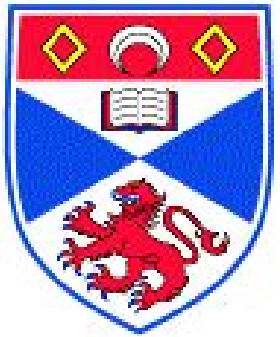

The computer is the new microscope

Simon Dobson

SICSA Professor of Computer Science
School of Computer Science, University of St Andrews UK

simon.dobson@st-andrews.ac.uk
http://www.simondobson.org

Introduction

- Computer science sits at the heart of the 21st century's greatest challenges
  - Climate, security, energy, …
- My aim tonight
  - What *is* computer science?
  - How does plentiful computing power change how we do science, and the science that we do?
  - Examples from sensing and sensor networks

Acknowledgements and dedication

EPSRC
Pioneering research and skills

ENTERPRISE IRELAND

sfi
science foundation ireland

sicsa* The Scottish Informatics & Computer Science Alliance

SEVENTH FRAMEWORK PROGRAMME

Les Wakefield, 1907 – 1998

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The pillars of science

- Models and theories
  - Formal mathematical descriptions of *what happens*
  - Principled explanations of *why this happens*
  - Testable predictions about *things so far unseen*

- Experiment
  - Determine *what happens in reality*
  - Controlled, isolated

The limits of science

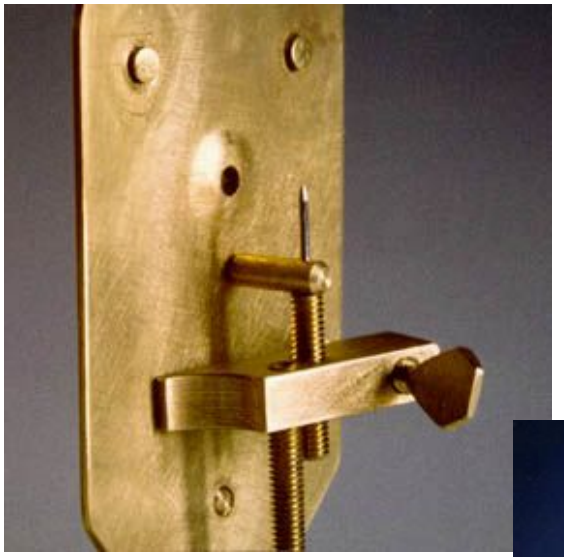
- Picture yourself as a 16th-century scientist trying to make sense of disease...

- Explain in terms of what you *know* and can *observe*
  - Noxious vapours
  - Pommanders, perfumes
  - What can be smaller than a flea?

Wikipedia

The microscope

- Hooke and van Leeuwenhoek
  - New animals and *styles* of animals
  - Life in places considered barren



Hans van Eijk, Microscopy-UK

MUSA

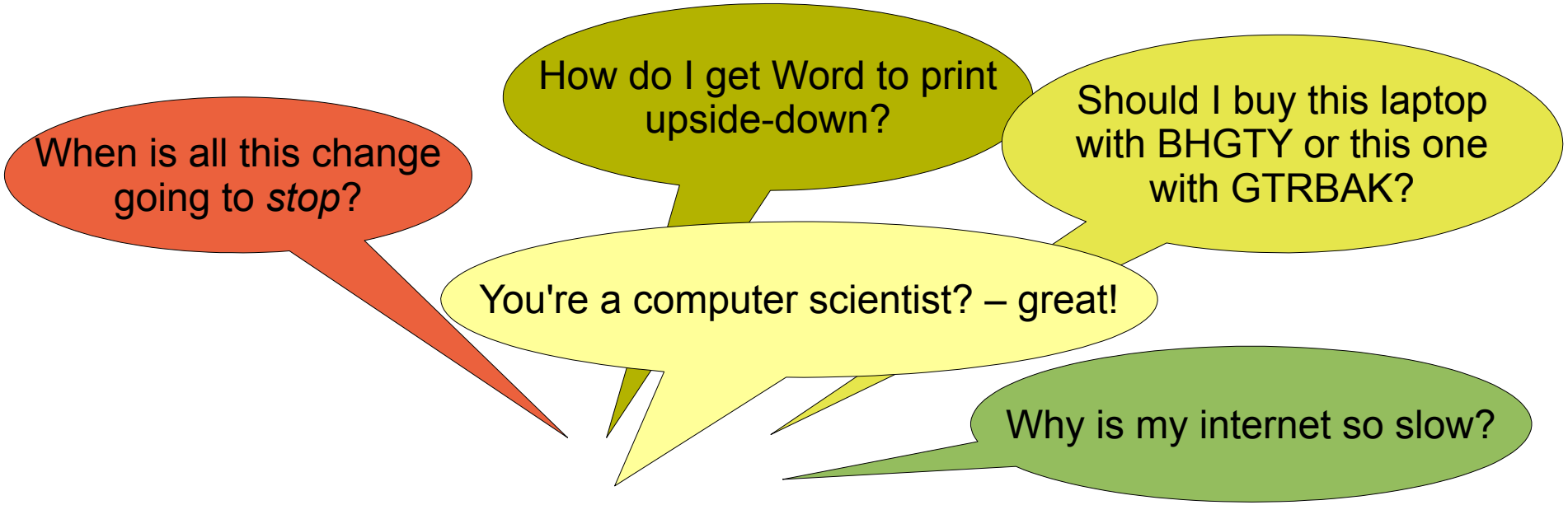
- What might this life be doing?
  - Could it affect humans? How?

