Usability in Real-World Context-Aware Applications

Carnegie Mellon

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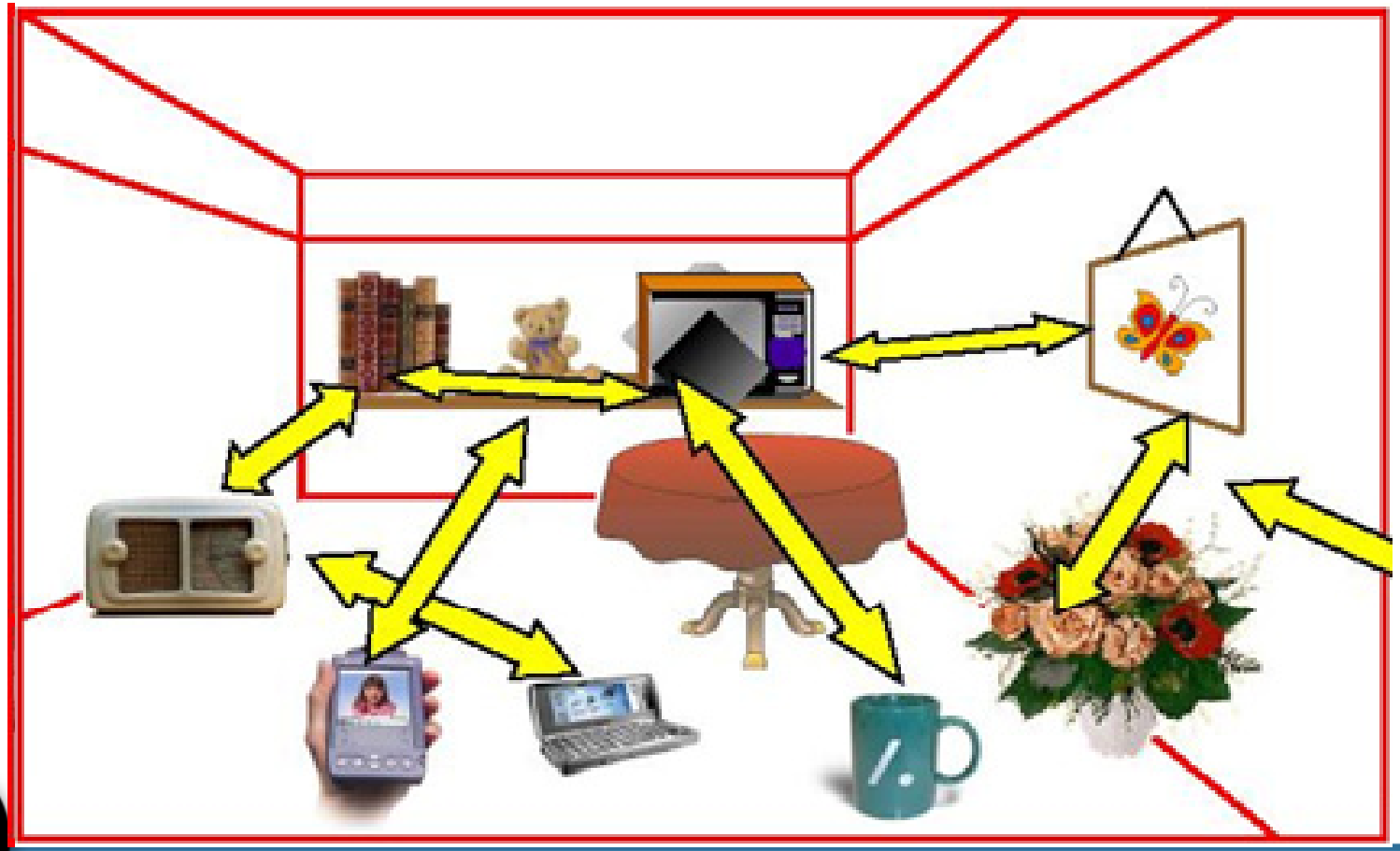
Overview of Ubicomp

- Computing embedded into everyday objects and environments, enhancing everyday activity



Context-Aware Computing

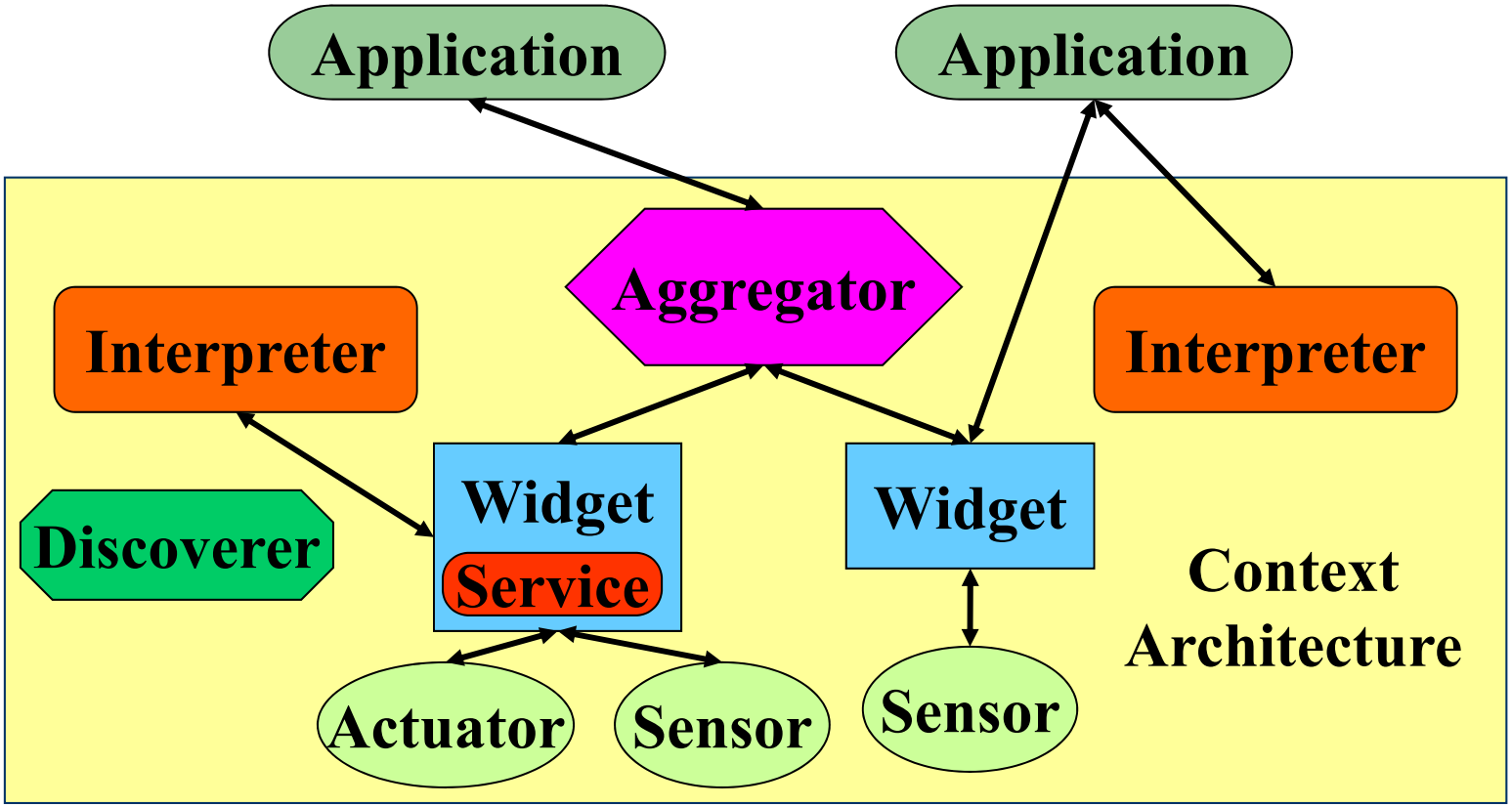
- Context: situational elements relevant to interaction between user, application, environment
- Context-awareness: situationally appropriate; apps adapting to context, increasing value to users
  - Using sensors and actuators to improve human-computer interaction and (computer-mediated) human-human and human-environment interaction
- Examples: tour guide, reminders, diary retrieval

Context-Aware Computing: History

- 1996: difficult to build simple context-aware applications
  - No abstractions for acquiring and using context from sensors or controlling actuators
  - Context coming from a number of distributed sources
  - No principles or process for designing applications

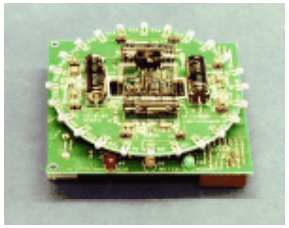
Long Long Time Ago
Thesis: Context Toolkit

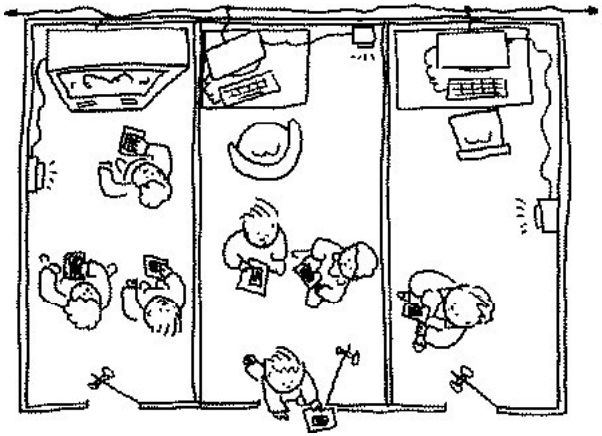
- Context Toolkit: supports programmers in building context-aware applications more easily

