Smart Homes for the Rural Population: New Challenges and Opportunities

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Abstract

"Smart" Homes (domestic environments in which we are surrounded by interconnected technologies that are more or less responsive to our presence and actions) seem increasingly plausible with the emergence of powerful mobile computing devices and real time context aware computing (Edwards and Grinter, 2001). Research at premier technology universities have given birth to home "labs" that experiment with sensors, cameras and monitors to study physical, behavioral and social consequences of such technologies on occupants of such homes. One of the most important problems that "smart" homes will eventually help to address is that of spiraling costs of healthcare. Using ubiquitous technologies to motivate healthy decisions can help prevent the onset of myriad medical problems (Intille, 2004). Moving the focus of attention from the health centers and hospitals to the working home through such technology interventions would eventually lead to decreased financial pressure on the traditional healthcare system.

This paper examines the challenges and opportunities in the design of "smart" technologies for preventive healthcare in rural homes. It summarizes findings from current ethnographic and demographic studies; and examines other contemporary research in the field of ubiquitous computing and "smart" homes. With the help of these studies, the paper lists different technical, social and functional challenges that we as designers may have to consider before designing "smart" homes for rural populations.

Introduction

The problem of the house

"The problem of our epoch is the problem of the house" – Le Corbusier

Architects of the 20th Century imagined that their new tools – electricity, steel, concrete, plate glass, mass production and fresh ideas about design – could be used to transform society for the better (Larson et al., 2004). Perhaps it did, perhaps it didn't. The problem of the house still remains; the only difference is that the house has changed. Today's homes are not just well designed; they are also "intelligent". Intelligent thermostats adjust the interior temperature based on the temperature outside; the digital video recorder knows when your favorite TV program is on and records it so that you can watch it later; the microwave can connect to the internet to calculate how long you should defrost your dinner. However, with new intelligence, comes new problems. Eventually we will live in so-called "smart" homes and the architects of the 21st century have to be concerned about more than the just the "chassis" of the house. These "smart" homes offer new opportunities to augment people's lives not just with good design, but also ubiquitous computing technologies that will provide users with increased communications, awareness, and functionality (Weiser, 1996). With new tools such as inexpensive computing, almost-free electronics, wireless communication, high performance materials, and new design, fabrication, and supply-chain technologies (Larson et al., 2004), we are today equipped with perhaps more than the architects of Corbusier's times. But as with Corbusier's architects, are we perhaps in awe of these new tools available to us? Are we oblivious to the change that is happening in the pervasive computing realm and do we as architects need to understand the use of these tools as more than just material for design?

The computer is taking over my house

Weiser (Weiser, 1996) talks of three waves of computing – the first wave was mainframe computers; the second wave, personal computers; and the third wave is referred to as *ubiquitous computing*. Ubiquitous computing can be defined as a method of enhancing computer use by making many computers available throughout the physical environment, while making them effectively invisible to the user (Morris and Lundell, 2003).

Before we start talking of how incredulous (or not) such a claim seems, let us first take a look at two pervasive technologies that were once unique but is invisible to us today. The first is the written word; the birth of the writing system coincides with the transition of hunter-gatherer societies to more permanent agrarian encampments when it became necessary to count one's property, animals or measures of cultivation. A natural result of the cultivation and storage of grain was the production of beer. It is not surprising, therefore, that some of the very oldest written inscriptions concern the celebration of beer and the daily rationing allotted to each citizen by the elite of these communities. It took thousands of years for man to develop the written language and thousands more before it became accessible to the common man. The second technology is electricity- at the turn of the century, the homes of the wealthy were often outfitted with electrically-conducting rails in the floors; "electricity girls" equipped with metal shoes and wearable light fixtures, would entertain party guests by moving from room to room, carrying their own illumination (Edwards and Grinter, 2001).

Today, the written word and electricity is so pervasive that we have difficulty imagining that they were once considered novel technologies used only by the elite rich for vanity and control. Computer scientists believe that the same pervasiveness will one day be true of computers. The signs are already here - the same chip that landed the Eagle on the moon is running your laptop today, what one day used to take a whole room to fit, can be held in the palm of your hand. As architects, we should be ready to design for a future where affordable sensing and computation will find its way into nearly everything man-made, including building components (Larson et al., 2004).

