Ubiquitous Computing and Domestic Technologies

People-Oriented Computing

11.11.2019

Agenda

- Announcements
- Ubiquitous Computing (cont.)
    - Theories and methods for design and application
- Domestic Technologies
    - Background to smart homes
    - Early smart home research
    - Challenges for smart home design
    - Addressing barriers to success
- Walkthrough of sample exam questions

Announcements

- Lab on Wednesday, 13.11.2019
- Exercise posted on OLAT
- Project assignment #2 will be assigned next week, due 2.12.2019
  - Project is to be done and submitted individually (i.e., not in groups or pairs), BUT...
  - You will be required to find someone to complete an interface walkthrough for your analysis and you may use a fellow POC student

Learning Goals

After this lecture, you should

- Be familiar with background concepts pertaining to smart homes
- Have knowledge of some early smart home research as well as later systems
- Be aware of classic challenges to domestic technologies
- Have a familiarity with approaches to address the complexity of smart home technologies

Ubiquitous Computing

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."

Ubiquitous Computing

What is necessary to realize the **human-centered vision of ubicomp**?

- Defining the appropriate physical interaction experience
- Discovering general application features
- Theories for designing and evaluating the human experience

Ubiquitous Computing

What is necessary to realize the **human-centered vision of ubicomp**?

Defining the appropriate physical interaction experience

What **form** does the interaction take? How do we interact with the system?

Defining Appropriate Physical Interaction Experience

New approaches to input and output

- Implicit input
- Multi-scale and distributed output
- Seamless integration of physical and virtual worlds

Ubiquitous Computing

What is necessary to realize the **human-centered vision of ubicomp**?

How should the technology **work**? How does it **function** and what does it **support**?

Discovering general application features

Discovering General Application Features

Functions that support daily activity

- Context-aware computing
- Automated capture and access
- Continuous interaction

Context-aware Computing

- Using implicitly sensed context from physical and electronic environment to determine the correct behavior of a service
- Intended to make interactions with services more seamless and less distracting from everyday activities
  - E.g., cars that recognize the driver and adjust the environment to him/her
  - Smart thermostat systems that learn your schedule and adjust the heat in your home accordingly

Automated Capture and Access

Human recording and retrieval of information is generally inefficient, incomplete, and error prone, especially when there are multiple relevant streams of data

Automated Capture and Access

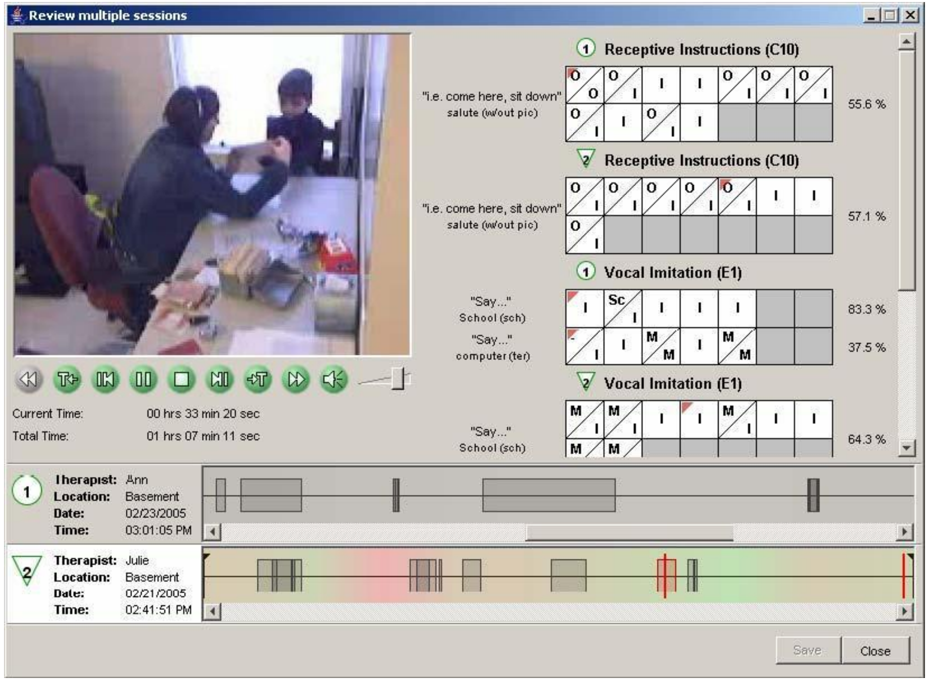
- Automated recording of information from events has long been regarded as both valuable and dangerous
- Computational tools can remove or reduce the burden of recording and organizing information

Automated Capture and Access

Focuses on preservation and recording of live experiences for review or access in the future as well as access interfaces

- E.g., classroom activities, meetings, special events, conversations
- Vannevar Bush's idea for the Memex was an early example of a capture and access technology for textual artifacts and other documents

