Making Technology Homey: Finding Sources of Satisfaction and Meaning in Home Automation

Leila Takayama, Caroline Pantofaru, David Robson, Bianca Soto
Willow Garage, Inc.
68 Willow Road, Menlo Park, CA 94025 *

Michael Barry
Point Forward
818 Winslow Street
Redwood City, CA 94063†

ABSTRACT
Home and automation are not natural partners–one *homey* and the other cold. Most current automation in the home is packaged in the form of appliances. To better understand the current reality and possible future of living with other types of domestic technology, we went out into the field to conduct need finding interviews among people who have already introduced automation into their homes and kept it there–home automators. We present the lessons learned from these home automators as frameworks and implications for the values that domestic technology should support. In particular, we focus on the satisfaction and meaning that the home automators derived from their projects, especially in connecting to their homes (rather than simply controlling their homes). These results point the way toward other technologies designed for our everyday lives at home.

Author Keywords
home automation, need finding

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: User Interfaces—*User-centered design*

General Terms
Design, Human Factors

INTRODUCTION
A home is shelter, safety and a place where things are just so. A home is connection to family, a home is personal, a home provides relaxation and an escape. A home is welcoming, warm, cozy, informal. In this way, many homes strive to be "homey" [27].

In contrast, many home automation technologies are not homey at all. For example, mounting cameras throughout a home can feel like an invasion of privacy [11, 10]. Yet, some technologists see a future for automation throughout and controlling our homes [18, 28]. How can we successfully and acceptably bring automation into the home without hiding behind the title of "appliance"? How do we make technology "homey"?

Figure 1. Howard's and Alan's professionally-installed home automation system interfaces (top). Irwin's and Brian's mobile interfaces for their home-brewed home automation systems (bottom).

To explore these questions, we present in this paper a set of interviews with technology users who have been experiencing these issues daily: home automators. We employed the product design method of "need finding," derived from Cultural Consensus Theory [35, 40], conducting home-based interviews and walk-throughs with experienced home automators. Home automation can certainly be a complicated domain, fraught with difficulties and frustration [9]. However, the findings from our interviews implied a much more nuanced story.

Good product designs satisfy people in terms of use (i.e., what can I do with it?), usability (i.e., how easy is it to use?), and meaning (i.e., how does it relate to the rest of my life?). "Meaning communicates the story of the product

*{takayama, pantofaru, robson, sotob}@willowgarage.com
†mbarry@pointforward.com

UbiComp '12, Sep 5-Sep 8, 2012, Pittsburgh, USA.

or service. It is an organizing vision that surrounds use and usability, and provides the product or service with emotional resonance" [4]. The key ingredient of *meaning* comes from Bruner's sense of meaning-making as a culturally situated process that is often shared and communicated via narrative stories [8]. So the goal of our interviews was to hear the stories that people tell about the value they have found in or created from their home automation systems.

Putting industrial technologies into a home environment can completely change the meaning of a technology. For example, security systems for a commercial business are about maintaining profits and guarding one's business; in contrast, security systems for domestic homes are about protecting and investing in one's family (e.g., [1]). As opposed to industrial motivations for using automation for control and efficiency, we argue that satisfying domestic needs involves *connecting to the home and family*. Given these differences, it is difficult to incrementally extend industrial automation into the home [32]; we may have to rethink and reframe home automation.

To gain a deeper understanding of the meaning of automation technology in the home, we explored the meaning-making that goes on around the technologies that translates into a sense of satisfaction. We posit that the frameworks and the sources of value drawn from home automation will inform future home technologies by drawing inspiration from the successes while avoiding the pitfalls.

RELATED WORK

Computer systems in the home have been well-studied by multiple communities, including the human-computer interaction (HCI) community. Presented below is a brief review of this ongoing research, situating the current study within this body of literature.

Smart and Connected Homes

Ongoing projects have invested in domestic living spaces to conduct ubiquitous computing research. Labs such as the Georgia Tech Aware Home [25] and MIT's House_n [22] are able to test research prototypes with users who visit or stay in the living space. Research in these spaces has provided us with useful insight into the challenges of the smart home (e.g., impromptu interoperability, lack of a system administrator in the home, system reliability) [15]. Laboratory smart homes are excellent tools for exploring issues of usability.

In contrast to the smart home lab-based research, our study focuses on people who are already living with their own systems in their own homes, everyday. Our informants have confronted the challenges of long-term integration of automation into common tasks, in a home shared with family members and visitors, under the stresses of hectic work and social lives. These conditions are difficult, if not impossible, to simulate in a laboratory environment [38]. These conditions reveal the meaning of "home" and "home automation."

In addition to the notion of the smart home, we are now seeing trends toward the connected home [21], i.e., networked homes that incorporate Internet technologies, social media, etc. The growing number of computing technologies have given birth to a new set of "digital housekeeping" tasks that are becoming a part of overall household management [33, 39]. Within this household management structure there is often a guru who is responsible home network management [31]. It is suggested in [33] that the guru position can even be used to control or manipulate family dynamics.

A number of recent studies have looked at monitoring air quality, water use and electricity usage throughout the home [17, 19, 23, 26], however they do not attempt to change or control the quantity being measured. Intelligent temperature monitoring and automation systems [28, 36], on the other hand, are promising for reducing energy consumption, but also reveal the difficulties of unexpected family schedules or family disagreements about correct settings.

