Actionable Sensing

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Sensors & sensing

- Sensors generate data representative of physical phenomena
  – examples: imagery, acoustic, seismic, acceleration
- Applications often require networks of sensors
  – examples: area, environmental, or building monitoring
- Communication has traditionally been the key problem
  – examples: routing, power, mobile ad hoc networks
- Sensors are increasingly viewed as (low-level) services

An emerging challenge

- Sensor systems are typically stovepipes
  - created for a specific purpose (task)
  - often controlled by a single vendor (stack)
- Example: a home with separate networks for security, entertainment, healthcare, etc
- Challenge: **open sensor/task architectures**
  - Why can't you ask your Kinect box to help keep your home secure, and monitor your health?

The "knowledge management" perspective

- Knowledge management:

  "Getting the right knowledge

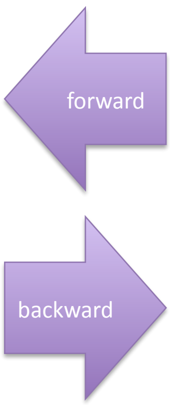
  to the right people

  at the right time, in the right place"
- Knowledge is seen as "actionable information"
- **Sensor networks research has been overly-focussed on input (data) at the expense of output (informing human action)**

Actionable sensing

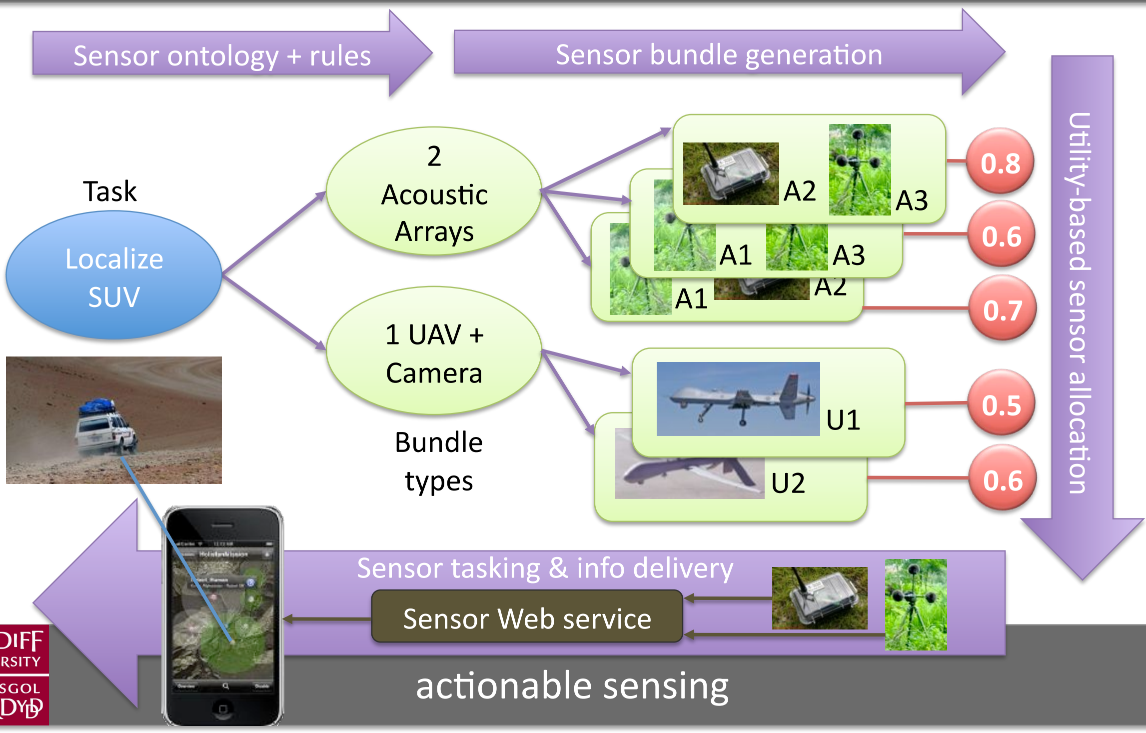
- Organising and optimising the deployment and configuration of a sensor network to the provision of a set of users' tasks
- Key issues:
  - representation of tasks at an appropriate level
  - accounting for value of information
  - transparency: hiding features of the sensor network from users

