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Research Faculty Summit 2012

ADVANCING THE STATE OF THE ART



Predictions, Decisions, and Intelligence in the Open World

Eric Horvitz
Distinguished Scientist

July 16, 2012

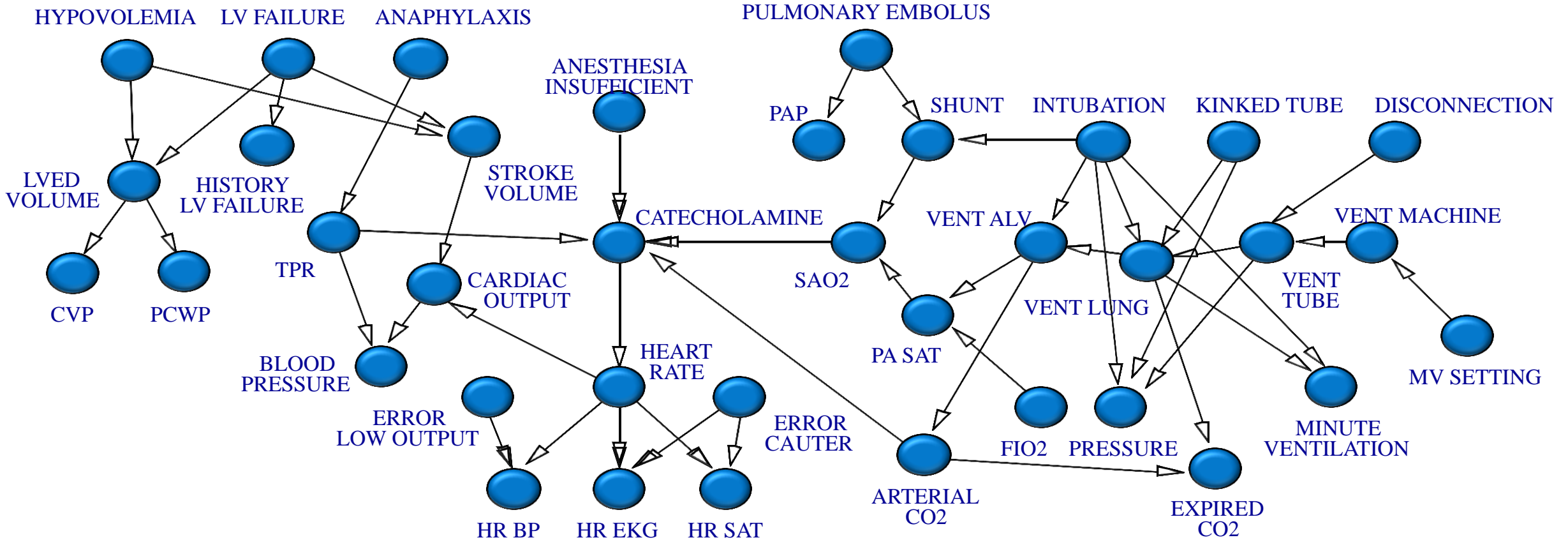


Exciting Times

- ↑ Computation & memory
- ↑ Connectivity & data
- ↑ Learning & reasoning prowess

Opportunities & directions

Advances in Capturing Expertise

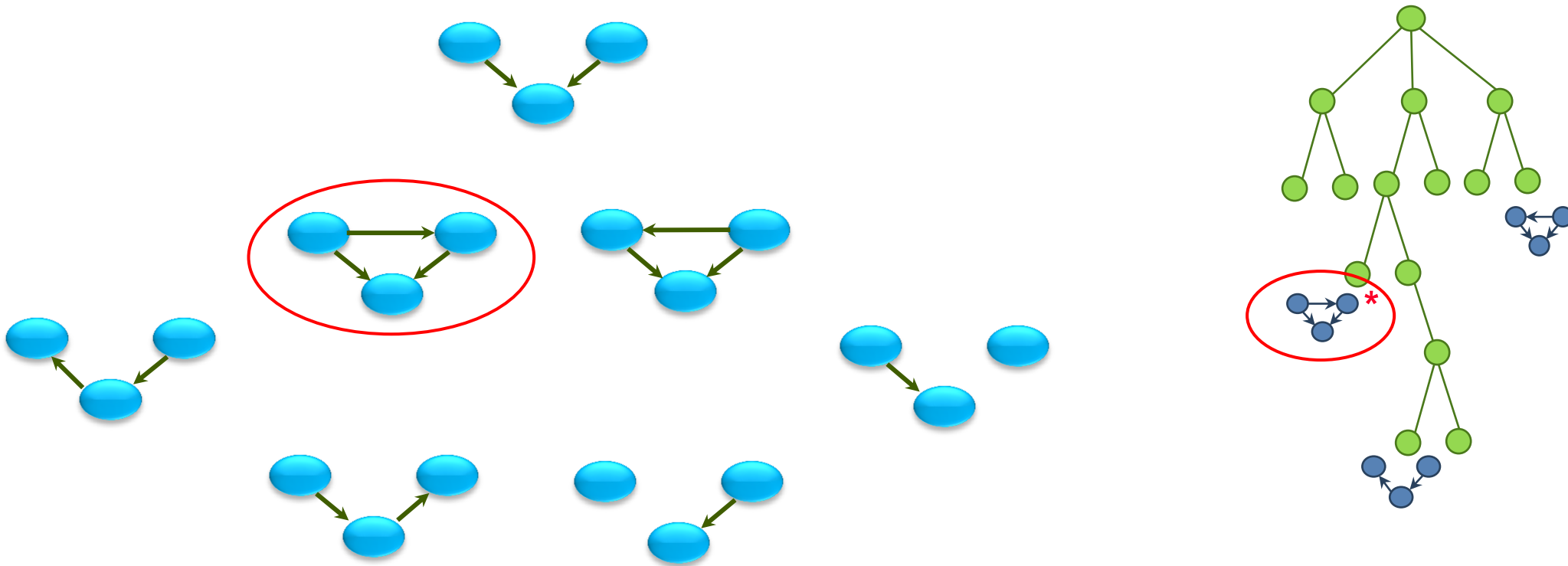




Learning Predictive Models from Data

New access to large amounts of data

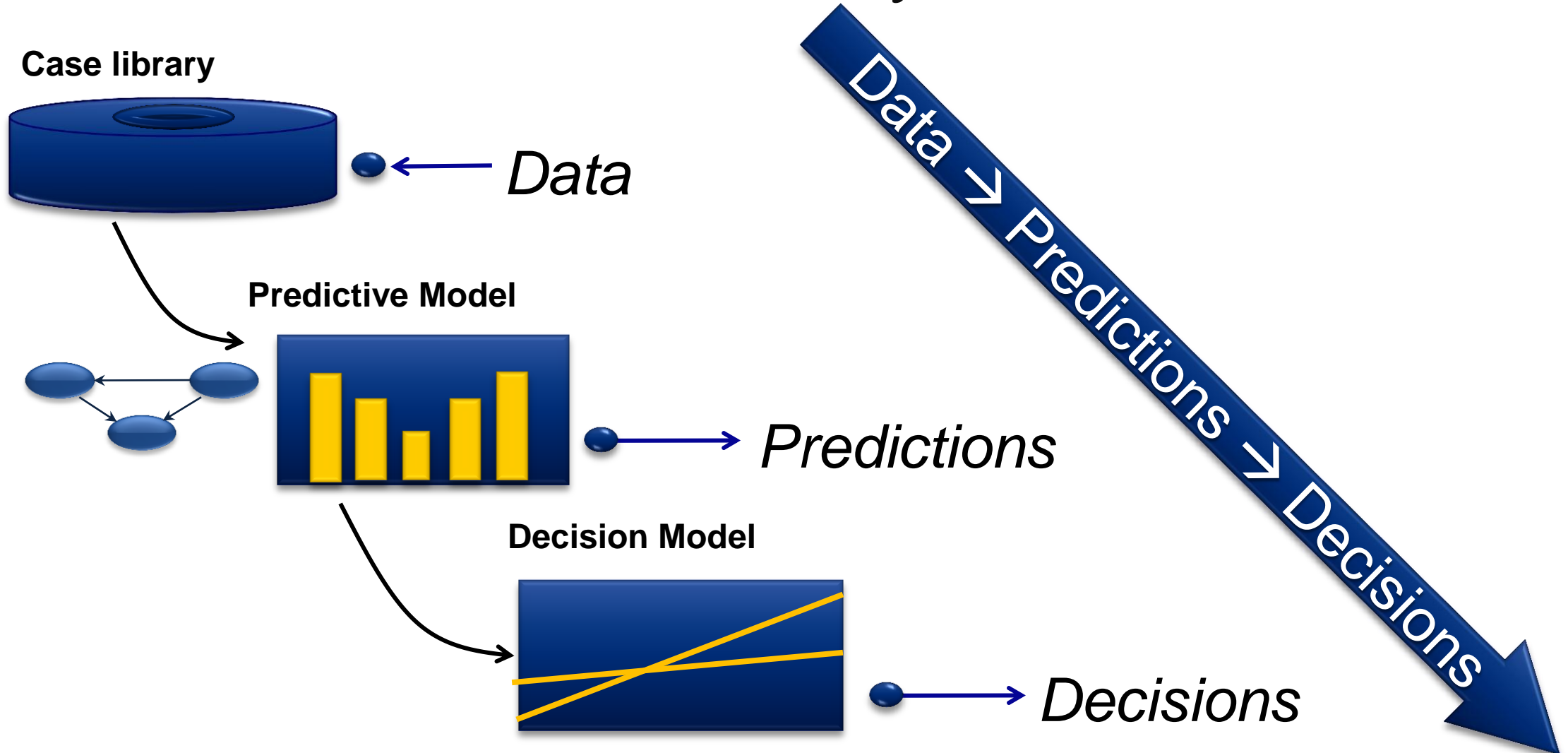
Procedures for learning predictive models





Data → Prediction → Decisions

Best actions under uncertainty



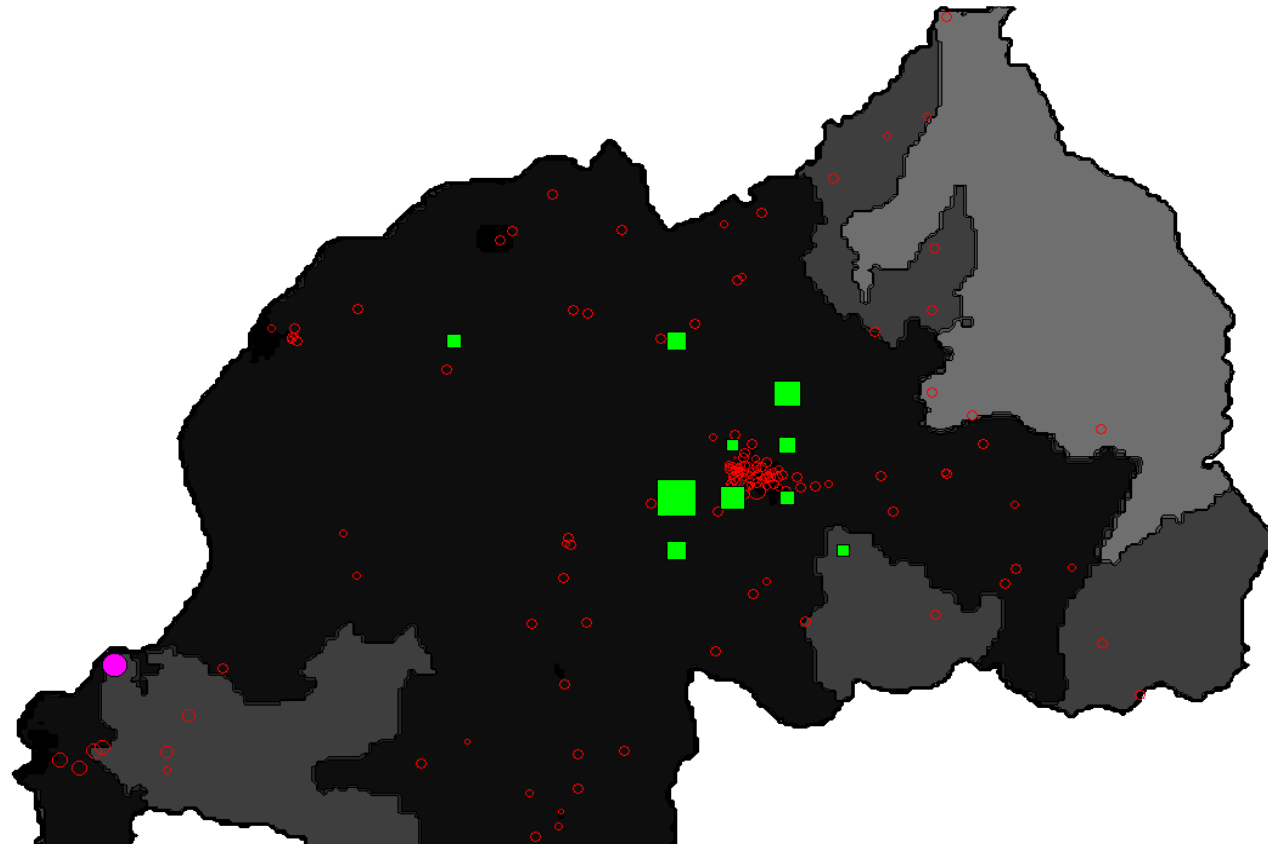


Exciting Directions

Ambient, "in-stream" data resources

Example: *Lac Kivu* earthquake, Congo

Rwandan call densities: 6 days, 140 cell towers, 10.5m calls





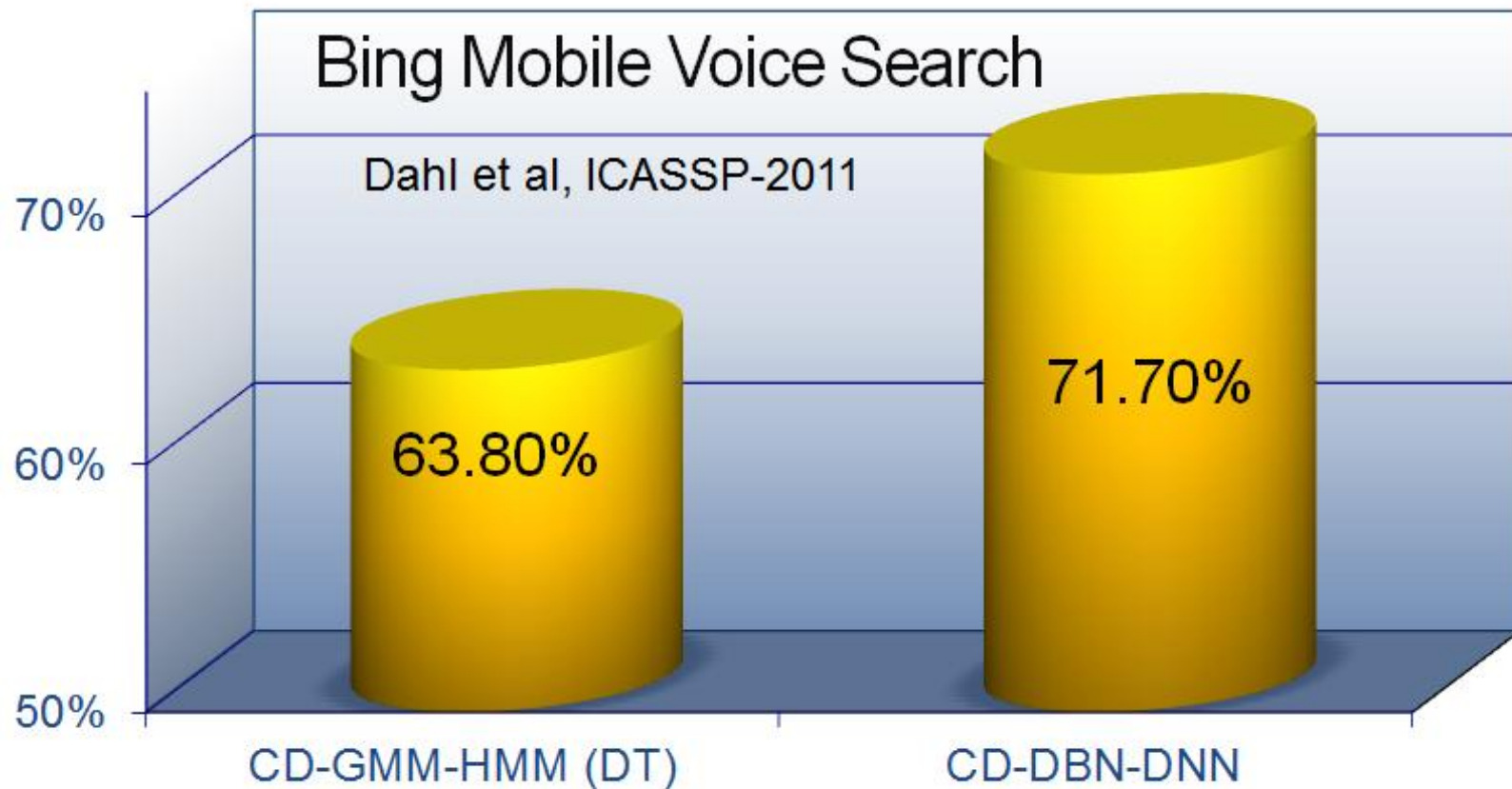
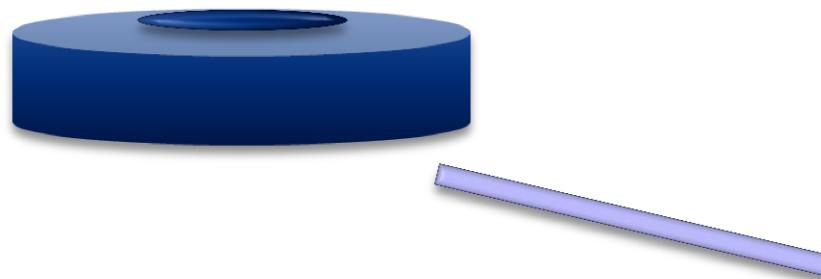
Exciting Directions