As "smart" homes become realities in urban centers, it is inevitable that such technologies will eventually trickle down to the rural home. The question is, as we begin to design for rural centers, do we work with the same constraints as those of our urban counterparts or do we develop a new guidelines and standards? Do we design for the

same ethnographic issues as those in urban centers or do we evaluate the different settings to inform our designs?

Background

The people of my village

The image of the agrarian village is no longer the American dream. Demographic changes and economic re-structuring create significant challenges for the rural population of America. Couple this with new lifestyles and comforts - the myth of the extended farm family breaks down. Bryden (Bryden, 2002) explains how longer life expectancies and lower rates of natural population growth, have changed the demography of America's villages:

1. The rural population is "older" than the urban population in the USA. 11.9% of the total population is aged 65 or over, while 13.9% of the non-metropolitan population is 65 or over.
2. The non-metro population is older than the metro population with a median age of 36 in 1998, compared to 34 for the metro population.
3. The rural elderly are poorer than their urban counterparts, and the incidence of poverty increases with age, ethnic group, and geographical remoteness.

This demographic imbalance is a significant problem in many rural states, especially since these states are also actively encouraging policies to attract retirees. Attracting retirees, claims Bryden (Bryden, 2002), is a good economic development policy but there are both costs and benefits. Not only is the aged urban population now migrating to the villages, there is also a universal tendency for many young people to leave their rural homelands to gain education, training and experience.

He categorizes people living in rural United States into five types:

1. indigenous poor who lack the resources in the form of employment or employment pensions
2. relatively well-off indigenous people, who have sufficient resources to hire home help or pay for privately provided assisted living
3. less well-off return-migrants at or near retirement age, returning to a family home, to be near relatives and friends
4. better-off return-migrants
5. incoming retiree migrants without local connections who are generally more educated and materially better off. (Bryden, 2002)

No doctor in the house

The problem with such a changing demography is that the healthcare system is not adequate to adjust to this change. Aging results in decreased performance of abilities - physical: ability to provide for one's need; psycho-cognitive: ability to act and participate; and social: fulfill one's role in the society.

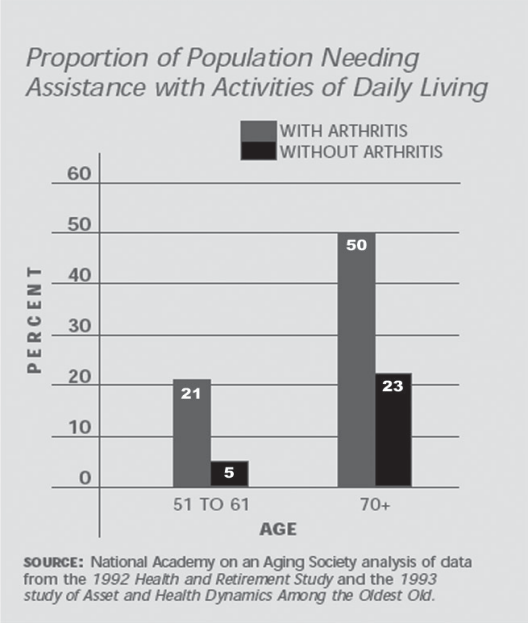

Figure 1. *Proportion of Population (per age) needing Assistance*

However, rural healthcare systems work differently from urban healthcare. Small, rural hospitals in addition to being the only source of emergency care are often a community's only resource for health care services such as long term

care, home health services and out-patient services (Bryden, 2002).

Problem of lack of health care providers: Rural healthcare systems are burdened by the cost of healthcare services and the lack of health care providers. Mississippi for example has one of the lowest active physicians to population ratio in the country.

