sidebar: An Example of Preparing, Making, Testing, and Analyzing a Paper Prototype

The designers wanted to make the phone interface intuitive, but in some cases they had what seemed to be equally viable ideas about how to implement functionality. During the design phase a number of questions arose, for example:

- Would users adopt an object–verb approach (for example, looking up a number first and then dialing it) or verb–object approach?
- Which was the easier method of searching for stored phone numbers: scrolling through the entire list or a divide-and-conquer method using the left-hand buttons to divide the list into successively smaller chunks?
- Should they create novice and advanced modes, where only a subset of functionality would be available by default and the user would need to explicitly access the more advanced functions? Or would this just be confusing?

The team conducted four tests of their paper prototype. Users were asked to complete various tasks (such as calling a previously stored number or transferring a call) by touching the paper prototype buttons and to explain their actions aloud as they went. One of the team members played Computer, swapping screens in response to the users' actions. There was also a physical model of the phone sitting on the desk so that users could see what the real phone might look like, but they interacted only with the paper prototype.

The team got answers to their original questions and more. Users naturally used the object–verb method, so there was no need to support the verb–object approach. The divide-and-conquer method for searching was better than scrolling, although eventually the team came up with a type-in search method that was superior to both. The novice mode did not work. Although hiding advanced options seemed like a good thing, it was too hard for users to find them when they were needed — they had no idea where to look.

From Snyder, C., *Paper Prototyping*. Morgan Kaufmann, 2003, with permission.

Figure 15-7

Ritual Roasters Café was originally prototyped using cardboard boxes. (Photo © Timothy Vollmer, licensed under Creative Commons Attribution 2.0, found on Flickr)

Paper prototyping can extend to the environmental scale. There is a long tradition of scale models and maquettes in stage design, architecture, and industrial design. In some cases, designers have gone beyond models to simulating a complete immersive experience using paper and cardboard.

For example, the owner/designers of Ritual Roasters Café (Figure 15-7), a San Francisco café, prototyped their entire interior design in cardboard.[14] They first developed patron personas: the commuter grabbing a cup on the way to work, the freelance writer working on a story, parents with strollers meeting mid-afternoon, the couple on a first date, etc. They wanted the café furniture and fixtures to direct the traffic flow while creating a good experience for each persona. Yet they felt that CAD models would not help them predict how they would feel in their long, narrow, high-ceilinged space with all the furniture installed. With years of café work behind them, they had a sense of what proportions worked, but only at café scale. They could not translate that expertise into a smaller scale model. They decided to simulate the space using cardboard appliance boxes to represent counters, tables, and chairs. They then spent several days moving boxes around until the distances between the door, the coffee counter, the sofas, and different sized café tables felt right for the experiences they wanted to create. Then they documented the exact location of every box for their architects, who adjusted the building plans appropriately. Ritual Roasters Café went on to win critical acclaim for its architecture.

[14] Thanks to Eileen Hassi, owner of Ritual Roasters Café, for this case study.

Figure 15-8

Wizard-of-Oz prototype. (Photo © Michel Jansen, used by permission, found on Flickr)

15.1.4 WIZARD-OF-OZ

At some point a design team needs questions answered beyond what is possible with participants' imagination applied to props. Wizard-of-Oz prototyping simulates a technological effect, but a person "behind the curtain" does the work of the computer (Figure 15-8).[15] Say a team is developing a handheld ultrasound machine to replace the bulky machines on rolling carts. A paper prototype, or even a plastic mockup, can answer whether the controls are arranged in a way that makes sense to the operators of the ultrasound machine. But using an ultrasound machine is a highly interactive experience and exploring the interactive experience may be impossible without an ultrasound of an actual human. Unfortunately, it is highly impractical to make multiple working prototypes with different layouts. However, it may be possible to simulate the experience using a real ultrasound machine operated by a hidden operator, and fake controls operated by test users. As an operator uses the simulated portable ultrasound machine, someone watches what that person says they are doing and simulates the results using the controls of another machine hidden behind a partition.