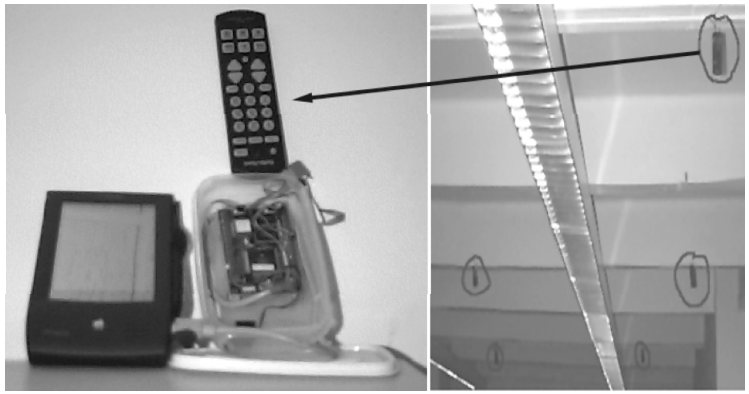


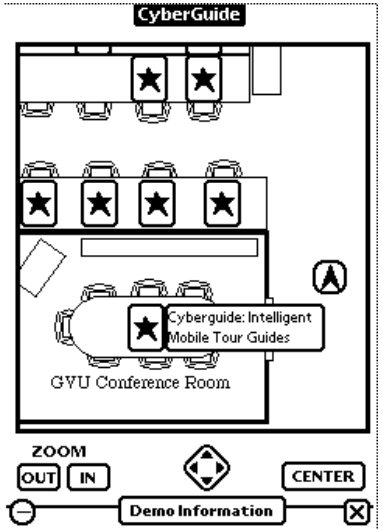
CHI 99, ISWC 99, UBICOMP 00, UBICOMP 01, UIST 02, CHI 03, HCI Journal 01, ToCHI 04

Context-Awareness: A Maturing Field









Context-Awareness: A Maturing Field

StepGreen
CMU

Child's Play
Georgia Tech

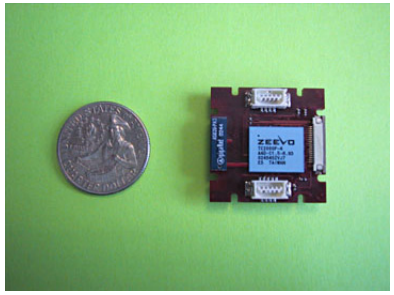
Activity Compass
U of Washington

Systems are more complex and compelling

Systems are More Complex: Sensors

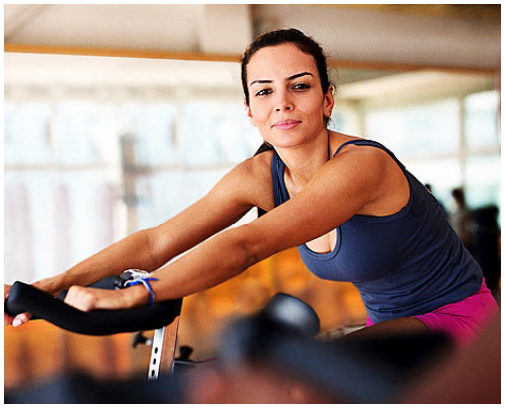
- Human activity useful, and necessary, input to context-aware systems
- Easier to collect information about human activity:
  - Improved software and inferencing
  - Improved sensors



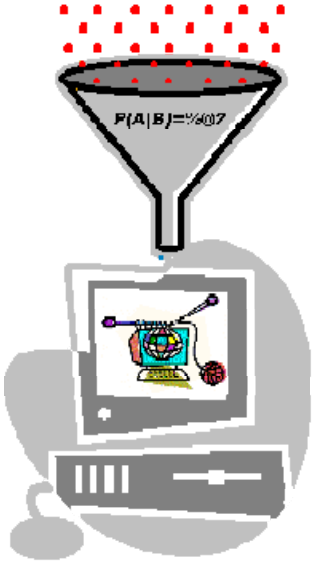



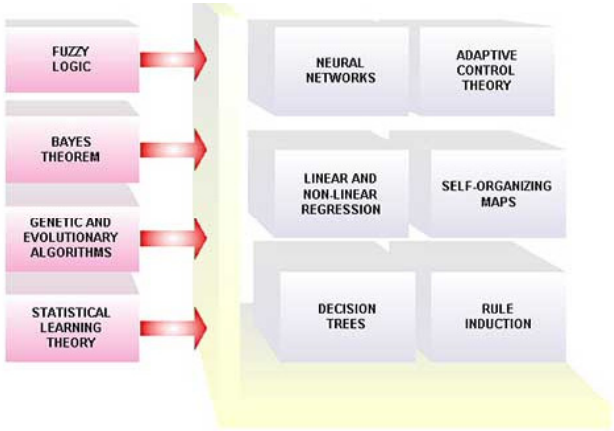


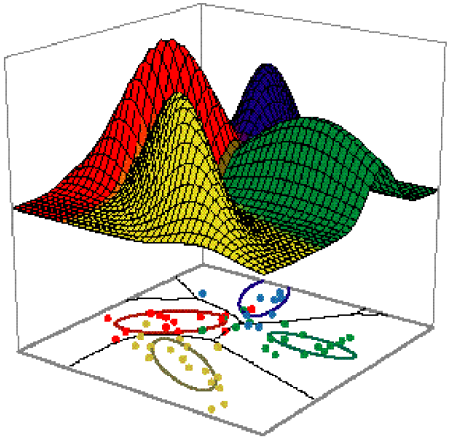
Complex Systems: Human Activity



Complex Systems: Intelligence







Complex Systems: Adaptation

Context-Awareness: Holy Grail

Divine human intent

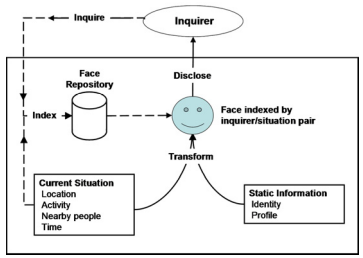
Location is commonly used as a proxy for intent

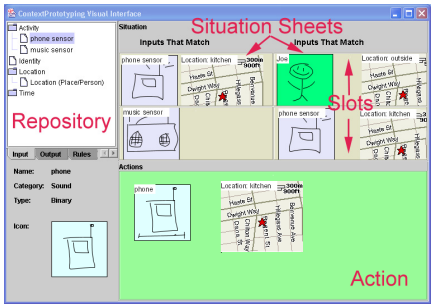
Human activity is often a better proxy

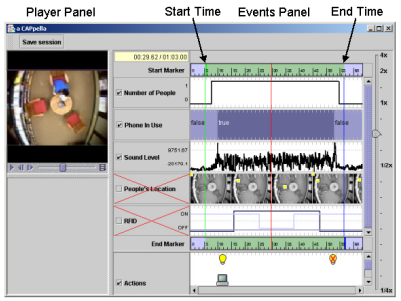
Context-Awareness: Growing Pains

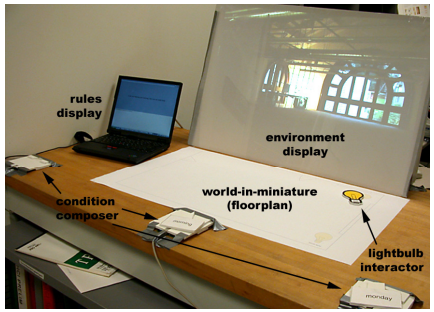
- Research issues to resolve when dealing with real-world and complex context-aware systems
  - Privacy
  - Evaluation
  - Error recovery
  - Development support

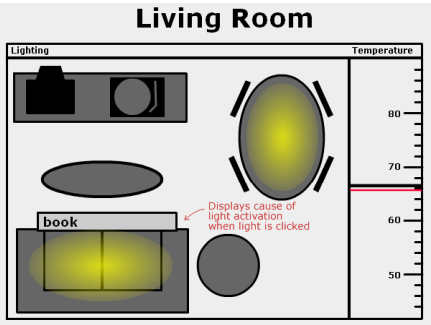
- End-user support (business logic)
- Information overload
- Modeling
- Intelligibility