Technology affects science

- Technologically: a new way *to do science*
  - What other micro-things are there?
  - What kinds of instruments can we make to leverage what we can now see?
  - Can we build things in the micro-world?

- Conceptually: new *science to do*
  - Microbiology, micro-ecology
  - Micro-effects have macro consequences
  - What other consequences might there be?

And so to computer science...



- A much-misunderstood discipline
  - Would you ask a microbiologist what kind of bleach to buy?
  - So what *is* computer science?

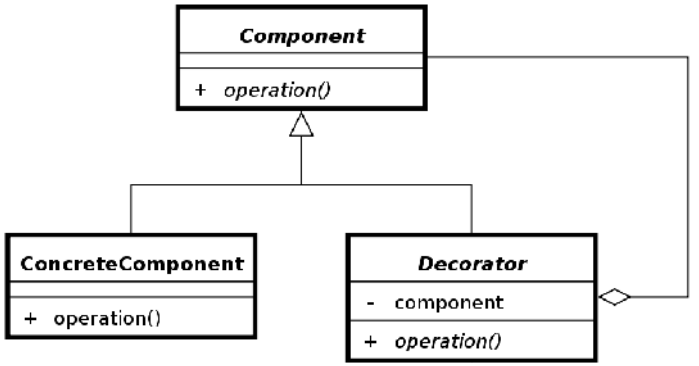
A useful analogy – 1

Computer Science

Microbiology

A useful analogy – 2

Computer Science



$$\textsc{Exp multiply}\quad \frac{\Gamma \vdash a : \texttt{int} \qquad \Gamma \vdash b : \texttt{int}}{\Gamma \vdash a{*}b : \texttt{int}}$$

Microbiology

John Scheid, Go Science Seven

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Significance

- The real significance of computer science has little to do with computers

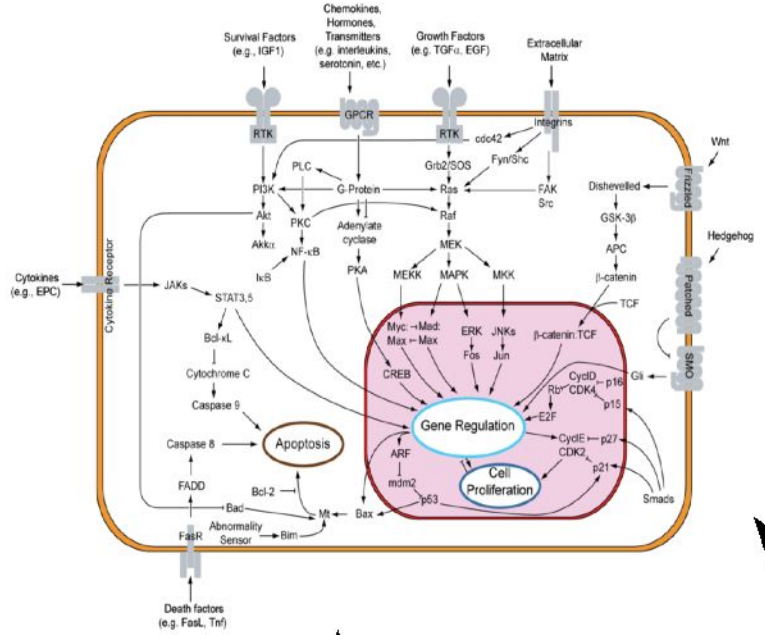
- "Procedural epistemology"
  - Precise imperative descriptions
  - How processes are performed
  - How information is structured and knowledge assembled
  - Intellectual benefits above and beyond their mechanisation

Abelson and Sussman. *Structure and interpretation of computer programs.* MIT Press. 1985.