Abaris



Captures relevant events for one-on-one therapy sessions for children with developmental disabilities

Makes information available to therapists

Continuous Interaction

- Providing continuous interaction moves computing from localized tools to constant, ubiquitous presence
- Focuses on informal daily activities (rather than goal-oriented tasks)
- E.g., fitness trackers, notifications on a smart watch, chronic illness management, mindfulness

Continuous Interaction

Informal daily activities present new challenges for design

- Rarely have a clear beginning or end point so design cannot assume common starting point or closure
- Interruptions should be expected
- Multiple activities operate concurrently and may need to be loosely coordinated
- May consist of a number of subtasks that are loosely bundled

Ubiquitous Computing

What is necessary to realize the **human-centered vision of ubicomp**?

How do we understand the problems we are trying to address? How do we understand the impact and effects of the technology?

Theories for designing and evaluating the human experience

Understanding Interaction in Ubicomp

As with CSCW, understanding ubicomp interaction is more complicated than understanding interactions between a single user and a single machine

Understanding Interaction in Ubicomp

Various models and methods are applicable to ubicomp, including:

- Activity Theory
- Situated Action
- Distributed Cognition
- Ethnography
- Cultural Probes

Knowledge in the World

- Traditional models of cognition and interaction (e.g., Model Human Processor) focus on internal cognition
    - Three independent units for sensing, cognition, and motor activity, each with its own memory
- Complexity of ubicomp systems lends itself to models that consider both “knowledge in the head” and “knowledge in the world”

Activity Theory

- A descriptive theory that recognizes **traditional concepts such as goals, actions, and operations**
- Treats goals and actions as **fluid based on the changing state of the world** rather than a priori plans
- Emphasizes the **transformational properties of objects** that carry knowledge and traditions
- Ubicomp systems informed by activity theory would focus on transformational properties of artifacts and fluid execution of actions and operations

Situated Action

- Theory that **rejects the notion of pre-planned goals** as the motivation for action
- Emphasizes the **improvisational nature of human behavior** based on the changing world
- Ubicomp systems informed by situated action would emphasize improvisation and seek to add useful knowledge to the world to shape actions
- Evaluation of systems would emphasize real-time observation and reject post-hoc explanation