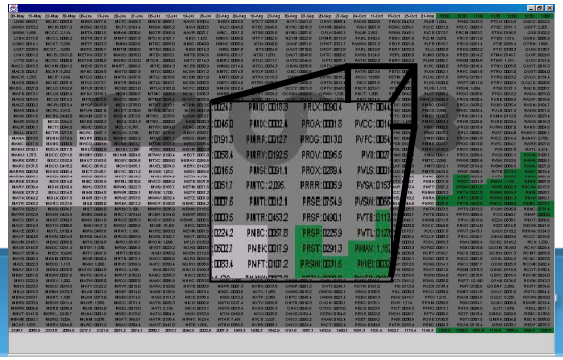












Context-Awareness: Growing Pains

- Not unique to context-aware applications, just different

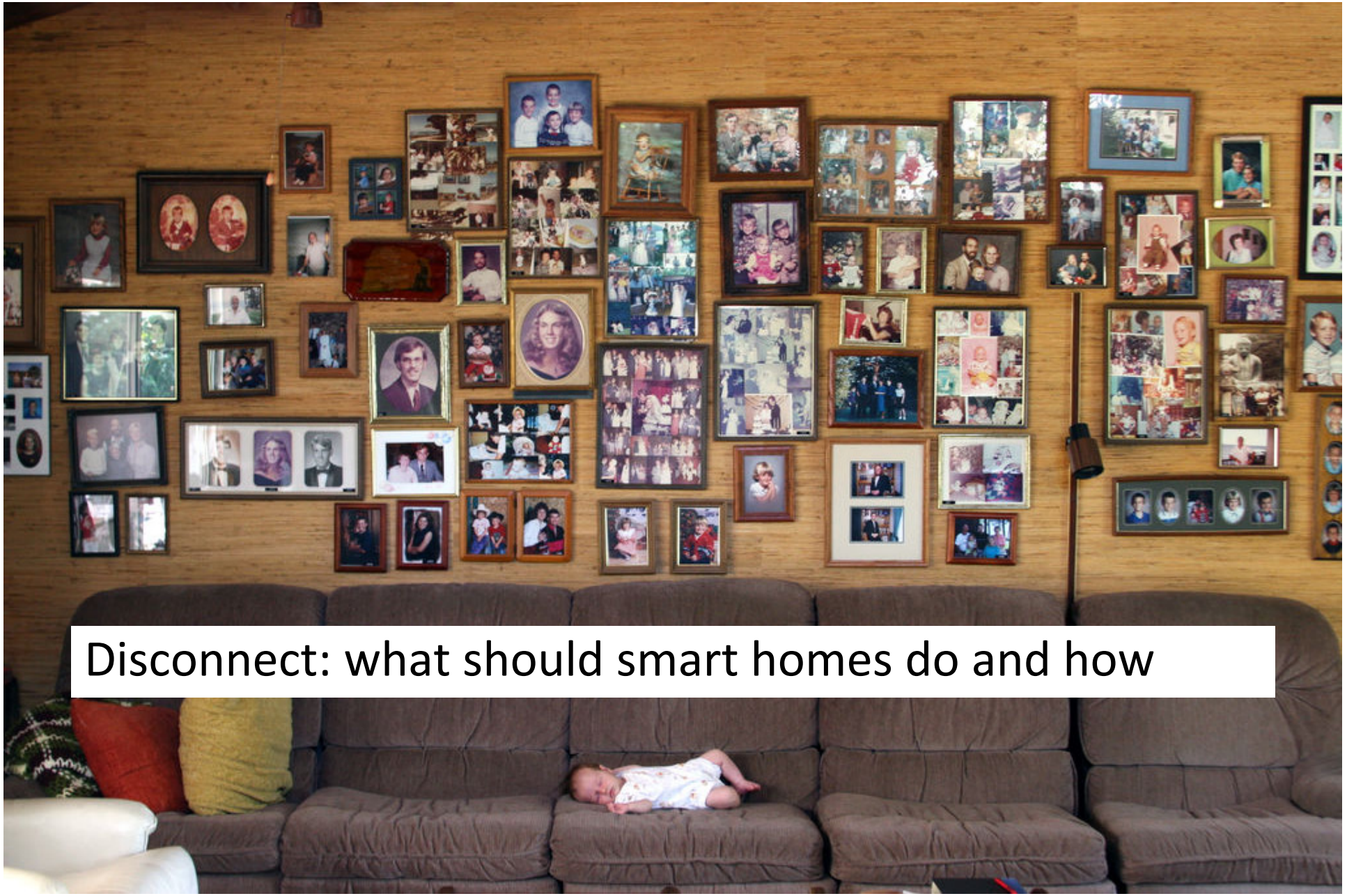



A Research Methodology

- Pick a really compelling topic
  - Read
  - Brainstorm
  - Just try something
  - Observe real people doing real activities

- *Collect information about the relevant human (and system) behavior*
- *Model that behavior*
- Leverage that behavior to build a compelling application with a *focus on usability*
- Evaluate it to make sure it works as you expected

Dual- Income Families: Research Problem



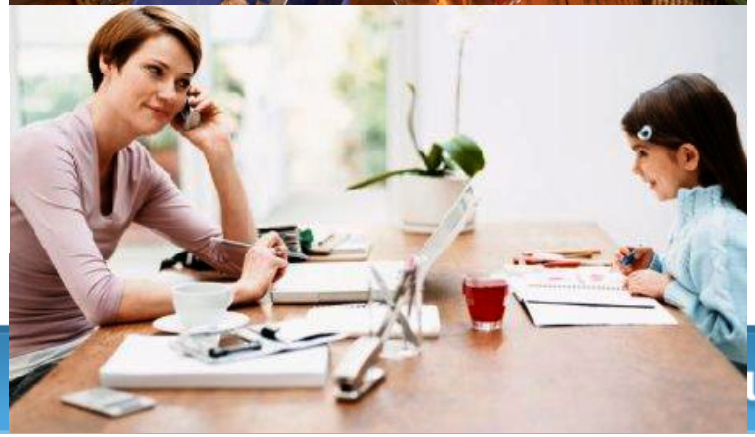
Disconnect: what should smart homes do and how

Research Problem

Support what families value: time, activities, relationships

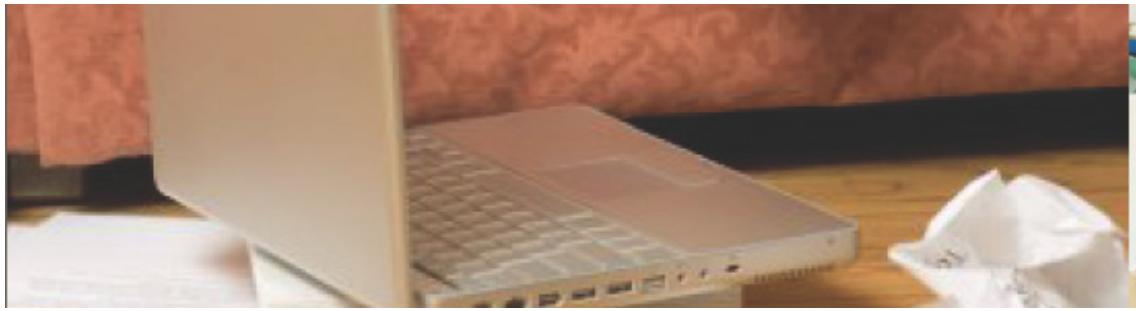
Focus on Dual-income Families

- Largest segment of US population and growing
- Live logistically complex lives that drive aggressive and experimental use of communication technology



Why Families Feel Out of Control

Swamped with responsibilities from kids activities and jobs

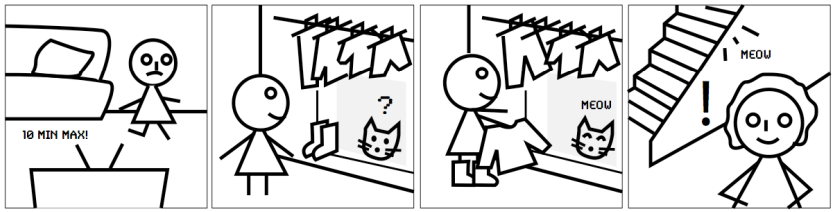


Findings: Master “Busyness”

Parents want to master managing numerous activities

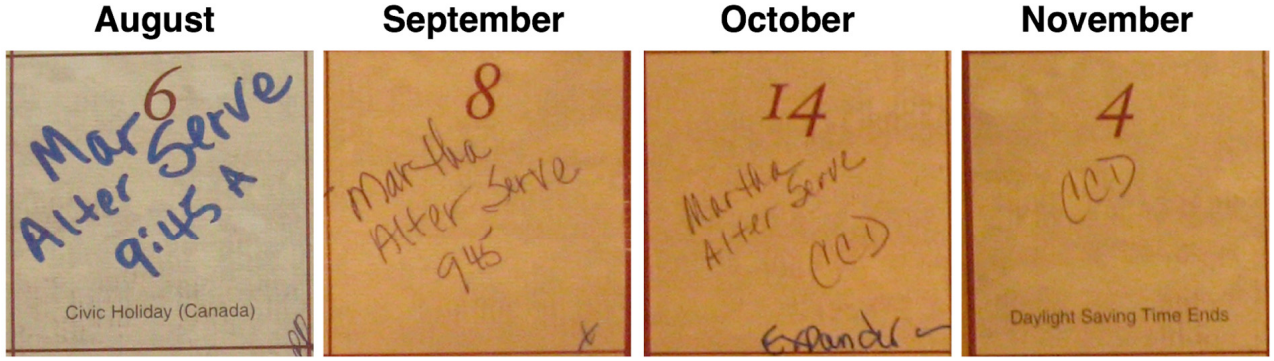
Studies we conducted

- Fieldwork (Ubicomp 2006)
  - Principles of smart home design
- Speed Dating (Ubicomp 2007)
  - New design process between ideation and implementation
  - Helps design the right idea rather than designing the chosen idea right
  - Step over the line to get feedback