The third pillar

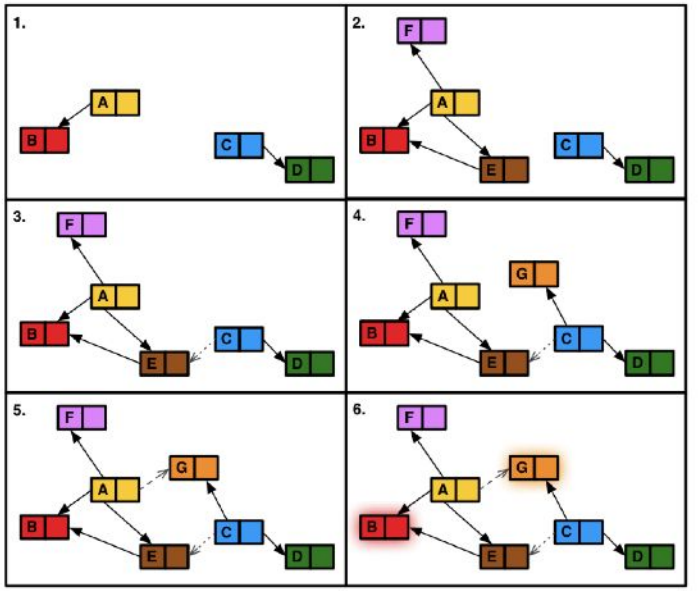
- Automation of observation and analysis
  - *Simulate* what we can't experiment on directly
  - *Mine* volumes of data for models
  - *Observe* phenomena at any scale
  - *Adapt* to what we see
  - Conceptualise change as *discrete processes*
  - Model *relationships* and *provenance*
  - Describe the *analysis* a scientist would make, allowing it to happen automatically in the field

Interactions in both directions



Wikipedia

Using process algebras to describe biological processes



Systems Biology

Biology

Bio-inspired Computing

Using biological and chemical metaphors to structure distributed computing

Computer Science

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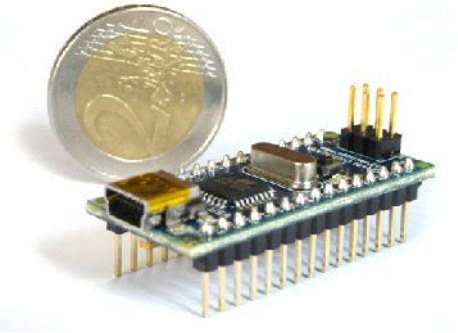
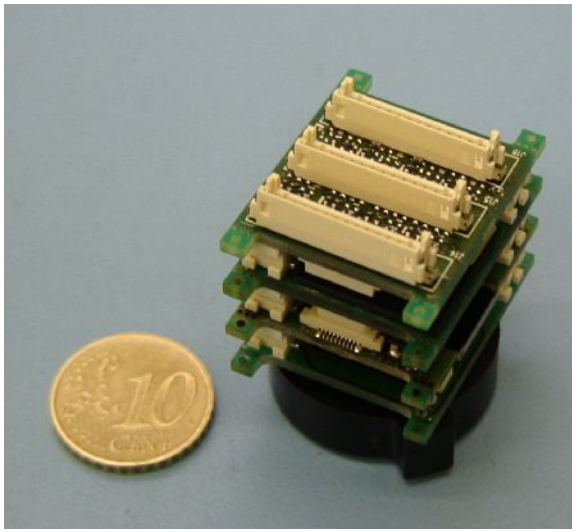
Sensor and sense-ability

- The most exciting new frontier
  - Active data collection
  - Computing and communications
  - Tiny, low-power
  - Network them together to get capabilities





What this gives us – reach

- Embed computing into the real world, close to the phenomena of interest
  - Detailed, long-term collection
  - Work in hostile or unpleasant environments for long periods
  - A viable alternative to graduate students...