Causality

Active learning

Lifelong learning

Deep learning





Learning & Inference in the World

Four efforts

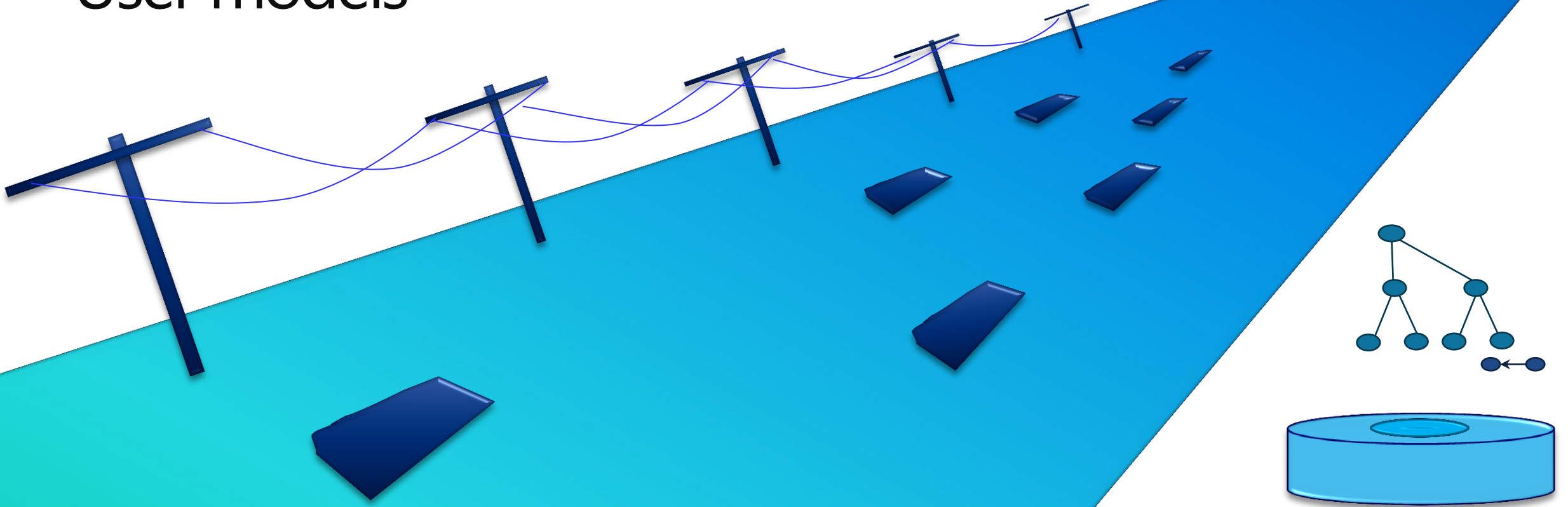
- Transportation
- Healthcare
- Citizen science
- Integrative AI



Transportation

Heterogeneous data sources

User models





Fusion of Heterogeneous Evidence

Multiple views on traffic



Incident reports

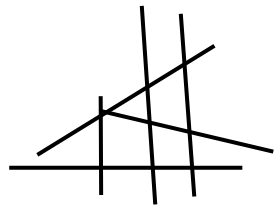


```
Operator ID: Nick
Heading: INCIDENT
Message: INCIDENT
INFORMATION
Cleared 1637: I-405 SB
JS I-90 ACC BLK RL CCTV
1623 - WSP, FIR ON SCENE
```

Weather



Road properties
& topology



Day & time



Event store

Major events



Predicting Future Flows

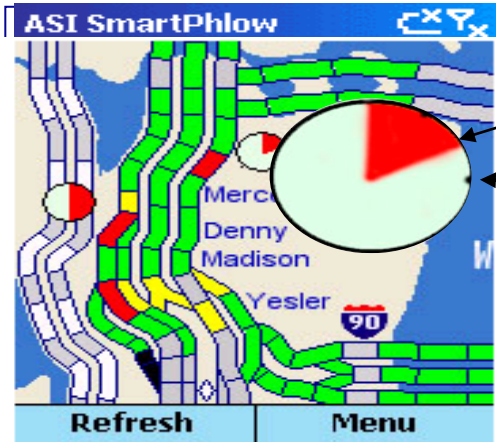
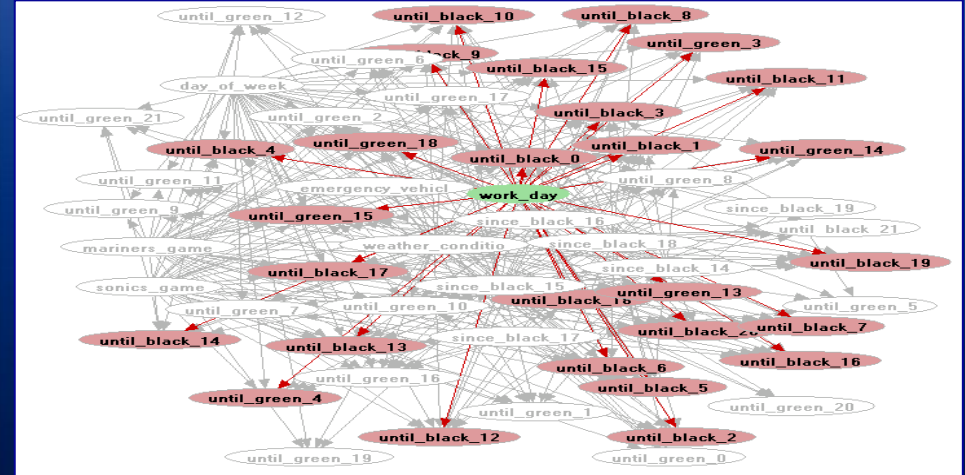
- System-wide status & dynamics
- Incident reports
- Major events
- Weather
- Day & time
- Road properties & topology
- Holiday status

Traffic prediction service



- Event store
- Learning
- Inference

Core predictions



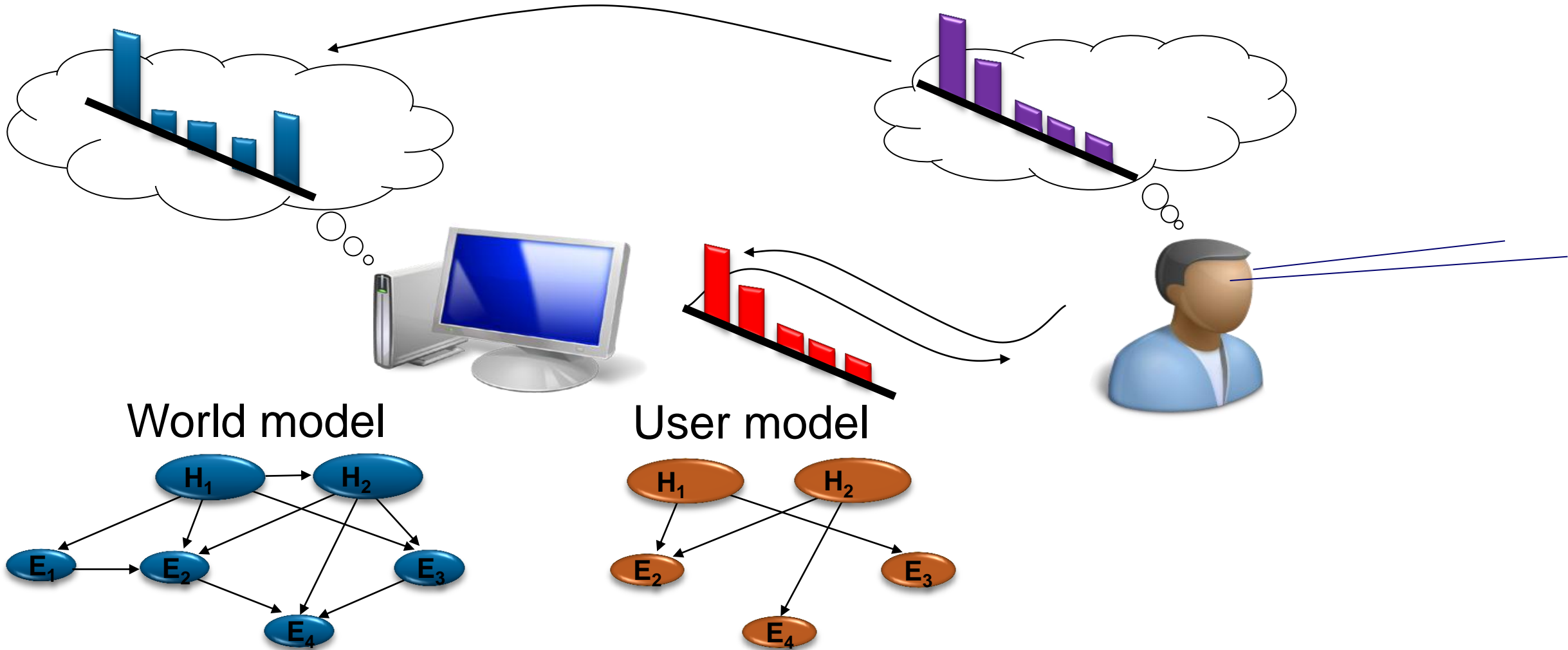
Max likely time jam will last

System's confidence



Beyond Domain Focus: Models of User

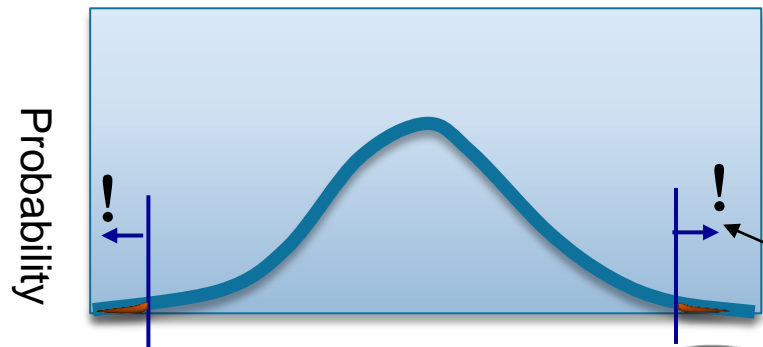
Extend system with model of user's knowledge





Models of Surprise

Learn what surprises people
...now and in the future



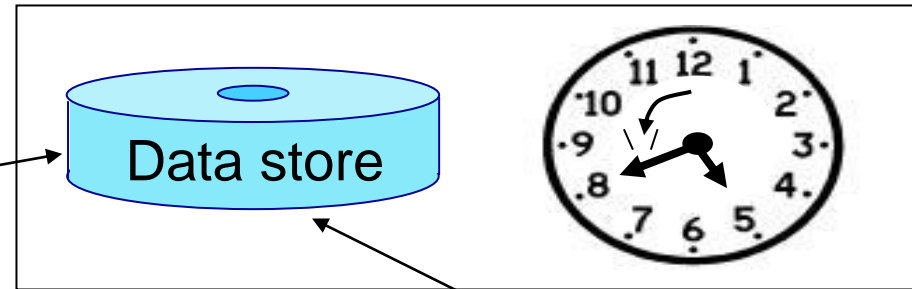
Future traffic

- Major events
- Weather
- Time and day
- Holiday status



Human Forecaster

Database of *surprising* events



Events at $t-T$

- System-wide status & dynamics
- Incident reports
- Sporting events
- Weather
- Time and day
- Topology
- Road properties
- Holiday status

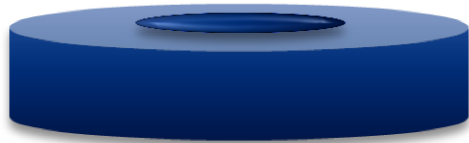


Machine learning

Integrating Surprise Forecasting

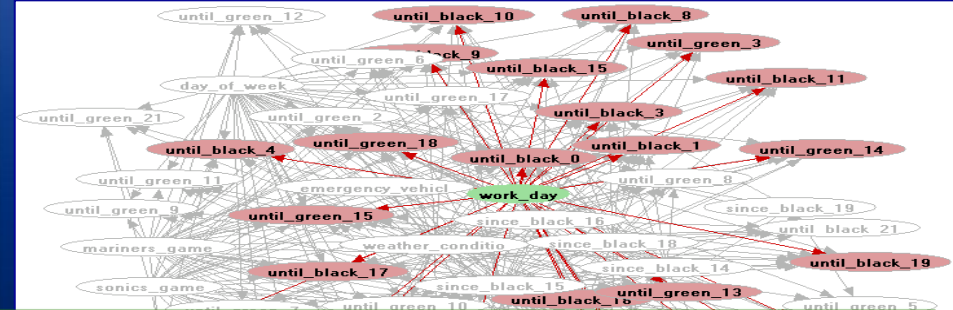
- System-wide status & dynamics
- Incident reports
- Major events
- Weather
- Day & time
- Road properties & topology
- Holiday status

Traffic prediction service

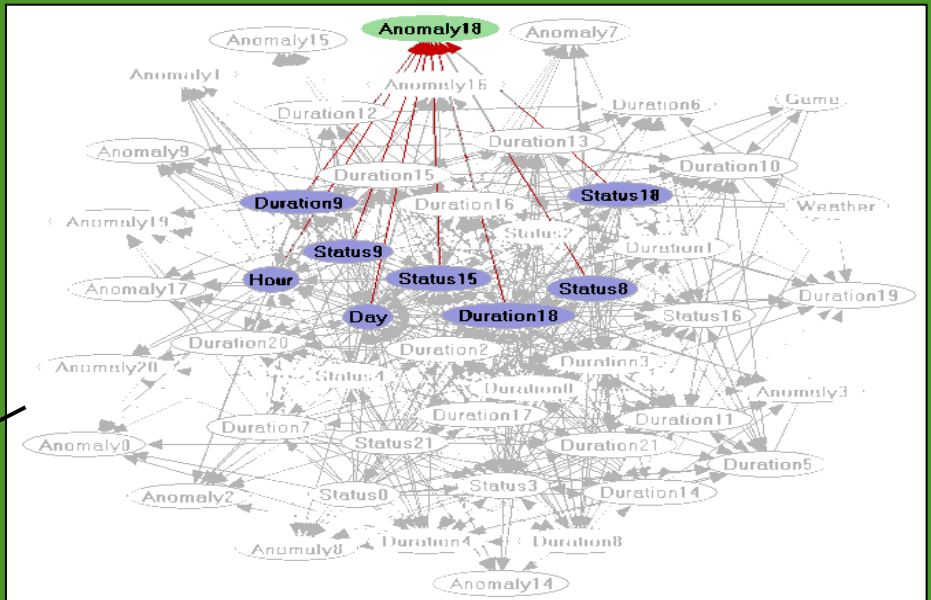


- Event store
- Learning
- Inference

Core predictions



Surprise forecasting models



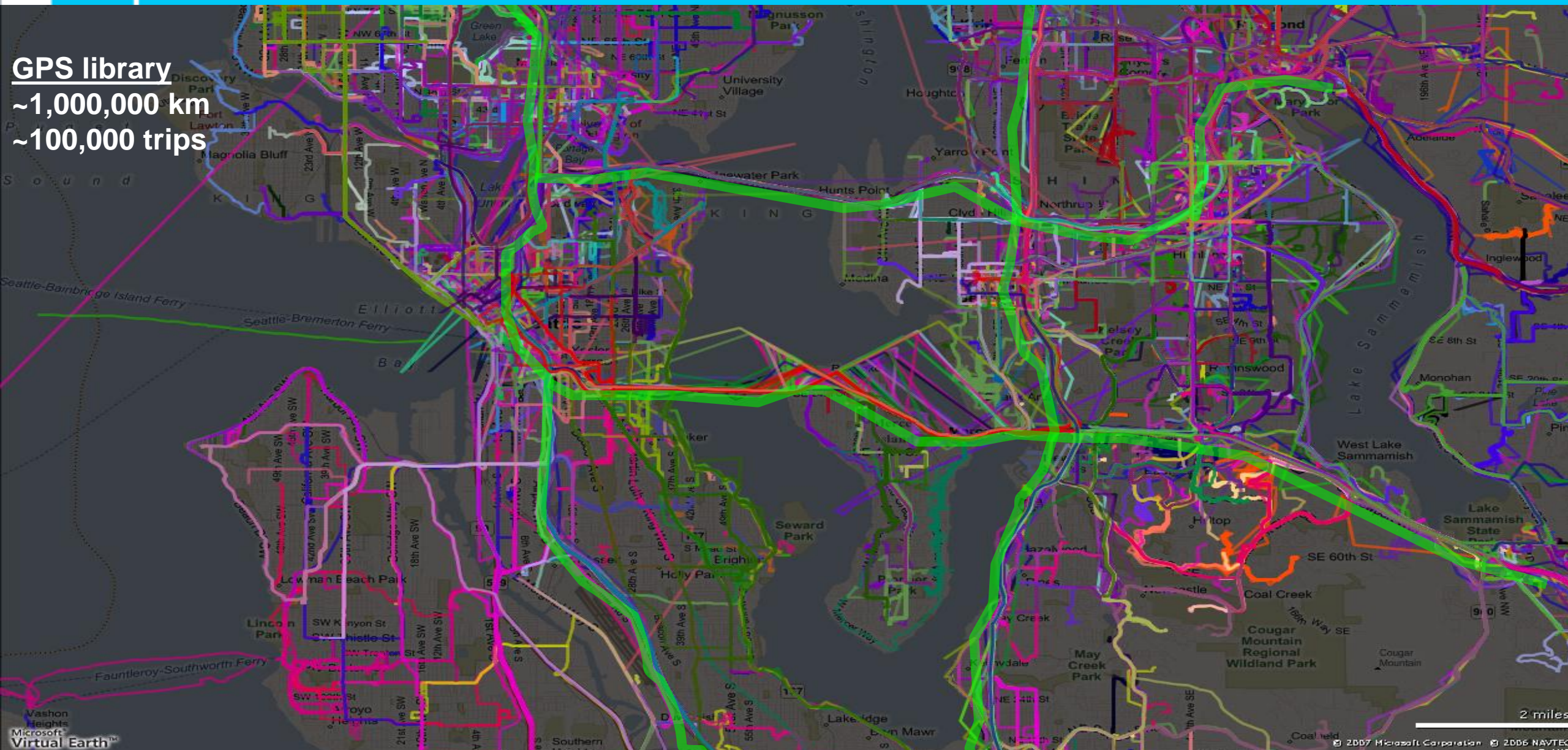
- When my route will likely clear in
- A surprising situation is noted at one of my bottlenecks
- A surprising situation may occur within a half hour

Settings for e-mail or SMS alerting...