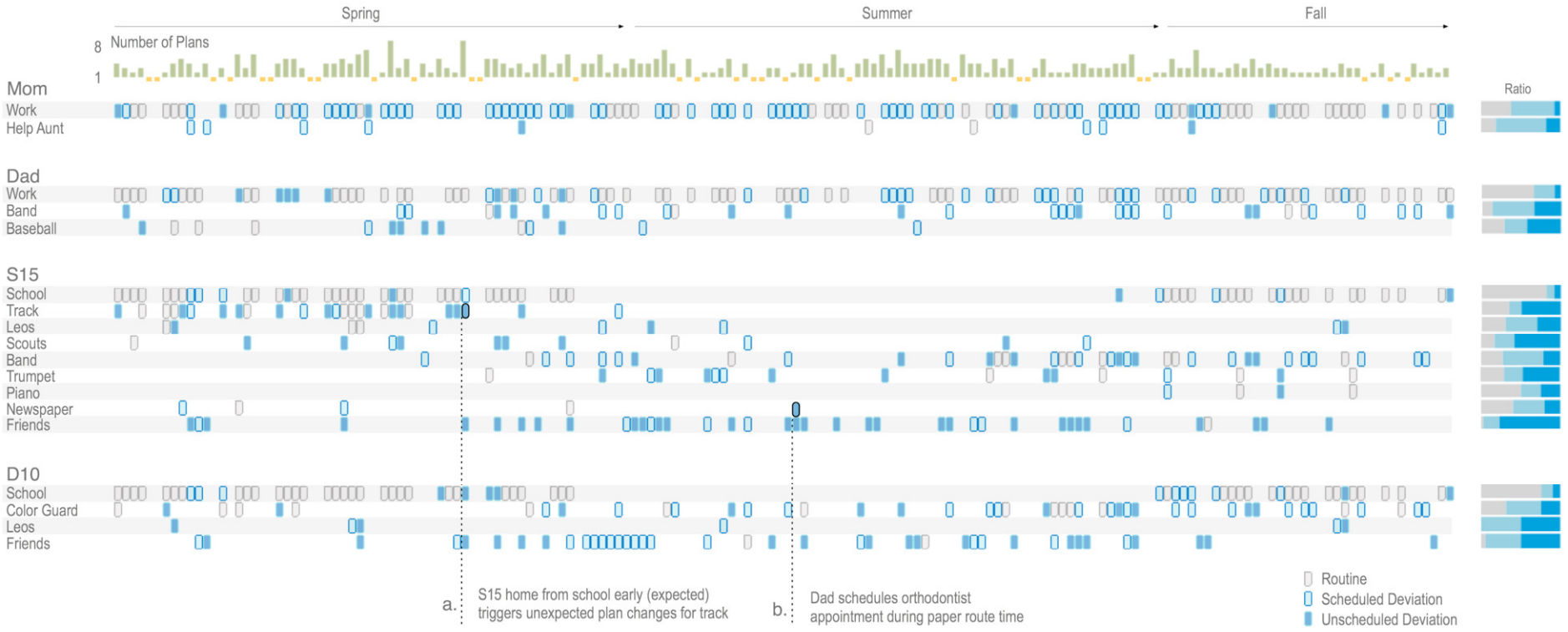
- Understanding Routines (CHI 2010)
  - Massive data collection
  - 6 months, 6-8 families, instrumented Blackberry phones
    - Calling information, SMS content/meta, Email content/meta, GPS
    - Weekly photo of main calendars
    - Phone interviews every night
    - Home visits every 2 weeks

Findings: Sources of Information



Activity		S15	Mom	Dad
School	Start	6:35 am	6:40 am	7:00 am
	End	2:25 pm	2:45 pm	3:00 pm
Track	Start	2:25 pm	2:30 pm	3:00 pm
	End	5:00 pm	5:00 pm	5:00 pm
Boy Scouts	Start		7:00 pm	7:00 pm
	End		8:30 pm	9:00 pm
Paper Route	Start	5:30 pm	5:30 pm	
	End	6:30 pm	6:00 pm	

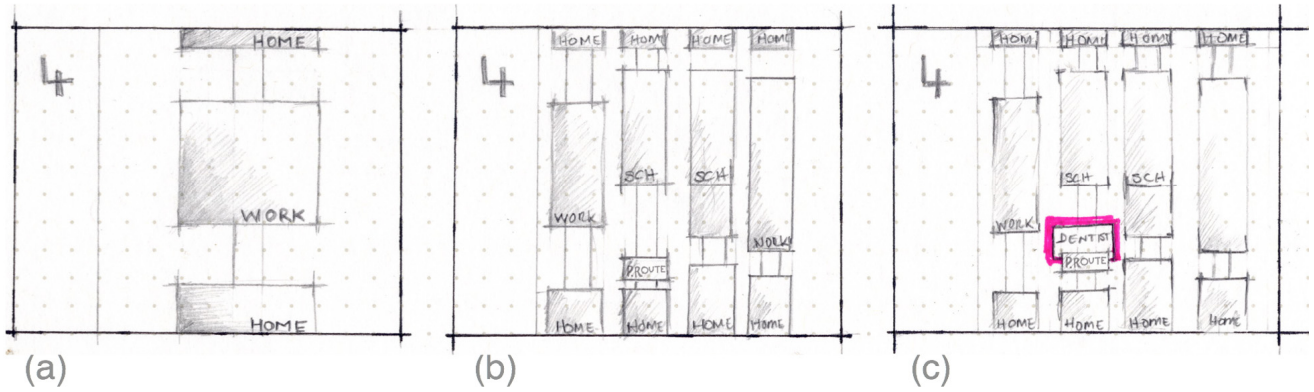
Findings: Opportunities



What can we do with this?

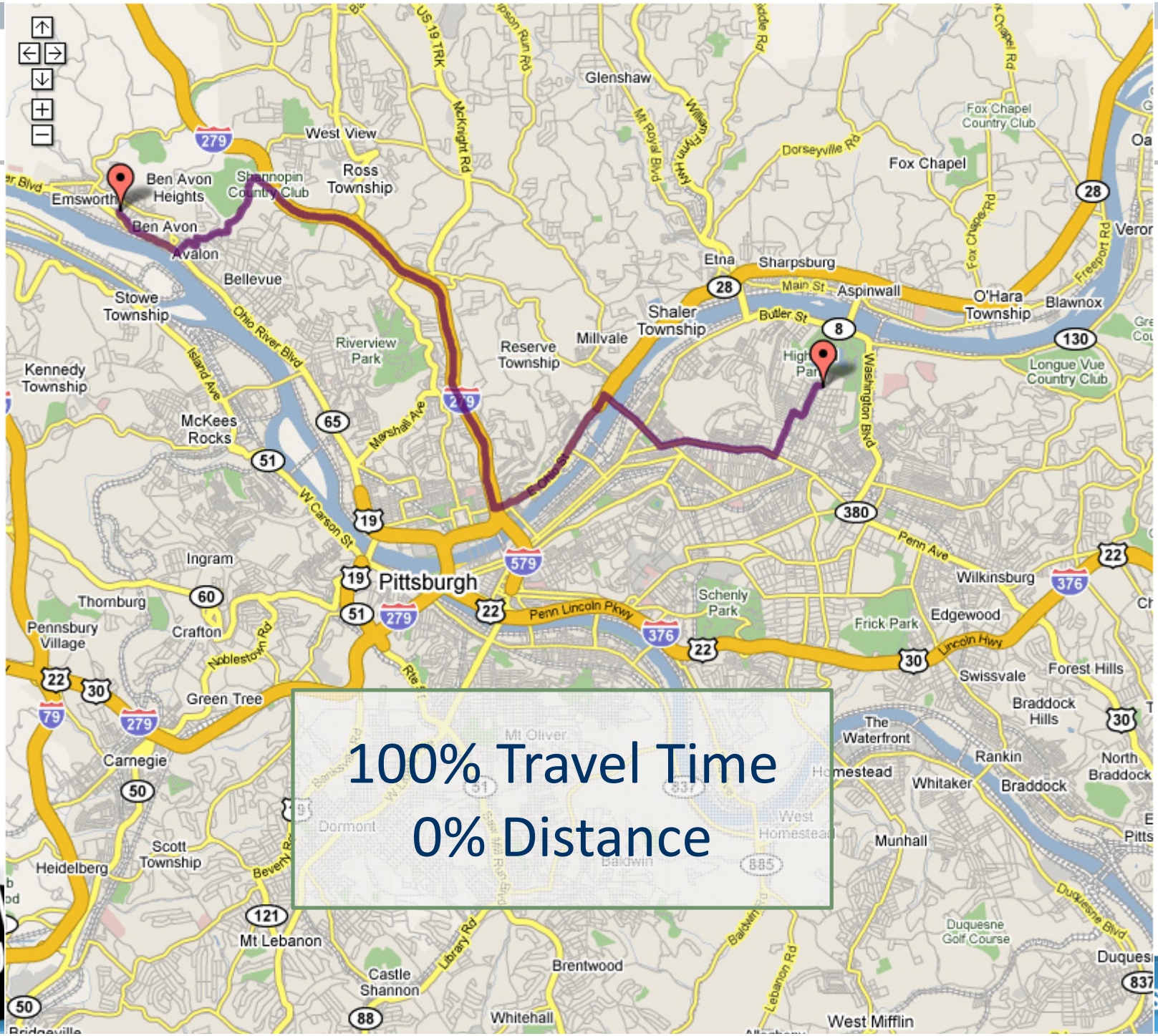
- Core technology [in progress]
  - Learn routines: Who, where, when
  - Predict deviations
    - How likely is it that you are going to pick up your child?