Forward & backward chains

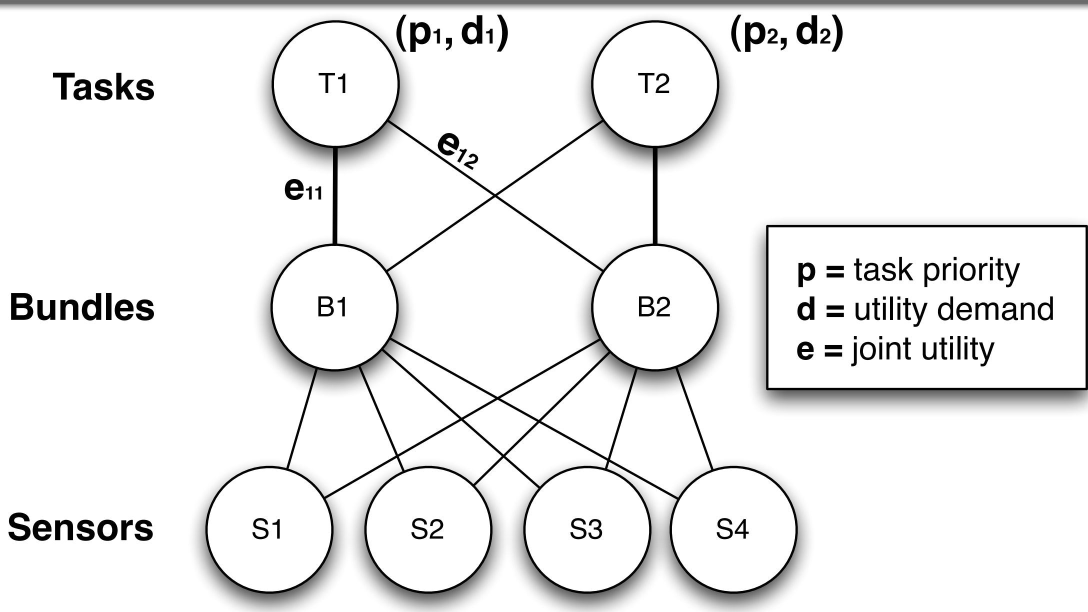


- **Data-to-decision**: a person needs to make a decision based on actionable information from sensors & sources
- **Intent-to-assets**: a person needs to determine what kinds of sensors & sources will help them achieve their intent, and thereby identify suitable assets

Walkthrough



Task-bundle-asset framework



Tasks

- Tasks are triples consisting of:
  - operation (defined in an appropriate task ontology)
  - area-of-interest (point or region)
  - time (instant or period)
- For example, using our NIIRS-based* task ontology, an operation is a pair:
  - operator (one of: detect, identify, distinguish)
  - operand (one or more entity classes)

*National Image Interpretability Rating Scale

Task examples

- Area monitoring:
  - detect SUV
  - localize vehicle
- Home monitoring:
  - identify person
  - localize Alun
- Environmental monitoring:
  - detect/identify animal