Extend Predictions to Unsensed Roads

GPS library
~1,000,000 km
~100,000 trips



2 miles

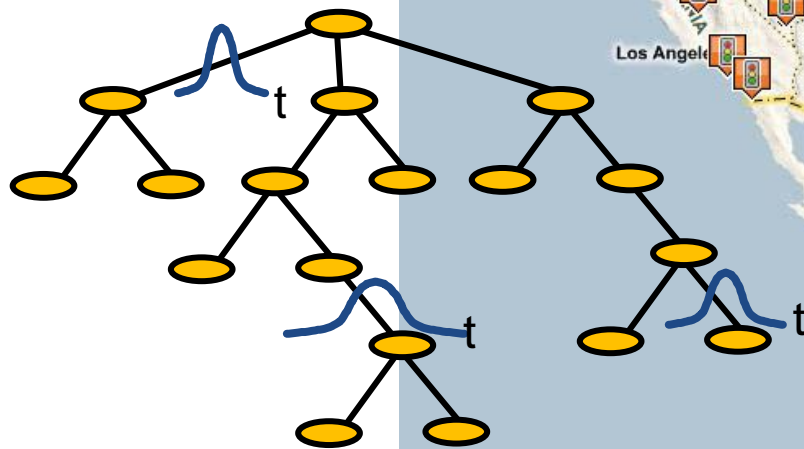


Clearflow

maps.bing.com

* Windows phone

- 72 cities across North America
- Flows assigned to ~60 million streets *every few minutes*





Clearflow

maps.bing.com

* Windows phone

Web Images Videos Shopping News Maps More | MSN Hotmail

Sign in Rewards Everett, Washington



directions



Maps

Web Videos Images Maps

Directions

My places

Map apps

Road

Bird's eye

Traffic

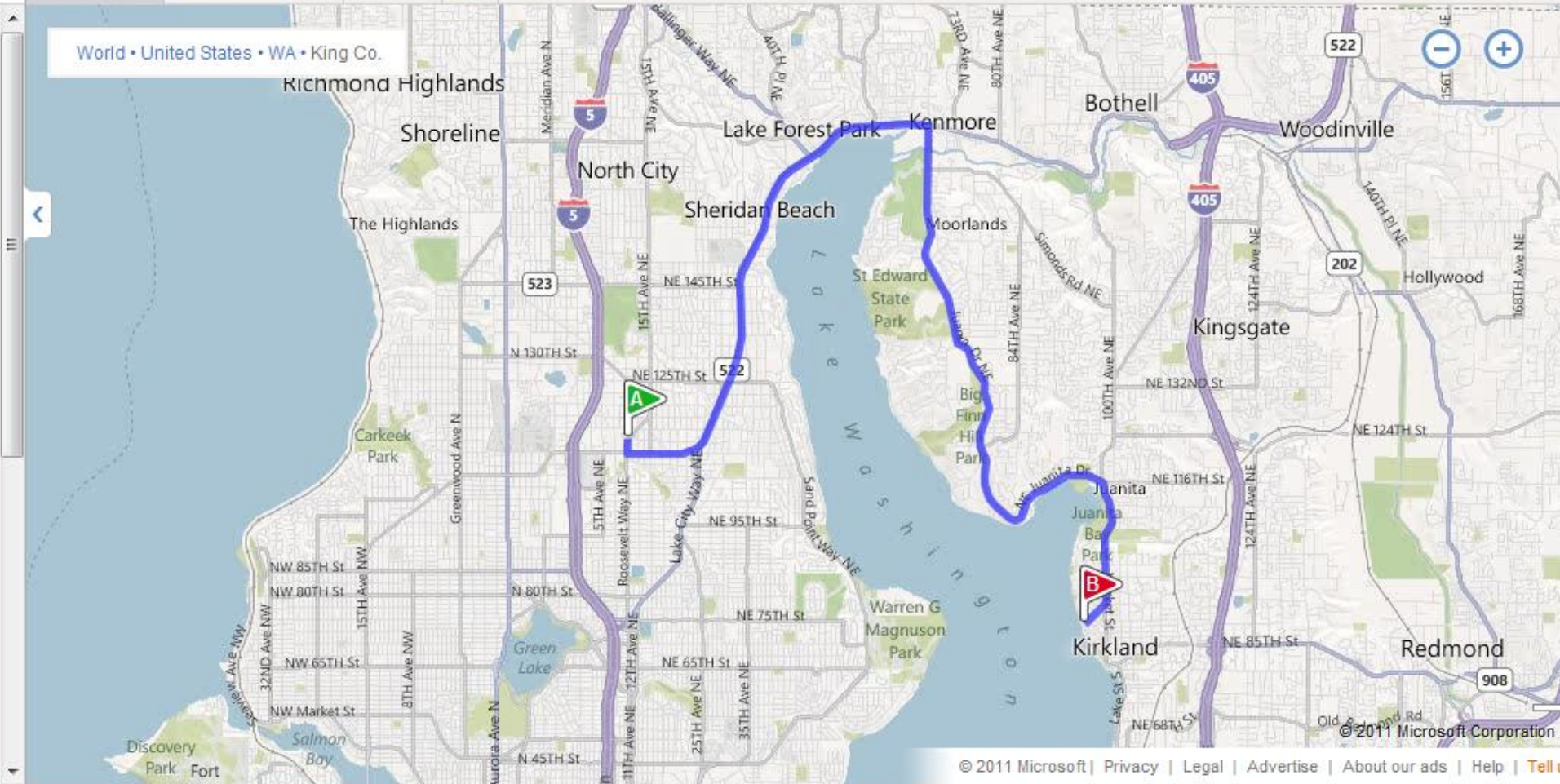
Print

Edit route

Route: 13.1 miles, 35 min
(rerouted based on traffic)
Go back to the previous route

11300 Roosevelt Way NE, Seattle, WA
98125-6228

- 1 Depart Roosevelt Way NE toward NE 113TH St 0.2 mi
- 2 Turn left onto NE Northgate Way ARCO/ampm on the corner 0.9 mi
- 3 Bear left onto WA-522 / Lake City Way NE 4.7 mi
Pass Taco Bell in 1.7 mi
- 4 Turn right onto 68TH Ave NE 0.5 mi
- 5 Road name changes to Juanita Dr NE 3.8 mi
Pass 76 in 1.7 mi
- 6 Keep right onto NE Juanita Dr 1.5 mi
- 7 Turn right onto 98TH Ave NE 0.7 mi
76 on the corner



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Done

Internet | Protected Mode: On

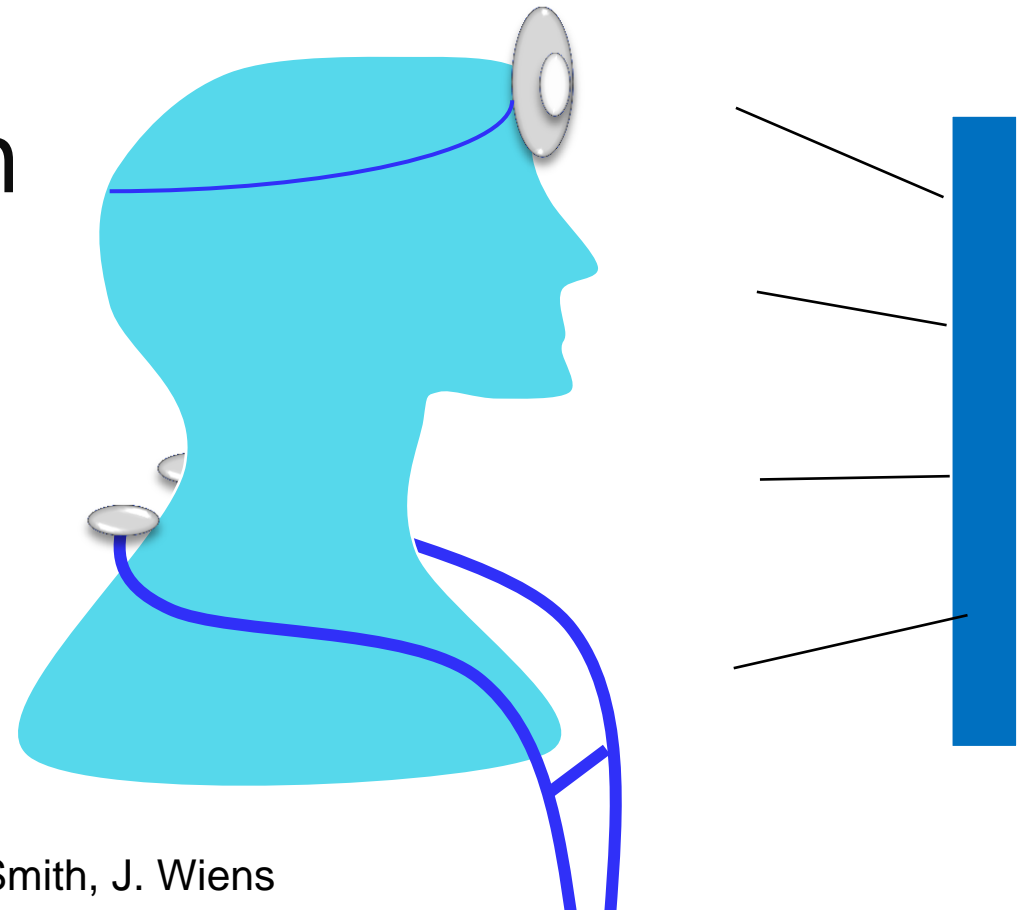


Healthcare

High-stakes challenges

Working across cultures

Coupling prediction & decision



Costly Challenge



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JOURNAL of MEDICINE

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SPECIAL ARTICLE

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Volume 360:1418-1428

[April 2, 2009](#)

Number 14

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Rehospitalizations among Patients in the Medicare Fee-for-Service Program

Stephen F. Jencks, M.D., M.P.H., Mark V. Williams, M.D., and Eric A. Coleman, M.D., M.P.H.

ABSTRACT

Background Reducing rates of rehospitalization has attracted attention from policymakers as a way to improve quality of care and reduce costs. We analyzed Medicare claims data from 2003–2004 to describe the patterns of rehospitalization in the United States to aid in planning the necessary changes.

Methods We analyzed Medicare claims data from 2003–2004 to describe the patterns of

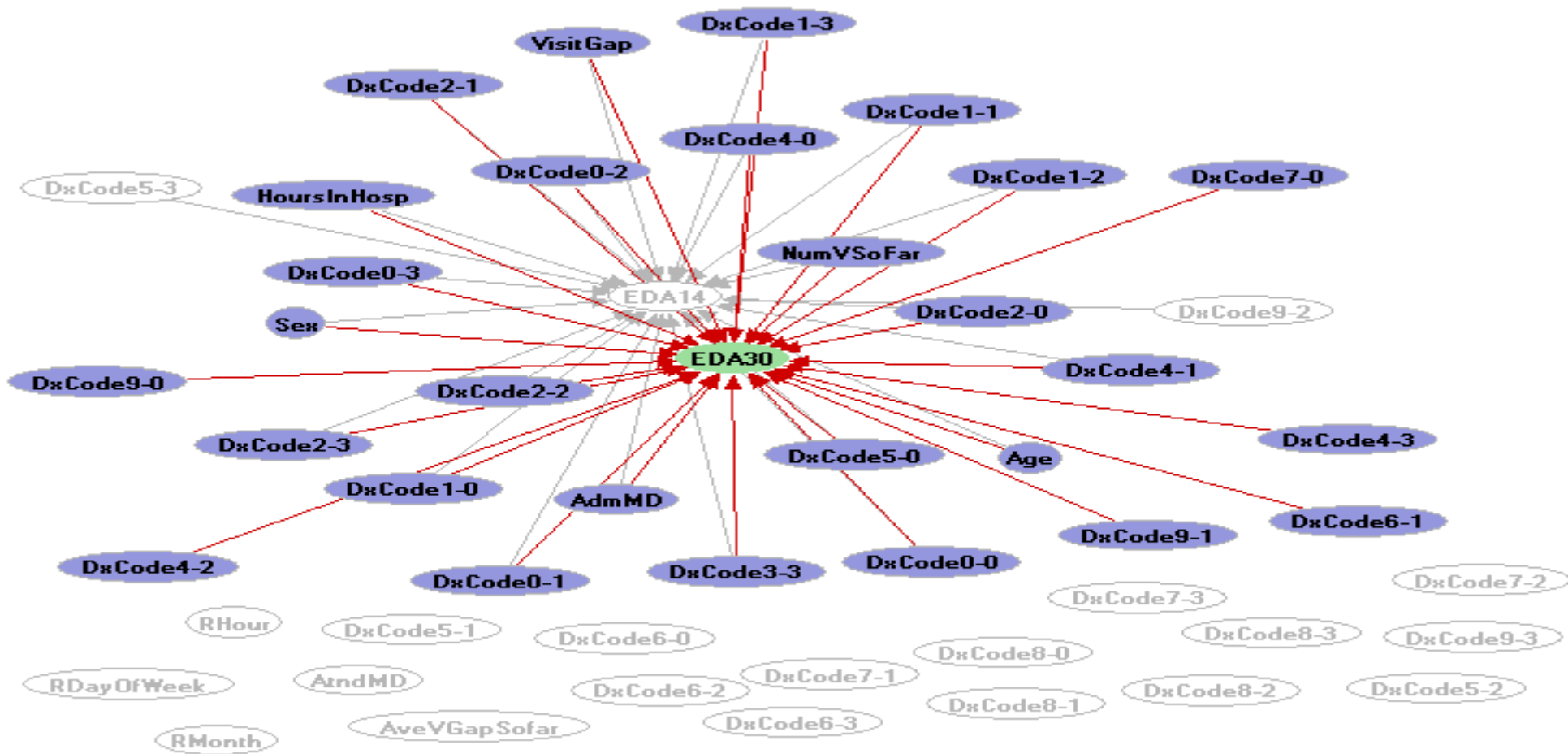
- ~20% within 30 days
- ~35% in 90 days
- **Estimated cost to Medicare in 2004: \$17.4 billion**



Learning from a Case Library

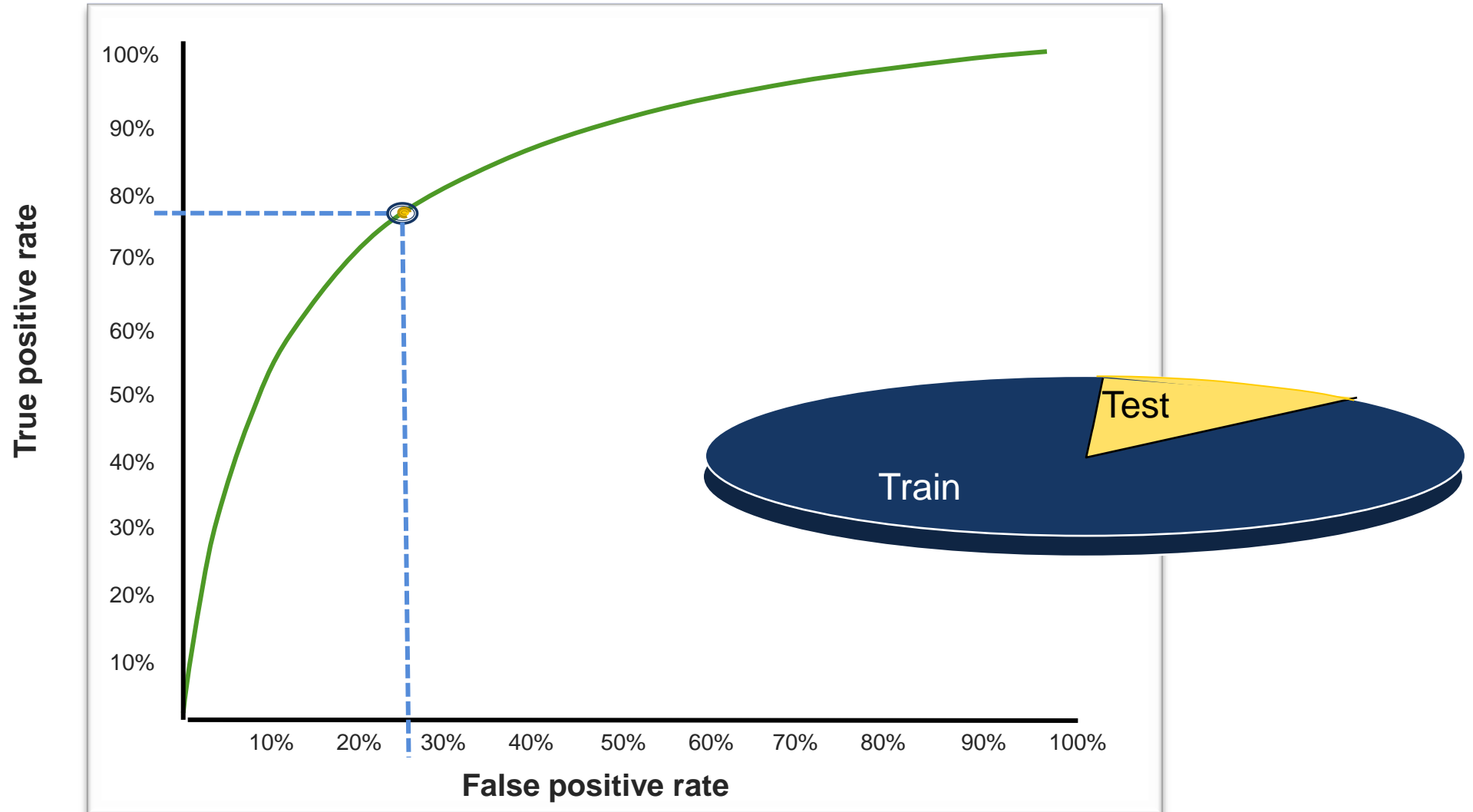
- Large hospital in Wash DC
 - All visits during the years 2001 to 2009 (e.g., ~300,000 ED visits)
 - Admissions, discharge, transfer (ADT)
 - Chief complaint in free text
 - Age, gender, demographics
 - Diagnosis codes (ICD-9)
 - Lab results and studies
 - Medications
 - Vital signs
 - Procedures
 - Admitting and attending MD codes
 - Fees and billing
- ~25,000 variables considered in dataset

Graphical Model for Readmission





Performance of Classifier



Identifying Discriminatory Evidence

| Weight | Feature description | Frequency |
|---------|---|-----------|
| 0.68398 | Dx0->2 = Excessive vomiting in pregnancy | 0.31% |
| 0.61306 | Dx3->2 = Personal history of malignant neoplasm | 0.28% |
| 0.58281 | Dx0->2 = Heart failure | 0.30% |
| 0.56708 | Dx0->1 = Nephritis, nephrotic syndrome, and nephrosis | 0.09% |
| 0.56649 | Dx3->2 = Heart failure | 0.28% |
| 0.54663 | Complaint sentence contains "suicidal" | 0.17% |
| 0.48415 | Dx1->2 = Disorders of function of stomach | 0.07% |
| 0.47257 | Dx5->0 = Diseases Of The Genitourinary System | 0.15% |
| 0.46136 | Dx0->2 = Chronic airway obstruction, not elsewhere classified | 0.10% |
| 0.44555 | Dx4->2 = Depressive disorder, not elsewhere classified | 0.10% |
| 0.44257 | Stayed 14 hours in the ER | 0.10% |
| 0.43890 | Dx0->1 = Other psychoses | 0.32% |
| 0.43513 | Dx0->0 = Diseases Of The Blood And Blood-Forming Organs | 0.46% |
| 0.42582 | Complaint sentence contains "dialysis" | 0.19% |
| 0.41888 | Dx0->2 = Depressive disorder, not elsewhere classified | 0.27% |
| 0.41302 | Dx1->1 = Nephritis, nephrotic syndrome, and nephrosis | 0.29% |
| 0.38506 | Complaint sentence contains "fluid" | 0.10% |
| 0.37474 | 69 < Age | 9.22% |



Multiple Predictions

- ED discharge → Inpatient within 72 hours
- Inpatient discharge → Inpatient within 30 days
- CHF discharge → CHF inpatient within 30 days
- Death within 30 days
- Inpatient → infection within 48hrs, 72hrs, stay
 - *C.Difficile, MRSA, VRE*

Team

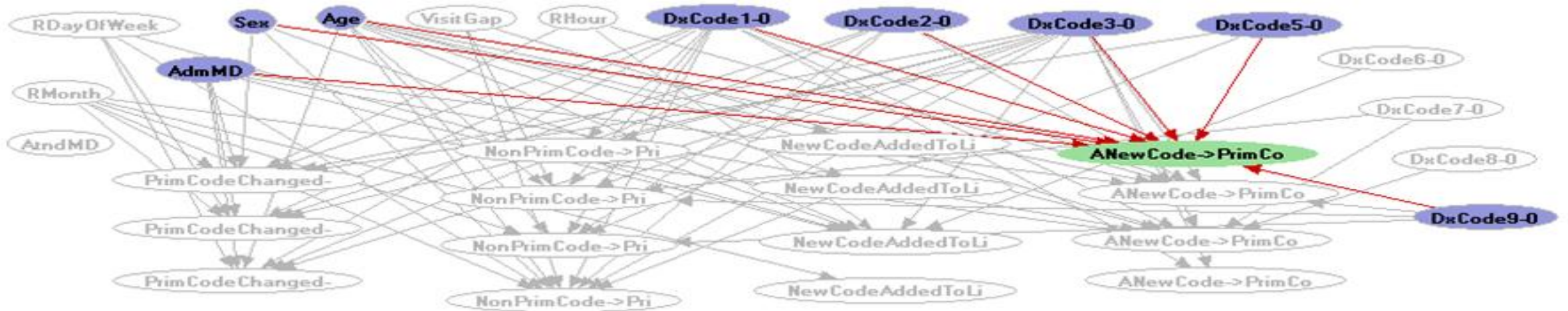
M. Bayati, M. Braverman, E. Horvitz, P. Koch, P. Oka, J. Wiens , N. Donegan, L. Pic-Aluas, G. Ruiz, M. Smith



New Kinds of Models: Predict Surprises

Predict readmission surprises:

"The patient you're discharging will likely return within 3 days with a 1^o diagnosis that is not currently on the chart."