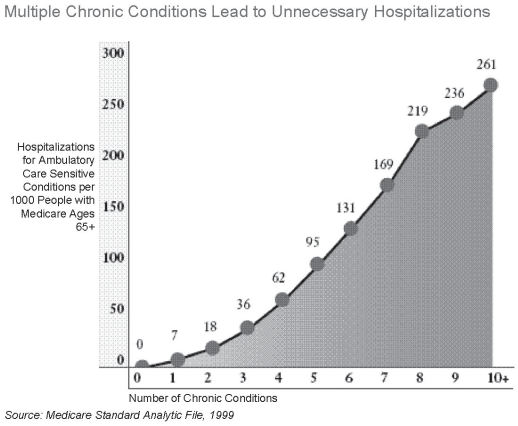

Figure 2. *Unnecessary Hospitalizations*

Problem of cost: Medicare and Medicaid systems are often the only sources of revenue for rural hospitals. Yet a recent report shows that Medicare spending for rural counties was significantly lower than for urban counties. To further aggravate the situation, the Medicare reimbursement system assumes that it is cheaper to deliver health care in rural areas, and its reimbursement rates for rural health providers is correspondingly lower than it is in cities (Bailey and Nemet, 2002).

Problems of access to healthcare: In a study (Bailey and Nemet, 2002) of 'elderly health care utilization in New Orleans County", 69% of the respondent's physicians were located in the two main population centers. Those traveling to the nearest hospital faced a round trip of 160 miles, often necessitating an overnight stay.

There is also a lack of access to private and public transportation by the rural elderly and the poor. Many small rural centers do not have public transportation systems and often not even taxi services. This impacts the elderly and the poor who do not own a car or are unable to drive one.

I don't want to leave my house

One solution to the problem is to move the elderly to assisted living centers and nursing homes; while other solutions include the diversification of hospital services. The "swing bed" program allows patients to stay in the hospital beyond the end of their acute stay and receive nursing services they need. However, in the following study conducted by Forrester Research in 2003, it was found that although nursing homes house almost 1.5 million seniors and one-third of those have been there for

GEOGRAPHIC AREA	TOTAL ACTIVE PHYSICIANS	TOTAL PER 100K POPULATION
UNITED STATES	727,573	257.9
NORTHEAST	185,439	345.7
SOUTH	237,788	236.5
EAST SOUTH CENTRAL	36,899	216.4
MISSISSIPPI	4,931	173.1
WEST SOUTH CENTRAL	65,952	209.1
NORTH CENTRAL	152,573	236.6
EAST NORTH CENTRAL	108,711	240.5
WEST NORTH CENTRAL	43,862	227.7
WEST	151,773	239.2

Table 1. *Active Physicians per 100K population*

Source: American Medical Association. Physician Characteristics and Distribution in the U.S.,2002-2003 edition. Chicago, 2002.

more than three years, *77% of American consumers say that nursing homes are a last resort for themselves and their family members* (Boehm et al., 2004).

The above statistics echo concerns that the current clinical model of healthcare is not working at an optimal level. As a result, it is an ideal time to initiate changes within people's lifestyles and homes to help augment the current model of healthcare. One suggested alternative is a *prevention rather than crisis management approach*. Research has shown the significance of moving the focus of attention from the health centers and hospitals to the working home through technology interventions (Intille et al., 2003).

Ubiquitous computing for proactive healthcare

Technology

Computer scientists envision that one of the first uses of ubiquitous computing at home will be in the field of proactive healthcare. Intille (Intille, 2004) claims that the using technology in homes would be one way of potentially reducing the spiraling medical costs. He mentions two trends in computing will allow the introduction of computing within the architecture of a home:

1. The rapid adoption of powerful mobile computing devices. These devices can be used to collect and process sensor data from wearable wireless sensors and convey this information to the user. Future devices will be smaller, lighter, inexpensive, and available in a variety of form factors.
2. The emergence of real-time context aware computing. A context aware computer can automatically infer what a person is doing from sensor data.

Morris and Lundell at Intel Research identify different ubiquitous computing technologies that could potentially be used in homes (Morris and Lundell, 2003):

- *Wireless broadband/networks* - to allow communication between devices
- *Biosensors, Activity sensors, and bodily diagnostics* – non intrusive real time monitoring of users and occupants
- *Information fusion and inference engines* – that must ferret out inherent noise and correctly infer high level behaviors from low level sensor data
- *Ambient displays and actuator displays* – to enable communication between the user and the system