The specific method used depends on the application, but some examples show the range of possibilities:

- Buxton (2007) described a project where a small portable device was simulated by giving participants a small video monitor and pointing a video camera at a large display. The resolution was low, but worked well to give the designers an understanding of how such a system would work. Such tethered displays are popular when exploring wireless device design. Screens and controls can be embedded in materials such as Styrofoam. The tether connects a screen to a bulky computer, which does all the processing. That way, different sizes and configurations of screens and controls can be tested without the difficulty of engineering the hardware.
- Fogarty et al. (2005) wanted to understand when and where people accept technological interruptions in everyday life. Rather than first taking on the very hard problem of developing sensors that could recognize whether a person was speaking, writing, sitting, typing, eating, alone, etc., they decided to limit the problem by

[15]The Wizard-of-Oz technique is named after the L. Frank Baum children's book of the same name, where the fearsome wizard is revealed to be just a man hiding behind a curtain, who uses basic technological props to simulate magical powers. In interaction design, the term and concept was developed in natural language research (Gould et al., 1983). Language recognition technology was still quite primitive, so the researchers simulated it using people trained to simulate the capacities of researchers' limited language recognizers.

figuring out which sensors mattered most. They asked people to simulate sensors as they watched a video. When someone did a certain action, the human sensor simulator would click an appropriate button on a custom interface that then recorded the time in a video recording when an activity took place. When they tabulated the results their "human sensors" had produced, they discovered that several kinds of sensing were much more relevant than others, which removed the need to actually build many of the sensors they had planned.

- Paulos and Goodman (2004) used a Wizard-of-Oz study to understand whether technologies for communicating social relationships affect people's experience of environments. They sent research subjects on walks through Berkeley, California, with a human guide who verbally simulated the output of a handheld device that displayed social relationships. At specified intervals, the guide stopped, described the output of the hypothetical device, and asked the participants to act out their responses. The researchers used these reactions to understand which relationships to focus on when they went on to build actual social awareness technology. By verbally describing the device's output, they moved the focus from the technological components of the experience to how people felt about the crowds around them.

15.1.5 VIRTUAL/AUGMENTED/MIXED REALITY

When simulating actual circumstances is impossible, such as combat or emergency response situations, it may be possible to simulate that environment using virtual reality or a combination of virtual environments and real devices. Virtual reality worlds and game engines provide the technological infrastructure for constructing environment simulations that can be used as either information overlays on real situations (augmented reality) or in conjunction with physical devices (mixed reality).

For example, Streefkerk et al. (2008) (Figure 15-9) wanted to design handheld devices for providing information to police support. Instead of heading straight to accident sites, they used the Unreal Tournament video game engine to simulate situations of distress. Their system combined a real handheld device with a video game engine. Police officers could use the proposed handheld devices to respond to different virtual situations without having to leave a lab. This allowed the designers to create specific situations, to work with whole teams of officers simultaneously (at different computers), and to analyze people's actions using log files kept by the game engine.

Figure 15-9

Screenshot of USARsim, an urban search and rescue simulator used to develop rescue robot and automated vehicle behavior. (From Wang et al., "USAR: A game based simulation for teleoperation." In Proc. 47th Ann. Meeting Human Factors and Ergonomics Soc., *2003. With permission; Software and Screenshot GPL.)*

15.2 SKETCHING USER EXPERIENCES

> The best prototype is one that, in the simplest and most efficient way, makes the possibilities and limitations of a design idea visible and measurable.
>
> *Lim et al. (2008)*

Note: This section owes a huge debt to *Sketching User Experiences: Getting the Design Right and the Right Design* (Buxton, 2007), which passionately argues for bringing the philosophy of sketching to all design.

Speed, flexibility, and disposability are key qualities for prototypes at the beginning of a user experience design process. Many ideas need to be generated, investigated, tested, and discarded to understand the boundaries of the design space and the capabilities of the proposed technologies. Teams that program software and lay out circuit boards too soon risk burdening themselves with distracting details before defining core functionality and user experience goals.

In practice, it is often better to introduce technology constraints too late rather than too early. Of course, digital technology will inevitably enter the picture because it is the medium of expression for ubiquitous computing. However, because making interactive digital technology is likely the most expensive part of any development process, the challenge is to introduce it at the right point and manage investment in it carefully.

A key component to agile product development is the iterative dialog between designers and engineers. The techniques described here will help progressively explore and define functionality from simple to increasingly complex, and polished, technological solutions. The emphasis shifts from idea generation and design to engineering and manufacturing throughout the process. There is no "handoff" from design to engineering, only prototypes of ever-increasing fidelity.

15.2.1 LOOKS-LIKE/WORKS-LIKE PROTOTYPES

One way to speed up the experience sketching process is to stop trying to package all of a project's relevant aspects into a single object. It is possible to extract some of those aspects and prototype them individually or in well-defined clusters. Selective prototyping reduces the complexity of each prototype and allows a design team to focus its efforts while working in parallel.