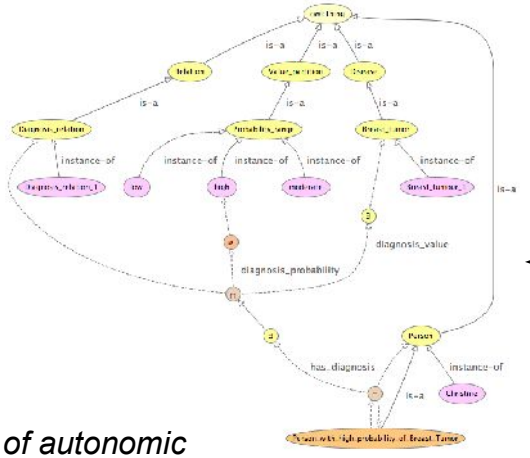
- Data capture is *active*
  - Change observations over time
  - Look for events, rather then just data

The sensor-driven systems loop

SENSE

1. Observe the real-world system

2. Use the data to populate and maintain a model of that system in a computer



ANALYSE

DECIDE

3. Decide on actions to take based on the model

ACT

4. Take those actions, thereby affecting the system being observed

Adapted from Dobson *et alia*. *A survey of autonomic communications*. ACM Trans. AAS. 2006.

Example

ACT

Change the spin speed

SENSE

Weigh the clothes

We know that wet clothes are heavier than dry ones, and we know how heavy the clothes were when they were put in the machine

ANALYSE

"These clothes are still *x*% wet"

DECIDE

If the clothes are getting dryer, we should slow the spin speed; otherwise, we should speed up or keep going as we are