- Applications
  - Calendars that assist with planning by making routine information more accessible and deviations more prominent
  - Calendars that assist with planning new routines
  - Reminder systems that only remind you when you forget



Modeling Driving Behavior

- Study of drivers revealed (not surprisingly) that they have different driving preferences


100% Travel Time
0% Distance
Pittsburgh
Ben Avon
Ben Avon Heights
Emsworth
Avalon
Bellevue
Stowe Township
Kennedy Township
McKees Rocks
Ingram
West View
Ross Township
Shannopin Country Club
Riverview Park
Reserve Township
Millvale
Glenshaw
Etna
Sharpsburg
Shaler Township
Aspinwall
O'Hara Township
Fox Chapel
Fox Chapel Country Club
Blawnox
Longue Vue Country Club
Thornburg
Pennsbury Village
Crafton
Green Tree
Carnegie
Scott Township
Heidelberg
Mt Lebanon
Castle Shannon
Brentwood
Whitehall
Mt Oliver
Dormont
West Homestead
Baldwin
Munhall
Duquesne
Duquesne Golf Course
West Mifflin
Homestead
The Waterfront
Whitaker
Rankin
Braddock
North Braddock
Braddock Hills
Swissvale
Forest Hills
Wilkinsburg
Edgewood
Frick Park
Schenly Park
Penn Lincoln Pkwy
Penn Ave
Lincoln Hwy
Ohio River Blvd
W Carson St
E Ohio St
Marshall Ave
Island Ave
Noblestown Rd
Washington Blvd
Butler St
Main St
Dorseyville Rd
Freeport Rd
Fox Chapel Rd
McKnight Rd
Library Rd
Lebanon Rd
Baldwin Rd
Beverly Rd
Duquesne Blvd
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65
51
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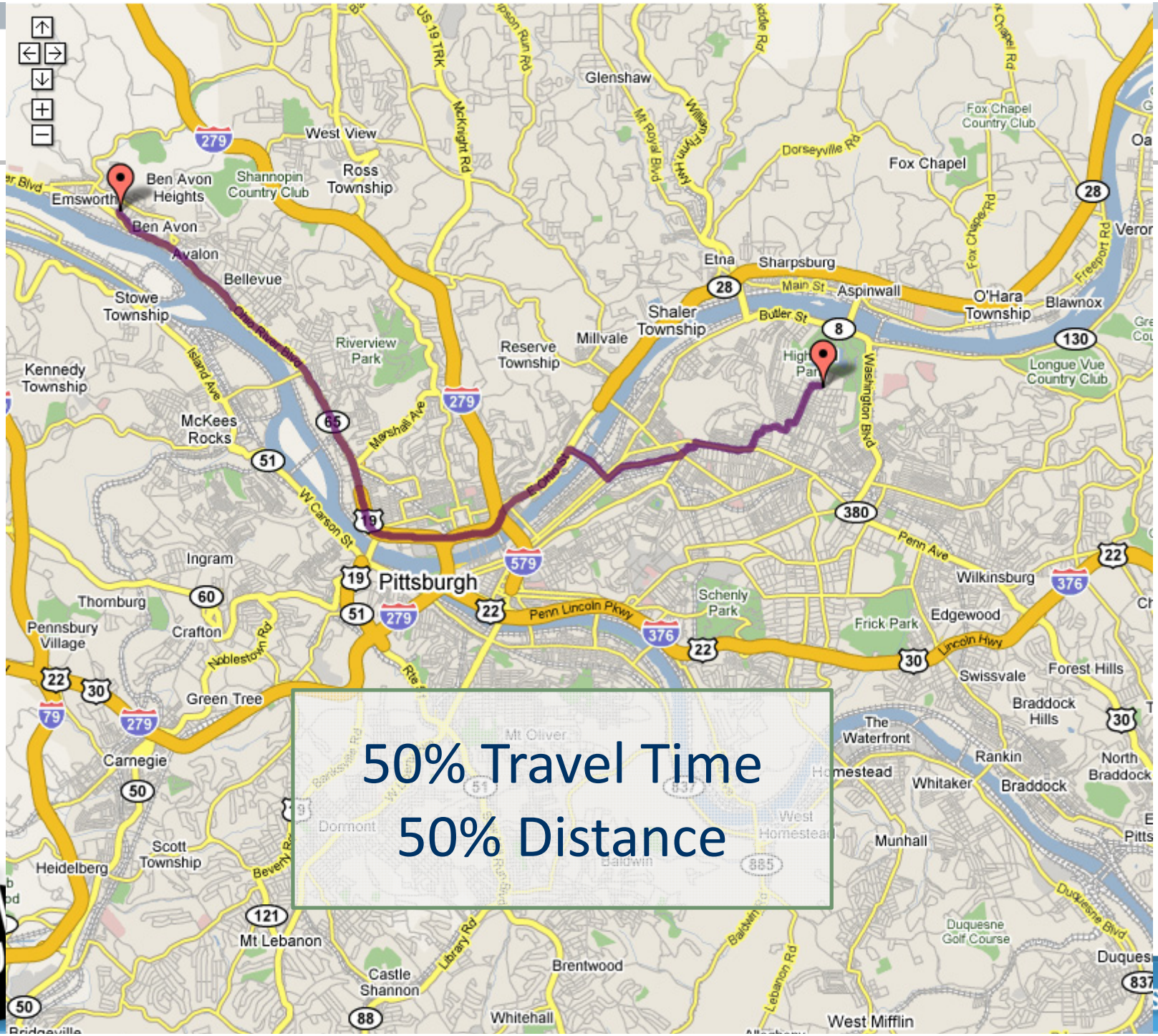
60
50
121
88
837
885


50% Travel Time
50% Distance
Pittsburgh
Emsworth
Ben Avon Heights
Ben Avon
Avalon
Bellevue
Stowe Township
Kennedy Township
McKees Rocks
Ingram
Thornburg
Pennsbury Village
Crafton
Green Tree
Carnegie
Scott Township
Heidelberg
Mt Lebanon
Castle Shannon
Brentwood
Whitehall
West Mifflin
West View
Ross Township
Shannopin Country Club
Glenshaw
Fox Chapel
Fox Chapel Country Club
Sharpsburg
Etna
Aspinwall
Shaler Township
O'Hara Township
Blawnox
Millvale
Reserve Township
Riverview Park
Longue Vue Country Club
Schenly Park
Frick Park
Edgewood
Wilkinsburg
Swissvale
Forest Hills
Braddock Hills
The Waterfront
Rankin
Whitaker
Braddock
North Braddock
Munhall
Duquesne Golf Course
Homestead
West Homestead
Dormont
Mt Oliver
Baldwin

If costs double 73% would avoid toll roads

Monmouth University/Gannett New Jersey Poll , Jan. 2008

Fewer left-hand turns saved UPS
3 million gallons of gasoline

New York Times (Dec. 9, 2007)


Congestion can cause
frustration and “road rage”