Typically, experience design prototypes cluster into three categories:

- Works-like prototypes (sometimes known as *engineering models*) focus on functionality. These are technological proofs of concept. In the beginning, these prototypes ask: How might it work? Later, more finished prototypes prove that the device can actually do what people expect from it, need from it, want from it, etc.

- Looks-like prototypes (sometimes known as *styling models*) are industrial design and visual design explorations. They deal with what Garrett calls the skeleton and surface layers (Chapter 2): what the device feels like when held and manipulated, what associations its visual design evokes, how well it communicates its functionality to its audience, etc.
- Sample content simulates the information displayed.

The level of detail in a prototype varies greatly throughout development. Buchenau and Suri (2000), for example, created a works-like prototype of an airplane interior using conference room chairs for a bodystorming (Chapter 14) exercise. They used this simulation to explore how different layouts worked for eating, sleeping, etc.

Autodesk, the CAD software company, advertises that using their Inventor software as a looks-like prototyping system allows designers to "quickly evaluate multiple design variations by creating realistic, accurate, and compelling imagery from 3D CAD data — helping reduce the time, cost, and need for building physical prototypes" (Autodesk, 2009).

A final kind of prototype, known as the demonstration model (or functional prototype), is one that both looks and works like the final product. These models come late in the development process, and usually serve to function as communication tools for fundraising and corporate communication or to test a design for mass production.

15.2.2 REPURPOSING AND HACKING

> At the second toy company, participants [. . .] prototyped a handheld wireless controller for a TV game. They took the controller's barrel from a soda bottle, and they built the grip from a Gyration wireless mouse that uses a gyroscope to sense tilt, transforming that tilt data into cursor movement. A custom-made plastic mold joined the two pieces into one unit. They then used the wireless mouse's cursor and click events to animate graphics on a laptop (used as a stand-in for a television set) running Adobe Flash.
>
> *Hartmann et al. (2008)*

A design is rarely so novel that it has no precedent among existing products on the market. Modifying existing products can be a shortcut to understanding whether a planned design will work in practice.

Toy designers regularly make prototypes by removing some functions from existing interactive toys and adding their own. In the highly competitive character-driven toy world, hacking an existing themed product (say a Tickle Me Elmo or Barbie) quickly creates a more compelling presentation of an idea than describing it. It is also a much more economical solution than building

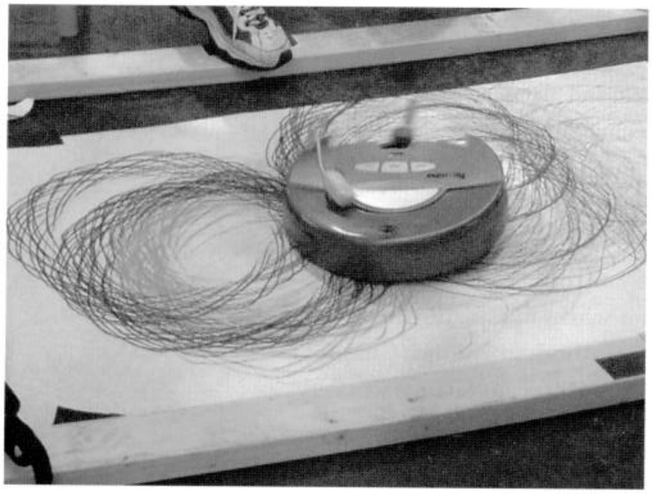

Figure 15-10

Tod E. Kurt's hacked Roomba floor drawing robot. (Photo by Tod E. Kurt. With permission.)

a toy from scratch. To potential investors, the designers can say "It's like a Tickle Me Elmo, but it can understand 50 phrases and react to them." For initial play testing, engineering an entire toy from scratch to test one new feature makes little sense.

Some companies encourage such re-use by engineering hackability into their products. iRobot included a communication port on their Roomba vacuum cleaner, which led Tod E. Kurt (2006) to develop dozens of ways to use a Roomba besides cleaning floors: as a drawing tool (Figure 15-10), a musical instrument, a remote controlled moving camera, etc. By treating every already existing industrial object as a set of components, hardware hacking turns the existing material world into a giant toolbox.