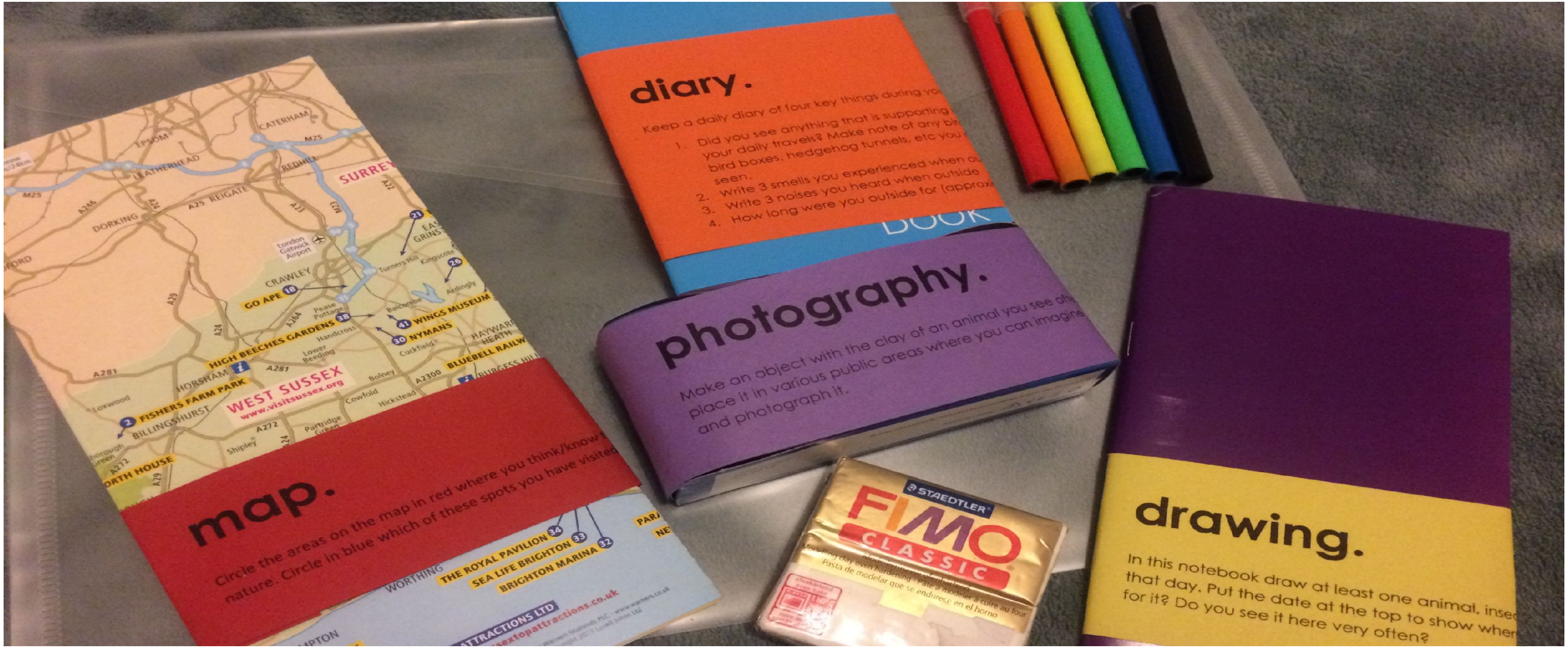
Distributed Cognition

- Another theory that **de-emphasizes internal human cognition**
- Treats humans as a part of a larger system in which the **knowledge is distributed among the components**, including humans and objects
- Objects themselves act as **triggers for action** and **reflect the state of the system**
- Ubicomp systems informed by distributed cognition would focus on larger system goals rather than individual interactions or appliances and focus on how information is encoded in objects and transmitted

Ethnography

- Descriptive approach based in anthropology that focuses on **observation of everyday practices in situ**
- Recognizes that people's **conscious conceptions** of what they do are **incomplete and inaccurate**
- Valuable for gaining **rich understanding of settings and practices**
- Used to **inspire design** rather than as a way of finding solutions

Cultural Probes



Source: doctordisruption.com

Cultural Probes

- Developed by Bill Gaver as a way of of gathering rich data from people without the intrusion of observation
- Small packages of items with guidelines for use **designed to provoke and record comments** given to people to use in their own environments
    - E.g. drawing pads, single-use cameras, voice recorders, diaries, activity workbooks
- Used to understand **what is significant** for the people in the environment and to convey **aspects of the environment's culture** to designers

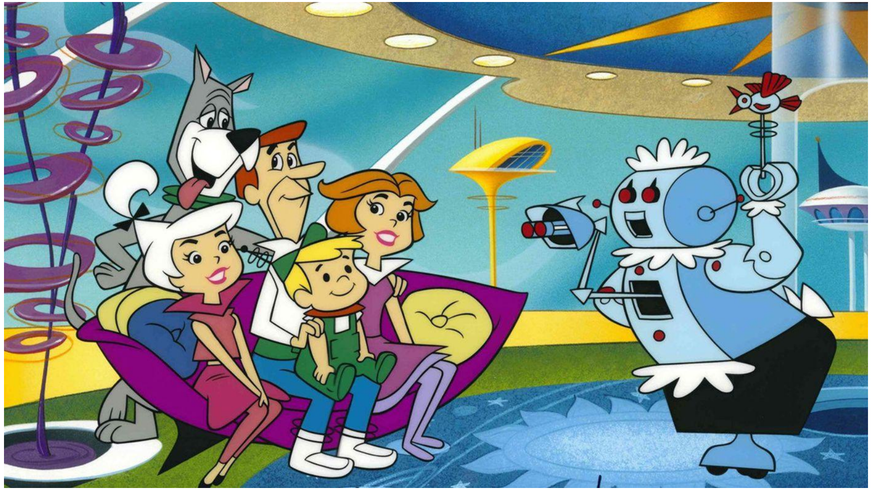
Evaluation of Ubicomp Systems

Evaluation of Ubicomp systems is also more challenging than evaluation of single user-single machine interactions

- Ubicomp often relies on cutting edge or novel technology that are not yet reliable and robust
- Hard to test systems in real world deployments
- Often long-term use in “living laboratories” or real world settings are necessary to understand their real impact

TECHNOLOGIES AND THE HOME

Domestic Technologies



Originally conceived of as the application of technologies in the home (e.g., appliances or home automation) often with the intention to increase efficiency or reduce work

Domestic Technologies

In actuality the reduction of work is questionable because access to technologies has also changed expectations

- E.g., increased adoption of washing machines for clothes led to societal shift in expectations for cleanliness of clothes so workload did not decrease

Domestic Technologies

- Domestic environments are extremely diverse and challenging to understand
- Questions go beyond technology to sociology, culture, politics, and psychology
- Technologies that prescribe procedures or practices are generally undesirable

Domestic Technologies and Ubiquitous Computing

Extremely broad field that considers many aspects of the home, including

- Efficiency
- Safety
- Entertainment
- Communication
- Comfort
- Coordination
- Health and wellness
- Etc.

The "Smart" Home

A term frequently used to refer to homes augmented with technology or a home of the future

- Sensors
- Actuators
- Cameras
- Microphones
- Displays
- Speakers
- Robots
- Appliances

The “Smart” Home

- Today’s modern homes are already filled with “smart” technologies
  - Audio and visual entertainment technology that can be controlled from a mobile phone
  - Voice controlled agents
  - Smart thermostats
  - Ubiquitous high-speed wireless internet
  - Appliances that automate chores (dishwashers, washing machines, robot vacuum cleaners)
  - Sensor-activated lights
- Are most modern homes “smart” now?

