BehaviorScope: Interpreting Behaviors using Distributed Sensors

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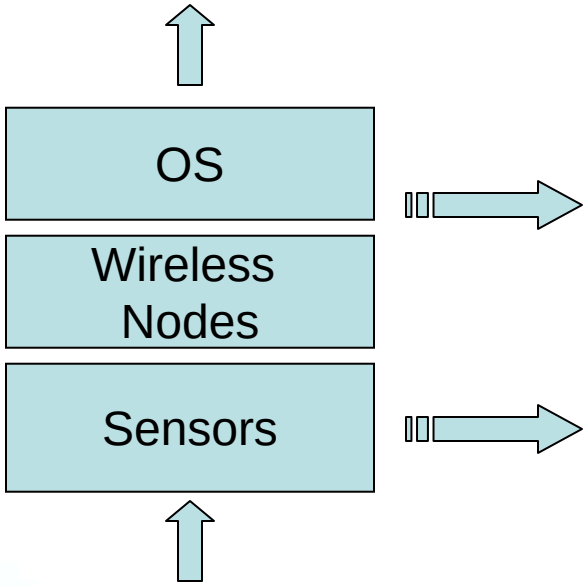
The BehaviorScope: An Asynchronous Distributed Autonomous Computer – Sense, Interpret & Act

Outputs: Behaviors, actions, intentions
To: network, apps, Internet, actuators



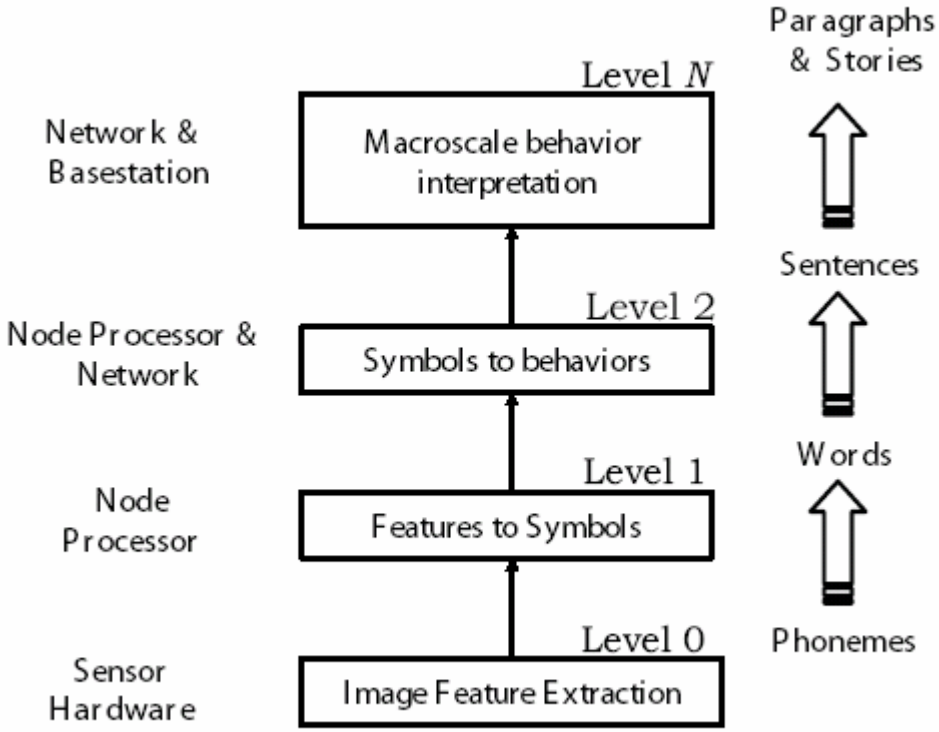
Provide descriptions as a set of rules
Sensory Grammars Inference Framework
(Programming Abstraction & Middleware)

Privacy preserving, ultra-low power imagers
Visual Human Filters
Sensing Abstractions

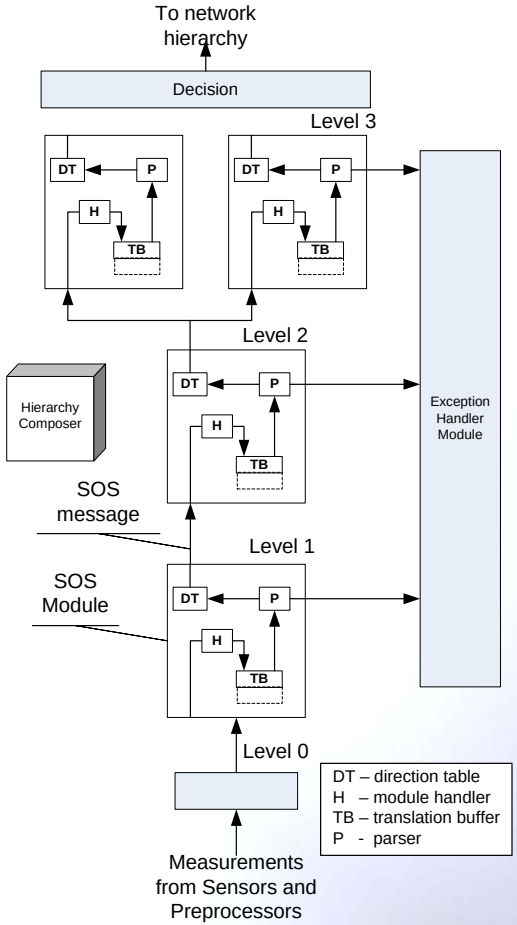
Inputs: Environment stimuli
(e.g human motion in space)