The general principles of hardware hacking are:

- Take things apart to become familiar with other designers' solutions. The more familiarity a design team has with existing solutions, the less they have to reinvent (intellectual property concerns notwithstanding). In some cases it is not even necessary to take products apart: others have already done so and documented the autopsy. Many Web sites show teardowns of late model hardware, dissecting products, and identifying what they find with high-resolution pictures and parts lists.
- Make a library of products that have interesting industrial design qualities or functionality. Some products will make great skins for new functionality, while others will be good platforms for augmentation or just inspiration.
- Break things. It is nice to be able to undo any hack (all of Kurt's Roomba hacks are completely reversible), but not necessary. Virtually every product ever manufactured is available used on eBay. People who void their warranties can just buy a replacement and start again. Working with hardware means accepting the lack of an undo command.

Sidebar: Design for Hackability and Self-Disclosure

Like iRobot's Roomba, all products should be as hackable as possible, given the economics of manufacturing them. Hackability should not be seen as an invitation to give away intellectual property, but as a cheap research strategy. It is impossible for companies to anticipate all possible uses for their products. Post-Its, for example, have a universe of different uses.

Companies have trouble making even one version of a product successful in even one market, not to mention every possible market. Competitors who desperately want to steal intellectual property to compete directly will do so regardless of whether a product is well documented. But people who may want to slightly adapt that product to a new use, and broaden its customer base in the process, will not be able to if it is completely locked down. The most effective way to encourage such tangential repurposing is through simple documentation of internal functionality.

For example, WowWee, a toy company, clearly labels all of the connectors on their circuit boards in English, rather than a company internal code. Plain-English labeling is both hacker-friendly and completely free. Epic Games intentionally made the Unreal Tournament game engine open and documented, and it has now become a standard platform for virtual/augmented reality experimentation. Apple Computer gives away a sophisticated development environment and documentation with every computer it sells, turning every buyer into a potential developer of software to sell future Apple computers.

With the price of storage dropping quickly, we also have the potential to create self-disclosing devices (Greenfield, 2006; Sterling, 2005). Self-disclosing devices have built-in documentation of ownership, licensing, purpose, and operation. These devices can include instructions for how to disassemble them and recycle them safely.

15.2.3 TOOLKITS, BREAKOUT BOARDS, AND SKETCHING IN HARDWARE

Sometimes it is necessary to build devices "from scratch," but this does not mean "from the basic components." Many recent products make it much easier to assemble sophisticated hardware components into interactive prototypes, translating the ideas of object-oriented software development into hardware.

Developed specifically for ubiquitous computing user experience design prototyping, the Arduino[16] I/O board (Figure 15-11) has become the most popular platform for such prototyping. It blends the idea of easy-to-learn microcontrollers, pioneered by the Parallax Basic Stamp, with a rich development environment and active user community, such as that cultivated by LEGO Mindstorms. More Important, the Arduino also depends upon and extends an existing community of open-source development for the arts. From the start, it was programmed with Processing,[17] an Open Source language developed for use by artists and designers. The openness of the Arduino platform means

[16] The home page for the project is at http://www.arduino.cc. Other similar platforms include the Make Controller, EZIO, Phidgets, I-CubeX, Basic Stamp, Wiring, BeagleBoard, etc. There are many I/O platforms, each with its own strengths. But the Arduino has the largest and most active designer and artist user community, which is why it is emphasized here. Bug Labs sells a high-level plug-and-play I/O module with components that snap together like LEGO blocks, requiring almost no knowledge of electronics or programming.

[17] Several projects now allow the Arduino to be programmed with (and communicate to) Adobe Flash (using Tellart's NADA or NETLab Toolkit), Cycling '74's Max/MSP, Institute of Advanced Media Arts and Sciences' Funnel, the MIT Media Lab's Scratch, and other development environments perhaps more familiar to designers.

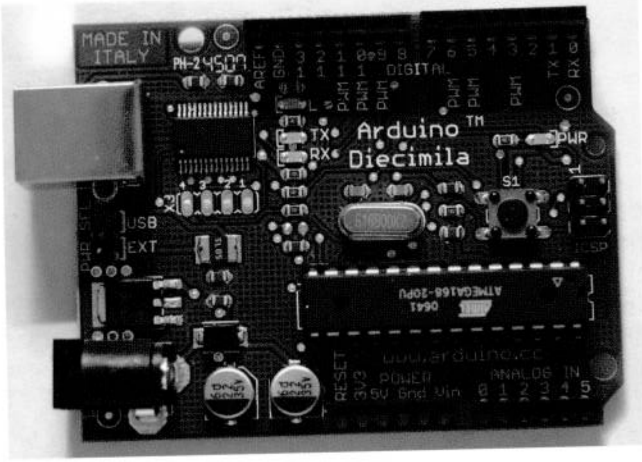

Figure 15-11
The Arduino I/O board. When used with its development environment, it makes building hardware prototypes much easier. (Courtesy Arduino)

that the Arduino community openly shares designs, techniques, and solutions. Derivatives of the Arduino hardware exist for wearable technology (the Lilypad Arduino), tiny form factors (Arduino Mini), and other specialized situations.