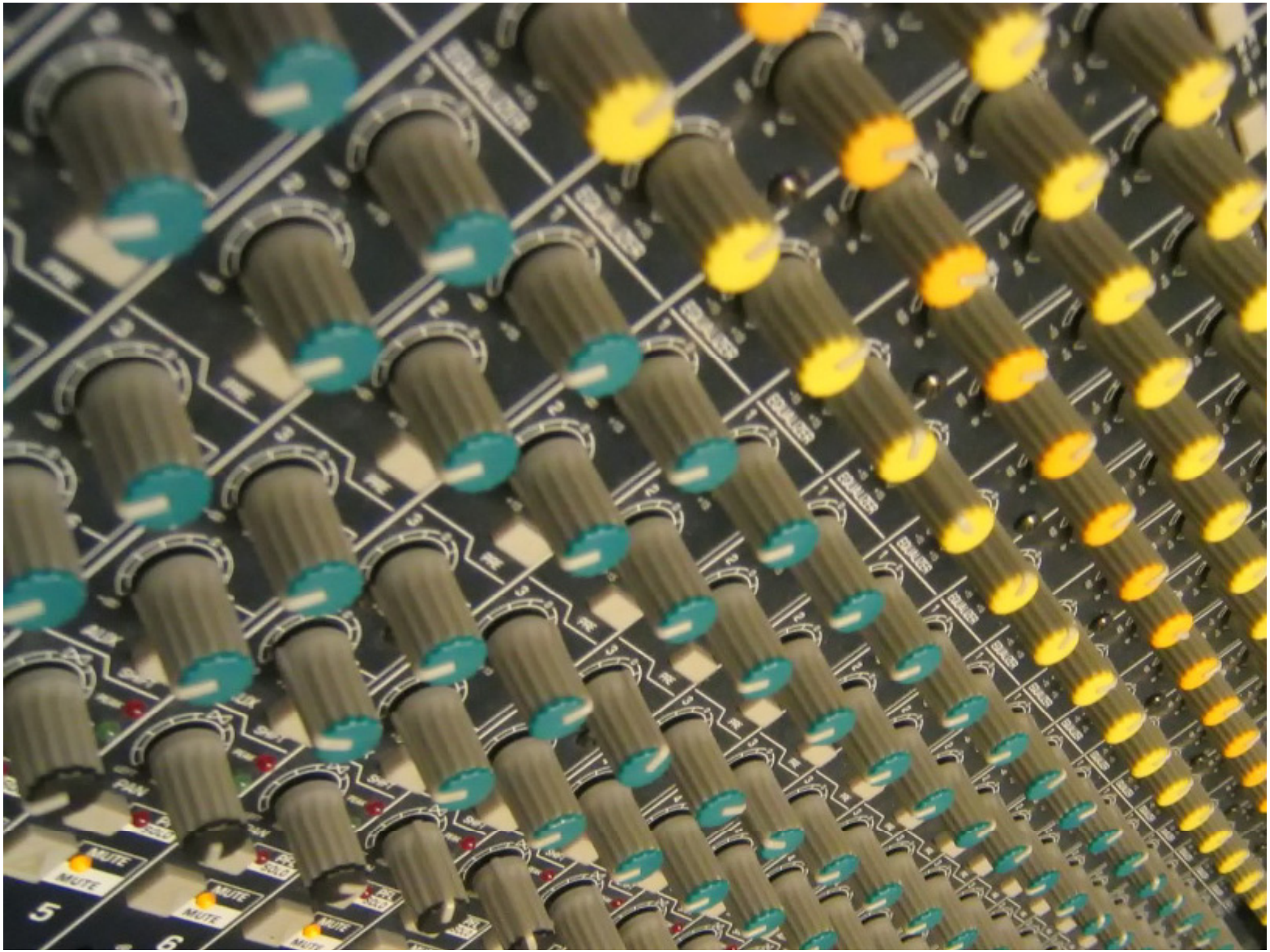
Routes should match the driver's skills

…and comfort levels

Accidents

Construction

Time of day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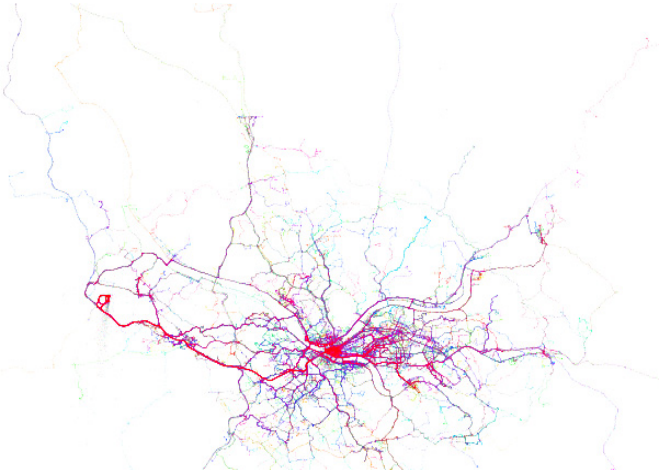
5
6

Problem: Modeling Elder Driving

- Independent mobility
- My grandfather doesn't drive the same way I do
  - Skill, experience, tolerance for traffic, fears (tunnels, icy roads)
- Needs personal route planning to match his preferences
  - Happier, more comfortable, and safer
- He can't articulate his preferences and writing generic rules is really hard
  - But, demonstrates his preferences all the time

Solution: Learn Driver Preferences

- Collected 130k+ miles (13k+ routes) of driving data from elder drivers and Pittsburgh Yellow Cab and



- Model each route as set of road segments, each with a set of features
- By observing what paths the driver takes, can learn preferences for different features

Solution: Learn Driver Preferences

- Produce personalized routes for a driver
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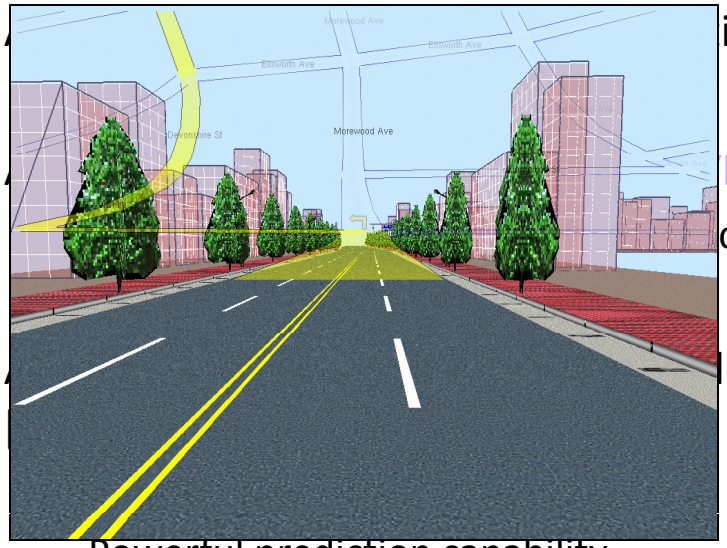
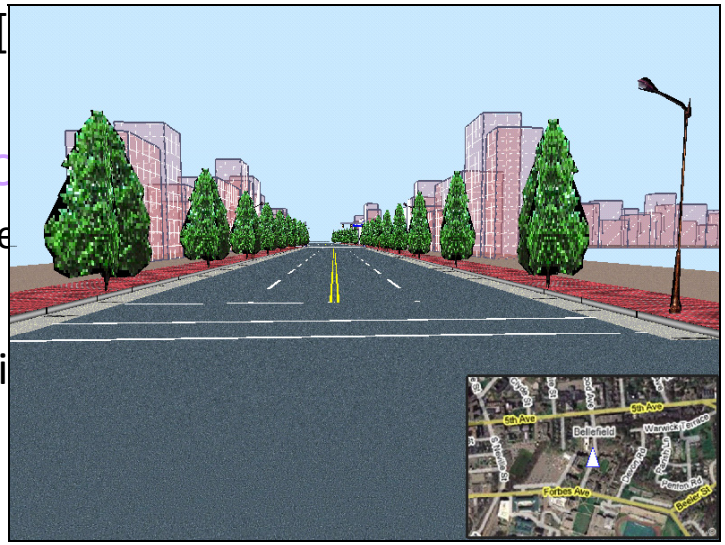
  - Powerful prediction capability





- Change the way route navigation systems work and help drivers remain independently mobile

[AAAI 2008, ICAPS 2008, Ubicomp 2008, ICML 2010]

Why Re-Route?

- When system re-routes a driver, many elders ask why or what-if

- Challenge here is to provide some detail about why the new route without adding additional distraction

On-demand vs. always-on

Level of detail about why the change

How do we determine why the new route was chosen

Level of detail about the new route

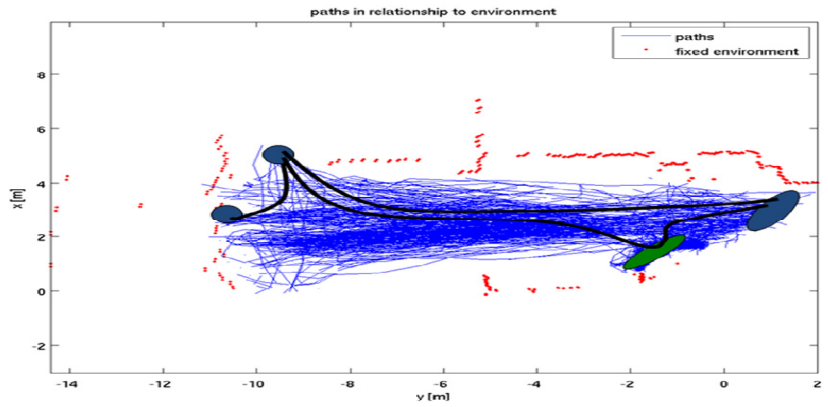
vs Increase in cognitive load from the new information [Ubicomp 2010]

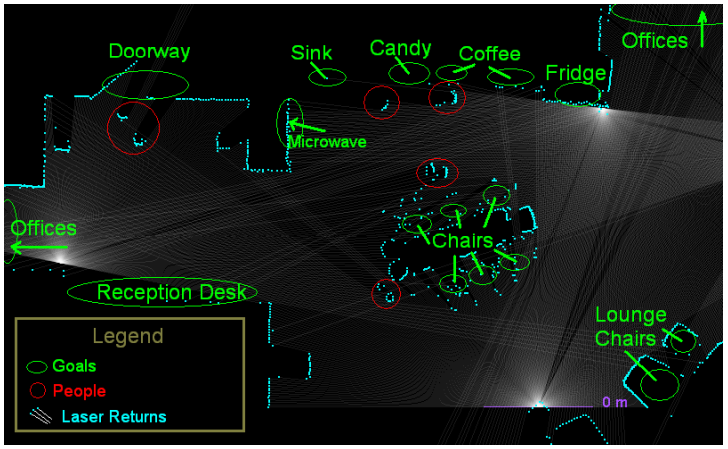
Purposeful Prediction: Walking

- Approach/algorithms can be applied in any situation where users demonstrate preferences regarding some human activity, which are hard for them to explain

- Another example: Predict the path someone takes
  - Autonomous vehicles, or systems that assist/alert drivers
  - Motorized wheelchairs, robots, … [IROS 2009]

  - Initial work done with people walking down a hallway [VIDEO]