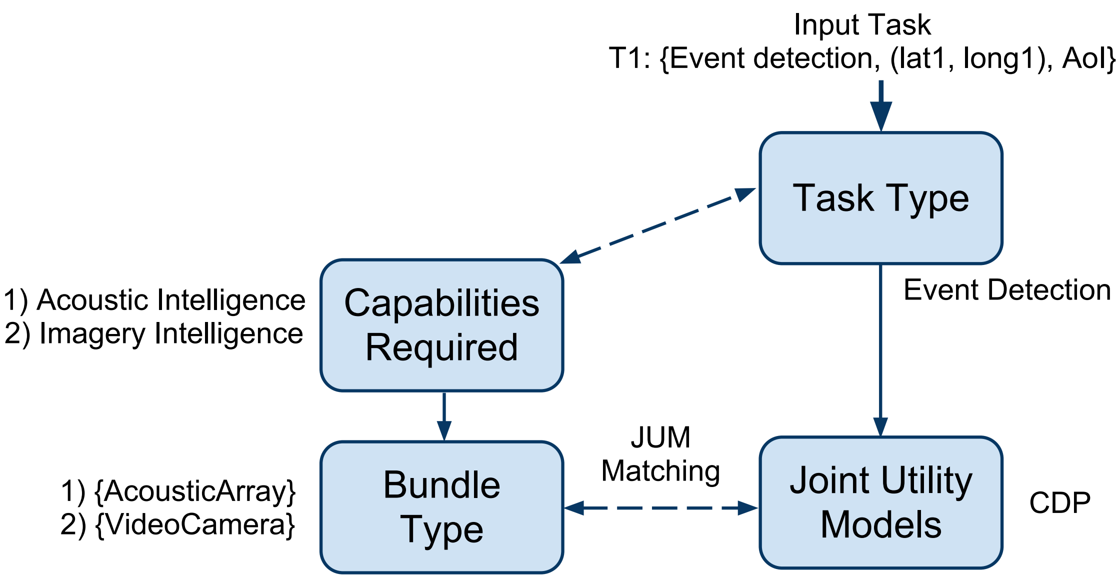
A knowledge-based approach

- **Qualitative knowledge**
  - Web ontology language (OWL) descriptions, rules

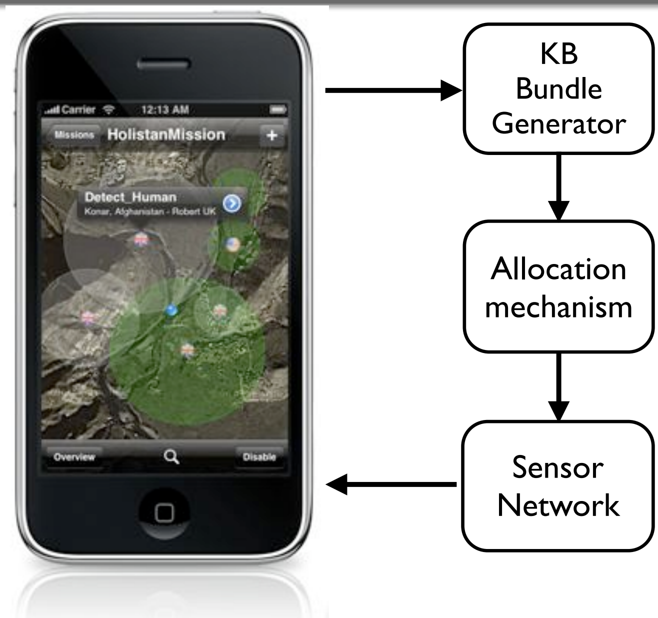
  defines what types of sensor (bundle) are appropriate for which task types
  - examples: vehicle identification can be done visually ("grade 4") or acoustically ("grade 2")
- **Quantitative knowledge**
  - joint utility models (functions)

  determines the value of a set of sensors
  - examples: cumulative detection probability; 2D-localization

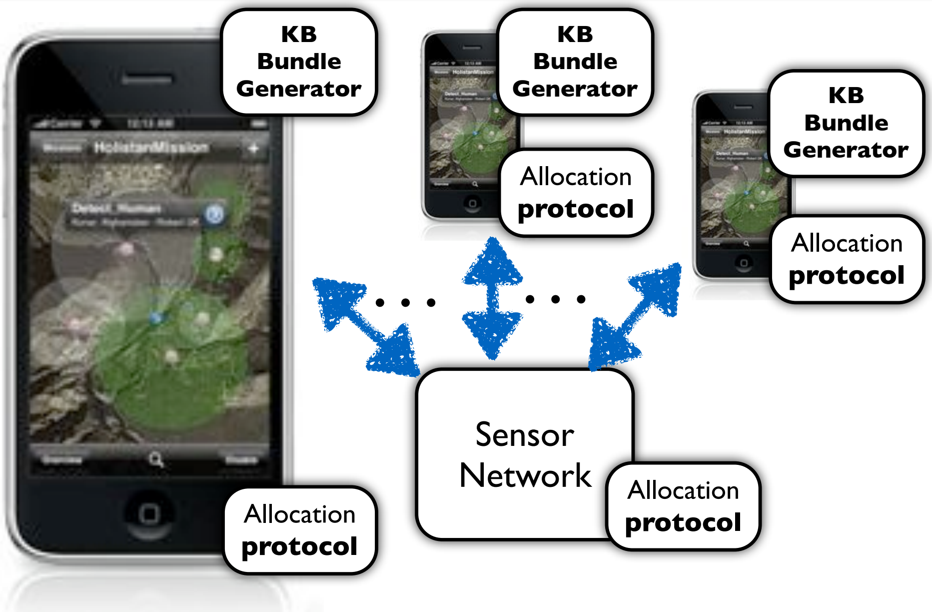
Reasoning procedure



Conceptual architecture



Distributed system architecture



Current work: sensor-task assignment

- Performance evaluation of the implemented distributed architecture, to establish
  - feasibility of implementing reasoner (knowledge-based bundle generator) on mobile device
  - relative effectiveness of a variety of task preemption strategies
  - costs of distributed approach in terms of messages exchanged
- (Comparison with a centralised architecture will follow…)