Current Focus: Assisted Living
Privacy preserving camera networks that operates on symbolic information

Sensory Grammars & Programming Abstraction

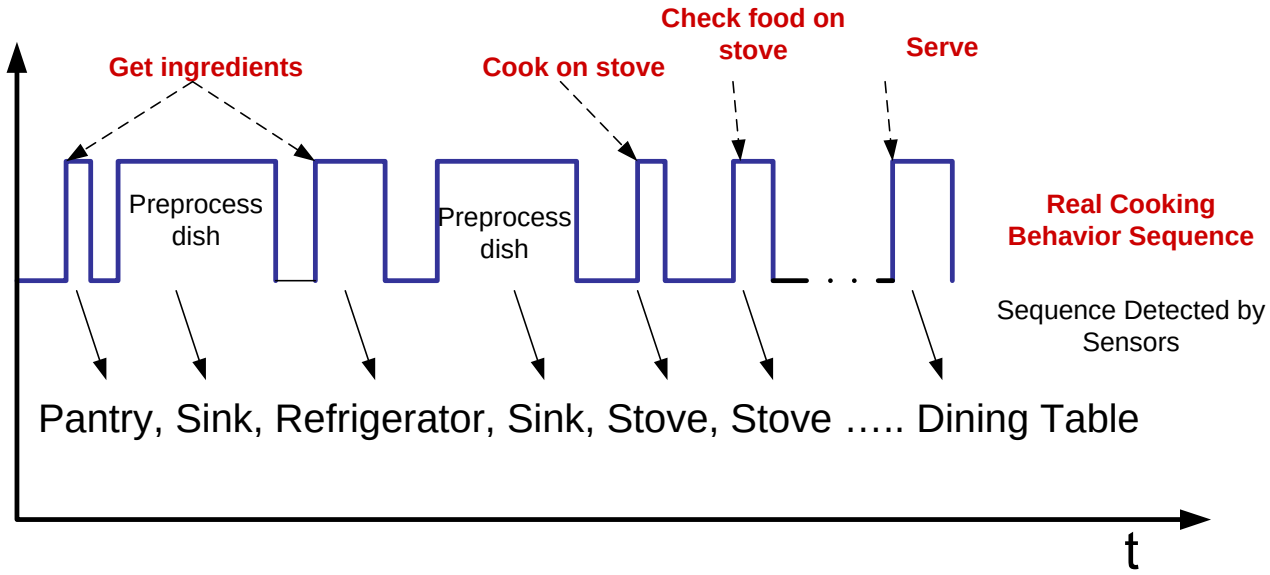


Automatic Code Generation in SOS



- Low-level measurements to macroscopic behaviors
- Bottom-up interpretation of data
- Multiple interpretations of the same sensor data
- Communication decisions and fault detection embedded
- Automated Code Generation from Simple scripts

Behaviors: Sequence of Actions in Space & Time



Behaviors: Sequences of actions in space & time

Parse string using a hierarchy of probabilistic sensory grammars

Multiple interpretations of the same data

Bottom-up interpretation, data gets interpreted and summarized inside the network

Two Distinct Paths of Abstraction

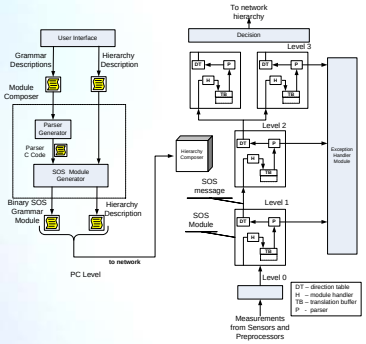
End Users

Application and/or Internet Abstraction
(plug & play applications independent of sensors)

Queries, Applications
& Services

Spatio Temporal Databases

Internet



Multimodal sensor network
& turnsors

Higher Level Semantic Interpretations

Programmer Abstraction

Rule Based System
Short Grammar Descriptions (scripts)
to reconfigurable node Level Code