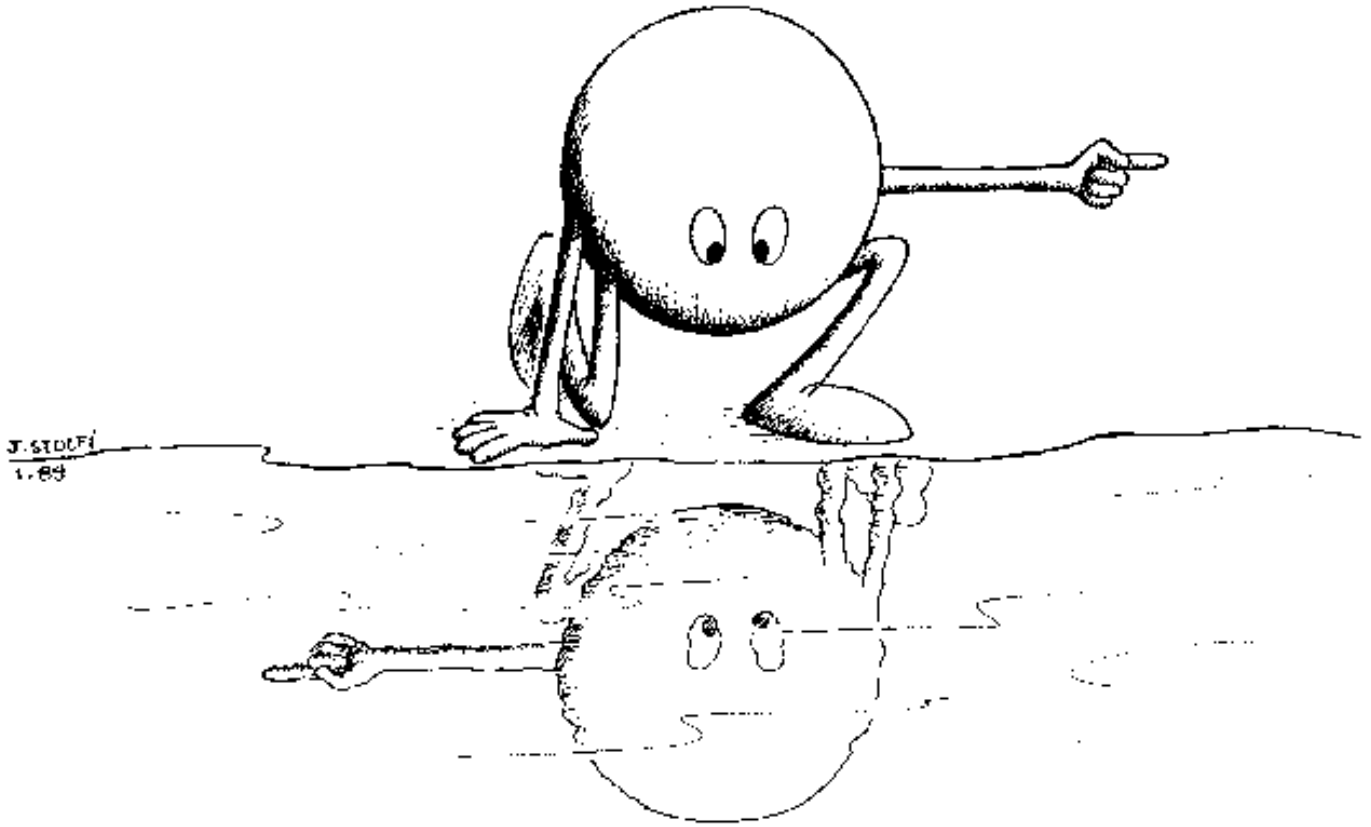
From a systems perspective

We don't know how wet the washing is, but we *can* measure how heavy it is...

...and we can use this to make some guess as to how fast we should spin the clothes...

...which *should* make them dryer...I mean lighter...

Where theory meets practice...

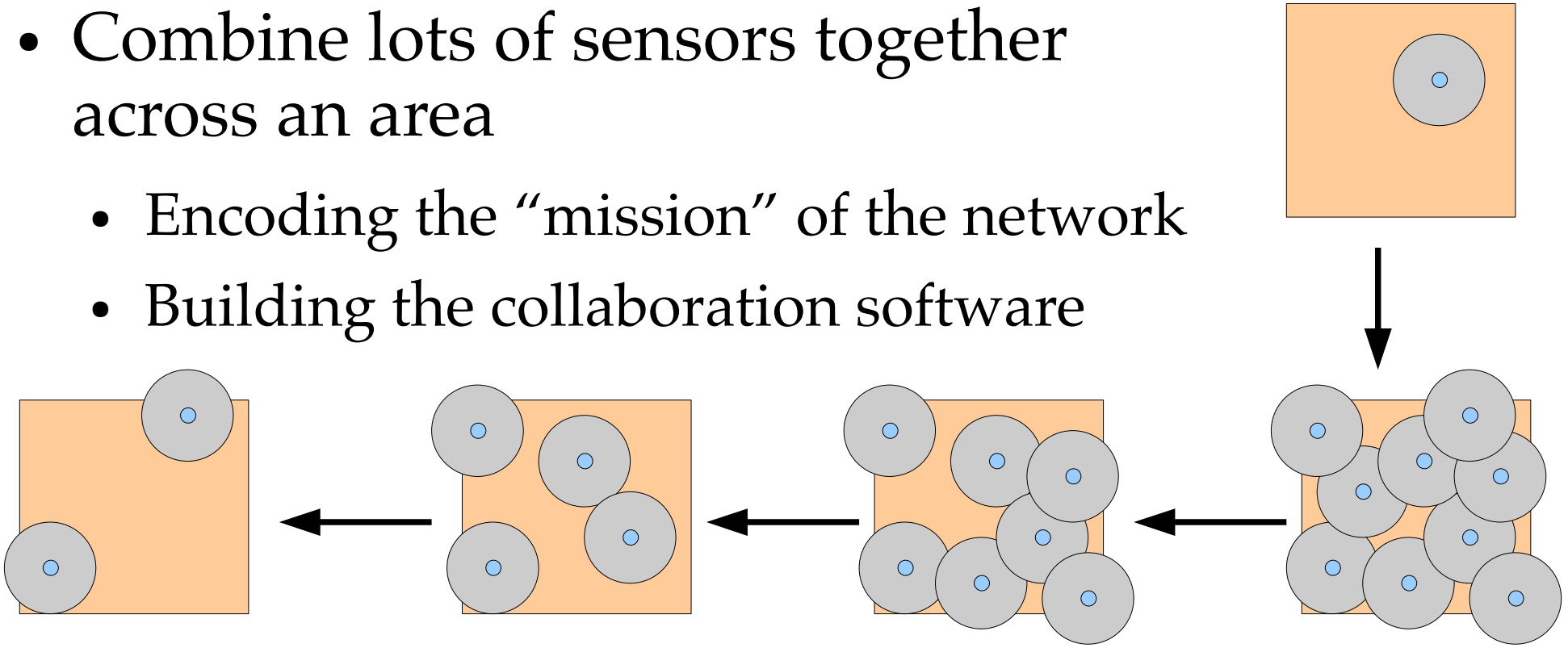


In theory, there is no difference between theory and practice. But, in practice, there is.