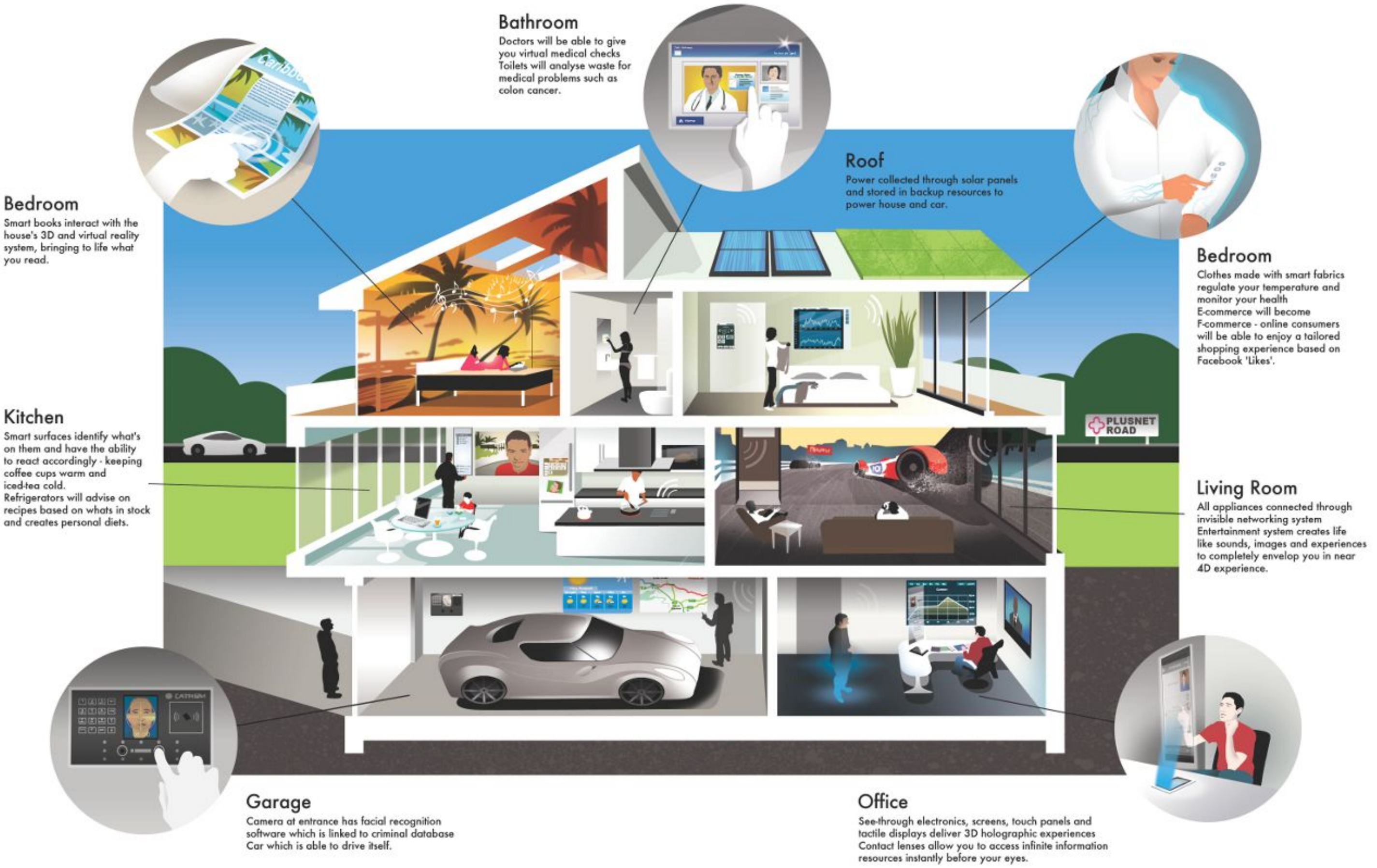
Definitions of a "Smart" Home

- "Domestic environments in which we are surrounded by **interconnected technologies** that are, more or less, **responsive to our presence and actions**." – Edwards & Grinter, 2001
- "A home [that] **adapts to inhabitants**" – Brush et al, 2011
- "Homes that **cleverly support** their inhabitants" – Mennicken et al, 2014

All definitions have a strong emphasis on the inhabitants of the home

Definitions of a “Smart” Home

- Strictest definitions include intelligence
  - Homes learn about inhabitants implicitly
  - Homes respond to inhabitants’ activities
  - Homes adapt and develop behaviors based on inhabitant activities
- Less strict definitions generally involve some automation
  - Possibly rule based, not as intelligent