Home Automation

Prior work on HCI in home automation includes an insightful case study of 20 American Orthodox Jewish families who used home automation to adhere to rules against manual operation of electronic devices during the Sabbath [41]. Although designing systems for more user control is often beneficial, in this situation surrendering control to an autonomous system better served the users' needs. Furthermore, home automation can provide important support for lifestyle choices (e.g., green living, slow living, and spirituality) [41]. These participants found spiritual meaning in using home automation, which does not necessarily generalize to broader populations.

More recent field studies with more varied samples of households uncovered key challenges for home automation [9], which are being addressed by ongoing research development of the HomeOS [14]. This research identified critical barriers for broad adoption: high cost of ownership, inflexibility, poor manageability, and difficulty achieving security. They also identified several themes for people's favorite aspects of home automation: convenience, peace of mind, and centralized management [9]. The study presented in this paper builds upon their work, but with a different focus: identifying fruitful research directions for domestic ubiquitous computing technologies through identifying values and meanings that are currently overlooked and underserved.

One of the primary values of home automation that has been touted for decades is the dream of controlling the home. Indeed, even architects such as Le Corbusier [12] promoted the idea of thinking of the home like an industrial building that is not so dissimilar from factories. Our research suggests that this does not match with people's meaning of "home".

The work of Kaplan and Kaplan [24] suggests that, for managing information, environments should be both *coherent* and *complex* at the same time, promoting both understanding and exploration. The work of Aipperspach et al. [2] extends this concept by suggesting that a house should be heterogeneous, with different uses of information and technology in different spaces. The study presented in [6] suggests that

another barrier to home technology adoption is the gap between users' expectations of products (especially with respect to interoperability) and the product reality.

STUDY DESIGN

Our study was motivated by a desire to learn about both the positive and negative aspects of home automation, and how they relate to the meaning of "home." Because of our interest in the cultural group of home automators, we drew our methods from Cultural Consensus Theory [35, 40]. This theory states that cultural beliefs are shared within a community. Because any given community member might vary in his or her degree of cultural competency, we interviewed a set of ten home automators.

The "need finding" methods [4] we used are drawn from Cultural Consensus Theory, focusing upon a reasonably coherent set of cultural group members, interviewing them separately from each other, and identifying responses (e.g., stories) that are consistent across informants. Each interview sought out the stories that people told about their home automation projects, aiming to tap into the underlying motivations for the projects and to learn from the household's experience of living with automation. Each visit consisted of a semi-structured interview and a tour of the home (when possible). This is similar to prior work that used need finding methods to identify the underlying needs in the hobby robotics community [29] and with respect to home organization issues [30] in order to identify promising directions for robotics research and development.

The insights gained from the interviews largely came from two sources. First, the home tours were invaluable, allowing us to see the home automation in practice, and reconciling informant's self-reported information with reality. The second source was stories. Informant stories recount situations in which beliefs or desires did not correlate with reality, which pointed us toward unsatisfied needs. Stories about highly satisfying were also useful for identifying the types of values that were actually found in current home automation usage.

This was an open-ended inquiry; we did not presume to understand current home automators nor their families. Instead, we approached each informant more as apprentices, who were looking to learn from the experts (the informants) by asking about their past experiences, current projects, and advice on how to get value out of home automation.

Each interview lasted 1.5 to 3.0 hours. We used an interview guide to cover a common set of questions with each informant, including questions about what the "home" means, their history with home automation, specific home automation project stories, how decisions are made about which projects to pursue and how, which projects have been most satisfying, which projects have been most frustrating, how house guests are introduced to the automation systems, patterns of home automation usage, plans for upcoming projects, and thoughts about other forms of automation in the home (e.g., robotic automation).

Informants

We interviewed ten home automators during the winter and spring of 2011, selecting for Innovators, Early Adopters, and Early Majority group members [34], who had experience with home automation technologies in their own homes. They were recruited through a professional recruiting agency and local contacts, using a screener that included questions about types of applications and communication protocols used, the availability of a partner for us to interview, ages and genders (recruited for a wide range). Whenever possible, we interviewed the other household members, who were typically early or late majority adopters coping with novel technologies. To increase the level of informant cultural competence, all of the informants lived in the San Francisco Bay Area in California, USA. See Figure 2 for more details.

The informants in this sample were selected for the wide variety of home automation systems that they have installed and used (e.g., X10, Stargate, Z-wave, Insteon, Crestron) for a wide variety of common applications (e.g., lighting control, home security, music and home theaters, climate control, irrigation) as well as uncommon applications. Six of the ten home automators installed their own systems, whereas the other four paid for professionally installation.

While we set out to recruit a more balanced sample of genders, both the professional recruiters and our own recruitment efforts were unable to find female home automators. This is an interesting issue for further exploration but is out of scope for this paper. The automators' ages ranged from approximately 35-65 years. None of the automators had young children, but some had high school-aged children or grown children who had moved out.

Many of our informants had deep technical expertise in engineering, but several of them expressed a decreasing interest in tinkering with home automation. As Alan put it, "I don't want to... fiddle with that anymore. I want to plug and play." Charlie expressed the same sentiment; he had tinkered with home automation for over a decade and was ready to switch over to more consumer grade products (e.g., buying from Home Depot as opposed to specialty electronics shops).