Jan L.A. van de Snepscheut

Coverage and robustness

- Combine lots of sensors together across an area
  - Encoding the "mission" of the network
  - Building the collaboration software



- Maintain data quality as system degrades
  - Take care with conclusions

Kamal, Bleakley and Dobson. *Packet-level attestation (PLA): a framework for in-network sensor-data reliability*. ACM Trans. Sens. Net. 2012. To appear.

Sensor fusion

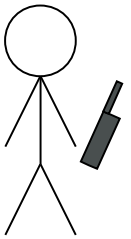
- Combine evidence from different sources
- Models of what we *expect* to happen
- Situation recognition

Diary says he should be here

...but he doesn't keep it completely up to date

Camera sees him here

...but he's got a really average face

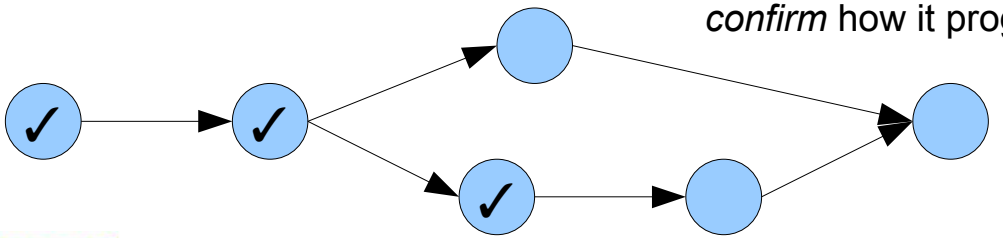


Cell towers see his phone here

...but that's only got a precision of 100m

...and he might have had his phone stolen

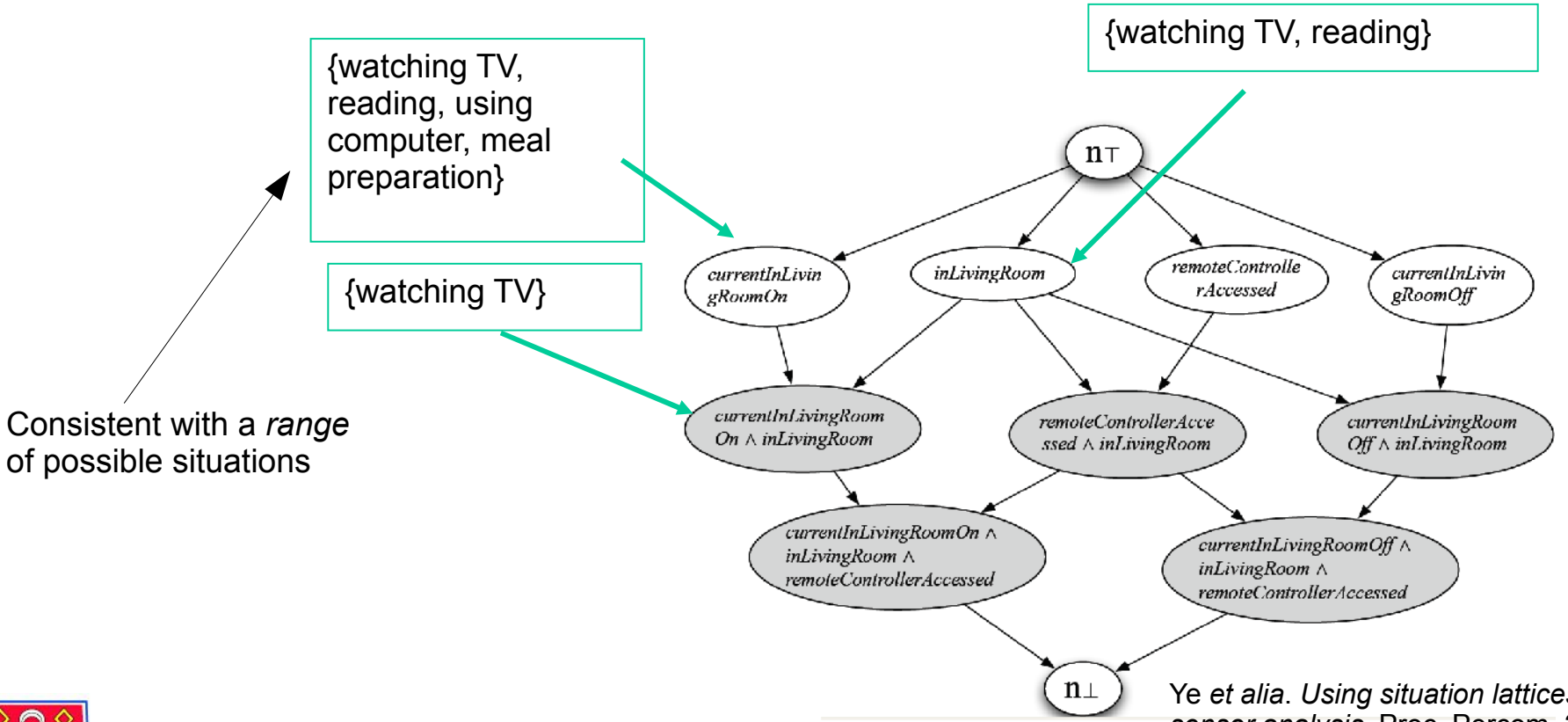
Model the process we *expect* to see, use sensor information to *confirm* how it progresses