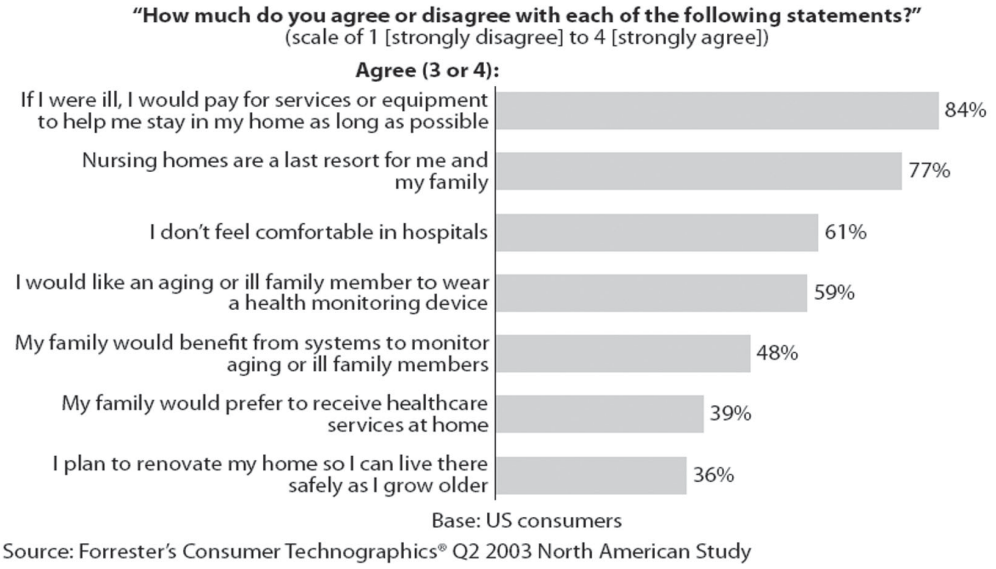

Figure 3. *Preferences of healthcare*

- *Natural interfaces* – that enable communication through natural media built into the lifestyle of the user

Eventually these technologies will be integrated with architecture and design; used not just to cure sickness and help people with cognitive decline, but also to promote wellness throughout all stages of life. Currently, MIT (MIT-TIAX PlaceLab, 2004) and other premier institutions are developing "living laboratories" – places where the concepts of ubiquitous computing (sensors, cameras, monitors) can be studied with real-life users. These laboratories are developing and testing several products that can be introduced into the architecture of a house, to track, monitor and provide feedback to the resident. Such technologies can successfully motivate *long-term* healthy decision making, and thus delay or even prevent the onset of medical problems such as obesity and chronic illnesses, alleviating the pressure on the traditional healthcare system (Intille, 2004).

Adoption

Several independent studies show us that the American population is more receptive of technology solutions and health monitoring systems than ever before. A major reason for this shift is perhaps the wide acceptance of congruent technology (internet, cable television, cell phones) by the American consumer. In one such study, Forrester Research shows:

Since we are primarily looking at a rural population, it is also important to consider adoption of new technologies these areas. In our own ethnographic studies we charted the following biases that rural populations carry:

1. Economic bias: Most of the current rural population has little or no access to any sort of computing, leave alone ubiquitous devices. Much of the population does not even have access to common household devices. Even if they did have the facility to buy these devices and were willing to do, they may not have the economic resources to do so.
2. Cultural bias: Culturally rural areas are not accustomed to the use of technology solutions to solve problems. Due to problems of availability and accessibility, a rural person would consider technology as his/her last resort.
3. Lifestyle bias: The lifestyle of rural America is significantly different from that of the urban. Current designs are usually created with the largest user base in mind– the urban buyer. Hence, some of these solutions may not be suitable for use in rural areas or even if they are, may not be used in the same manner by rural users.

Ethnographic studies by Intel Research (Morris and Lundell, 2003) however shows that in spite of these cultural, ethnic and socioeconomic barriers to adoption of new technologies; there is more enthusiasm for hi-tech solutions among extremely low income caregivers with very little previous exposure to computing than with those with significantly higher financial resources.