Translation: Research → Open World

Readmissions Manager for Microsoft Amalga

Reducing Hospital Readmissions is an Impending Priority

Overview

One in five Medicare inpatients is readmitted within 30 days. The Centers for Medicare and Medicaid Services (CMS) considers 40%-75% of these readmissions to be preventable.

In October 2012, CMS will begin to track readmission and impose financial penalties on hospitals with higher-than-expected readmission rates for certain conditions. Other payers will certainly follow.

It is clear that hospital admissions and readmissions are becoming a critical parameter for tracking care delivery from both a financial and quality perspective.

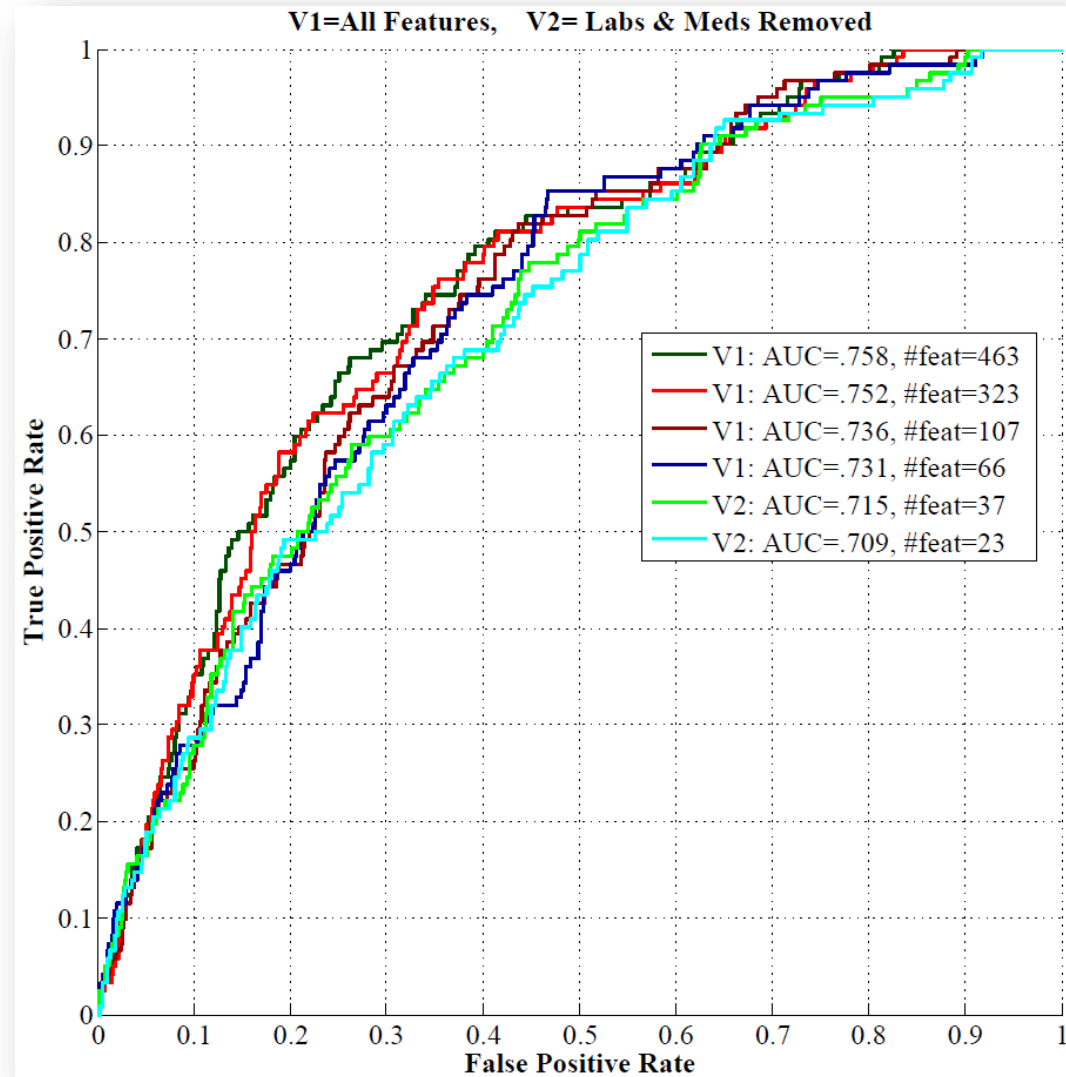
Readmissions Manager for Microsoft Amalga is an innovative solution to help organizations address this very important business need.



Readmissions Manager Targets Avoidable Hospital Readmissions



Engineering for Tractability and Availability





Predictive platform goes live...

Microsoft Amalga - recazang



US - Sample Hospital

M3L Inp/Inp Readmission Prediction Last...

Filter

Sort

Shortcut

Find

Zoom-in

Refresh

System

None

All ro...

Dev

Data Mining

Info

Input

Forms

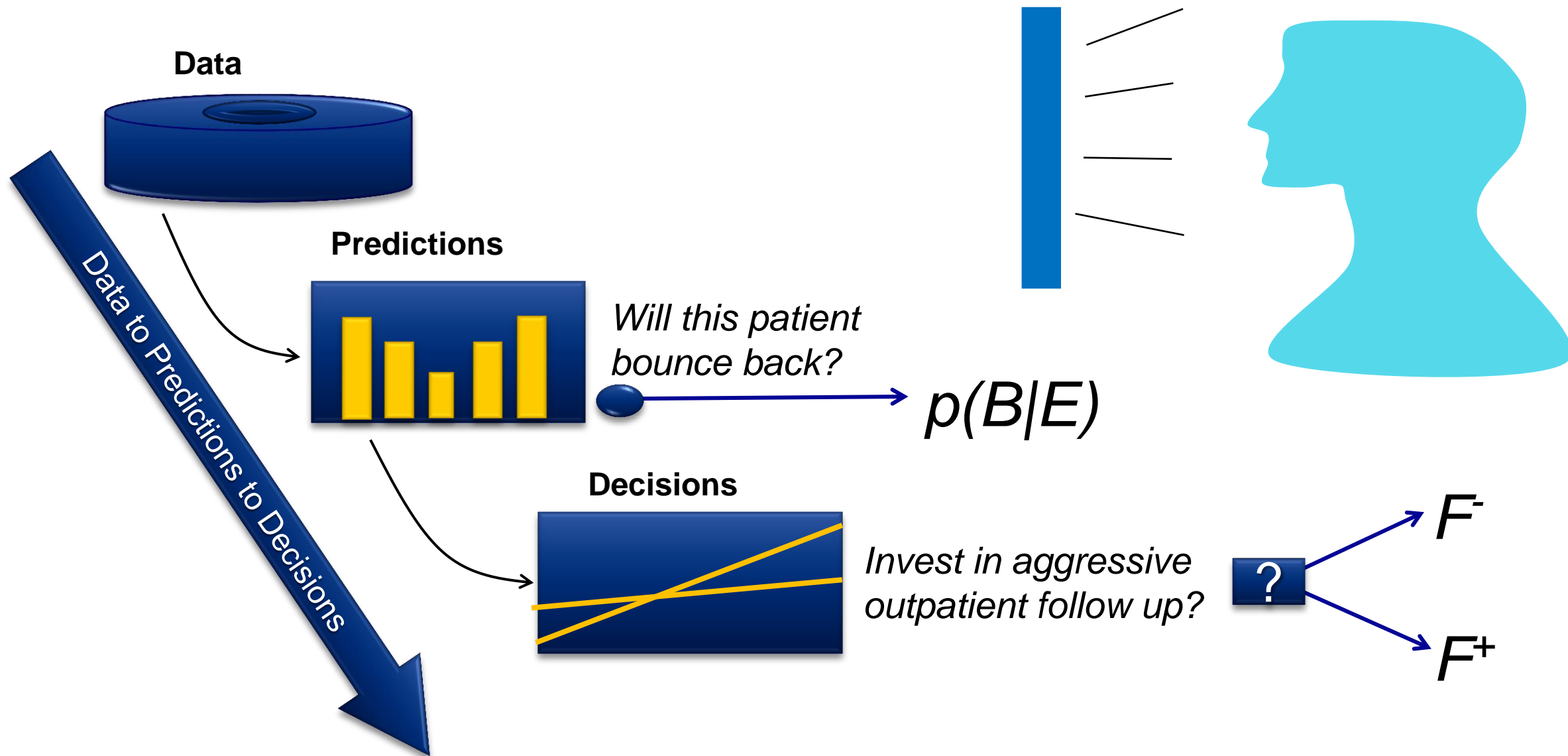
Admin

Dashboard

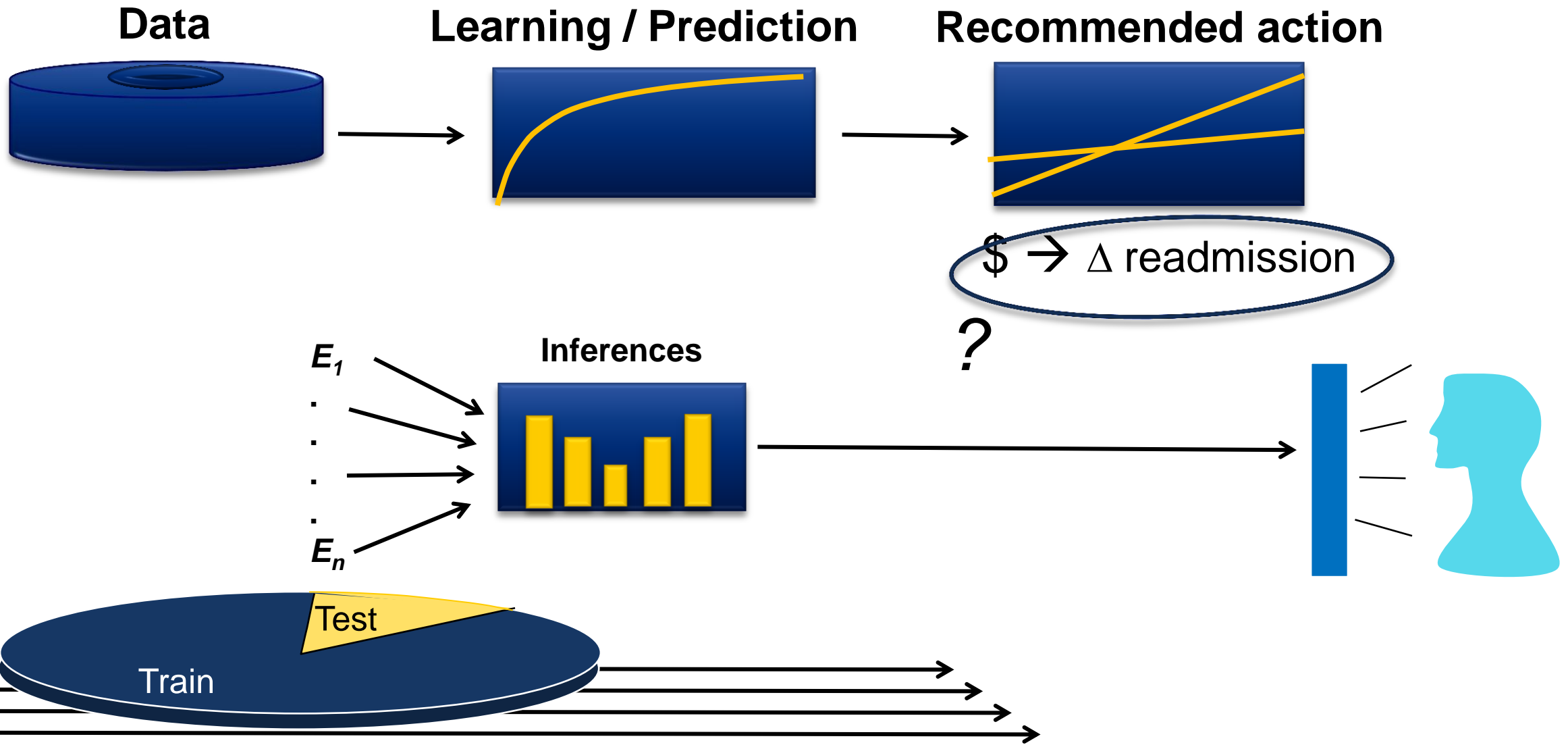
New Task

| ACCOUNT | ADMITDTTM | DISCHARGEDTTM | AGE | SEX | PROB_NUM_% | FACTOR |
|---------|------------------|------------------|-----|-----|------------|-------------------------------------|
| | 12/03/2010 14:57 | 12/08/2010 18:03 | 62 | F | 37.9 | Num past 6m visits = 6 to 10 / P |
| | 12/08/2010 18:45 | 12/08/2010 18:45 | 74 | M | 32.72 | stayed <1 day in the hospital / Pa |
| | 11/16/2010 16:14 | 12/08/2010 18:50 | 48 | M | 30.83 | Patient had dx = Chronic renal fai |
| | 12/02/2010 13:49 | 12/08/2010 18:14 | 68 | M | 29.05 | Patient had dx = Disorders of fluid |
| | 12/01/2010 05:26 | 12/08/2010 18:55 | 44 | M | 28.54 | |
| | 12/01/2010 19:08 | 12/08/2010 18:13 | 61 | M | 27.36 | Patient had dx = Acute renal failu |
| | 11/30/2010 21:50 | 12/08/2010 18:52 | 70 | M | 18.05 | Patient had dx = Other personal |
| | 12/08/2010 08:51 | 12/08/2010 18:45 | 68 | M | 16.57 | stayed <1 day in the hospital |
| | 12/03/2010 20:32 | 12/08/2010 17:50 | 80 | M | 16.18 | Patient had dx = Disorders of fluid |
| | 12/01/2010 01:13 | 12/08/2010 18:06 | 79 | M | 15.52 | |
| | 12/08/2010 18:39 | 12/08/2010 18:39 | 22 | F | 14.53 | stayed <1 day in the hospital / Av |
| | 12/08/2010 19:01 | 12/08/2010 19:01 | 25 | F | 14.42 | stayed <1 day in the hospital / Pa |
| | 12/08/2010 18:05 | 12/08/2010 18:05 | 24 | M | 14.39 | stayed <1 day in the hospital |
| | 12/08/2010 18:26 | 12/08/2010 18:26 | 53 | F | 13.59 | stayed <1 day in the hospital / 44 |

Data → Predictions → Decisions



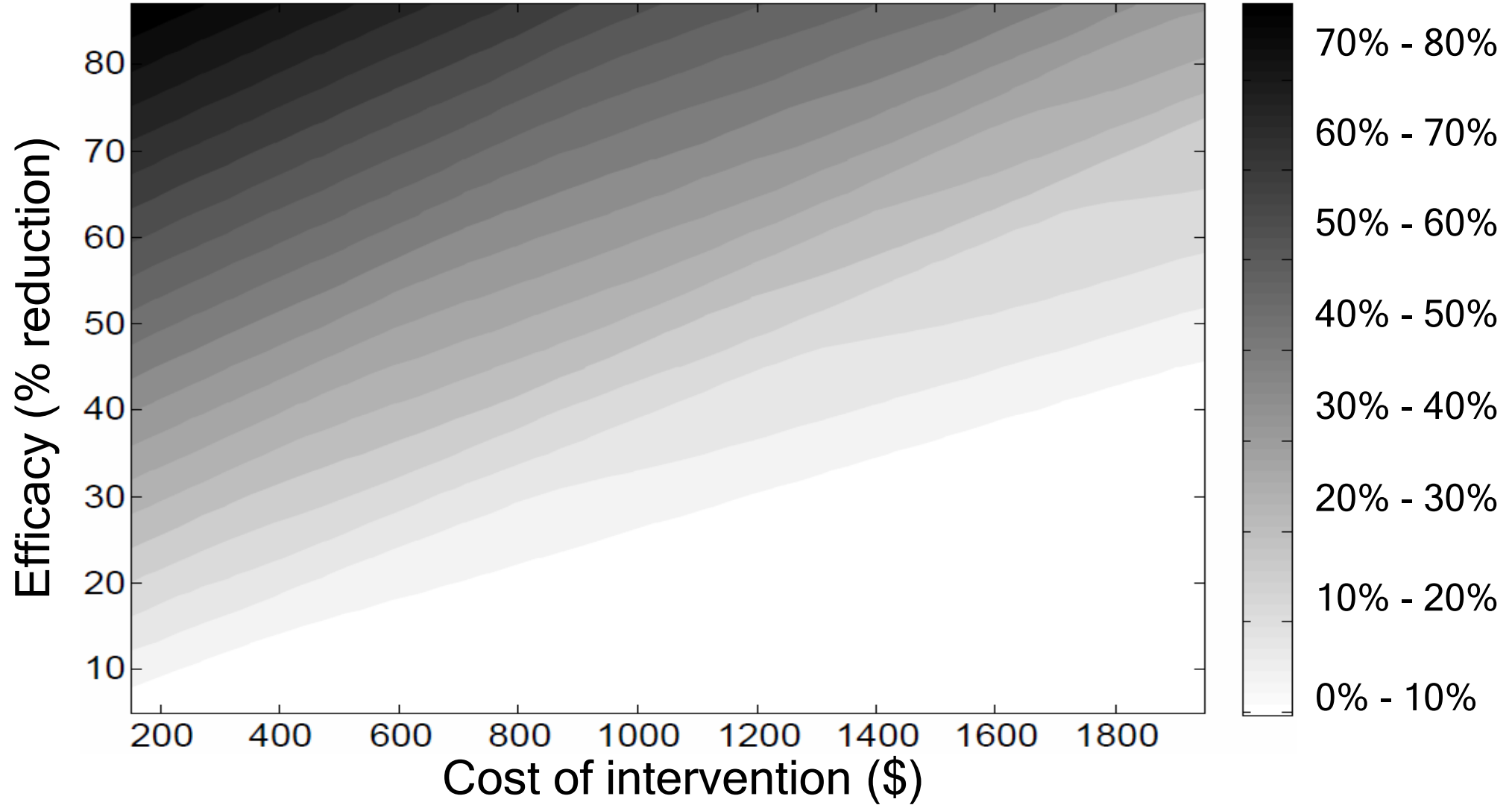
Expected Value of Fielding System for Population