Simple analog and digital I/O is important, but most ubiquitous computing user experiences require more complex capabilities. Many technologies (networking, wireless telephony, environmental sensing, position sensing, etc.) are hard to master. Many designers have complained of the expertise gap between prototyping trivial interactions (pushing a button turns on a single LED) and the rich experiences that designers know are possible (vibrate a phone when an apartment nearby is renting in a given price range).

Fortunately, a number of companies now make specialized breakout boards that make complex technologies easier to work with. Some breakout boards just ease the process of temporarily soldering components, but others provide easy-to-connect building blocks of functionality to people without engineering degrees. For example, Spark Fun Electronics[18] sells a GPS chipset breakout board that turns the GPS into a plug-in component.

The combination of an inexpensive hardware prototyping platform, an easy-to-learn programming language, active online user communities, and powerful (but simple) breakout boards heralds a new era of sketching in hardware.

Hardware sketches are simple systems designed to quickly explore design directions using actual electronics. A typical hardware sketching toolkit contains six classes of components:

1. Host computer: This is used to program stand-alone components and provides services (such as downloading and processing data from the Internet) that would be difficult to replicate in a specialized device. One goal of sketching is to do the least work to express an idea, and general purpose computers are flexible, sophisticated tools for doing that.
2. I/O board: This contains a stand-alone processor, enabling digital and analog inputs and outputs. The processor communicates to the host computer and acts as the interface between digital information and the analog physical world. It takes sensory input from the world outside the processor, interprets it as digital data, and can signal to output devices in response.
3. Sensors: An enormous number of electronic sensors measure a bewildering number of external phenomena . One list (Wilson, 2005) of classes of sensors includes: acceleration,

[18]http://www.sparkfun.com.

shock, vibration,
humidity, light, r
sensors are availa
capacitive sensing
4. Actuators: These
response to the re
actuators than ser
servo-controlled n
piezoelectric cerar
5. Specialized compo
their own devices a
MP3 decoders, net
GPS receivers, GSM
powerful (and mos
and availability crea
6. Basic components:
electronics compon
transistors, capacito
boards minimize the
components by inclu

It is possible to con
replicate virtually any
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that it gives designers
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an MP3 decoder mo
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ling to add a GPS rece
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shock, vibration, chemicals, electrical fields, magnetism, liquid flow, force, weight, humidity, light, radiation, pressure, sound, temperature, position, etc. Many of these sensors are available on inexpensive breakout boards. Other classes of sensors — buttons, capacitive sensing pads, bend sensors, etc. — sense human action.

4. Actuators: These are devices that affect change in the world outside the processor in response to the results of information processing. There are only slightly fewer types of actuators than sensors: familiar video displays, blinking lights and speakers, solenoids, servo-controlled motors, electrically controlled pneumatics, electroactive polymers, piezoelectric ceramics, memory wire, etc.
5. Specialized components: Many sophisticated electronic functions once found only in their own devices are now retailed as convenient units of functionality. These include MP3 decoders, networking modules, audio amplifiers, digital cameras, memory cards, GPS receivers, GSM phone interfaces, etc. These are both the most specialized, most powerful (and most expensive) components used in hardware sketching, but their power and availability creates enormous power.
6. Basic components: These are traditional electronics components such as resistors, transistors, capacitors, and wires. Many I/O boards minimize the required number of such components by including them on the board.