PlusNet 2027 house concept

EARLY FORAYS INTO SMART HOME RESEARCH

Early Smart Homes – “Living Laboratories”

- Early smart homes were research laboratories designed in the form of living spaces
- Infrastructure for smart homes was expensive and difficult to deploy in real homes; test systems instead built in laboratories
- New technologies could be tested and demonstrated, and experiments could be run

Living Laboratory

- MIT’s House_n (~2002)
- One-bedroom apartment with sensing technology placed in nearly every part of the home
- Applications built atop sensors using information collected from them
- Allowed for the study of behaviors, testing of new technologies, learning about what can be sensed in a home

Living Laboratory

- Georgia Tech Aware Home (~1998)
- 3-story home augmented with sensing technology and control infrastructure
- Applications built atop infrastructure with particular emphasis on health and wellness:
    - Technologies to support aging in place
    - Technology to support caring for children with developmental disabilities

Digital Family Portrait

- Georgia Tech Aware Home project (2001)
- Focus on aging in place
- Promote lightweight communication of wellness status of senior adults to their adult children
- Intended to support privacy in communication and daily awareness

Digital Family Portrait

- Influential idea because of emphasis on wellness and privacy
- Represented a move away from the notion of smart homes as focused on efficiency and automation

Current Commercial “Smart” Home Technologies

Research Smart Home Technology Ideas

CHALLENGES FOR THE DESIGN OF SMART HOME TECHNOLOGIES

Challenges for Smart homes

Foundational 2001 work by Grinter and Edwards laid out key challenges for the future of smart homes

Challenge One: The “Accidentally” Smart Home

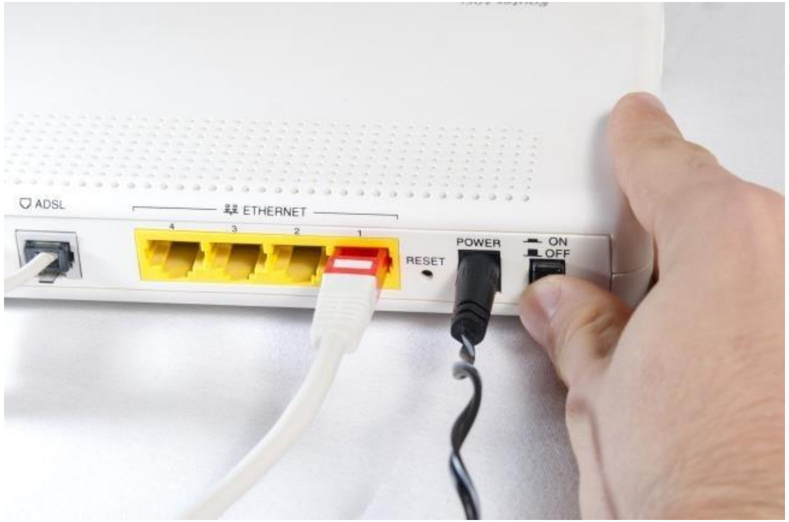
- Pervasive infrastructure for ubiquitous computing does not exist in most homes
- Houses require specific outfitting for ubicomp technologies
- Homes that are not intentionally built as smart homes must be upgraded to support new technologies creating problems of interoperability between systems
    - E.g. if you get on a neighbor’s wireless, you might also be able to access their speakers

Challenge Two:
Impromptu Interoperability

- The ability to interconnect between systems and devices with little or no advance planning will often be desirable
- It is not easy to predict what future services or devices will need to connect with each other
- If people cannot predict or know which services can interconnect, it will lead to frustration and poor interaction with the home

Challenge Three: No Systems Administrator

- Increasing complexity of computing technology in the home leads to need for increasing knowledge to administer and maintain
- Cannot expect that all homes will have a systems administration expert (just as homes usually do not have an electrical or plumbing expert)
- Challenge is to design technologies that require no on-site expert to maintain



Challenge Four:
Designing for Domestic Use

- There is a lack of understanding of domestic environments to inform the design of smart home technology
- Real technology use can differ greatly from its intended use
- Classic example – initial vendors of the telephone did not regard it as having a social function
- Predicting the ways in which technology will affect and disrupt the home environment is extremely challenging so studies of routines and practices are necessary

Challenge Five: Social Implications of Aware Home Technologies

- Technologies in homes have important social implications
- Privacy is a key concern because many systems rely on collection of data and context
- Machines for automating work may change expectations and shift the burden of work without reducing work
- Increased access to media and communication has changed the activities of children and the responsibilities of parents
- Technologies alter routines in ways that cannot be predicted and have massive impact on the home and society