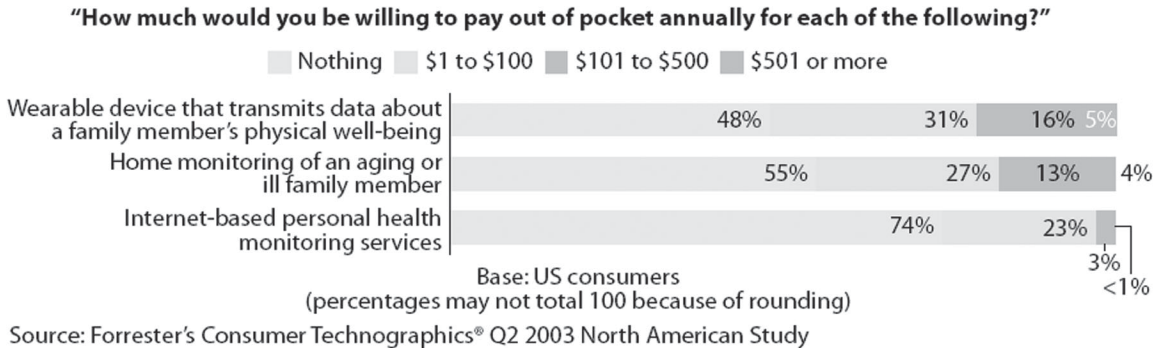

Figure 4. *Adoption of technology by US consumers*

Smart Homes for the Rural Population

In their paper, Edwards and Grinter (Edwards and Grinter, 2001) present seven challenges from technical, social, and pragmatic domains for using ubiquitous computing at home. Although these challenges are true for most homes, we believe that the rural home is different. As we move towards designing in rural areas, it is paramount to develop similar constraints that are unique to rural homes. These constraints would then form the framework for the design and ultimately the implementation and maintenance of the technology. In the following part of this paper, we present the challenges that we believe will be the challenges of the rural "smart" home. In order to initiate a discussion on what constitutes a "smart" home for rural America, it is important to think like the rural person. Thus, we present our challenges in the form of concerns a rural person may have when first introduced to "smart" home technology:

"I can't afford it"

The limiting factor for computing initiatives for healthcare in rural America will not be lack of need, lack of interest, or immature technology; it will be the lack of funding (Boehm et al., 2004).

Ubiquitous computing initiatives are available today – for those who can pay out of their own pockets. The rural population is significantly poorer than its urban counterpart. The irony of the situation is that it is the rural population that perhaps requires these technologies more than those in the cities; poor healthcare centers, poor outreach of medical facilities, and even lack of access to health providers. One way that these technologies can reach the rural poor is if the government mandates legislation to include them as part of the medical insurance system or subsidize the technology to enable initial penetration. Similar subsidies were available to the rural public with new technologies like the telephone and electricity. Initial subsidies allowed the rural owner to purchase these technologies; drive the price down; thus make the technology an essential commodity. However, only five states – California, Kentucky, Louisiana, Oklahoma, and Texas – have passed legislation mandating reimbursement of tele-medical consults that would be covered if treatment occurred in the traditional face-to-face mode. Forrester Researcher estimates that only beyond 2010 will third party payments be initiated for preventive healthcare technologies in the house (Boehm et al., 2004). The challenge for us designers is to work with government agencies in order to introduce these technologies into rural architecture. The initiative may begin with population centers and finally trickle down to the rural poor. As more people begin to use these technologies, the government will realize the importance of such designs and mandate legislations to make them insurable.

"I don't know how to use it"

In early days of the computer, system administrators were an important part of the everyday running of the system. As computer systems became more ubiquitous the role of the system administrator shifted to the user. But rural America is still not tech-savvy enough. More often than not technologies, common in the cities, have not reached these rural communities. When they do, people don't always know or want to know how to use them. It is important thus to make these systems as uncomplicated as possible. One method is to shift the intelligence from the device to the network. Traditional appliances, like telephones or televisions are commonly accepted because the intelligence of the system lies in the network and not the device. The home only contains the most simple and minimal "front end" functionality needed to access the network (Edwards and Grinter, 2001). It is paramount that future designs also be able to scale as well as degrade gracefully. A component that fails should not bring the rest of the system down. In addition to the workability of these systems, insurance companies may also demand to see certain levels of safety (meeting regulations and codes, seismic tolerance etc.). In short, the "smart" home of the future must also be a reliable home of the future.

"Where do I buy it?"