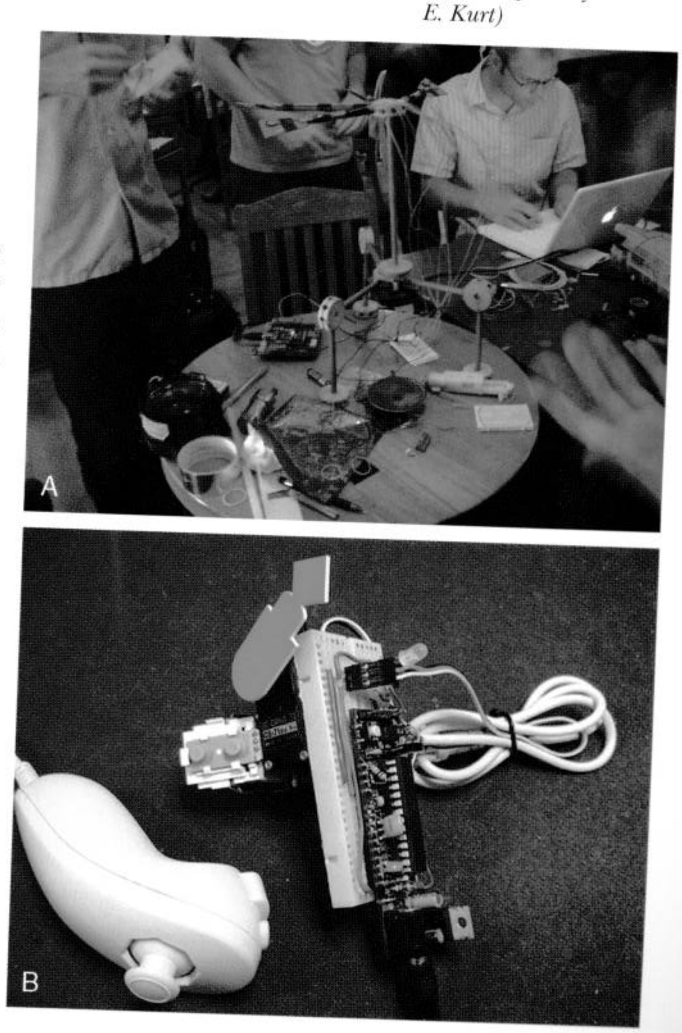

Figure 15-12
(A) Prototype devices sketched quickly using available materials and inexpensive controller boards. (B) Wiimote nunchuck hack. (Sketching in hardware 2007 photo by author; Wiimote nunchuck hack and photo by Tod E. Kurt)

It is possible to combine these components to replicate virtually any existing familiar consumer electronics. But the power of the technique is that it gives designers the ability to experientially explore design concepts much more quickly than developing fully realized technologies using traditional engineering methods. For example, an MP3 decoder module can be quickly coupled with a memory card, capacitive sensor, and audio amplifier to create an audio player. This is an interesting start. It becomes more compelling to add a GPS receiver to the ensemble and convert the sketched pseudo-iPod to a location-specific audio tour device. The resulting product may not be pretty (Figure 15-12A and B), but it can function well enough for a quick tryout. In the author's annual Sketching in Hardware conferences, groups of designers and developers conceive and build complete working systems in about two hours using toolkits like the ones previously described.

Note: See *Making Things Talk* (Igoe, 2007) and *Physical Computing: Sensing and Controlling the Physical World with Computers* (O'Sullivan and Igoe, 2004) for in-depth hands-on guides to sketching in hardware written for designers and artists with no formal engineering training.

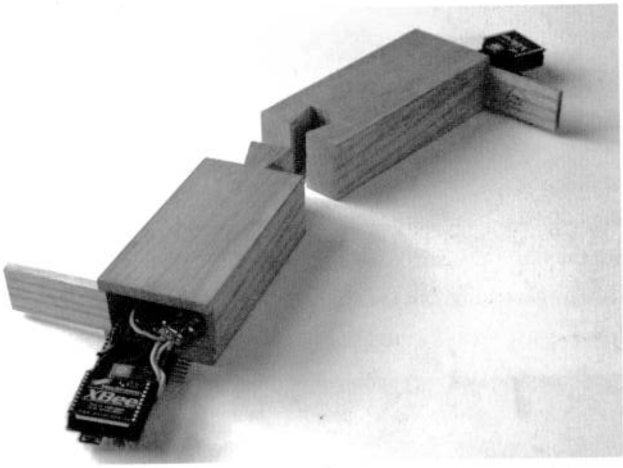

Figure 15-13
A sketch of an heirloom electronic device from Matt Cottam (2009). (Courtesy Matt Cottam)

Cottam (2009), for example, used lightweight technology prototyping components to explore the heavyweight idea of "a harmonious intersection between tradition and technology, between natural materials, high craft and digital functionality" (Figure 15-13). The ready (and recent) availability of hardware prototyping toolkits allowed him to explore a highly conceptual topic on his own, as an industrial designer with no electronics engineering training.

Sketching in hardware is only becoming easier for non-engineers. New paradigms of rapid prototyping are evolving that combine hardware and software development, industrial design, social networking, and lightweight manufacturing (Anderson, 2010). Prototyping hardware is on its way to becoming as familiar as foamcore, and breakout boards may be as common as software libraries and clip art.