Challenge Six: Reliability

- Reliability becomes increasingly challenging when systems are embedded in the home environment
- It can be unwieldy to patch or upgrade devices in the field
- If systems are interconnected, designers also need to take care that a failure in one component does not bring down the rest of the systems
- Evidence of this challenge in the transition from conventional phones and televisions to digital counterparts

Challenge Seven:
Inference in the Presence of Ambiguity

- Systems that attempt to understand what the inhabitants are doing have long been a goal but have met with mixed success in reality
- How smart should a home be? How much inference is required for a smart home to be successful? How to fix incorrect interpretations?
- Challenge is to figure out what functions of the home are only possible through inference, what can be achieved with limited inference, and what requires an “oracle”

ADDRESSING BARRIERS TO SMART HOME SUCCESS

Studies of Smart Homes

- Commercially available home automation systems
- DIY home automation
- Uses of smart appliances

Home Automation Study (2011)

- Study by Microsoft Research & University of Washington (Brush et al.)
- Study of 14 homes with home automation technology (professional and DIY systems)
  - Why inhabitants installed technology
  - Their experiences living with it
  - How they handled guests and security issues

Home Automation Study (2011)

- Found that most technologies pertained to lighting, security, media, or environment
- Systems offered peace of mind and some conveniences

Home Automation Study (2011)

Uncovered barriers to use

- High cost of ownership in terms of time and money and little desire for additional functions
- Lack of flexibility because of poor interoperability between systems and limitations in configurability
- Poor manageability because of unreliable behavior, slow response time, complex user interface and need to hire professionals
- Concerns about security because of remote access, cameras, group permissions

Home Automation Study (2012)

- Study conducted by Mennicken et al. at University of Zurich
- Focused on people living in automated homes or in the process of building automated homes using professional commercial systems

Home Automation Study (2012)

- Uncovered various motivations for installing smart home technologies
  - For the sake of modernity
  - For the “hobby” hacking aspect
- Interestingly, participants were less interested in the direct benefits of the technologies, was not regarded as a “game changer”
- Often a strong mismatch between who desired the technology and who experienced its effects

Roomba Study (2007)

- Conducted by Sung et al. at Georgia Tech
- Investigation into domestic robots and the adoption and use of Roomba robotic vacuum cleaners
- Focused on the relationships between people and their technologies, and how intimacy affects perception of technology
- Looked at messages posted on a Roomba forum and interviewed 30 Roomba owners

Roomba Study (2007)

- People gained happiness and joy from the Roomba even though it did not reduce work for them, and even created new work – enjoyed it like a pet
- People anthropomorphized Roomba, referring to them as family members, giving them names, ascribing gender, describing emotional remorse at exchanging a defective unit
- Indicated that feelings of intimacy could override issues of reliability and function

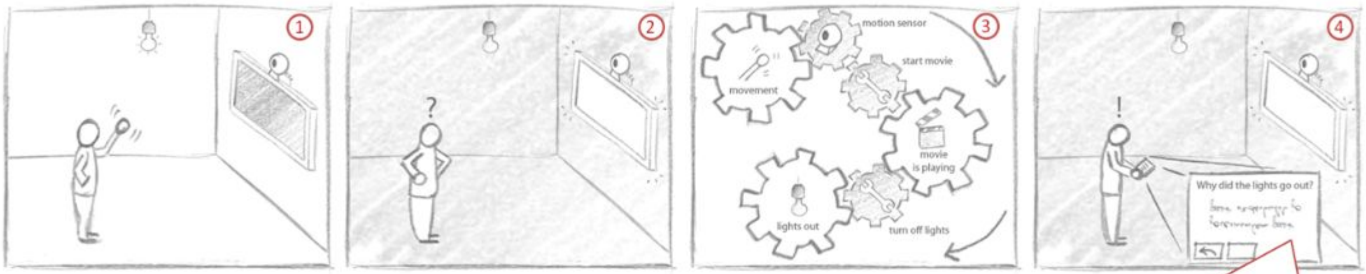
Facilitating the Smart Home Experience

- Smart homes present clear challenges for inhabitants
- Complexity and inflexibility of the technology pose limitations for value and functionality
- Steps towards solutions may include:
  - Interfaces to help people understand what is going on in their homes
  - Interfaces to help people program the functionalities in their homes easily

PervasiveCrystal

- System designed by Vermeulen et al, University of Hasselt
- Keeps track of recent events in smart homes
- Presents list of available “why” or “why not” questions depending on recent events
- Automatically generates responses by linking smart home events to triggers
- Allows users to “teach” the system by invoking undo or fine grained control to adjust system behavior