Expected Value of Fielding System for Population

Congestive Heart Failure: Train: 2004-2007 / Test: 2008

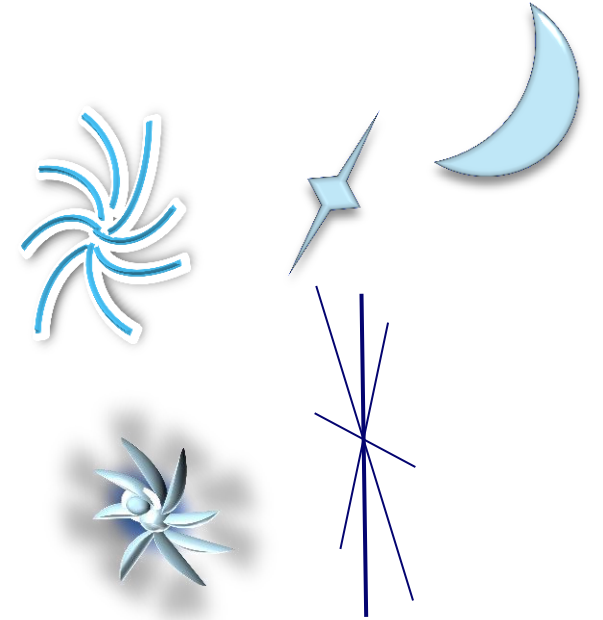
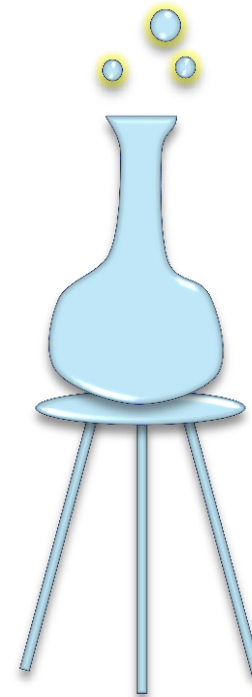
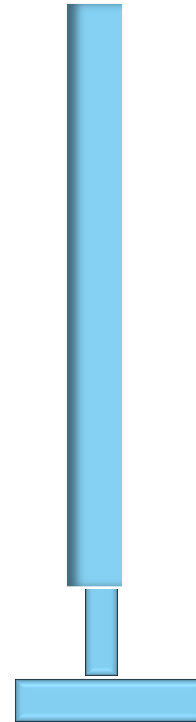
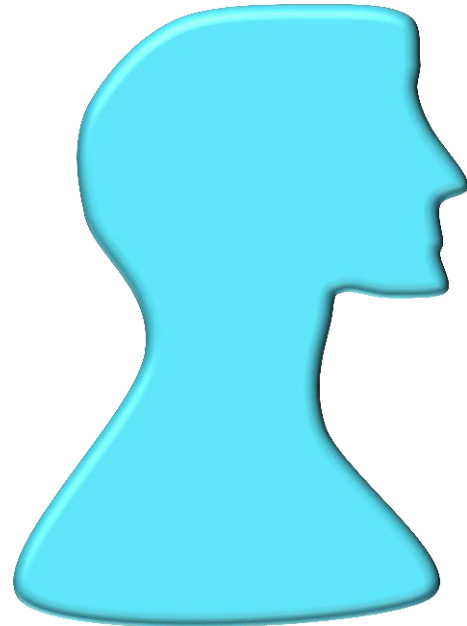




Citizen Science

Human + machine intelligence

Multiple roles of machine intelligence



Zooniverse: Classification & discovery in astronomy

Sloan Digital Sky Survey:

$\sim 10^6$ galaxies, $\sim 120\text{k}$ quasars, $\sim 225\text{k}$ stars

Galaxy Zoo

View & classify galaxies online

886k galaxies, 34m votes, 100k participants



Classification & Discovery in Astronomy

GALAXY ZOO

2

[Home](#) [How To Take Part](#) [My Galaxies](#) [Contact Us](#)

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[- INVERT GALAXY IMAGE](#)

[+ ADD TO MY FAVOURITES](#)

Classify Galaxies

Answer the question below using the buttons provided.

Is the galaxy simply smooth and rounded, with no sign of a disk?



Smooth



Features or disk



Star or artifact

[Need help?](#) [?](#)



Classification & Discovery in Astronomy

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Smooth



Features or disk



Star or artifact

[Need help?](#) ?



Sloan Digital Sky Survey: Image Analysis

453 features

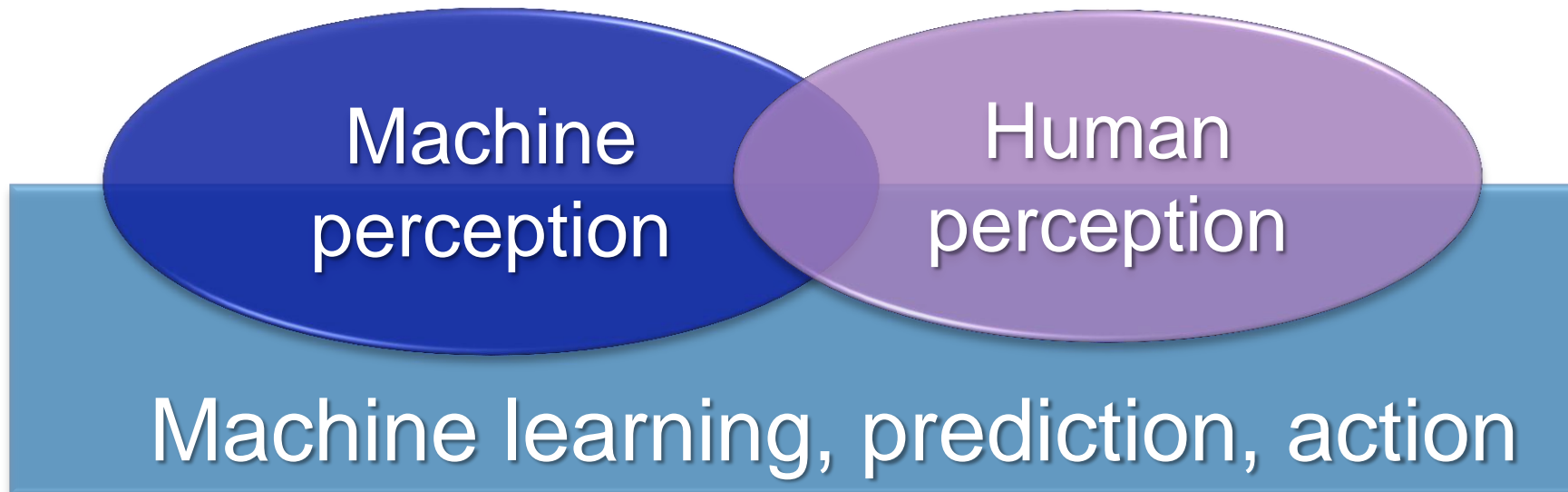
| Attribute | Description |
|---------------------|---|
| $petroMag_{ug}$ | Petrosian magnitude colors. A color was calculated for four independent pairs of bands in SDSS (u, g, r, i, z). |
| $petroRad_u * z$ | Petrosian radius, transformed with redshift to be distance-independent. |
| $invConIndx_u$ | Inverse concentration index. The ratio of the 50% Petrosian magnitude to the 90% Petrosian magnitude. |
| $isoRowcGrad_u * z$ | Gradient of the isophotal row centroid, transformed with redshift to be distance-independent. |
| $isoColcGrad_u * z$ | Gradient of the isophotal column centroid, transformed with redshift to be distance-independent. |
| $isoA_u * z$ | Isophotal major axis, transformed with redshift to be distance-independent. |
| $isoB_u * z$ | Isophotal minor axis, transformed with redshift to be distance-independent. |
| $isoAGrad_u * z$ | Gradient of the isophotal major axis, transformed with redshift to be distance-independent. |
| $isoBGrad_u * z$ | Gradient of the isophotal minor axis, transformed with redshift to be distance-independent. |
| $isoPhiGrad_u * z$ | Gradient of the isophotal orientation, transformed with redshift to be distance-independent. |
| $texture_u$ | Measurement of surface texture. |
| $lnLExp_u$ | Log-likelihood of exponential profile fit. |
| $lnLDev_u$ | Log-likelihood of De Vaucouleurs profile fit. |
| $fracDev_u$ | Fraction of the brightness profile explained by the De Vaucouleurs profile. |