While new homes may eventually be built for such smart applications, existing homes are not designed as such (Edwards and Grinter, 2001). It would be also presumptuous to assume that someone who does not want to move to a nursing home will consider moving out of a house that holds their past. An acceptable alternative is to develop another (retiree) home that in some way resonates with their earlier home. In both situations

it is important for us to understand that most "smart" technologies used in the homes will be bought piecemeal from a local convenience store or a large specialty store. The challenge for the architect is to anticipate change in the designs of their spaces when these technologies are brought together gradually. It is also important that affordances are made for old devices to be removed and new devices to be added without the inconvenience of changing the basic design. What designers must also assure is the impromptu operability as well as interoperability of these technologies. Architects must eventually design spaces that will not end up as islands of functionality but connect seamlessly as a whole. One way to ensure such a design is to draw on the way people use spaces and designs currently; another is to study the behavior of people in natural settings informing us the best configuration of space and technology.

"Will it interfere with my life?"

One of the most important challenges of stitching ubiquitous computing into architecture is to create a non-disruptive environment. The problem of today's technology is that it conflicts with the real world which is a "highly analog" environment (Edwards and Grinter, 2001), presenting a great deal of ambiguity and unpredictability. These technologies must not only accommodate differences across individuals but also differences across households.

Rural "smart" homes must present information attuned to the lifestyle of the user. The challenge is to design for the rural lifestyle: what works in the city may not work in the village. Current emergency response systems work fine if you fall in the house, but if you fall in the garden while watering your tomatoes, you may have a problem (Coughlin, 2001). Elderly people also live differently from younger people. Morris and Lundell's study showed that elders seemed to designate "command centers" (a kitchen chair, a bed) that served as a base for entertainment, eating, work, and socializing. Unless the technologies are designed within easy reach of these command centers, they may not be used at all (Morris and Lundell, 2003). Designers must understand that in the rural home, cultural and social biases will take precedence over technical and aesthetic biases. It is important then to re-analyze the designs built for rural households; asking questions of whether it will work with the lifestyle of the user or not.

"Will it take over my home?"

Science fiction movies and books have ingrained into the minds of people that when computers reach our homes, *they* will be in control. Real research however takes a very different route. People feel strongly when a computer takes all the decision; it makes them feel insecure and out of control. The best method is to abandon the "shut up and eat your mush" approach and take a more "here are your options" approach. Leave all control for decision making to with the user but instead provide just-in-time information highlighting the benefits of engaging in particular behaviors. Instead of trying to wrench control from the user, the computer should reward a behavior using powerful motivational strategy of positive reinforcement operant conditioning (Intille, 2004). Such long term rewards to the user will ensure that the behavior change should be sustained even on the removal of the interface. The designer must make the choice between persuasive (indicating that it is time to take medication) and coercive mechanisms (forcing the person to take medications). Most "smart" home technologies also have severe privacy implications. Even the most subtle design may be too intrusive for a rural family. Using sensors and cameras to monitor a user may not be acceptable by certain communities, even though such a solution would be the most apt for the problem they face.

If "smart" technologies have to be accepted by the larger rural community, it must eventually be designed for them and with them. Without the involvement of the end user, these technologies may never find use off the store shelf.

"I don't want to be isolated"

The last thing a designer wants is to isolate the inhabitants of his/her designs from the real world. Any technology should aspire to catalyze rather than replace human interactions (Morris and Lundell, 2003) and social connections. Any system that remotely offers the idea of isolation faces the danger of immediate rejection. Morris and Lundell (Morris and Lundell, 2003) claim that socializing is a strong motivation for participation in healthy behaviors and that socially isolated members of their group were often less satisfied, less optimistic

and in poorer states of health than their active counterparts. Our studies show that there is a large increase in the number of rural elderly that live alone and a decrease in the number of married couples and couples with children. Most rural elders are retirees whose children have moved away to a large city or to another part of the country or the globe. Many of these children still have backward ties with their parents and grand parents – often concerned for their health and well being. Successful aging requires the elder to reach a balance between self-confidence on one hand and comfort with increasing reliance on others on the other (Morris and Lundell, 2003). Design of "smart" homes should eventually address the issues of a rural population that is living alone, yet looking for connections to their children (and/or other relatives) and vice versa.