Prototype Network using XYZ and Intel iMote2
Camera nodes

Assisted Living Application: Cooking Detection

Recognition of complex activities using maps and locations

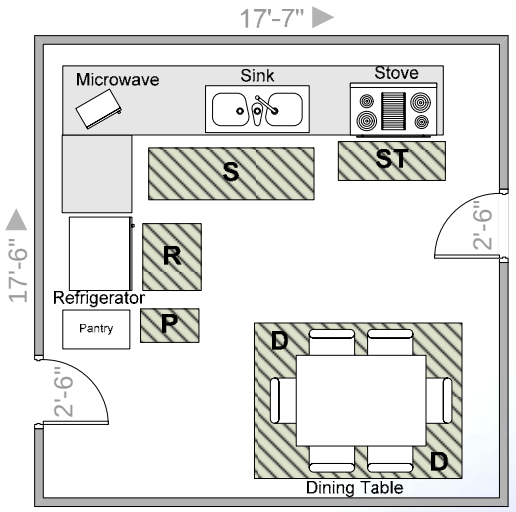
Monitor the entire house as a rule-based system

- From simple actions to abstract behaviors using the same model: trends, rules, behaviors

Current result: cooking recognition, invariant to dish & cook

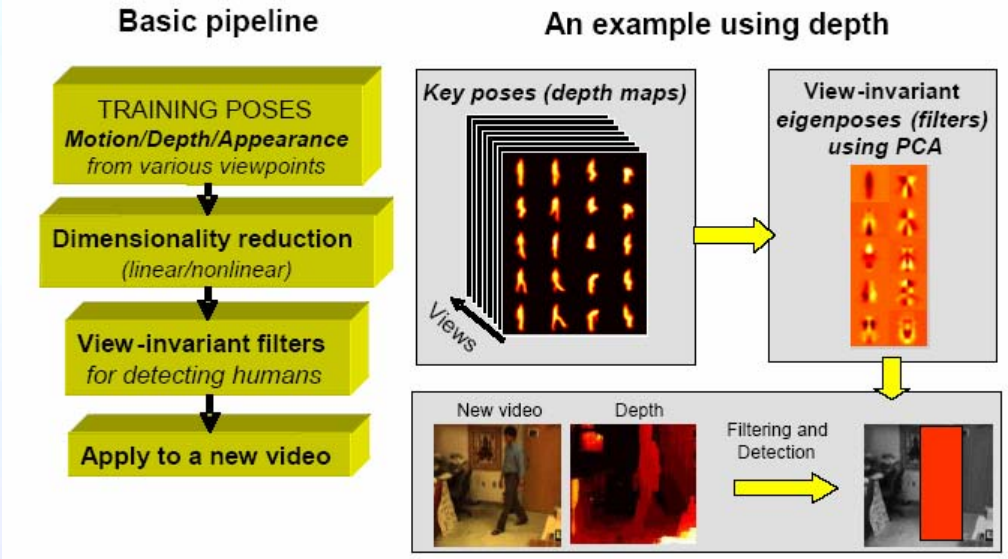
- 18 lines 2-level grammar automatically transformed to 2600 lines of C code on sensor node

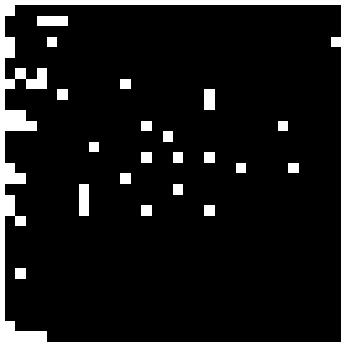
Kitchen is observed with a camera with fisheye lens



Develop a kitchen model, specifying the areas visited during meal preparation

Ultra-Low Power Privacy Preserving Cameras & Visual Human Filters





Start processing @pixel level
Output Symbols NOT images
• Turnsor, cooking sensor, etc

In collaboration with E. Culurciellow (Yale), Y. Aloimonos and A. Ogale, U. Maryland, CS

Interesting Problems

Signals-to-semantics

- turn low level data into something meaningful

Sensors

- bridge the gap between cameras and PIR
  - Detect people them, count, understand and reason w/ motion & postures

Time

- as a sensing modality & cross-layer synchronization

Learning

- (grammars) from data – grammar induction and other tools
  - Distributed parsing & time relationships
  - Selective storage @ the leafs

Classify Privacy Levels

Mechanisms for multimodal fusion

- with grammars
  - Instead of fusing multiple distributions

Programming abstraction models

- Script-based programming – BUT proof of Hypothesis comes first

Power

- orthogonal approaches to duty-cycling: information reduction & HW architecture -> more rigorous information filtering

References

- D. Lymberopoulos, A. Ogale, A. Savvides and Y. Aloimonos, ***A Sensory Grammar for Inferring Behaviors in Sensor Networks***, to appear in Proceedings of Information Processing in Sensor Networks(IPSN), April 2006
- T. Teixeira, E. Culurciello, E. Park, D. Lymberopoulos, A. B. Sweeney and A. Savvides, ***Address-Event Imagers for Sensor Networks:Evaluation and Modeling***, to appear in the Proceedings of Information Processing in Sensor Networks (IPSN), April 2006
- A. Barton-Sweeney, D. Lymberopoulos, A. Savvides, ***Sensor Localization and Camera Calibration in Distributed Sensor Networks***, to appear in the Proceedings of IEEE Basenets, October 2006

For updates refer to: http://www.eng.yale.edu/enalab