Mesh Human & Machine Intelligence

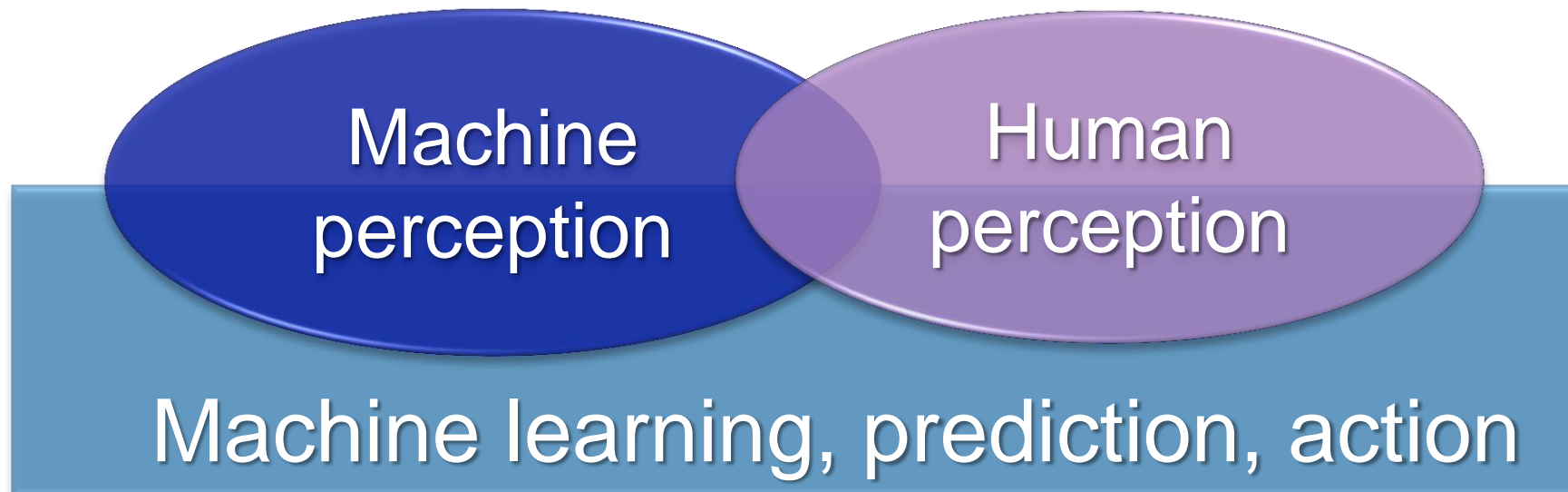
Fuse human & machine perceptual effort

Optimize task routing & stopping



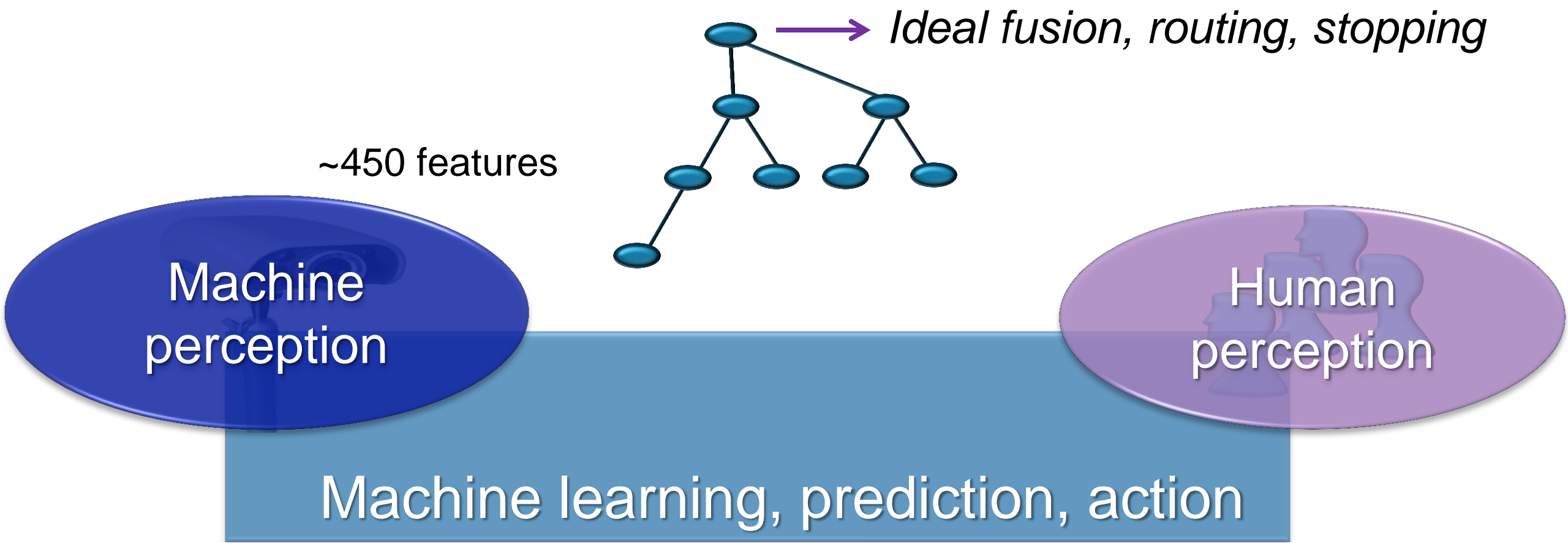


CrowdSynth & Zcion



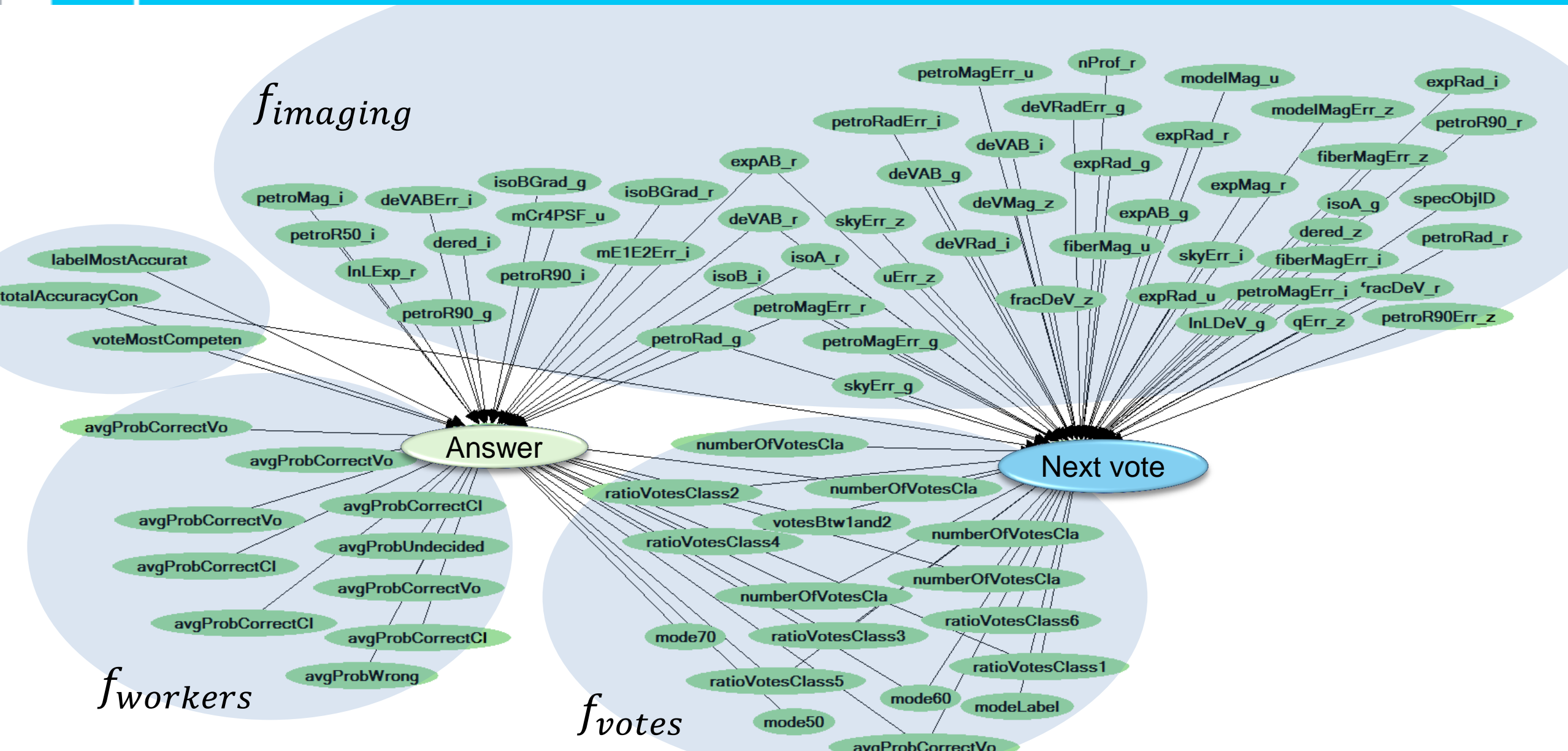


CrowdSynth & Zcion



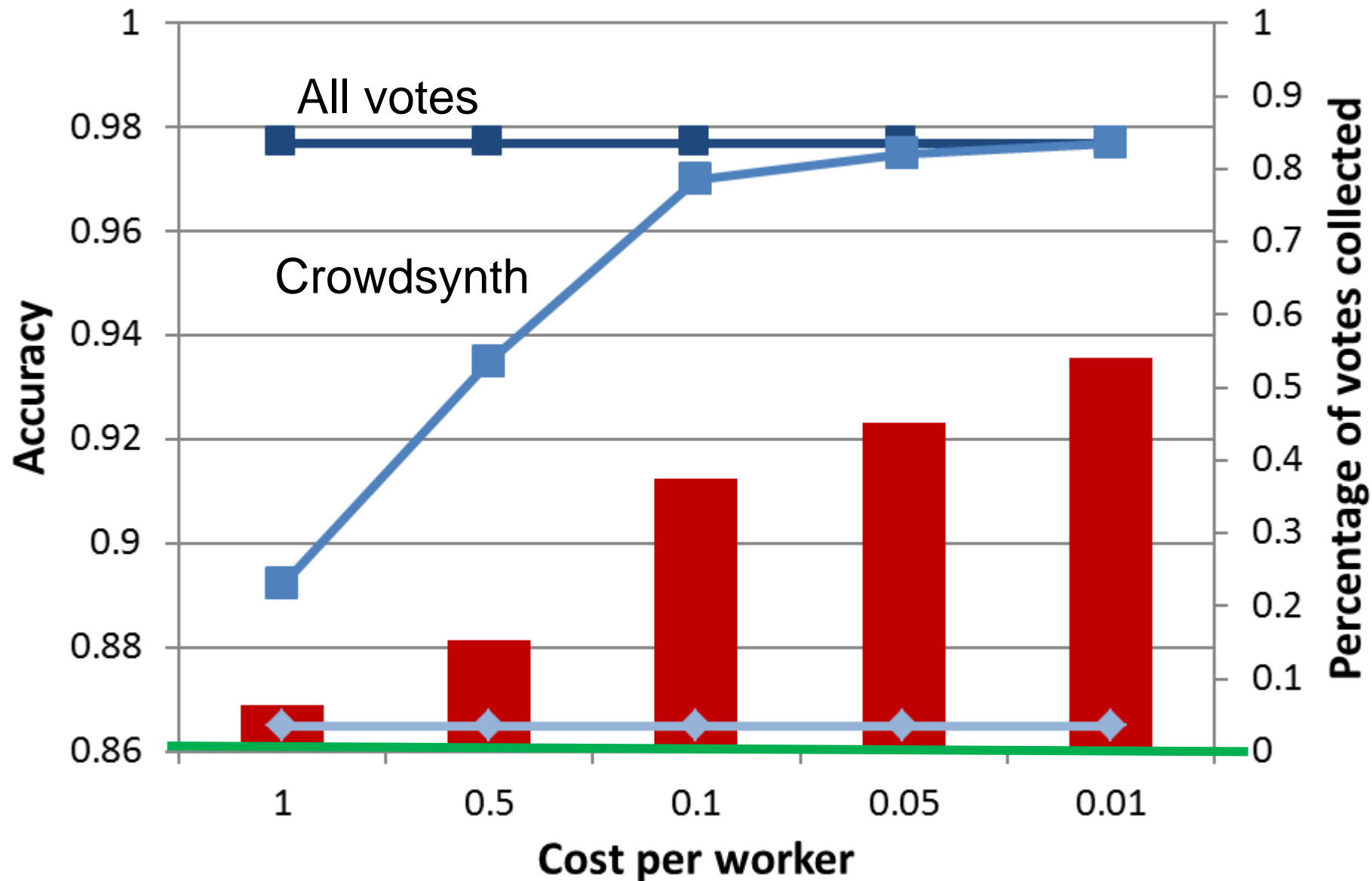


Predict Next Votes & Ground Truth



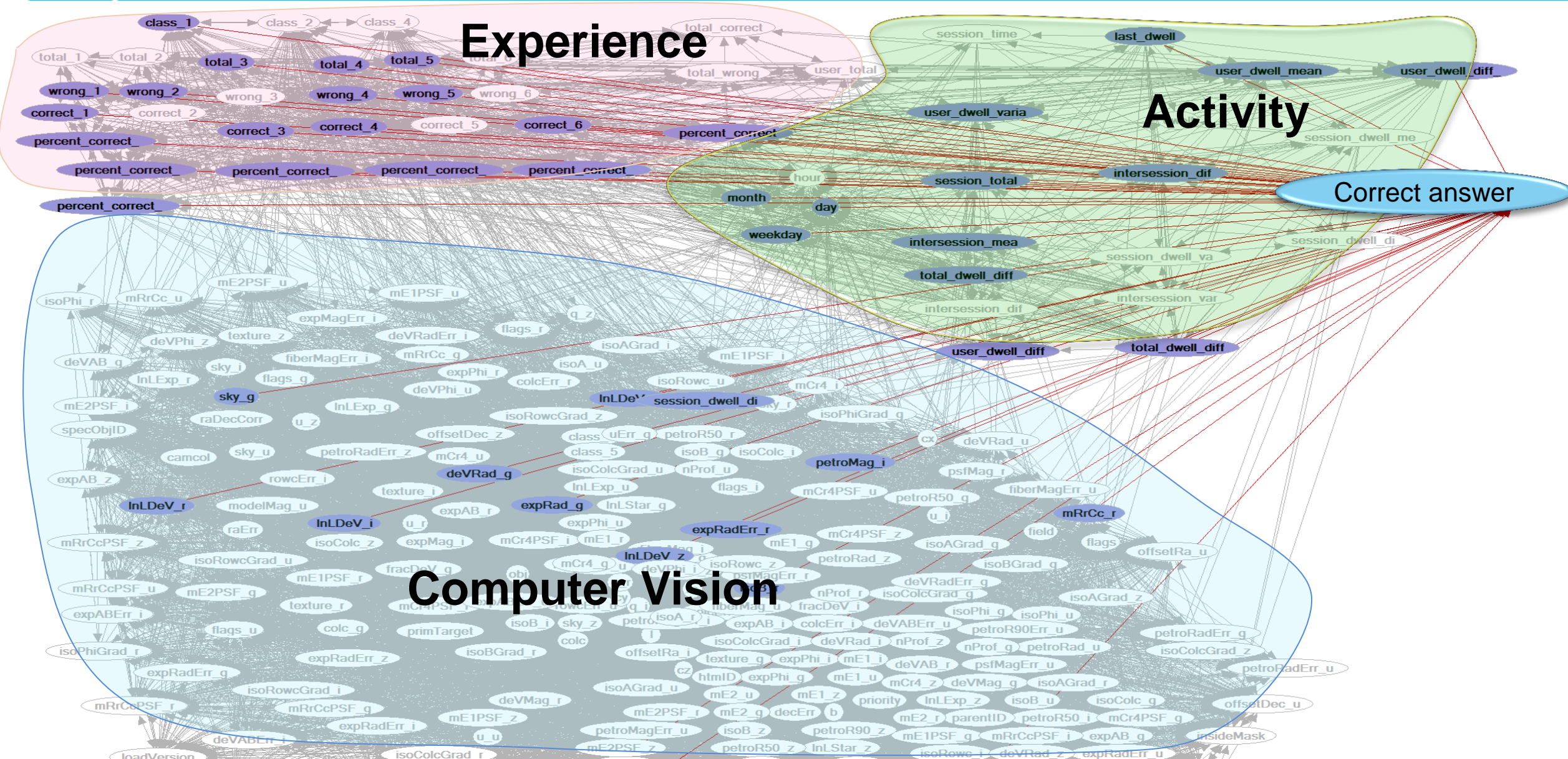


Predict Next Contributions & Ground Truth



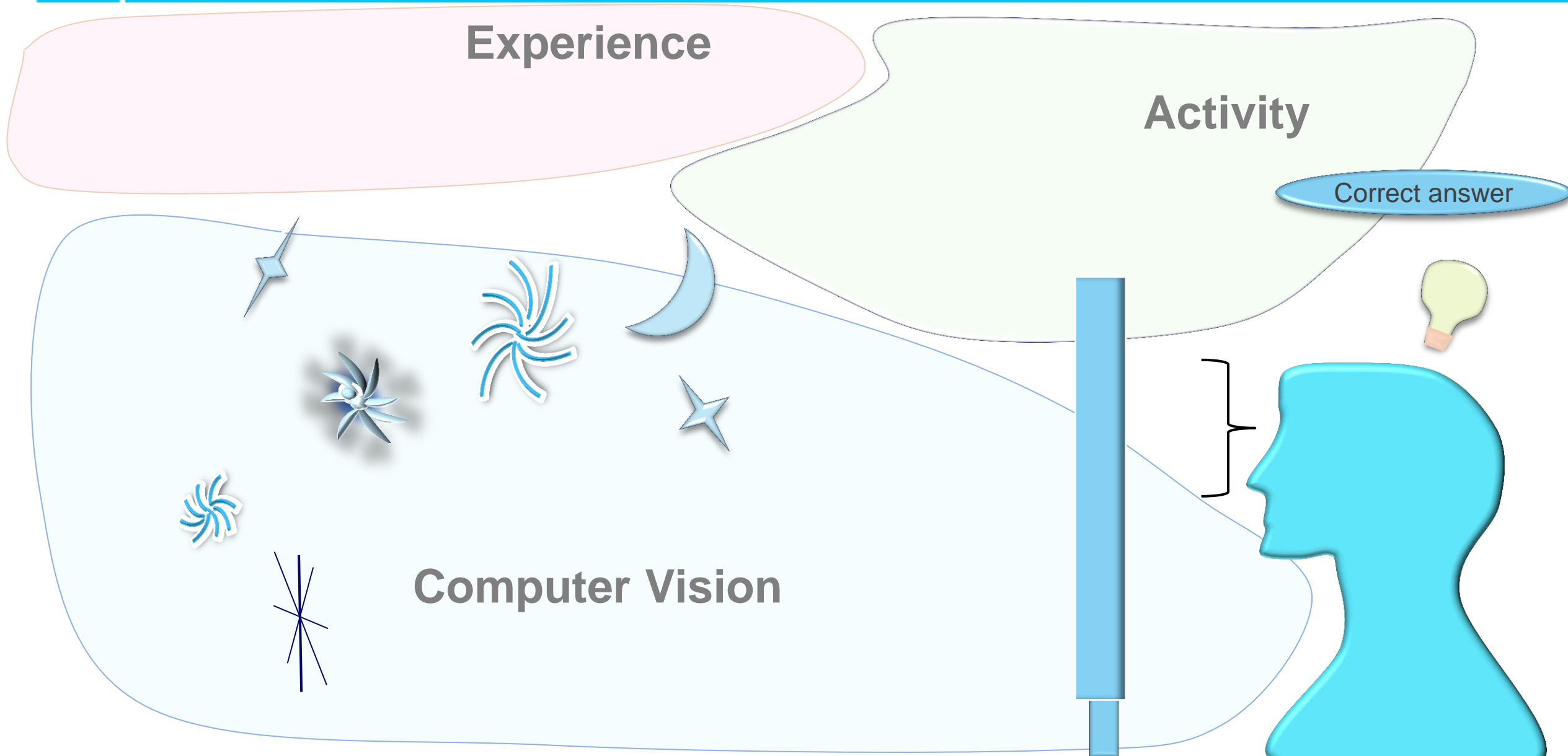


Learn about Abilities & Engagement





Learn about Abilities & Engagement

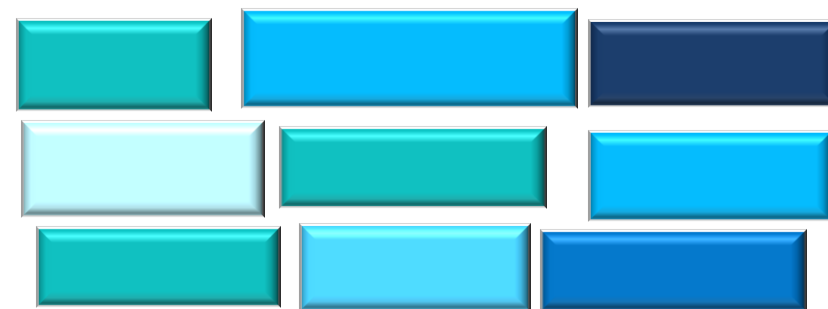
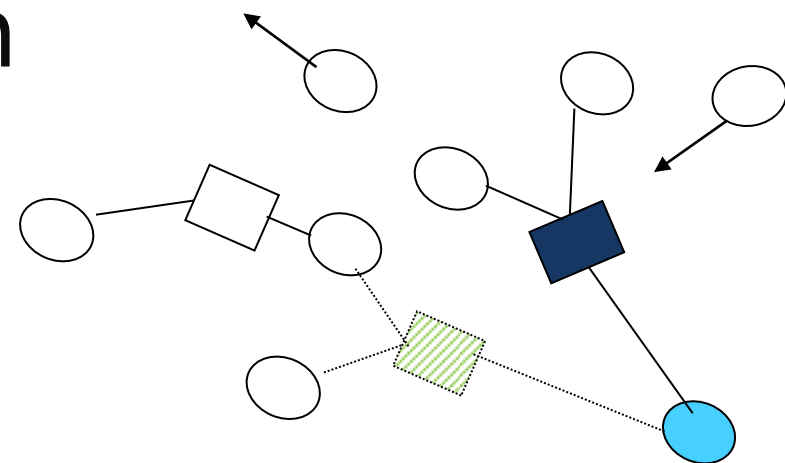
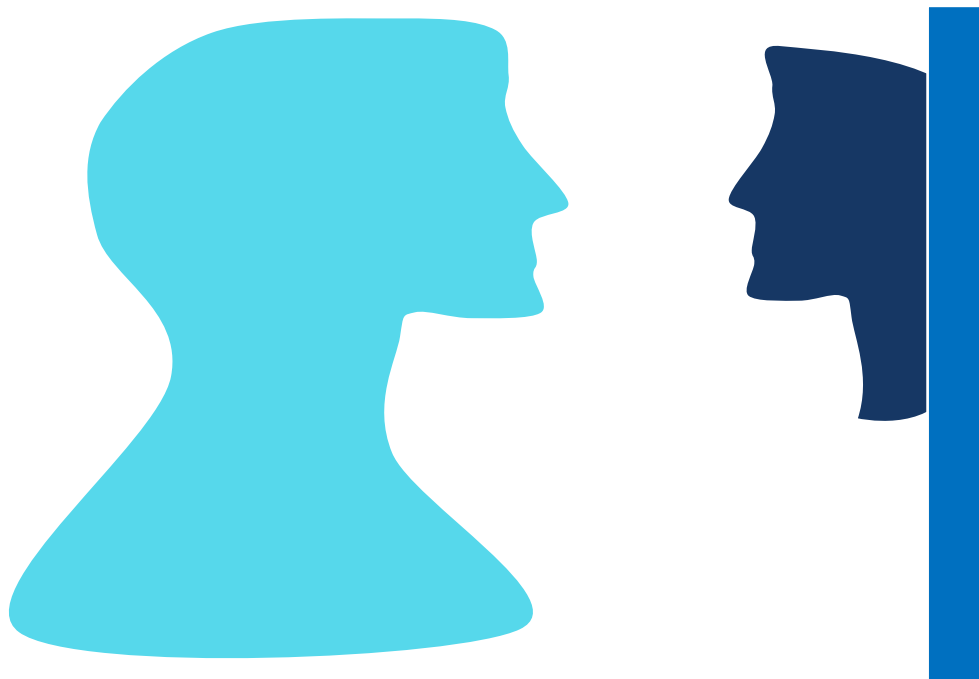




Dreams of Richer Machine Intelligence

Intelligence via composition

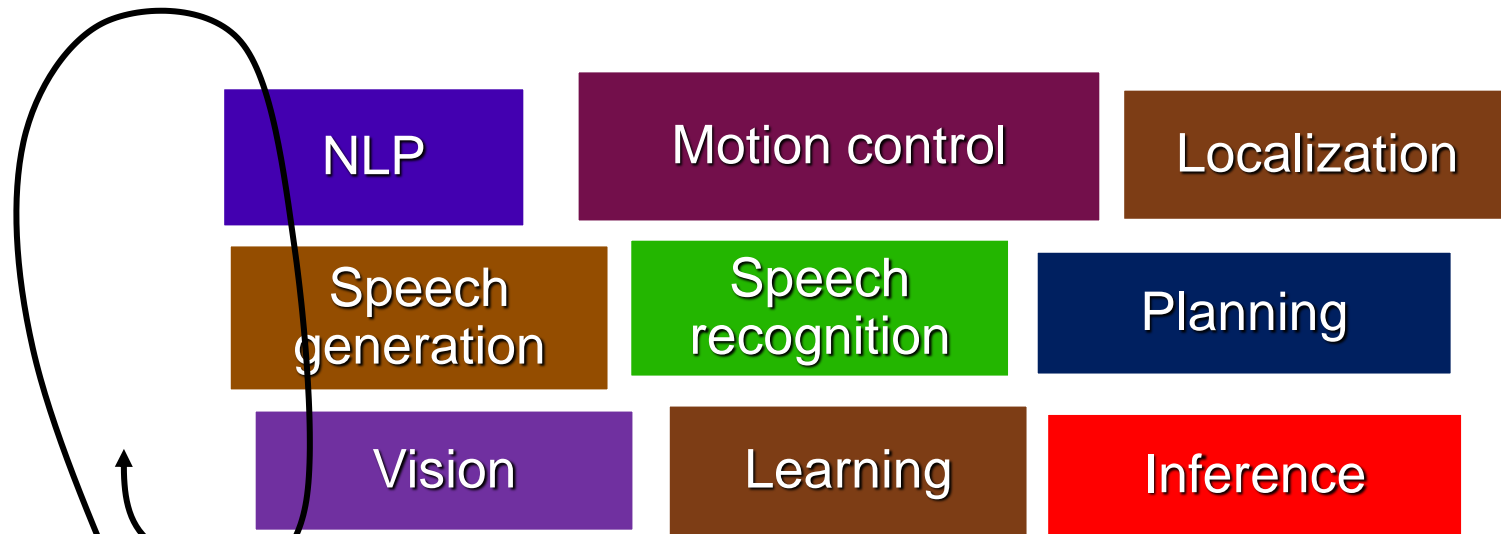
Principles of situated sensing & action





Integrative AI: Intelligence via Composition

- Leveraging tapestry of components
- Understanding synergies & dependencies
- Whole more than sum?



Whole $\gg \sum_i \text{part}_i$?



Situated Interaction Project



Studying Multiparty Situated Interaction

The image displays a complex software interface for analyzing multiparty situated interaction. It features several overlapping windows and panels:

- Top Left:** A wide-angle camera view of a modern building lobby with red seating and large windows. The status bar at the top reads "SYSTEM STATUS [FPS: 0.00] IsListening".
- Top Right:** A smaller camera view focusing on a smiling woman in a blue jacket. The status bar also reads "SYSTEM STATUS [FPS: 0.00] IsListening".
- Bottom Left:** A camera view from a different angle in the lobby, showing a white reception desk. The status bar reads "SYSTEM STATUS [FPS: 0.00] IsListening".
- Right Panel:** A "Select tracks to view" window with a list of elements and frames. The "Current" view is selected, and "F:11" is highlighted in blue.
- Bottom Center:** A "Clarence [F:\Logs\20080821\092533_wfacetracks.xml]" window. It includes a menu bar (File, View, Tracks, Data, Analysis, Help), playback controls, and a timeline. The timeline shows "Absolute time" and "Sources" with a list of elements and their corresponding activity bars (Annotations).
- Bottom Right:** A panel with checkboxes for "Actors", "Interaction Tasks", "Reactive state", and "Display configuration".

The Windows taskbar at the bottom shows the system clock as 3:44 PM.