Ye, Dobson and McKeever. *Situation identification techniques in pervasive computing: a review*. PMC. To appear.

Models of situations

- "Meeting" *vs* "Meeting with mother"
  - Capture this using a lattice relating observations to the situations with which they are consistent



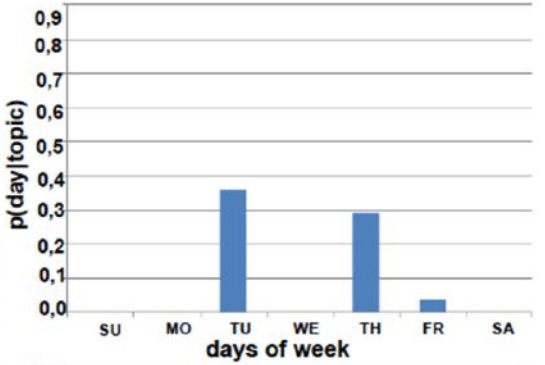
Ye *et alia*. *Using situation lattices in sensor analysis*. Proc. Percom. 2009.

Application: assisted living

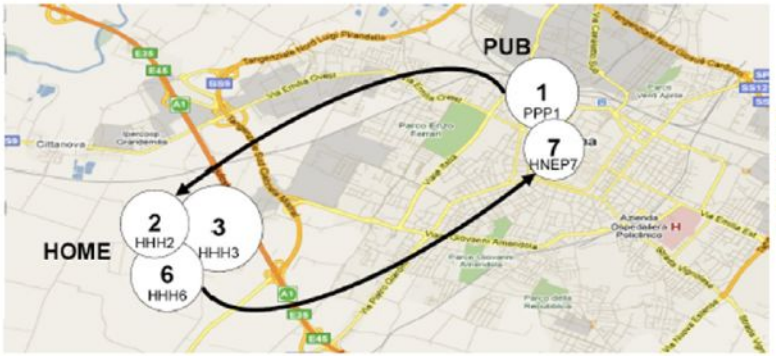
- Improve situation recognition
  - Identify what's happening from sensor data
  - Predict future activities

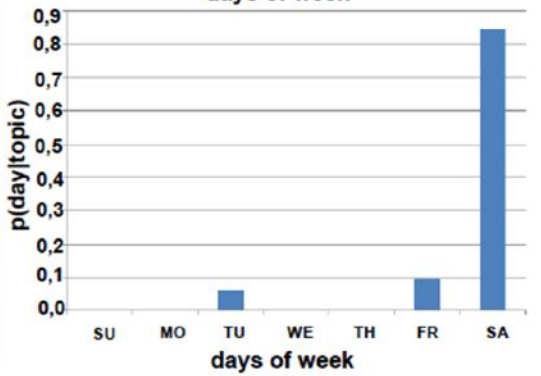
Rosi *at alia*. *Social sensors and pervasive services: approaches and perspectives*. Proc. IEEE PerCol. 2011

TOPIC 0	
word	p(w|z)
W W W 6	0,16
H H H 3	0,12
W W W 4	0,08
W W G 5	0,03
G W W 5	0,03



TOPIC 21	
word	p(w|z)
H H H 3	0,12
P P P 1	0,10
H H H 6	0,10
H H H 2	0,07
H NE P 7	0,02