Lightweight reasoner: lookup table

Task Type	Recommendation
1	$(BT_1 + JUM_1)$
1	$(BT_2 + JUM_2)$
2	$(BT_3 + JUM_1)$
2	$(BT_2 + JUM_1)$
2	$(BT_2 + JUM_2)$
…	…
N	

A complete set of NIIRS tasks requires approximately 4500 task types; in practice there appear to be few BTs & JUMs.

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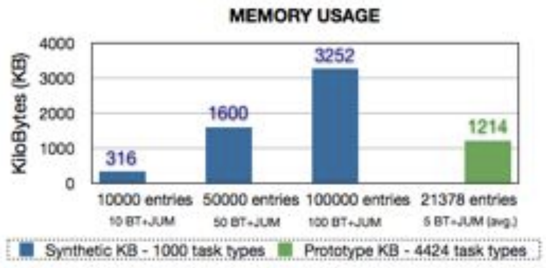
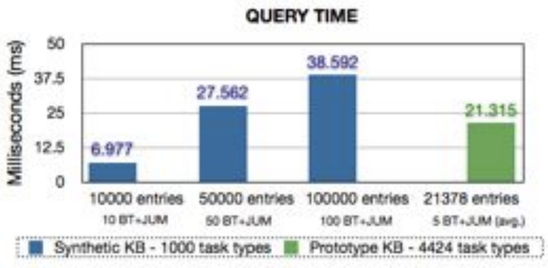
Feasibility of mobile implementation



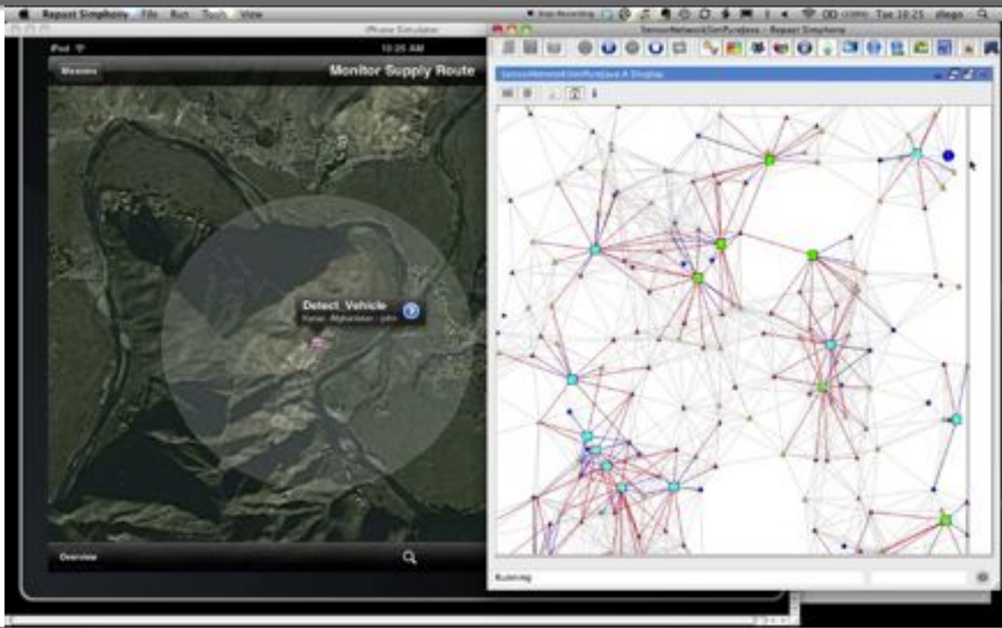


Memory usage and query times are manageable and grow linearly as lookup table size increases (tested on iPod Touch).