PervasiveCrystal

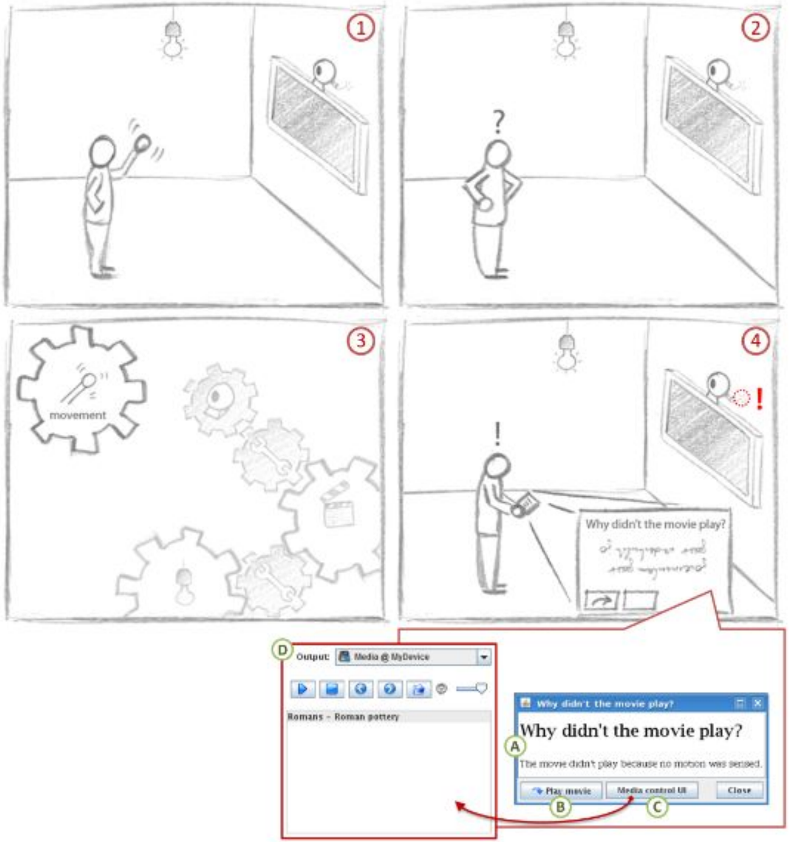


Bob waves at a motion-aware display to start a movie.

A movie starts playing, but the lights also go out. Bob wonders **why**.

Two rules interacted with each other.

PervasiveCrystal



Jigsaw Puzzle Interface

- Interface for end-user programming by Humble et al. at Swedish Institute of Computer Science and University of Nottingham
- Provided a simple interface for specifying the behaviors of technologies in the home, i.e., programming with little programming knowledge

Jigsaw Puzzle Interace

Identified three types of “transformers”

- Physical to digital transformers – turn physical effects into digital effects
- Digital to physical transformers – transforms digital information to drive a physical device
- Digital transformers – act upon digital information and effect digital information to allow for more complex behavior

Jigsaw Puzzle Interface

Seed Scenario #1. A Common grocery item is missing from a kitchen cupboard

Using the pieces shown below, **GroceryAlarm** is connected to **AddToList,** which is then connected to **SMSSend**. **GroceryAlarm** reports the missing item after a certain time interval and the missing item is added to an electronic shopping list. This list is periodically sent via SMS to a mobile phone.

GroceryAlarm: Generates names of missing groceries in the cupboard. It detects groceries moving in and out and if one is away more than 30 minutes it is said to be out.

AddToList: Takes an element string and adds it to the list it publishes into the dataspace.

SMSSend: Takes a message string and sends this as SMS to the given phone.

Jigsaw Puzzle Interface

Provided simple graphical editor for composing “programs” for smart home behaviors