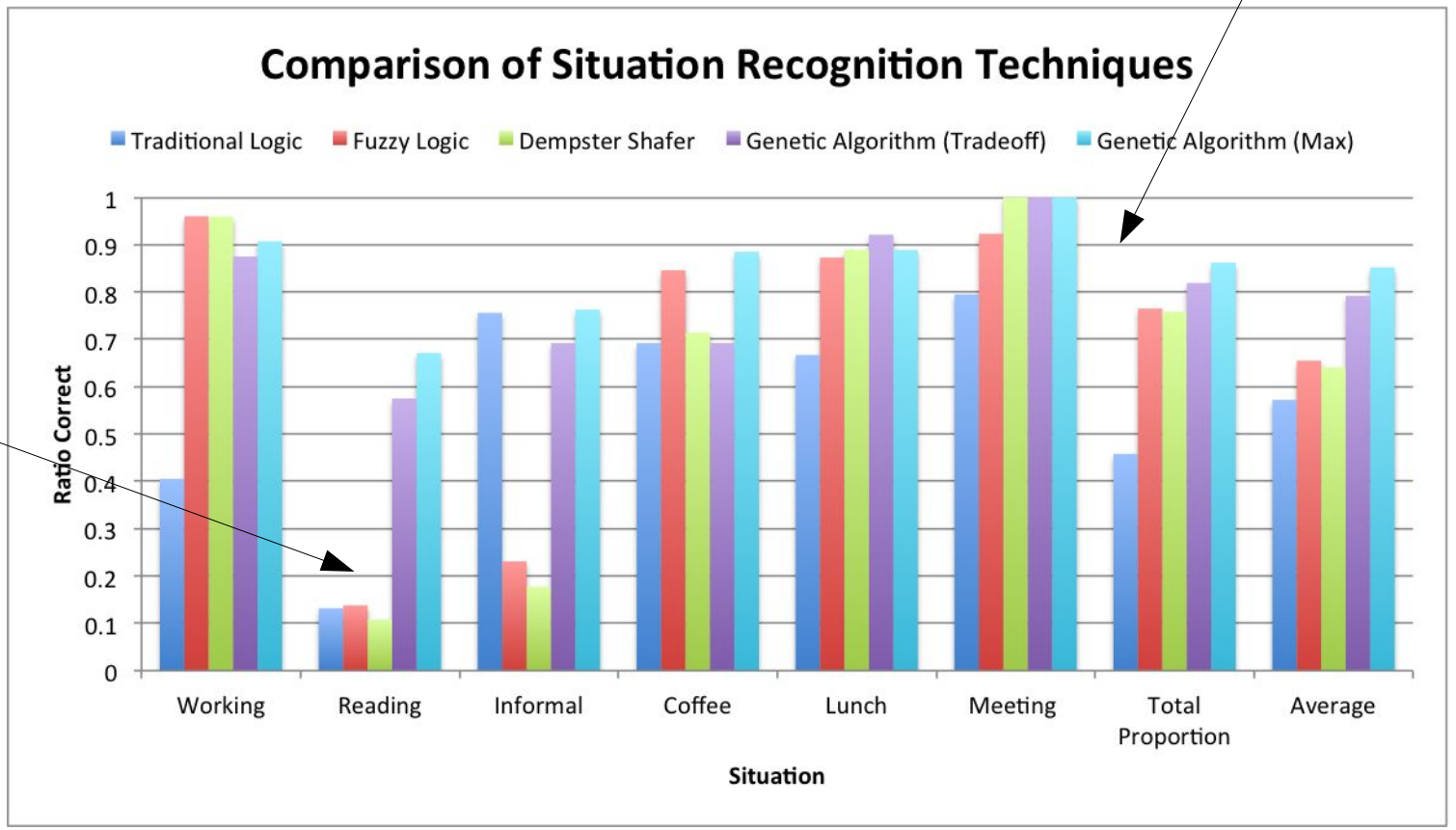


Interpretation

- Even a small amount of data can provide good classification

Very characteristic activity that can be sensed

No direct sensing of these activities



Where this research is going

- Focus on the high-level issues
  - How to we effectively program sensor networks?
  - How do we interpret what we're observing?
  - How do we match network adaptation to their scientific mission?

Dearle and Dobson. *Mission-oriented middleware for sensor-driven scientific applications*. J. Internet Serv. App. 2012. To appear.

- Theory meeting practice
  - Mathematically well-founded
  - Experimentally deployed and verified

Two things to take away

- The techniques of computer science offer enormous potential benefits
  - New ways to think about the science that we do
  - Do science we couldn't do before

- Computer science sits at the heart of the 21st century's greatest challenges
  - Climate, security, energy, …
  - A microscope onto processes of global interest