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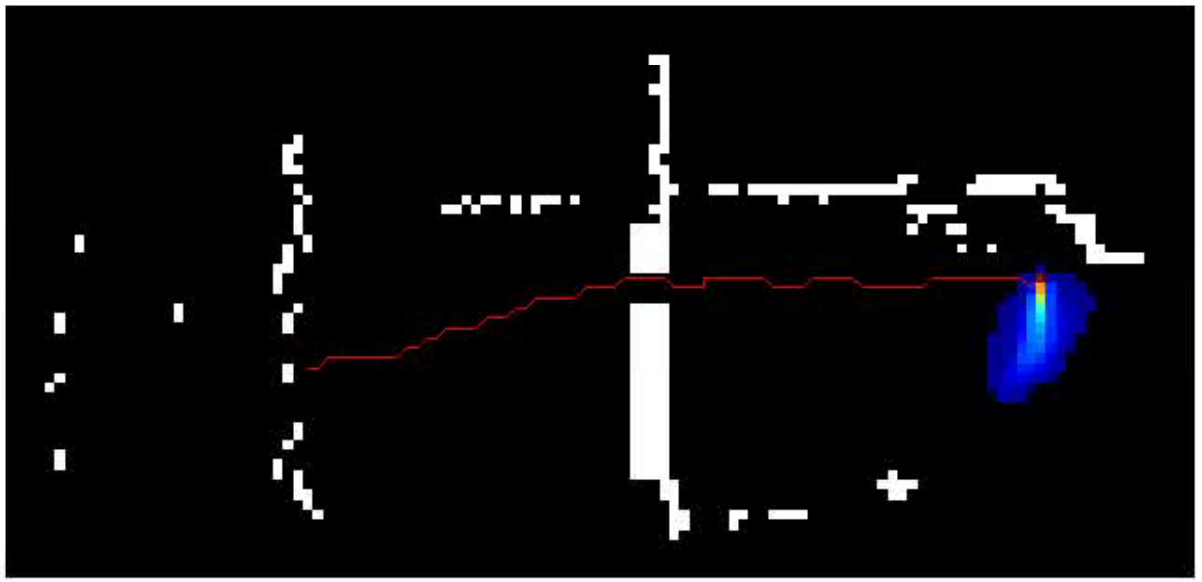
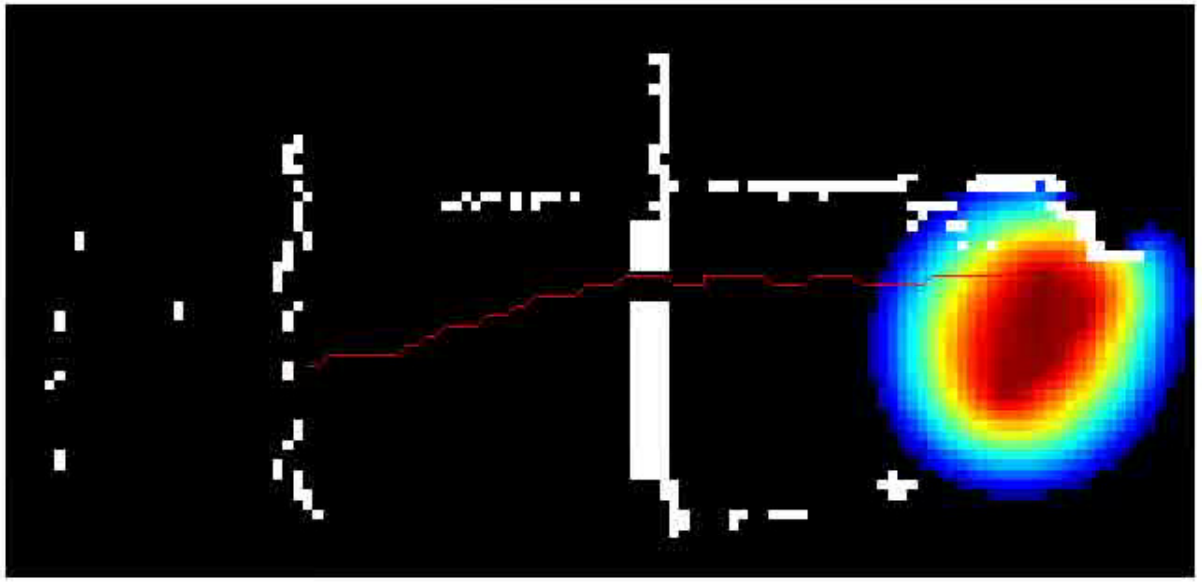
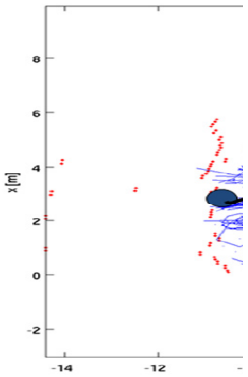
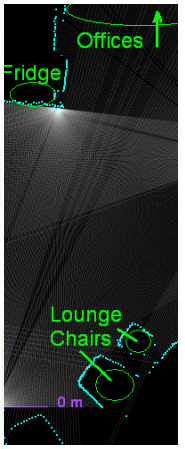
  - Auton
  - Motor
  - Initial









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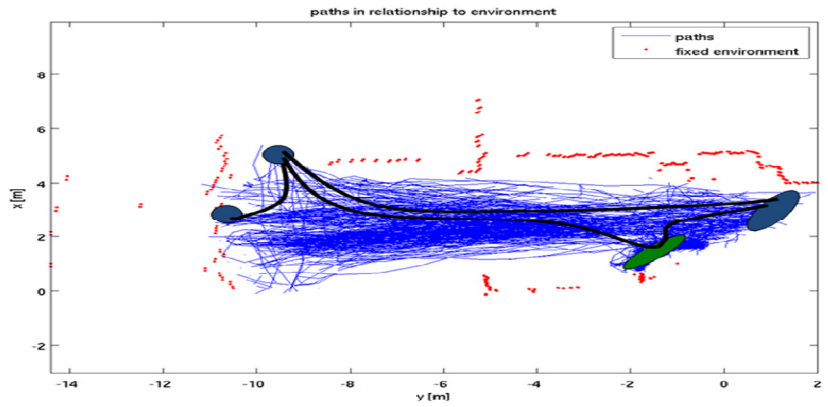
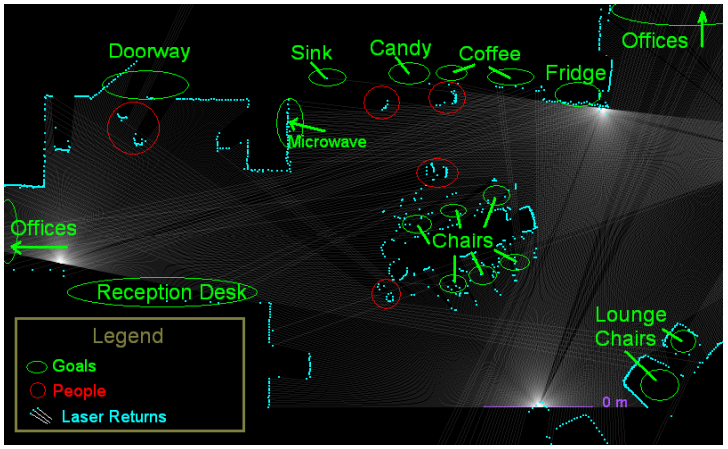
  - Motorized wheelchairs, robots, …
  - Initial work done with people walking down a hallway [VIDEO]

  - Predict when someone is returning home: control their heating/phantom load devices





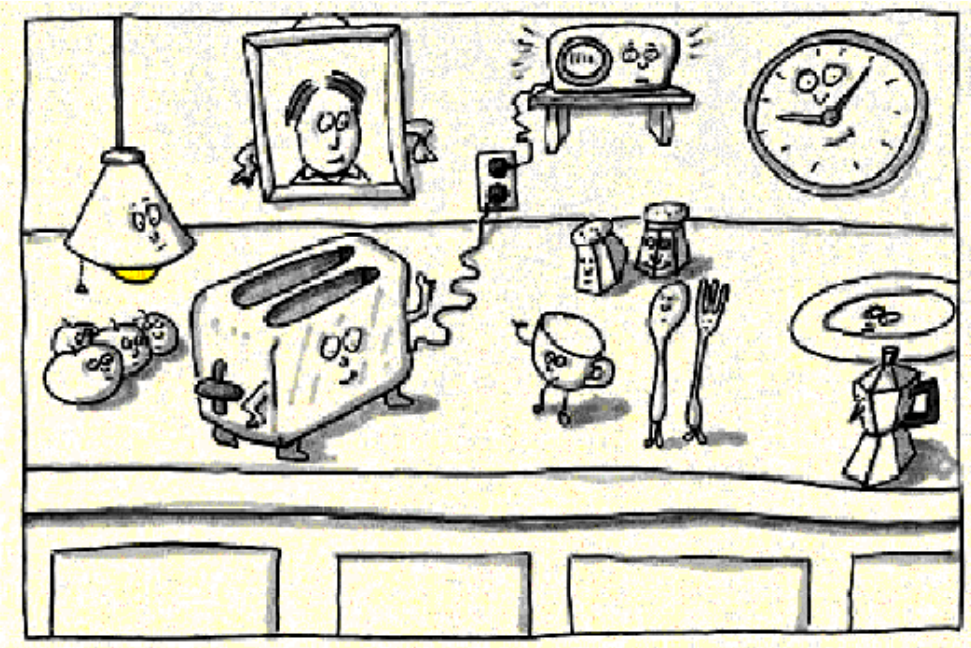
Summary of Modeling

- Can build ever more sophisticated models of human behavior
- Build purposeful models that address a particular need

- Dual-income family routines
- Elder driver behavior
- Assessing cognitive decline and impairment
- Motivating people to be more physically active, use fewer resources

Usability is Key [Ubicomp 2003, Interact 2003]

- Dourish, Abowd and Mynatt, Bellotti and others: lack of control in these environments
- Information collected, synthesized and used implicitly
- How do I know what's going on? (intelligibility)
- How do I change what's going on? (control)
- Who gets this information? (privacy)
- Is this another way to SPAM me? (overload)