Experimental testbed

- Implemented distributed coalition formation protocol in Java using Repast Simphony 2.0
  - Extended [Shehory & Kraus, 1998] with preemption, rebidding, & deadlines
- Deployed
  - 250 sensor nodes of 2 types
  - 50 user nodes
- Varied task creation rate from 1 to 7 tasks every 3 timesteps
- Task priority & utility demand generated with uniform random distribution

Demo



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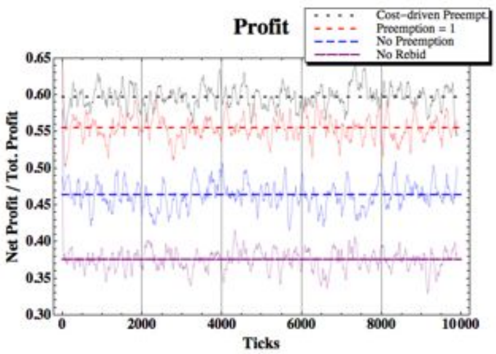
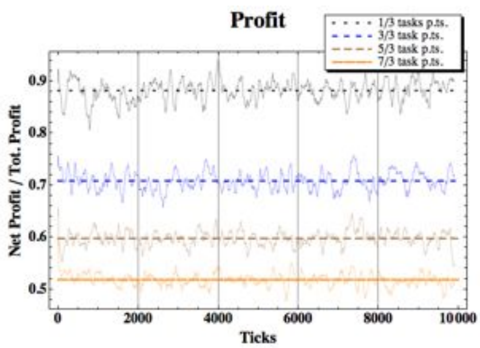
Results: task satisfaction





Profit significantly better with full preemption & rebidding; performance degrades with higher task arrival rates.

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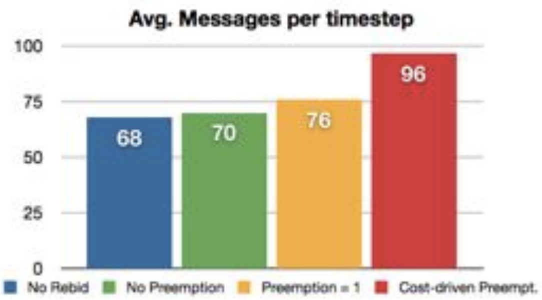
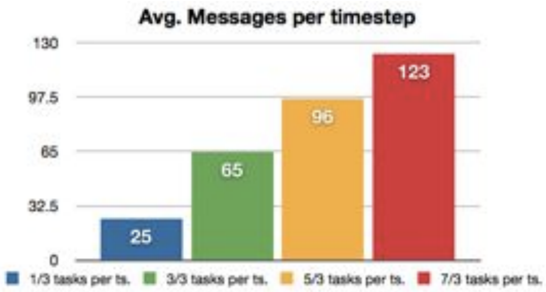
Results: messages exchanged





Message rates not excessive, though full preemption more costly; message rates increase linearly with task arrival rates.

Current work: information delivery

- Shifting the focus to "forward chaining":
  - **data to information to decision**
- Collaboration with SOHCS (physiotherapy)
  - use RFID "factory grade" technology to monitor patients' movements (wrist & ankle tagging)
  - create an open sensing platform based on Semantic Web ontologies & rules
  - proof-of-concept: generate equivalent quality-of-information as current clipboard-based monitoring

The need for "embedding"

- Sensor networks are tools; they need to be usable by end-users
- Fitting sensor network technology into the context-of-use means understanding that context
- We need to train "embedded sensorsticians"*
- Example: rainforest "local knowledge" project with BIOSI

image from *Jungle Times* Dec/Jan 2010/11

*"sensorstician" © M Williams

Conclusion & future work

- Fashionable to talk about "internet of things"

  … as distinct from "internet of people" …

  Challenge: creating an **internet of people <u>&</u> things**
- Our work is aiming to connect sensors & people through semantic models
  - make it easier for users to find and exploit sensors
  - make sensors & services (re)usable for a range of tasks

Social sensor informatics?

- People are often not deciding/acting/ intending in isolation
  - sensors & sources need to be shared
    - locally or globally
    - cooperatively or competitively
- People are sensors too
  - they can provide data ("HUMINT")
  - and metadata (local knowledge)

Questions?

Thanks for listening!

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