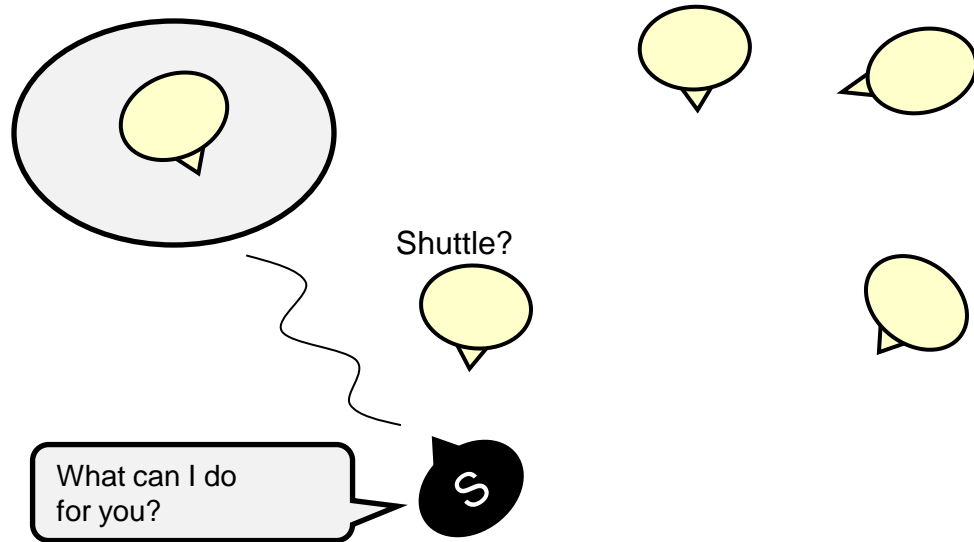
Models of Multiparty Collaboration

shuttle



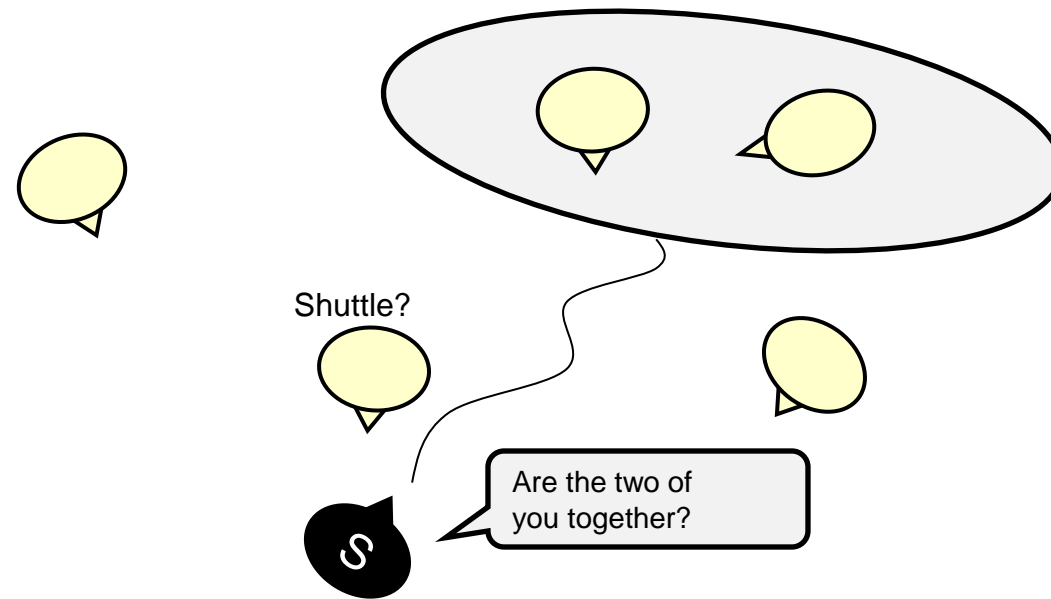


Models of Multiparty Collaboration










Models of Multiparty Collaboration

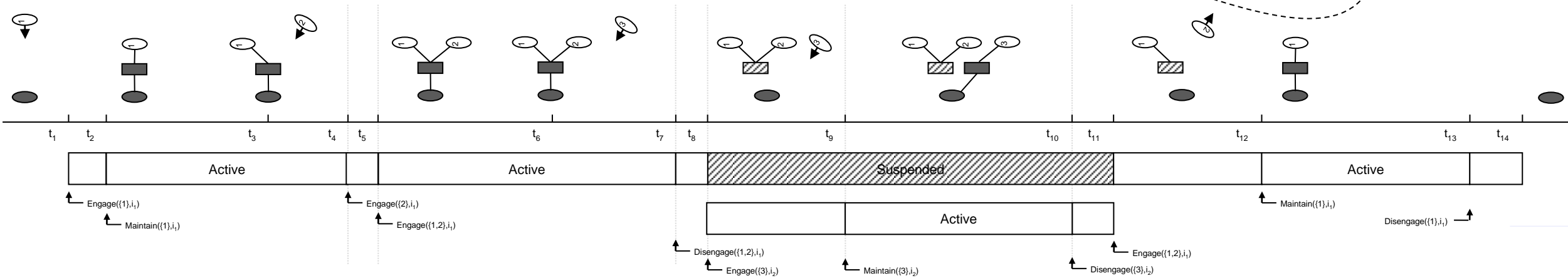
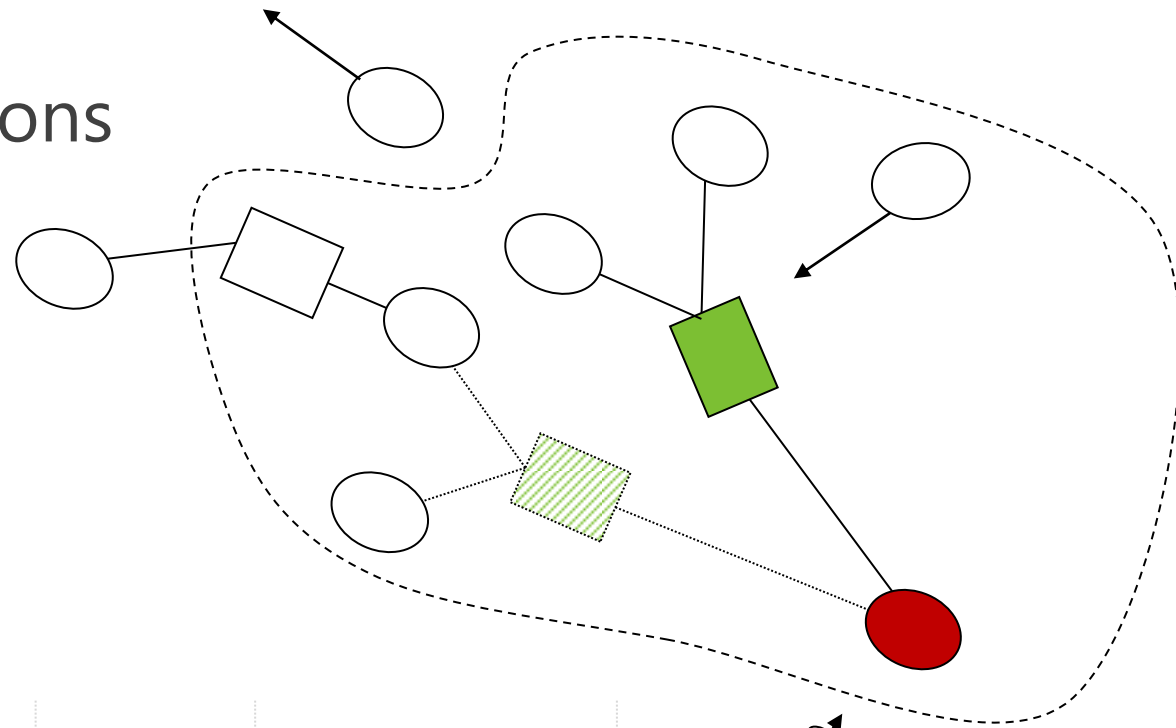




Contributions and Turns in the Open World

Track conversational dynamics
Time-critical turn-taking decisions

-  system
-  user
-  active interaction
-  suspended interaction
-  other interaction



Composing and Exercising a Platform



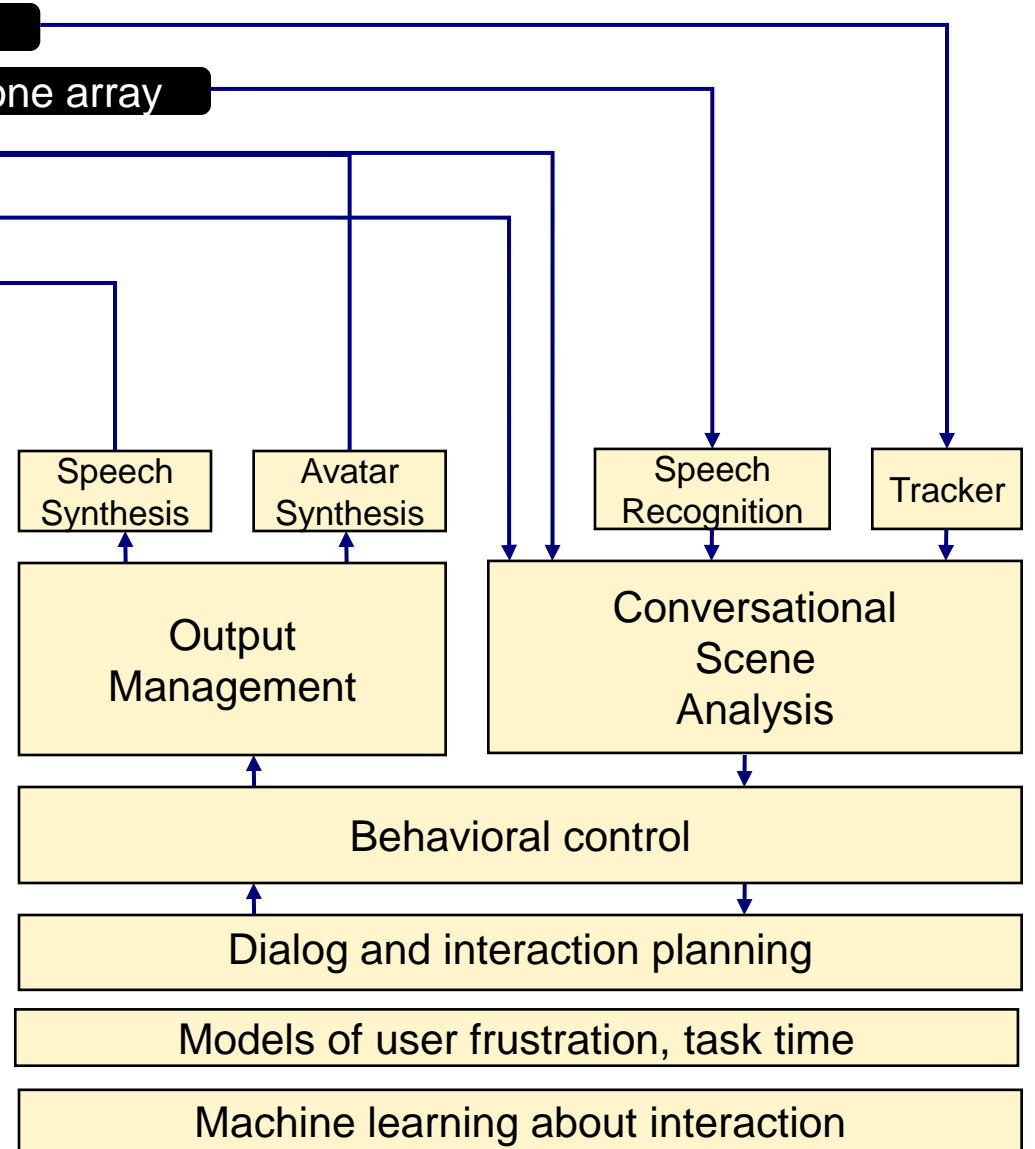
wide-angle camera

4-element microphone array

touch screen

card reader

speakers





Composing and Exercising a Platform

The image is a composite of three main visual elements:

- System Monitoring (Top Left):** Displays four graphs: CPU Usage (33%), CPU Usage History, Memory (1.56 GB), and Physical Memory Usage History.
- Video Feed (Middle Left):** Shows a woman's face. Above her is a 'shuttle reservation' interface with two orange progress bars labeled 'Waiting' and 'Number of seats'.
- Visualization (Right):** A large window titled 'Visualization' showing a 3D scene of a room with people. It includes:
 - SYSTEM STATUS [FPS: 3.92]**
 - IsListening**
 - AllowsBargain**
 - InConversation**
 - Person Data:** Three people are tracked with bounding boxes and labels: 'A:14' (1.00), 'A:15' (0.89), and 'A:16' (0.85). Each has associated attributes like 'Wear[Casual]', 'Affiliation[MS]', 'Engaged[0.27]', 'Attention[OnOther]', 'HasFloor', and 'Was SpeakingLast[ToOther]'. 'A:15' also has 'T:15 [Active]' and 'Goal[Shuttle]'. 'A:16' has 'Wear[Formal]', 'Affiliation[Other]', 'NoEngaged[0.04]', 'Attention[On System]', 'T:16 [Pending]', and 'Goal[Register]'.
 - Bottom Bar:** A series of green circles containing numbers 0, 9, 8, 7, 6, 5, 4, 3, 2.

Composing and Exercising a Platform



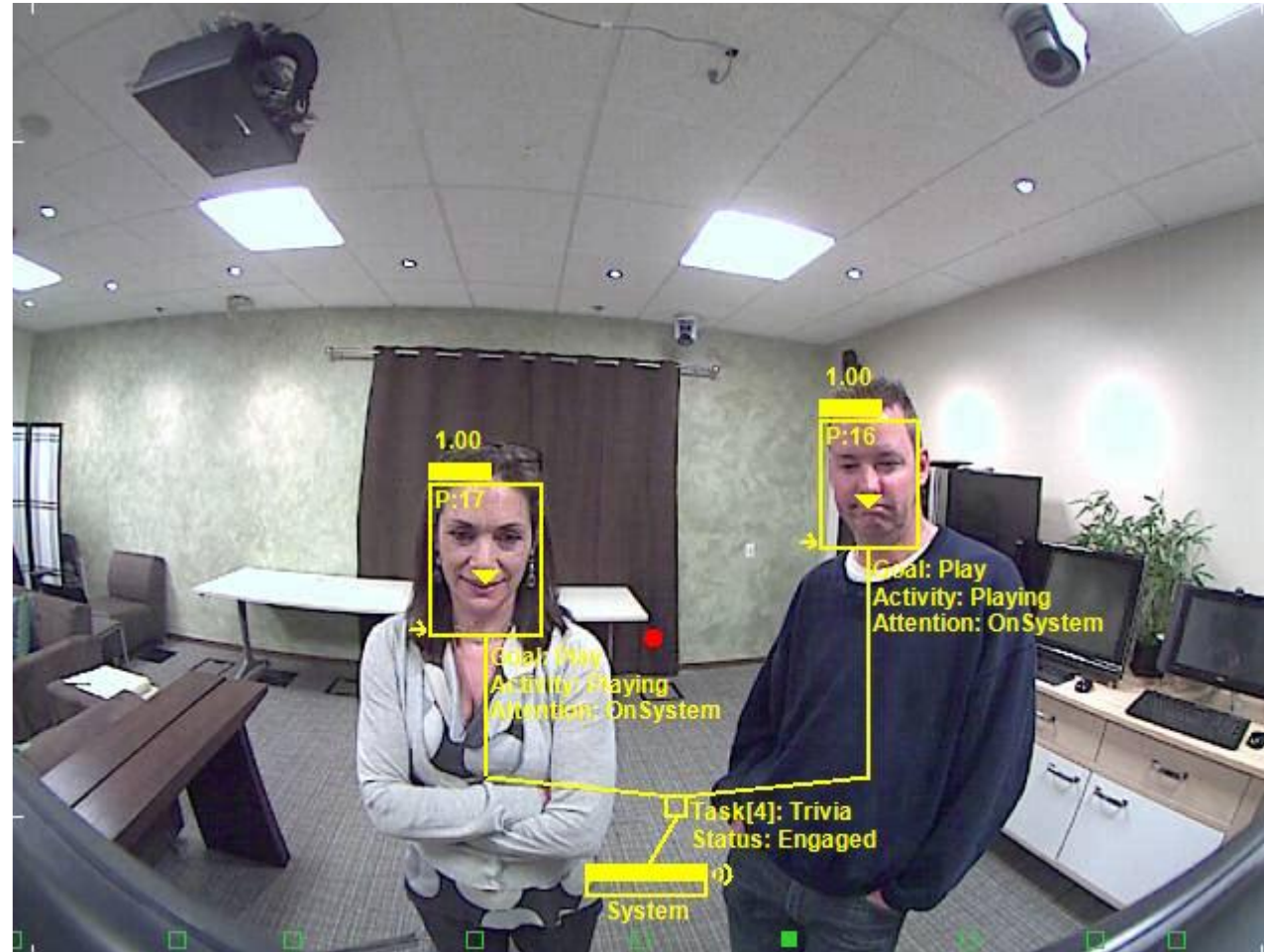


Multiple Experiments & Refinements



Multiple Experiments & Refinements

- P:** arrow indicates direction of attention
- P:** P has floor
- P:** P is the target of the floor release
- P:** P is releasing the floor
- P:** P is trying to take the floor (performs TAKE action)
- P:** P is speaking
- P:** P is an addressee
- indicates system's gaze direction