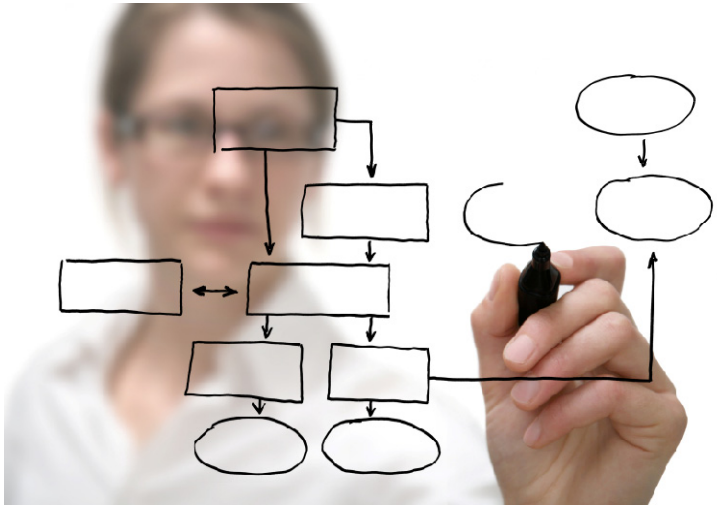


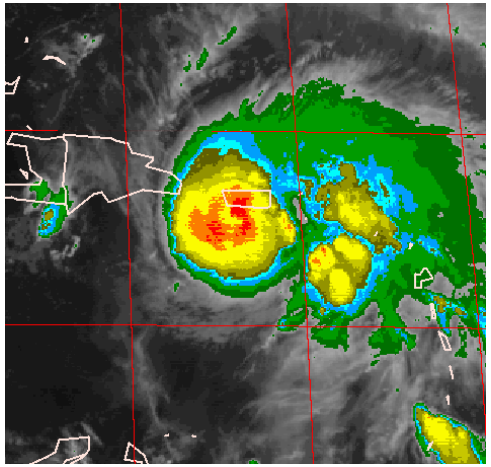
Rich Gold "Dancing Toaster"

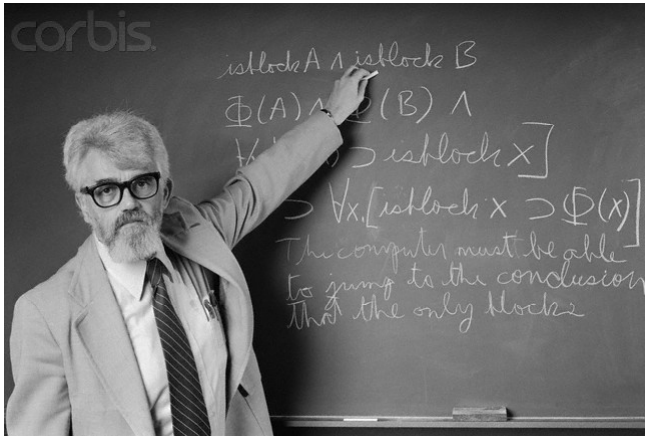
Intelligibility

- Intelligibility:
  - How well can a user understand what a system is doing and why?

- Why is this important?







Intelligibility of Human Modeling

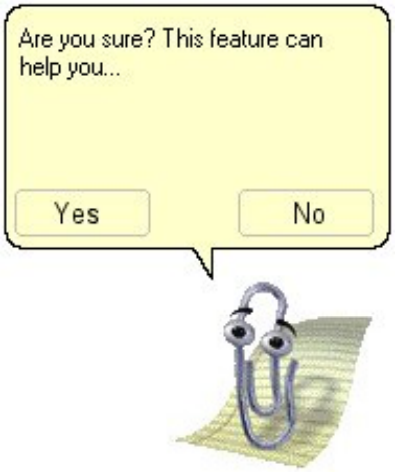
Users may misuse or abandon applications due to **lack of trust** (Muir 1994)

Intelligibility leads to improved **performance**, **trust**, and **acceptance** (Dzindolet 2003, Herlocker 2000, Muir 1994)

Particularly, context-aware applications need to be **intelligible** for them to be **usable** (Bellotti & Edwards 2001)

Intelligibility and Human Activity

- Leveraging real human context and realizing that you're not really getting at human intention
  - Clippy



Intelligibility and Human Activity

- Leveraging real human context and realizing that you're not really getting at human intention
  - Automated doors: not low-hanging fruit
    - Anyone remember the original Star Trek series?
    - Japanese doors [VIDEO]
    - Maintain doors? [VIDEO]

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Intelligibility and Human Activity

amazon.com

[Nikon SB-600 Speedlight Flash for Nikon Digital SLR Cameras](#)
by Nikon (Oct 2, 2003)
Average Customer Review: ★★★★★ (159)
In Stock

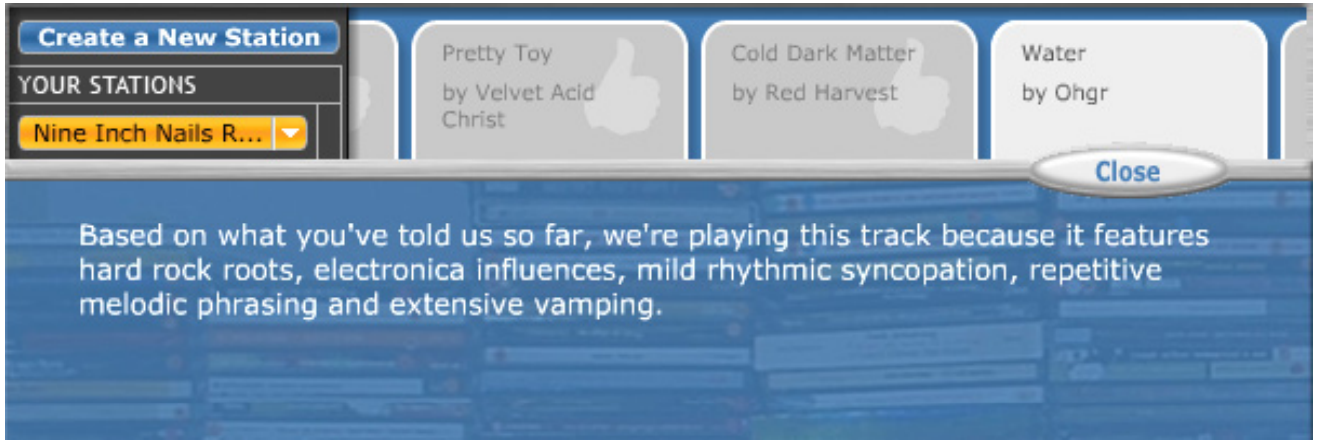
List Price: $249.99
Price: $178.10
40 used & new from $170.00

I own it Not interested Rate it

Recommended because you purchased **Nikon HB 7 - Lens hood** and more (Fix this)

Recommended because you purchased **Nikon HB 7 – Lens hood** and more (Fix this)

PANDORA®

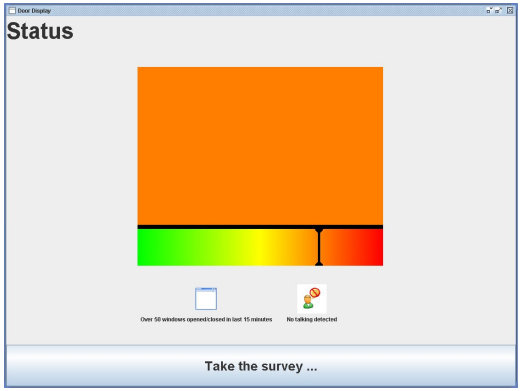


Challenge in Modeling Human Activity

- Leveraging real human context and realizing that you're not really getting at human intention
- Tremendous impact on context-aware applications

3 studies of intelligibility

- Initial attempt to provide intelligibility [CHI 2007]



- What kind of intelligibility helps? [CHI 2009]
- What intelligibility support do people want [Ubicomp 2009]

Intelligibility Type			General	Inappropriate-ness		Criticality		Goal-Supportive		Recommend-ation		Externalities	
				L	H	L	H	L	H	L	H	L	H
Application		Input					1						1
		Output					2				1		
	Model	Why	1	1	1	1	2						
		Why Not			1		1		2				1
		How	1	1	1	1	1			1		1	
		What If					1			1		1	
		What Else					2						
		Visualiza-tion	1	1			1	1			1		
		Certainty	1				2		1				
		Control	1		1		2						
		Situation					2						

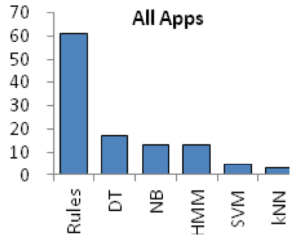
Intelligibility Toolkit [CHI 2009, Ubicomp 2010]

- Toolkit that supports the building of context-aware applications

  AND

- Supports intelligibility for free

- Developer builds their context-aware system as usual, using
  - Rules
  - Decision Trees
  - Naïve Bayes
  - Hidden Markov Models



- Specify what explanations they want, and toolkit generates them
- Specify the situational information, and toolkit provides appropriate explanations

Still needs work to make more human-understandable explanations

Closing Thoughts

- Listed many issues to address in building next-generation applications: modeling and intelligibility
- Modeling allows us to build more sophisticated adaptive applications
- Context is an abstraction/approximation for human intention
- Not remembering that it's an approximation can create other requirements, such as intelligibility

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