DISCUSSION OF RESULTS

To summarize the results of our need finding explorations, we will present lessons learned from informants' first explorations into home automation, where they found (or stumbled upon) satisfaction in their home automation projects, and how their household members responded. Following the need finding analytical process [3], we used stories as our unit of analysis to identify common themes and frameworks that cut across informants. To protect our informants' identities, we will use pseudonyms rather than real names.

Automator's First Explorations

Although we gathered stories about a wide range of home automation projects, certain applications were repeated in several interviews. For the automators, these applications seemed to be the lowest-hanging fruit technologically, natural extensions of existing business computing or more indus-

Pseudonym	Group	Installer	Location of Automation System	Professional Background	Household Size
Brian	Innovator	Self	Home	Automation of IT	3
Irwin	Innovator	Self	Home	Linux Sysadmin	2
Felix	Innovator	Self	Vacation home shared with Greg	Systems Engineer	1
Greg	Innovator	Self	Vacation home shared with Felix	Software Programmer	1
Charlie	Early Adopter	Self	Home	Senior Manager	4
James	Early Adopter	Self and Professional	Home	Tech Entrepreneur, Cog Sci	2
Howard	Early Adopter	Professional	Home	Senior Executive, CS PhD	3
Alan	Early Adopter	Professional	Only at second house	Tech Entrepreneur, EE	1
Daniel	Early Majority	Professional	Home and second house	Contract Manager	2
Ed	Early Majority	Professional	Only at second house	Train Controls Engineer	2

Figure 2. Demographics of Home Automators ($n = 10$).

trial automation, forming an obvious entry point into home automation. For each application area, we provide illustrative examples of the systems we observed, and highlight one particularly notable situation that reflected the users' needs. Unfortunately, the results of most of these attempts at incremental technology adaptation resulted in disappointment and systems that were unusable or lacked value; but there are still lessons to be learned from those disappointments.

Security

Many of the stories told by our informants revolved around security systems. For example, Alan had a security system installed to detect break-ins and help police identify the intruder, but what he really wanted to know was the location of the intruder so that he could run the other way. Ed and Howard both had motion-detecting security systems installed in their houses to detect break-ins; when triggered, those systems would call the police and the home owners. Felix's entry point into home automation was his own home-brewed security system installed in his vacation home which used video, audio, and motion sensors (which he referred to as "telemetry".) His house had been looted by a neighborhood kid, who had even left a trail of footprints leading to the neighbor's house. Because the neighbors and local police station were quite far away, the system played an unbearably loud noise inside the house to chase the intruder out (rather than try to alert people outside of the house).

Lighting

While lighting control was a very common application, it was more commonly a source of frustration than satisfaction, mostly because it is already so easy to turn on and off lights. Alan used the programmable lighting for mood setting when he hosted parties. In Charlie's house, the X10 sensors he had installed in the light switches became so sensitive to noise that the house lights would turn on and off, seemingly of their own volition. Howard found satisfaction in being able to make the house appear occupied even when the family was out of town. However, the actual system did not work; recording light behaviors (to be played back when the house was empty) over-ran the system's memory capacity, and so Howard had not yet actually used this feature. The one story that came out in favor of lighting control was Howard's use of the all-lights-off feature when he went to bed (in case he had forgotten to turn off the lights in a distant room). His daughter, finding herself in the dark, would protest, but she could easily turn her lights back on using local controls. As such, the all-lights-off functionality served as a signal to the household that it was time to go to sleep.

Energy

Solar power-producing systems (installed as panels on rooftops) were another common feature of many of these homes, usually the ones produced and installed by SunPower. Alan and Irwin were the most vocal proponents of solar power and pumping energy back into the power grid. Charlie and Irwin were particularly annoyed about not being able to see the progress of their solar power systems, to tap into the data about how much energy their solar systems were putting out moment-to-moment. Power monitoring was discussed by many of our informants, but only one of them had actually put together a system that he was satisfied with. Irwin hooked up his breaker box with sensors to monitor each of the circuits that ran throughout his home (Figure 3). He then created his own interface for monitoring each circuit's minute-by-minute electricity usage so that he could figure out exactly which of his appliances were using up a lot of power and when. He showed us how he could even tell when the fridge door had been opened. While this may seem like unnecessarily fine-grained level of detail, it was actually a response to a frustrating experience that Irwin and his wife had experienced when they first moved into their home. They received a several hundred (US) dollar power bill, which was unusually large for them. It took more than a month of searching the house for Irwin to figure out that there was a broken fan in the attic that was draining electricity. Since then, Irwin has kept close track of appliance use and optimized his overall household energy usage.

Climate control

Automated climate control systems, including actuated window shades, were also common across almost all house-

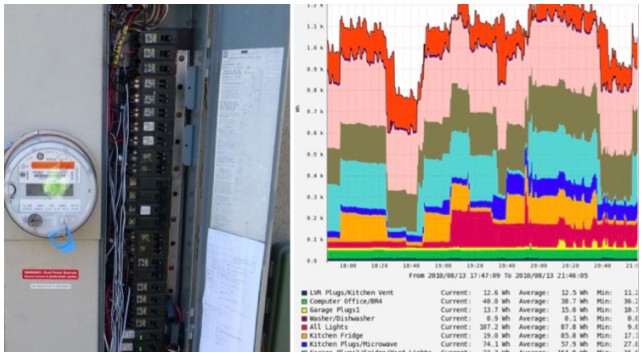

Figure 3. Irwin's home-brewed electricity use monitoring system.