Studies in the Wild





Current Focus: *The Assistant*



The Assistant

- Multiple components
Perception, learning, reasoning

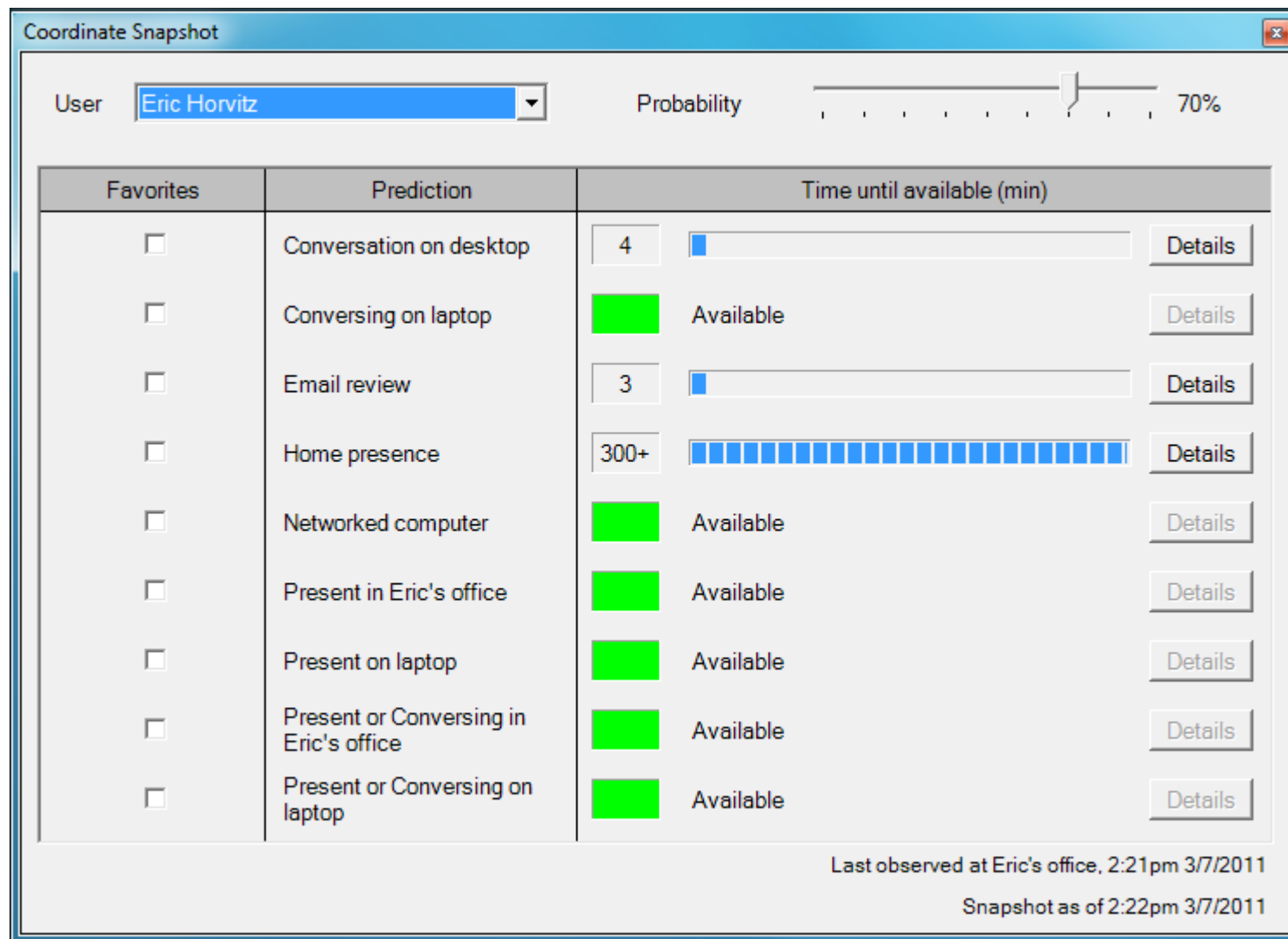


Multiparty Engagement & Dialog

Presence & Availability Predictor

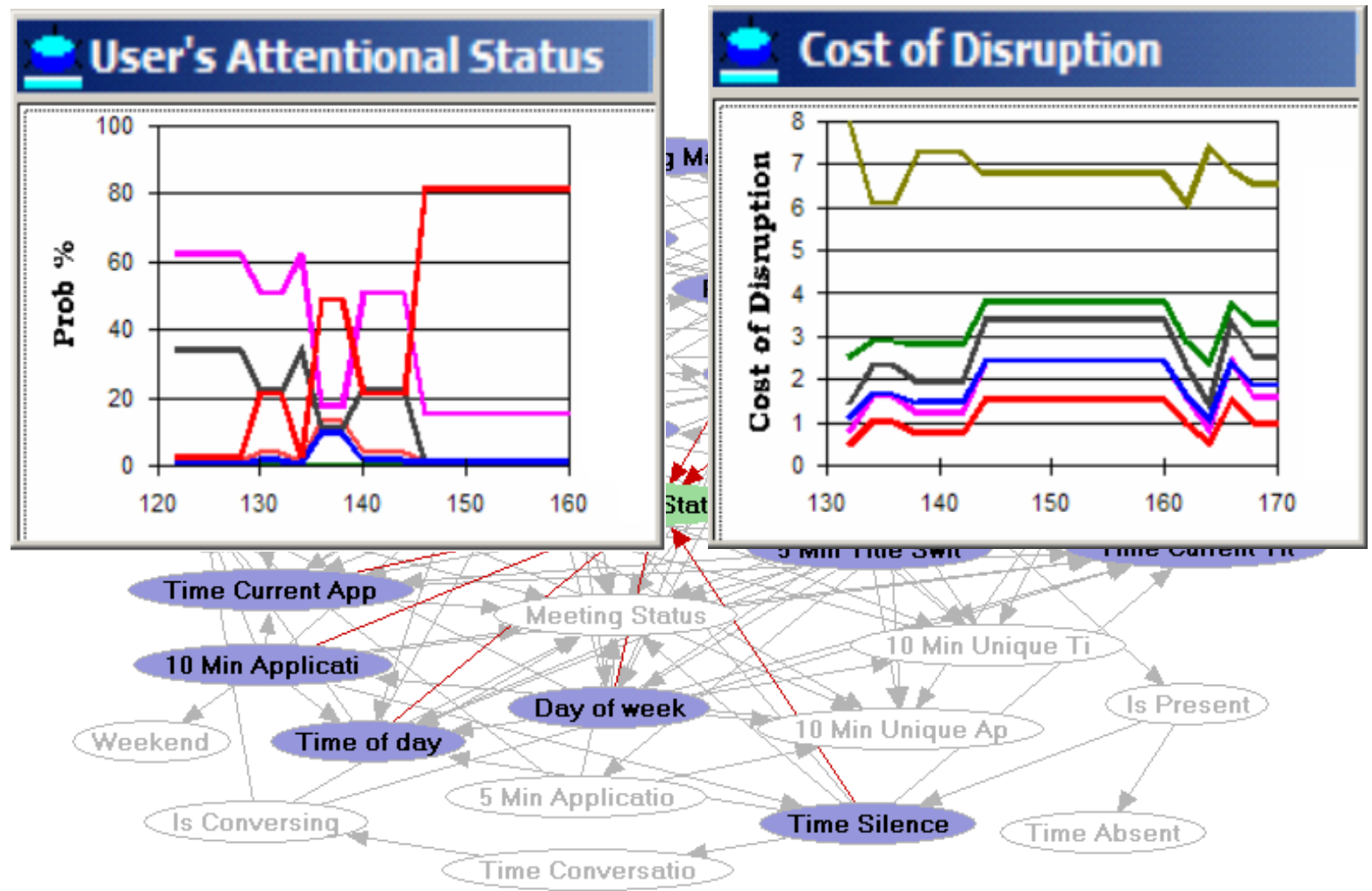
Awareness & Coordination

Coordinate: Presence & Availability Forecasting





BusyBody: Attention & Interruption



The Assistant

Personal Assistant

Microsoft Research

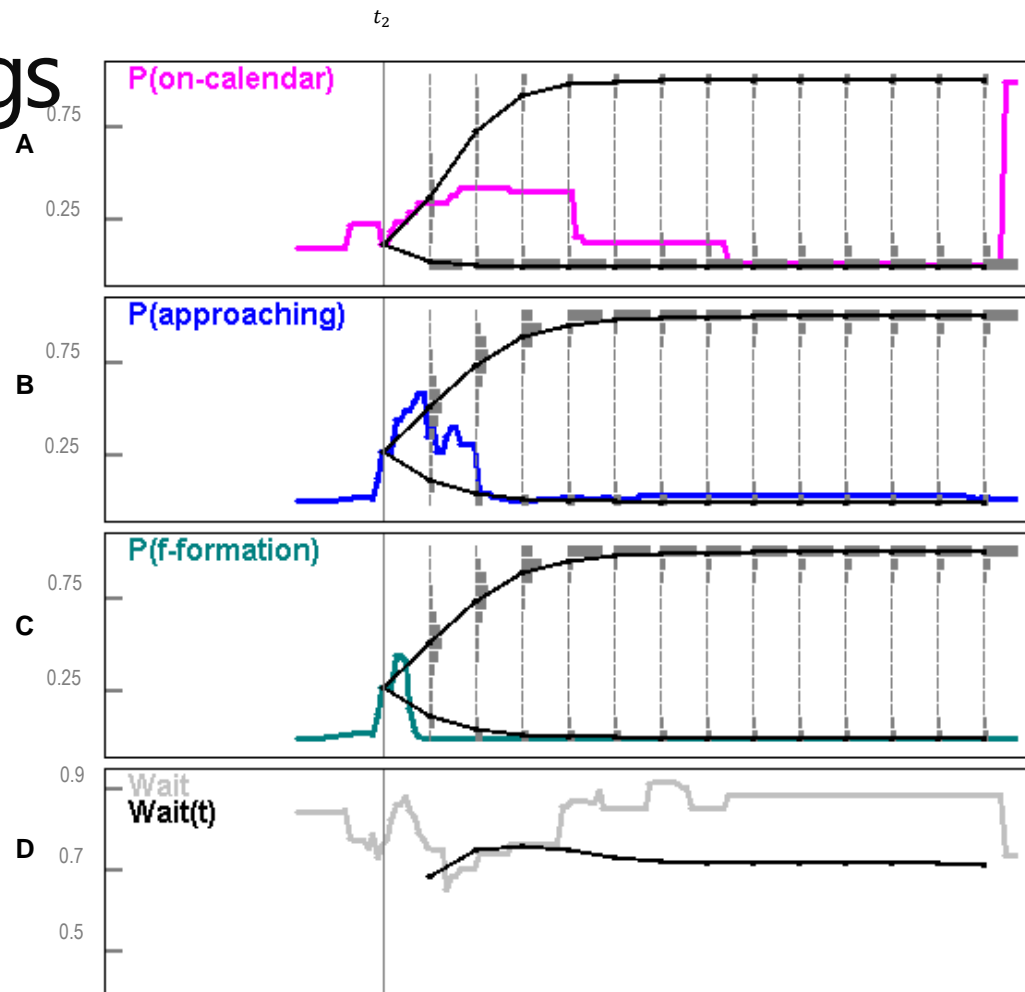
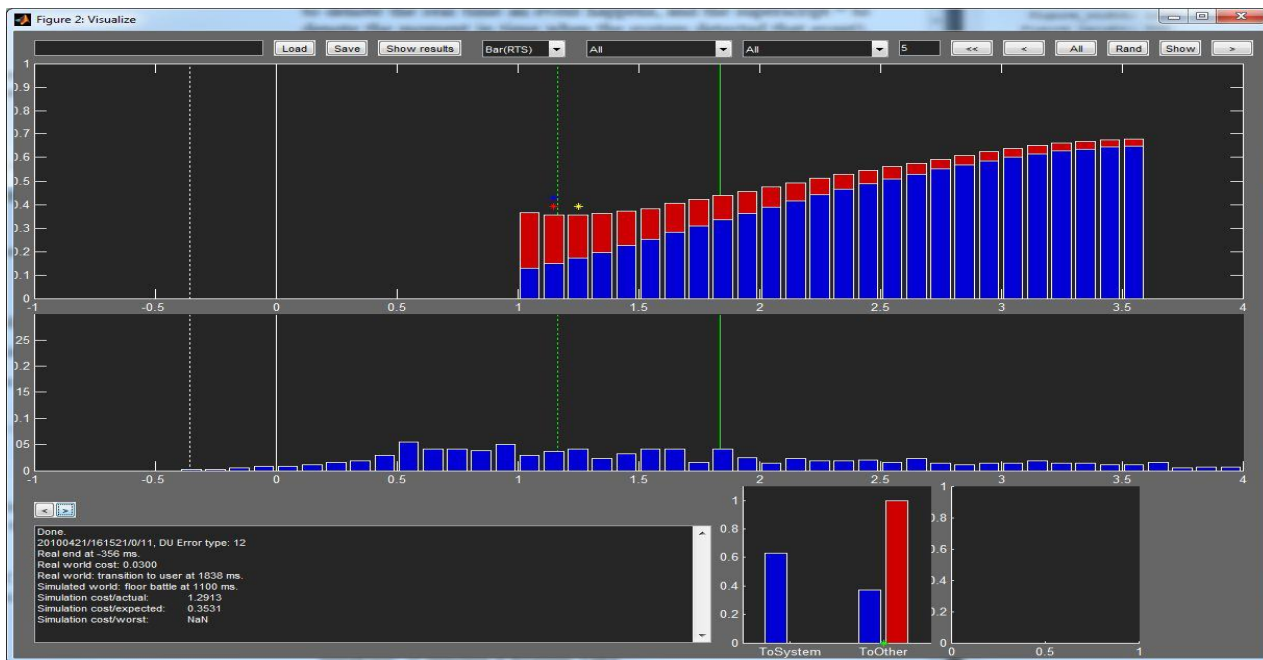


New Methods and Principles

Learning & inference from real-time streams

Information value in streaming settings

Time-critical tradeoffs



Multiple Applications of the Platform...



Project 3E



Privacy, Data, and Machine Learning

Urgency ...and optimism

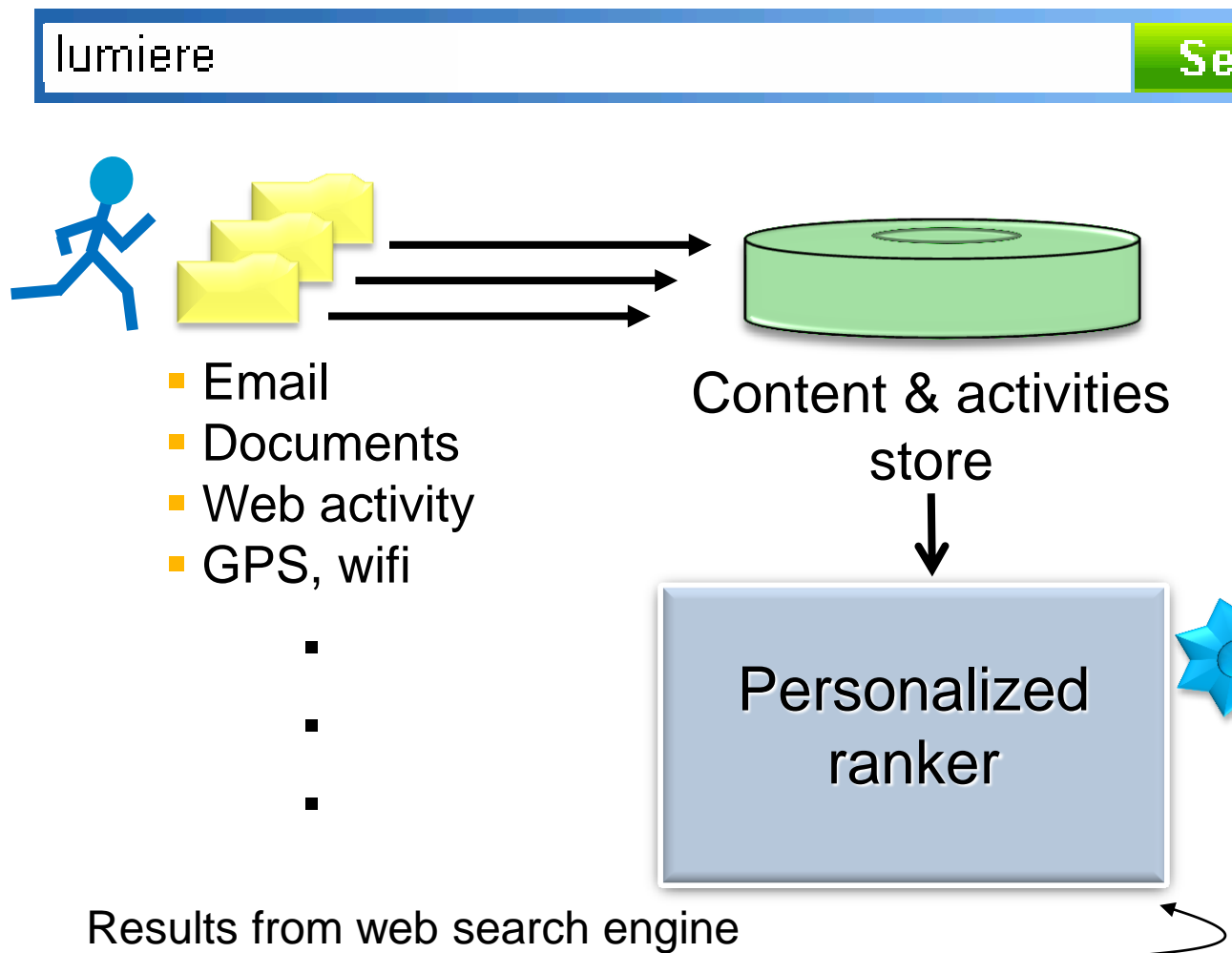
Clarity, preferences, and handles

Decision-theoretic mediation

Differential privacy

Protected sensing & personalization

Example: PSearch



The screenshot shows a search engine interface with the query "lumiere" in the search bar. The results page displays "Page 1 of 597,832 results containing lumiere (0.23 seconds)". A blue box highlights the top search results:

- My Search: [Personalized](#) [WebCache](#) [Desktop](#)
- [The Lumiere Project: Bayesian User Modeling for Inferring the Goals ...](http://research.microsoft.com/~horvitz/lumiere.htm)
- [Lumiere: Bayesian Reasoning, User Modeling, and Automated Assistance](http://www.research.microsoft.com/research/dtg/horvitz/lum.htm)

Below the highlighted results, other search results are visible:

- [Lumiere Magazine](#)
Lumiere Magazine
www.lumiere.com [Cached page](#)
- [Lumière Restaurant Relais Gourmand :: Home Page, News, Events](#)
... Lumière's renovations are now complete and we will reopen to the public Tuesday, April 5, 2005. Chef Feenie has finalised his new menus. You may view them here. February 15, 2005
»Exciting Changes ...
lumiere.ca/pages/index.htm [Cached page](#) 10/3/2005
- [Lumiere HD - Edit HDV on Final Cut Pro](#)
... new HDV format. Now you can edit your HDV footage, in real-time, without expensive hardware. Lumiere HD 2.0 will include full support for JVC's new ProHD line including the ...
www.lumierehd.com [Cached page](#)
- [LUMIERE: PATHWAY TO BEAUTY](#)

Example: Lifebrowser

Images
& videos

Desktop
& search activity

Appts &
events

Locations

Whiteboard
capture

Query

MemoryLens - Landmark Trainer


| Date | Subject | Landmark |
|--------------|---|---|
| Nov 17, 2010 | MSR Redmond Managers Meeting | <input type="radio"/> Yes <input type="radio"/> No |
| Nov 17, 2010 | pnewson 1:1 | <input type="radio"/> Yes <input type="radio"/> No |
| Nov 17, 2010 | Fun Snack Break | <input type="radio"/> Yes <input type="radio"/> No |
| Nov 17, 2010 | Edith Law | <input type="radio"/> Yes <input type="radio"/> No |
| Nov 17, 2010 | MSR Talk Series: Inclusive Design; Wendy Chisholm - Mi | <input type="radio"/> Yes <input type="radio"/> No |
| Nov 17, 2010 | MSR Talk Series: Cross-Compiling Android Applications t | <input type="radio"/> Yes <input type="radio"/> No |
| Nov 17, 2010 | Canceled: RRLT Meeting | <input type="radio"/> Yes <input type="radio"/> No |
| Nov 17, 2010 | jenn | <input type="radio"/> Yes <input type="radio"/> No |
| Nov 16, 2010 | Dinner with Mike Gillam, et al. | <input type="radio"/> Yes <input type="radio"/> No |
| Nov 16, 2010 | MSR Visiting Speakers Series: The Amazing Story of Qu | <input type="radio"/> Yes <input type="radio"/> No |
| Nov 16, 2010 | Placeholder for rollerblading (only if time and the weather | <input type="radio"/> Yes <input type="radio"/> No |
| Nov 16, 2010 | Stephanie Rosenthal PhD Oral Exam | <input checked="" type="radio"/> Yes <input type="radio"/> No |
| Nov 16, 2010 | Ece and Eric meeting | <input type="radio"/> Yes <input type="radio"/> No |
| Nov 16, 2010 | MSR Talk Series: Girls, Programming and Processing: E | <input type="radio"/> Yes <input type="radio"/> No |
| Nov 16, 2010 | Sue/Eric catchup | <input type="radio"/> Yes <input type="radio"/> No |

Most memorable


Date

Feb 4 2005

Fri




Thu



NRAC Italy Meeting


Wed

Tue









Farewell Party

Mon



MSMLS coord





Summary

- Applications of sensing, learning, and reasoning still in infancy
- Studies and themes
- Unprecedented value to people and society
- Principles → Applications → Principles ...

Microsoft^{*}
Research

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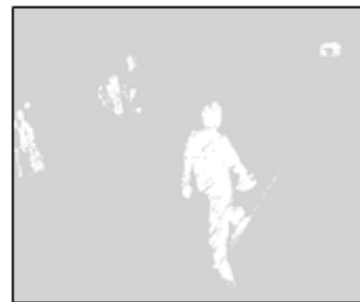
Microsoft[®]

3rd Generation Elevator



Captain Kirk never had to push a button to order an elevator on Star Trek—nor did he have to wave his arm or leg to keep the turbolifter door open if Spock was racing to get on. Elevators that require people to push a button to summon them, or to jam their hands and legs into closing doors to say, “Don’t close them just yet!” are remnants of the 20th Century. We’re testing out Project 3E (*3rd Generation Elevator*) in the lobby of Building 99. 3E is a cross-group effort at Microsoft Research, exploring the use of machine learning and perception to make automated doors more intelligent and elegant via intention recognition.

Video is recorded for research purposes by two cameras near the elevators, but stored images are modified so that people are not recognizable – see image to the right. No audio is recorded.



If you want to be removed from a recording, please email sifb@microsoft.com. Data is collected for research purposes as part of the Situated Interaction Project of the Adaptive Systems & Interaction group at Microsoft Research. For details, please see the privacy statement below. You may submit anonymous feedback at <http://anon99/>. To submit non-anonymous feedback, email anon99@microsoft.com