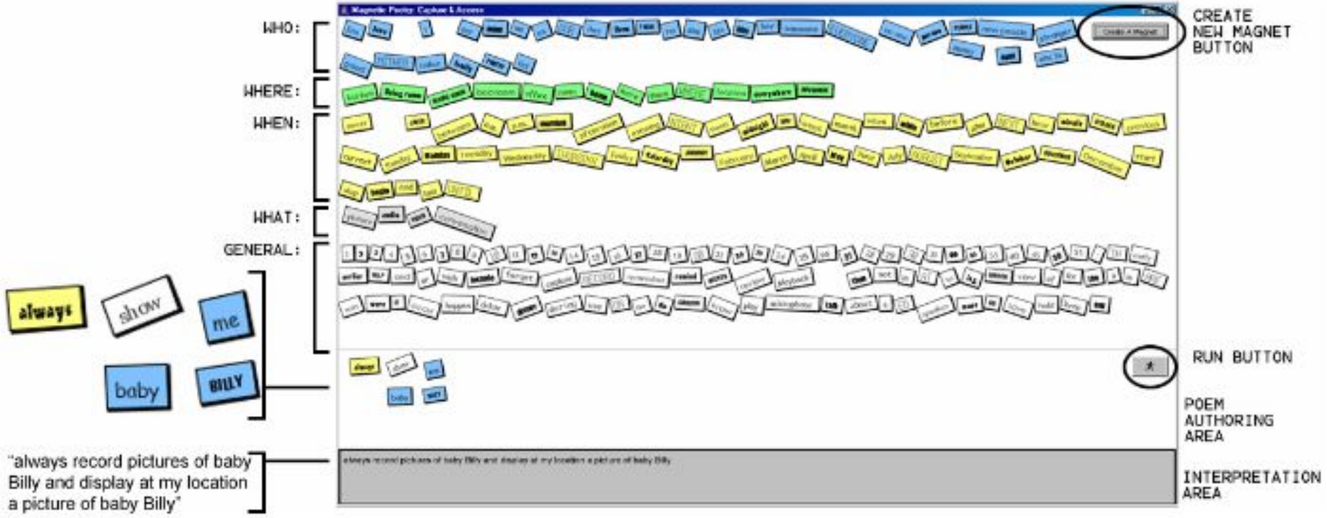
CAMP Interface

- Created by Truong et al. at Georgia Institute of Technology
- Offered a simple interface for end-user programming of smart home technologies, specifically for capture and access purposes
- Relied on magnetic poetry metaphor, required little to no programming skill


ALLY GREAT being
truly deprecated


please
what truly mad gorgeous fruit
munch ing
I gobble in the garden starving
how pretty these smell s
root s hang fluid ly
dangling under me like frazzled hai

CAMP Interface



In Summary

- Domestic environments present unique challenges for technology design
- Technologies need to consider untraditional approaches for input and output
- Smart homes pose barriers for intelligibility, maintenance and configuration
- Domestic technologies can have unpredictable disruptive effects on homes, families, and society

SAMPLE EXAM QUESTIONS WALKTHROUGH

Example Question 1. There are several models that are intended to represent or explain human behaviors and interaction. Which of the following models represents human interaction as three connected systems, each with its own memory and its own principles for operation?

a. Keystroke-Level Model
b. GOMS
c. Model-Human Processor
d. Seven Stage Model of Interaction

Example Question 2. Which of the following terms best describes the component of Pervasive Healthcare that focuses on encouraging healthy behavior and lifestyle choices among people without chronic illnesses or injuries?

a. Preventative care technologies
b. Hospital care technologies
c. Health maintenance technologies
d. Activities of daily living support technologies

Example Question 3. Which of the following phrases best describes the concept of implicit input technologies?

a. Technologies that provide explicit output even when no input is provided
b. Technologies that rely on natural interactions with the environment rather than explicit user interaction as input
c. Technologies that respond based on the state of the environment rather than the actions of individuals in the environment
d. Technologies that can produce different responses to the same input

Example Question 4. A person follows the link on the bottom of an email newsletter to unsubscribe to the newsletter. Clicking the link takes her to a page that says, "Thanks for reading our newsletter!" with other buttons or links. She is unsure whether she is still subscribed to the newsletter or has been unsubscribed. In a Seven-Stage Model analysis of this problem, at which stage is a breakdown occurring in the interaction?

a. Determining the sequence of action
b. Executing the sequence of action
c. Perceiving the state of the world
d. Interpreting the perception

Example Question 5. Which of the following historically important paradigms of interaction most revolutionized the way people think about information browsing and information storage in computing?

a. Direct Manipulation
b. Time Sharing
c. Hypertext
d. Interface Metaphors

Example Question 6. Interface metaphors have been widely applied in the design of computing systems to make new technologies easier to understand, less intimidating, and more enjoyable to use. Provide an example of a technology or system that you regularly use that makes use an interface metaphor that uses *real world objects or concepts* to represent *digital objects or concepts*.

1) State what technology or system you have selected. If it is not a well known technology (e.g., Gmail, Facebook) please provide a brief (2-4 sentence) description as well.
2) Explain what interface metaphor is being used. What is the real world system or concept that is employed, and what digital concept is it being used to represent? (2-5 sentences)
3) Provide 3 specific examples of how the metaphor is applied in the interface.

Example Question 7. Hospital care technologies are a key component of pervasive healthcare. Much of the focus of pervasive healthcare technologies for hospitals is on coordination, communication, and awareness among hospital staff. Groupware is therefore a prominent technology approach for hospital care.

Consider the Time/Space Groupware Matrix below:

	Same time synchronous	Different time asynchronous
Same place colocated		
Different place remote		

Provide **TWO** examples of **hospital care groupware technologies**, each of which represents a **DIFFERENT** quadrant of the matrix (you may choose which two quadrants of the matrix you would like to address.) You may use existing technologies described in the lectures, other existing technologies of which you know, or a technology of your own creation.

For **EACH** of the two technologies:

1) Provide a brief description of the technology including what it is, what it does, who its target users are, and what its function is in hospital care. Also please specify whether it is an existing technology or one of your own creation. (3-5 sentences).
2) State which quadrant of the Time/Space Groupware matrix is and provide a justification of why it falls into that quadrant. (2-5 sentences).