Figure 4. Dave's and Irwin's irrigation actuators and sensors.

holds. Howard installed window shades that could be controlled with wall panel interfaces in each of the rooms of his house. His kitchen sunlight could also open and close via wall panel controls, and closed automatically if the window detected water falling on it. Ed installed automated window shades in their second home, which had very tall, vaulted ceilings and tall windows. While he and his wife were happy with the automated window shades initially, she was frustrated when the batteries died. The batteries were very difficult to reach hidden inside of the top valence of the 20-foot-tall window shades. Irwin installed his own climate control system, which monitored local climates around many parts of the house and also monitored weather predictions from the Internet so that the system could autonomously open vents to the outside. Brian installed controllers for the drapes in their bedroom, a source of some amusement for his wife. She said that "the biggest laugh I've had was at about 2 in the morning and the drapes started to automatically open ... I just turned over and said ... 'Isn't technology and home automation wonderful?"'

Irrigation

Outside of the home, many families in our interviews showed us their automatic garden irrigation systems. Irwin used both an automatic watering system that took local weather patterns into account and used moisture sensors to detect whether or not the irrigation system was working properly (Figure 4, right). Similarly, Ed and his wife had installed a very large-scale irrigation system for their second home because the yard was several acres in size and took them a very long time to water. Furthermore, their home was in a very dry area that had recently experienced a large wild fire that had killed off most of the plants so they were especially sensitive to protecting the new plants. We happened to interview Charlie at a time when he was in transition from his timer-based mechanical irrigation system to a new, more programmable irrigation system. Because he had more than a decade of experience with unreliable home automation technologies (mostly X10 lights), he kept the mechanical system in place and used the new system in series with it; this way, the mechanical system would reliably stop the unnecessary flow of water if the new system failed.

Entertainment

There were also many types of entertainment systems, some that directly supplied content and some that created an environment for more traditional content. Daniel used automation to set up his home entertainment system (e.g., audio and video). Similarly, Howard had a professionally installed entertainment system that played music at any location throughout the house; his family also had a home movie theater and they hosted a summer concert series in their spacious garden. Alan used his home automation systems to entertain his guests in a very different way. As a competitive ballroom dancer, Alan felt that being able to provide his guests with dance performances and lessons was a valuable way of giving back to the dance community. He used home automation to set the lighting and music in the ballroom of his second house. He had grown up dancing; as an adult, dancing became his primary stress relief strategy after very long days at his semiconductor industry start-up.

Sources of satisfaction

Four of the ten households had notably supportive consumers of the home automator's projects, whereas many of the other households had lone home automators whose families were uninterested in the projects. Having a supportive partner seemed to be highly correlated with overall satisfaction with home automation projects. In this section, we will discuss the major sources of satisfaction amongst those households.

Virtuous

Brian and his wife formed a particularly effective way of communicating with each other about which home automation projects were valuable to the household and which were not. The way that Brian knows that a home automation project is virtuous is when "someone who is using it says, 'You know, could you get it to...' — and then they have some idea. That's the sense that, OK, it's valuable enough that they want to use it. They want to invest in it." He typically shows his projects to his wife, who tells him which of the projects are virtuous and which are not. Brian estimates that two out of his last hundred projects have been virtuous. One of those projects was the online family calendar that their household uses for coordinating their schedules. They had originally used a paper calendar on the fridge, but that was not accessible from outside the kitchen so Brian implemented his own online calendar (because he did not trust large companies to have that kind of personal information in the cloud). Consistent with prior work on household organizing systems [37], Brian's online system had been adopted in parallel with the existing fridge calendar, and were put to use simultaneously.

Figure 5. A framed mosaic of CanyonCam photos, a cherished gift.

Like a picture of your loved ones

Felix and Greg instrumented their vacation home. They were not only able to monitor the telemetry data that streamed from the various mics, cameras, water pressure sensors, etc., but they were also able to see how things were going outside of their vacation home. One of the webcams that they installed pointed outward to the neighboring canyon. This "CanyonCam" took a picture every hour and posted it online, where Felix and Greg could view it. This enabled them to create visualizations such as the noon-time sun throughout the year. To Felix, seeing the CanyonCam photos was "a little reminder of the happy things" and he compared it to having a photo of loved ones on your desk. When we asked him how often he checks the CanyonCam, he said, "If I'm here sitting at my computer, I look at it... pretty often. I don't do Facebook... but it's the same kind of addiction." In a separate interview, Greg showed us a framed photomosaic of CanyonCam photos that Felix had given him as a gift. See Figure 5. There was also another webcam that pointed toward the front garden, which Greg used to occasionally see the deer and mountain lions. This had special meaning to Greg, who believed that "home is where the critters are; home is where nature is." Their stories were the most vivid examples of how one could use webcams not just for security, but also for creating a sense of connection with a home.

See how things are going

A unique source of satisfaction that came from home automation technologies was Irwin's Blender Defender, which "defended" the kitchen counter from the cat by turning on the blender whenever it detected motion. He got the idea from a video he saw online and decided to build one for himself. It also took pictures of the cat when the motion sensor was triggered. This was a surprising source of value, allowing Irwin to check on their cat when they were out of town. As Irwin said, "I kept that to keep an eye on him [the cat] when we're not home, just to see how he's doing." Although this project began as a hobby project, it became a valuable source of satisfaction for Irwin and his wife.