Not only is it important to design for social interaction and connectivity, but also for shifts in social dynamics within real life situations. Edward and Grinter (Edwards and Grinter, 2001) mention that the challenge for us as designers is to be aware of the broader effects of our work, and to realize that even simple technologies (washing machines, telephones, televisions) can have broad changes on the dynamics of the home and society.

"Can I fix it myself?"

It is a challenge for designers to design systems that will ensure that the users understand the pragmatics of sensors, interpretation, and machine actions as well as they understand the pragmatics of devices in their homes now (Edwards and Grinter, 2001). The rural user has several constraints to the use of a design that is not evident in urban areas. Most rural homes often have accessibility issues – it may not be possible for a technician to make a round every fortnight to check on the components of the "smart" home. It is also contradictory to assume that users who do not have proper access to health centers will have access to large stores that can service these technologies and devices. The plausible solution to these problems is to create devices as simple as the ones they use today. Unlike current internet technology, which relies on devices at the edge of the network; future networks should be independent of the devices in the home.

The issue poses a pertinent question, what if it's not the device but the space itself that needs improvement – to adjust to new lifestyles, new situations? In such cases, it is important that the architect, instead of physically visiting the site and changing design, take on the role of a computational critic (Larson et al., 2004) – someone who, using the communication technologies, discusses with the users on how they can change the design to better suit the change in their lives.

Designers of technology solutions also assume that the users will use the technology in a particular manner; but users don't. They will always find novel ways to circumvent conventional thinking of the designer and carve out new uses for the solution. Predicting these circumventions may be difficult, but it is important that we pay attention to the use of these systems by actual rural users to understand not only the working but also the scope of use afforded by the solution. In case of elderly homes, a further dilemma is created by the fact that although the end users of such technology may be the elderly; the actual running of it may be done by younger stakeholders (children, grandchildren, caregivers etc.). Thus, designs have to not only account for front end interfaces but also back end interfaces that are easy to understand and fix.

The Role of the Architect

Products developed and tested in laboratories often fail when introduced into natural settings such as homes because they are often designed without understanding that human behavior in natural settings are strongly tailored to the settings themselves and to the behavior of the people nearby (Intille et al., 2003). One common trend we find among the research centers currently working on a new "lab" or a "home" is that the locus of attention is on technology. Many solutions from these labs are often based on technical rather than aesthetic or usable values; the architect can help by understanding the idiosyncrasies of the user. As a designer, he/she is capable of changing the product to meet the cultural, ethnic and the socioeconomic requirements of the user. But research needed to tap the potential of new architecture is fragmented and out-of context claims the Open Source Building Alliance:

Computer Scientists attend pervasive computing conferences to present visions of the future, but rarely does an architect attend. Architects gather to debate the latest design ideologies without

including those who actually make the systems and materials they will use. Health researchers propose visions of the "smart" medical home of the future, but without careful study of how the behavioral and non-medical needs of their patients will change when they leave the hospital for the home. Devices are prototyped for the home without evaluating their use in the complex mix of everyday activity (Larson et al., 2004).

Conclusion

The fact that this paper has remained a report of existing research and study of current conditions is intentional. We have used prevalent conditions and research to frame a set of unique constraints that will help us to develop designs in the context of rural America. We believe that such basic study of conditions is necessary to develop the problem (ask the question properly) before finding a solution (answer the question). At Mississippi State University's Design Research & Informatics Lab (DRIL), we are working towards research in the areas of actually using technology within homes for proactive healthcare. As we progress towards the next wave of architecture, it is important that the architects be aware and conscious of the change in the way we design homes. Through live projects and user studies, the DRIL works with undergraduate and graduate students to develop designs that use these technologies within the architectural framework of the rural home. Besides teaching the DRIL is also involved in multiple research projects exploring the acceptance of technology by Mississippi's population; the design and deployment of contextual devices and designs; and developing designs with rural/quasi-rural communities that can be acceptable and sustained by the people within or migrating to these communities.

It is our belief that only through the careful mediation of technical aspects of design with the phenomenological and the aesthetic, can we dream of using ubiquitous computing in our homes. Elegant and usable design will be achieved *only* through conversations between researchers in various disciplines and through widespread awareness of current literature and research in this realm. It is our hope that the above discussion will help us initiate a dialogue– to understand both the problems and the opportunities of designing rural homes of the future and to work together to find a common solution or set of solutions.

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