Peace of mind

To illustrate the kind of home automation he would want, Greg told a hypothetical story about being on a business trip and wondering if he left a library book in his back yard where the lawn sprinklers might soak it. He would like to be able to verify that the book was actually there before deciding to call a neighbor. He would feel comfortable asking someone to pick the book up if he was confident of its location. On the other hand, he would not feel comfortable asking someone to check and see whether he had left the book outside. Home automation that allows people to see what is going on in their home while they are away can provide a form of reassurance.

Monitoring the home does not always have a positive effect on peace of mind, however. Ed talked about receiving a series of alarm reports from different locations in his vacation home: the front door, the hallway, the family room, the upstairs hallway, and the game room. He described a vivid mental image of several people roaming through the house. "I'm just going crazy, thinking what am I going to do? I could see my new 60 inch TV going out the door!" When he found that all the alarms happened at the same time, he realized that it must have been a power outage and not a gang of thieves. However, the effect of his security system had been the opposite of reassuring. "I wondered if I was worrying less when I didn't know." Felix and Greg expressed a similar sentiment about professional security systems, which is why they made their own. Their security system was hand tuned with software filters that Greg wrote that specified exactly which combinations of sensor data should trigger emails, text messages, or phone calls to go to them.

Family communication

Some of our informants involved other household members in their automation projects. For example, Brian's family calendar was used for coordinating schedules between the parents and child of the household via their smart phones. Similarly, James used their centralized entertainment system to connect all of his family members' music collections together so that they could share their music and play it throughout the house. Consistent with findings from the American Orthodox Jewish homes case study [41] about families using automation to influence household behavior, Howard would use the turn-all-house-lights-off functionality to indirectly communicate with his teenage daughter about when she should be going to sleep. However, these stories of participation were rare compared to the stories about projects which the automator undertook on his own.

Household and Family Perspectives

Whenever possible, we interviewed other household members aside from the primary home automator. Other household and family members had quite different perspectives, which were critical to gather because they lived in the same homes and shared in the joys, pains, and decision-making that came with the home automation projects.

Living in a prototype

As Brian's wife put it, "For 30 years — we've been married 30 years — so it's kind of like living in a prototype." She understood and explained to us that Brian's deep curiosity and

Figure 6. One professionally installed automation system (left) and one home-brewed home automation system computer closet (right).

"insatiable desire to learn new things" was what motivated him to tinker with home automation projects. Although she was one of the most supportive and patient household members amongst our set of informants, she also had drawn the line about where home automation projects were allowed versus forbidden.

Respecting zones and territories

When Brian installed X10 light switches, his wife would try to turn on the lights in the house, but the switches were unreliable. That was when she told Brian, "leave the kitchen alone and leave my sewing room alone." As she explained to us, "I want to know if something will work consistently all the time. I appreciate the technology once it's stable but I don't appreciate the fondness he has of developing it." Similarly, Irwin's wife said, "If he starts to automate too many things in the kitchen and things start to be a little out of whack, I would be very impatient there." Irwin chimed in, "It's all a question of turf." She later explained their zones: "You see the [home automation and remote-controlled planes] stuff that he has in the garage? That doesn't fit inside of the home. It fits in the garage. I'm happy that he keeps that stuff out there. Within the home, we each have designated areas where we can sprawl out and have our own [belongings] laying around."

Learning from mistakes

Irwin's wife worked in the biotech industry so she was quite technical and worked with computers on a daily basis, but she still felt that the computer closet at home was very scary looking (Figure 6, right). She prefers that things be tidy and labeled so that she can, for example, troubleshoot the closet if necessary. One day when Irwin was out of town, she was woken up at 3am by a high-pitched beeping that she traced to the computer closet. Irwin was out of the country, staying in a bed and breakfast in Holland with a poor Internet connection, which did not allow a video feed. As a result, Irwin could not "see" into the closet and his instructions to his wife were imprecise and confusing. The closet had no power so many other appliances (e.g., the cable TV antenna) also stopped working. The doors still opened and closed and there were no fires, but it was a frustrating experience for Irwin's wife. Since then, Irwin has added a backup power generator for the computer closet.

Brian built a local media library server that hosted their photos (including people's names, music, birthdays of family members) so that they could answer a common question, "How old was grandpa in that picture?" They used this server to provide photos of their son to his grandparents. Brian calls this the "grandmother force," which he described as: "If a photograph of my grandchild is taken, I believe I have a constitutional, god-given right to my own copy of that photograph faster than your printer can print and you'd better get it right over to my house." In response to this force, Brian wrote software for his mother to run on a laptop, which would constantly deliver the latest photos from the media server. However, his mother refused to use the laptop. In hindsight, he said, "If I had a way to give her a photoframe that didn't plug into Flickr or Shutterfly... she would have been thrilled beyond belief. She wouldn't have gone on vacation without that photoframe. ... The laptop and its power plug and all of that was an intrusion on the environment that was not acceptable for my mother so she didn't use it."

FRAMEWORKS AND DESIGN IMPLICATIONS

Based upon the stories gathered from this set of informants, we generated several frameworks for making sense of the data and forming hypotheses to be tested in future iterations of this work. While we are unable to share all of the stories from this field work in this paper, we present a synthesis in the form of frameworks and design implications.

Values

There are several values that the home automators explicitly and implicitly showed to us, including (unranked):

- **Have peace of mind** in knowing that everything is OK at home. Do not make people worry, only tell users about things that they can do something about (e.g., Irwin's Blender Defender and Felix's homebrewed security system), which is consistent with prior work [9].
- **Optimize** by being ecologically conscious, saving money, or being true to one's sense of self, home, and family, by revealing data that shows progress, and providing immediate gratification toward optimizing goals (e.g., Irwin's energy monitor).
- **Experiment** by tinkering to learn and teach. Allow for reappropriation because it is going to happen anyway, and do not close off black boxes so that early adopters cannot tap into them (e.g., SunPower black boxes).
- **Entertain and impress others** by being a welcoming and gracious host for family and friends by making it fun and giving it a "wow" factor. Simply turning on lights is not enough because that is already easy to do (e.g., Alan's ballroom lighting and music).
- **Personalize the home** by making the home feel more like one's own and more like a reflection of one's sense of self (e.g., [27]). Make its aesthetic part of the home (e.g., Brian's mother's photo-viewing laptop vs. photoframe).

Failure and frustration

There are many causes for failures in home automation, including: (a) A situation in which only one person knows how to control it, consistent with [9], (b) Batteries that cannot always be reached or changed, (c) Signal distances, i.e., intermittent connectivity and wireless issues (consistent with [9]), (d) Crashes in software and hardware, and (e) Overreaching ones abilities in technology or to program. These are all usability issues in home automation.

While usability issues were not the main focus of the current work, we have identified some ways to address the causes of failure in home automation, including: (a) Design end-user interfaces, not just early adopter ones, consistent with [13], (b) Make batteries easy to reach and change or eliminate the need for batteries altogether, (c) Connectivity is a much larger research issue that will require more research and development, (d) Mitigate crashes in software and hardware (or at least make it easy to recover from them) and allow for more graceful degredation of system performance, and (e) Keep the system design simple enough for early adopters and early majorities, not only innovators.

The consequences of those frustrations and failures are critical to understand and address because they center around the meaning endowed upon automation technology in the home:

- **Humiliation** within the household and in front of visitors: let the system (or some third party) take blame for failures.
- **Relationship friction** between household members: provide value as early and obviously as possible so that the hassles of home automation might be worthwhile.
- **Anxiety** about false alarms and worrying about the house crashing: reveal as much *useful* information as possible to help the household members worry less without providing information about things that are uninterpretable or that the person cannot do anything about.
- **Cognitive dissonance** between how hard it is to get home automation to work vs. how smart I am: keep it simple or, at least, readily introspectable, and explicitly rate the automation technology in terms of what skills are actually necessary for using and maintaining it.

All of our informants had technical backgrounds and most of them worked in the computer technology industry, so it is notable that all of them suffered through struggles with installing, using, or maintaining their automation systems. As such, we believe that other households are likely to face similar household issues (e.g., humiliation and relationship friction) and personal issues (e.g., anxiety and cognitive dissonance), which must be addressed by thoughtful service recovery techniques and support.

The Frontier

Think of home automation as being a frontier that you can take on as a lone frontiersman or by striking out together as a frontier family. We found that most household satisfaction came from home automators who involved other household members in their decision-making about which projects to pursue and for what purpose (e.g., Brian soliciting feedback from his wife about which projects were "virtuous" and why). This is consistent with findings that there are benefits to introducing domestic housecleaning robots to multiple members of the family, not just a single family member [16]. Home automators were all striking out into uncharted territory, but we argue that bringing along the family, involving them in the project, and taking calculated risks (instead of just plain risks) are promising strategies for household satisfaction with adding automation to one's home.

Connect, not just control

While it is clearly beneficial to ensure that household members feel a sense of control of their homes [20] and their lives [13], that is not sufficient for automation technology to make a positive difference in their domestic lives. We found that the most satisfied home automators were the ones who focused upon connecting to the home and family members rather than simply trying to control it. The Canyon Cam, the Blender Defender, and the shared media library are prime examples of adopting a seemingly utilitarian technology for social purposes. These particularly satisfying home automation projects helped people to feel the warmth to looking at a picture of loved ones, to experience a sense of joy and relief in knowing that the cat is doing alright at home when left alone, and to share musical interests and tastes with family members in the household. In this sense, the home automation systems were treated more like loved ones and less like cold machines to be controlled and mastered.

This insight emerged from a framework we generated (see Figure 7) to lay out many examples of observed home automation projects. After trying out different combinations of variables, we laid the examples out in terms of how much of a fully automated closed-loop system it was (left) vs. open-loop (right) on the x-axis and in terms of how much the project helped with controlling the home (bottom) vs. connecting with the home and loved ones (top) on the y-axis. The most satisfaction and homey values were associated with the home automation projects in the top region of this conceptual space (green zone). The bottom right systems (e.g., solar panels, garden irrigation) seemed to be taken for granted, perhaps because they are largely hidden in the walls of the house. The bottom left systems (e.g., windows, timed lights) seemed to get lukewarm reception, perhaps because those tasks are trivial to do manually. This framework brought into focus the insight that home automators in our field studies generally found more value in connecting with the home as opposed to simply controlling it.

DISCUSSION

LeCorbusier once argued that "A house is a machine for living in. Baths, sun, hot-water, cold-water, warmth at will, conservation of food, hygiene, beauty in the sense of good proportion" (p. 95) [12]. In the context of the Industrial Revolution, this was a way of making sense of the house through the lens of mass production, efficiency, and productivity. However, this interpretation breaks down in the context of "homeyness". One's house is not just a building; it is a home that people not only live in, but that people also

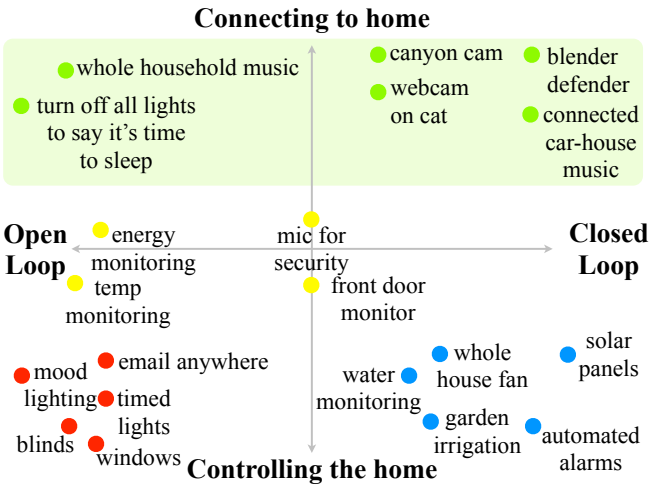

Figure 7. Populated space of home automation projects. We observed the most household satisfaction among projects in the top region.

use to construct their sense of self and family [27]. This is consistent with Bell and colleagues' statement that, "Efficiency is overrated" in the home [5]. To the architect, an urban housing block may seem like a machine to be mass produced, but to the person who lives in the home, it is more than that. For some people (e.g., Felix), a home can be like a member of the family, like a loved one.

We may want to reconsider the home as an entity to be cared for (even from a distance) like Irwin's cat. It is more than a valuable financial asset or piece of shelter; the home can be more of an actor in household members' lives, bringing them closer together (e.g., combining their music libraries and photos together to be shared as a family) and even bringing them closer to distant loved ones (e.g., sharing pictures with grandma).

FUTURE WORK

This study has provided insights into the general use of automation throughout the home. For our own work, we have a particular interest in the roles that robots could play in automating the home since domestic robots present the opportunity for using a wide variety of sensors (for monitoring and interaction), actuators (for mobility and manipulation), and artificial intelligence capabilities. In Brand's taxonomy of buildings [7], we could think of smart homes and robotic services are part of the "services" layer of houses; smart devices and domestic robots are part of the "stuff" layer of houses. Future work will expand upon these notions of incorporating technologies into the building itself (e.g., the services like plumbing and electrical wiring) in combination with devices that join the world of domestic "stuff."

For the interviews presented in this paper, we attempted to recruit home automators at different life stages and genders. However, we were only able to find male home automators, who were either young and without children or parents whose children were in high school or had already left for college and were only able to interview male home automators. Future work that more aggressively recruits for a balanced gender sample of informants would be ideal; however, it is unclear whether our sample is or is not reflective of the larger population of home automators. Future work can also learn from families with young children and older adults, who are in life stages that may have more urgent needs that might be met by domestic technology products and services.

CONCLUSION

The dream of having automated homes presents serious challenges to both technological innovation and design. To explore possible opportunities in home technology, we conducted a need finding study to learn about how home automation has been used in people's homes and why. We identified sources of satisfaction found in home automation, including having peace of mind, optimizing behaviors toward personal goals, experimenting to learn and teach, entertaining and impressing others, and personalizing the home to be more of a reflection of one's sense of self. These values align well with the notion of homey-ness [27], which is important for domestic technologies. Furthermore, we learned that the value of computation in the home does not necessarily come from having control over the home as if it were a machine; most satisfaction came from *connecting* with the home and family. These lessons from home automation point the way toward the design of domestic technologies that not only have clear use and good usability, but that (more importantly) align with the meaning-making in domestic life.

ACKNOWLEDGEMENTS

Thanks to our fellow interviewers Nathan Koenig and Melonee Wise, as well as to our informants and reviewers.

REFERENCES

1. ADT Security Systems. `http://www.adt.com`.
2. R. Aipperspach, B. Hooker, and A. Woodruff. The heterogeneous home. In *Proc. UbiComp*, pages 222–231, 2008.
3. S. L. Beckman and M. Barry. Innovation as a learning process: Embedding design thinking. *California Management Review*, 50(1):25–56, 2007.
4. S. L. Beckman and M. Barry. Design and innovation through storytelling. *International Journal of Innovation Science*, 1(4):151–160, 2009.
5. G. Bell, M. Blythe, and P. Sengers. Making by making strange: Defamiliarization adn the design of domestic technologies. *ACM Transactions on Computer-Human Interaction*, 12(2):149–173, 2005.
6. S. Bly, B. Schilit, D. W. McDonald, B. Rosario, and Y. Saint-Hillaire. Broken expectations in the digital home. In *Ext. Abstracts of CHI*, pages 568–573, 2006.
7. S. Brand. *How buildings learn: What happens after they're built*. Viking, 1994.
8. J. Bruner. *Acts of Meaning*. Harvard University Press, 1990.

9. A. B. Brush, B. Lee, R. Mahajan, S. Agarwal, S. Saroiu, and C. Dixon. Home automation in the wild: Challenges and opportunities. In *Proc. CHI*, pages 2115–2124, 2011.

10. K. Caine, S. Sabanovic, and M. Carter. The effect of monitoring by cameras and robots on the privacy enhancing behaviors of older adults. In *Proc. HRI*, 2012.

11. E. Choe, S. Consolvo, J. Jong, B. Harrison, and J. Kientz. Living in a Glass House: A Survey of Private Moments in the Home. In *Proc. UbiComp*, 2011.

12. L. Corbusier. *Towards a New Architecture*. Dover, New York, 1985.

13. S. Davidoff, C. Lee, M.and Yiu, J. Zimmerman, and A. Dey. Principles of smart home control. In *Proc. UbiComp*, pages 19–34, 2006.

14. C. Dixon, R. Mahajan, S. Agarwal, A. B. Brush, B. Lee, S. S., and V. Bahl. The home needs an operating system (and an app store). In *Proc. Hotnets*, pages 1–6, 2010.

15. W. K. Edwards and R. E. Grinter. At home with ubiquitous computing: Seven challenges. In *Proc. UbiComp*, pages 256–272, 2001.

16. J. Forlizzi and C. DiSalvo. Service robots in the domestic environment: A study of the roomba vacuum in the home. In *Proc. HRI*, pages 258–265, 2006.

17. J. Froehlich, E. Larson, T. Campbell, C. Haggerty, J. Fogarty, and S. Patel. HydroSense: Infrastructure-Mediated Single-Point Sensing of Whole-Home Water Activity. In *Proc. UbiComp*, 2009.

18. B. Gates. A robot in every home. *Scientific American*, pages 58–65, 2007.

19. S. Gupta, M. Reynolds, and S. Patel. ElectriSense: Single-point sensing using EMI for electrical event detection and classification in the home. In *Proc. UbiComp*, 2010.

20. L. Hamill. Controlling smart devices in the home. *The Information Society*, 22:241–249, 2006.

21. R. Harper. *The Connected Home: The Future of Domestic Life*. Springer, 2011.

22. S. Intille. Designing a home of the future. *IEEE Pervasive Computing*, 1(2):80–86, 2002.

23. Y. Jiang, K. Li, L. Tian, R. Piedrahita, X. Yun, O. Mansata, Q. Lu, R. Dick, M. Hannigan, and L. Shang. MAQS: A personalized mobile sensing system for indoor air quality monitoring. In *UbiComp*, 2011.

24. R. Kaplan and S. Kaplan. *The Experience of Nature*. Cambridge University Press, 1989.

25. J. A. Kientz, S. N. Patel, B. Jones, E. Price, E. D. Mynatt, and G. D. Abowd. The Georgia Tech Aware Home. In *Proc. CHI*, pages 3675–3680, 2008.

26. S. Kim and E. Paulos. inAir: Measuring and Visualizing Indoor Air Quality. In *Proc. UbiComp*, 2009.

27. G. McCracken. *Culture and consumptions II*. Indiana University Press, 2005.

28. Nest. `http://www.nest.com`.

29. C. Pantofaru and L. Takayama. Need finding: A tool for directing robotics research and development. In *RSS 2011 Workshop on perspectives and contributions to robotics from the human sciences*, 2011.

30. C. Pantofaru, L. Takayama, T. Foote, and B. Soto. Exploring the role of robots in home organization. In *Proc. HRI*, pages 327–334, 2012.

31. E. Poole, M. Chetty, R. E. Grinter, and W. K. Edwards. More than meets the eye: Transforming the user experience of home network management. In *Proc. DIS*, pages 455–464, 2008.

32. B. H. Rasmussen, L. Jansson, and A. Norberg. Striving for becoming at-home in the midst of dying. *American Journal of Hospice and Palliative Medicine*, 17(1):31–43, 2000.

33. J. Rode, E. Toye, and A. Blackwell. The domestic economy: A broader unit of analysis for end user programming. In *Proc. CHI*, pages 1757–1760, 2005.

34. E. M. Rogers. *Diffusion of Innovations*. Free Press, New York, 1983.

35. A. K. Romney, S. C. Weller, and W. H. Batchelder. Culture as consensus: A theory of culture and informant accuracy. *American Anthropologist*, 88(2):313–338, 1986.

36. J. Scott, A. Brush, J. Krumm, B. Meyers, M. Hazas, S. Hodges, and N. Villar. PreHeat: Controlling home heating using occupancy prediction. In *UbiComp*, 2011.

37. A. S. Taylor and L. Swan. Artful systems in the home. In *Proc. CHI*, pages 641–650, 2005.

38. P. Tolmie and A. Crabtree. Deploying research technology in the home. In *Proc. CSCW*, pages 639–648, 2008.

39. P. Tolmie, A. Crabtree, T. Rodden, C. Greenhalgh, and S. Benford. Making the home network at home: Digital housekeeping. In *Proc. ECSCW*, pages 331–350, 2007.

40. S. C. Weller. Cultural consensus theory. *Field Methods*, 4:339–368, 19.

41. A. Woodruff, S. Augustin, and B. Foucault. Sabbath day home automation: "It's like mixing technology and religion". In *Proc. CHI*, pages 527–536, 2007.