Feasibility of a multi-tier Cyber Physical System as a Self-Aware Entity

Kalle Tammemäe, Thomas Hollstein
Tallinn University of Technology
Dept. of Computer Systems

Self-Awareness of man made devices

- “Wise-man” puzzle test – passed by Nano-robots in 2015
  - Robot must know the rules of the game
  - Robot has feedback about its own actions through environment
  - Robot knows it is a separate entity from the other robots
- Typically
  - No idea what game is going on (“What the heck is going on”?)
  - No idea what feedback might come from the environment
  - No idea how to recognize other equal/peer entities

Systems have to learn
- behavioural pattern of the environment
- feedback to own routine actions

Nature

	# of neurons
• Simplest roundworm	300
• Fruit fly (Drosophila): • http://fruitflybrain.org	~150,000
• Ant	~250,000
• Honey bee	~960,000
• Cockroach	~1,000,000

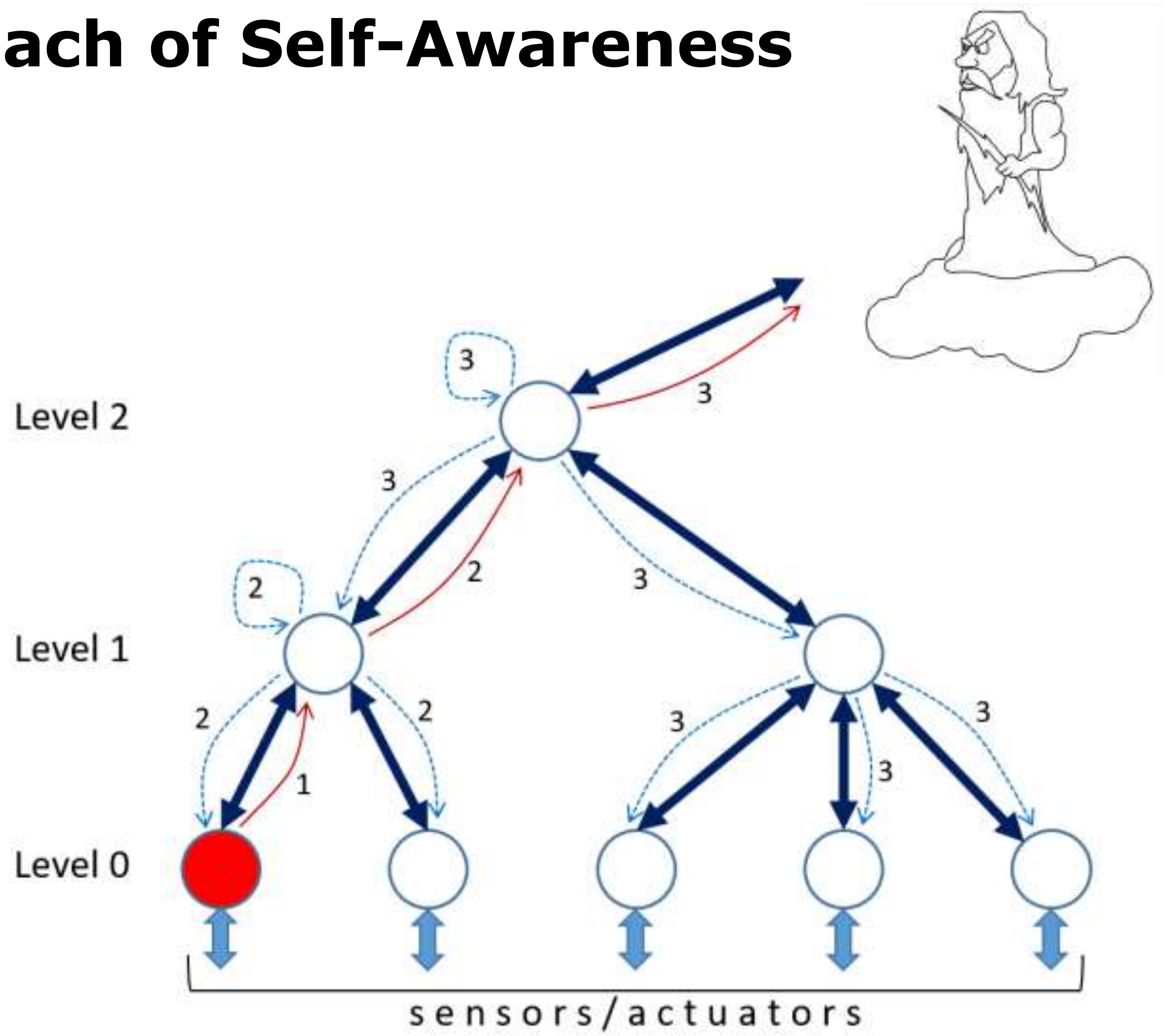
[https://en.wikipedia.org/wiki/List_of_animals_by_number_of_neurons]

Hierarchical approach of Self-Awareness

Cloud

Fog (gateway)

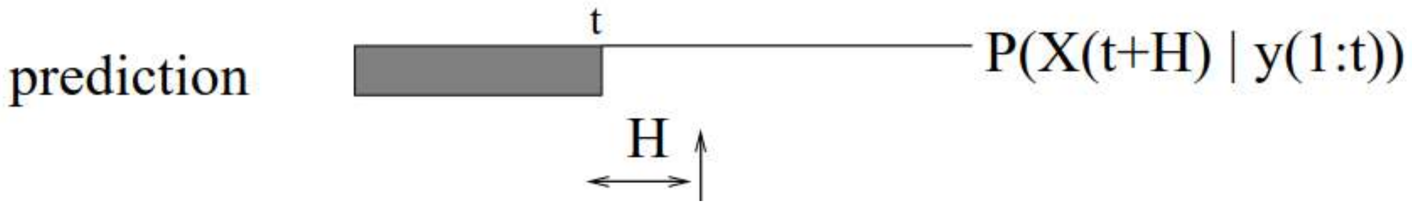
Mist (terminal nodes)



Learning at terminal node level

Ability to learn and predict probability of a distinct event in time

- Dynamic Bayesian Networks (DBN) – prediction the event at H



- DBN has (may have) exponentially fewer parameters than corresponding HMM and is (may be) faster - $O(T)$ instead of $O(T^3)$, where T is the length of the sequence [Kevin Murphy, DBN, 2002]

Predict ➔ Compare ➔ Alert or Pass

➔ Learn/Adapt

Learning at middle layer (fog) level

adaptive and/or reflective systems based on

- e.g. Hierarchical Temporal Memory - machine intelligence based upon the biology of the neocortex (numenta.com)
    - Spatial (SP) an Temporal Pooling (TP)
    - Sparse Distributed Representation (SDR)
    - Unsupervised Real-Time Anomaly Detection for Streaming Data
    - Typical implementation of HTM might need hundreds of MB of RAM
- Processing resources required:
    - GB magnitude of RAM + non-volatile backup for learned model of the environment
    - Successful deployment of HTM on Odroid (2GB of RAM, fast eMMC Flash)
    - Successful run of HTM Spatial Pooler on a ZYNQ-7020 SoC platform, resulting >five times of speedup compared to i7 based PC. The memory intensive input address generation can be outsmarted using LFSR [M.Kernel K.Tammemäe 2017].

MistBot – an edge node

MistBot:

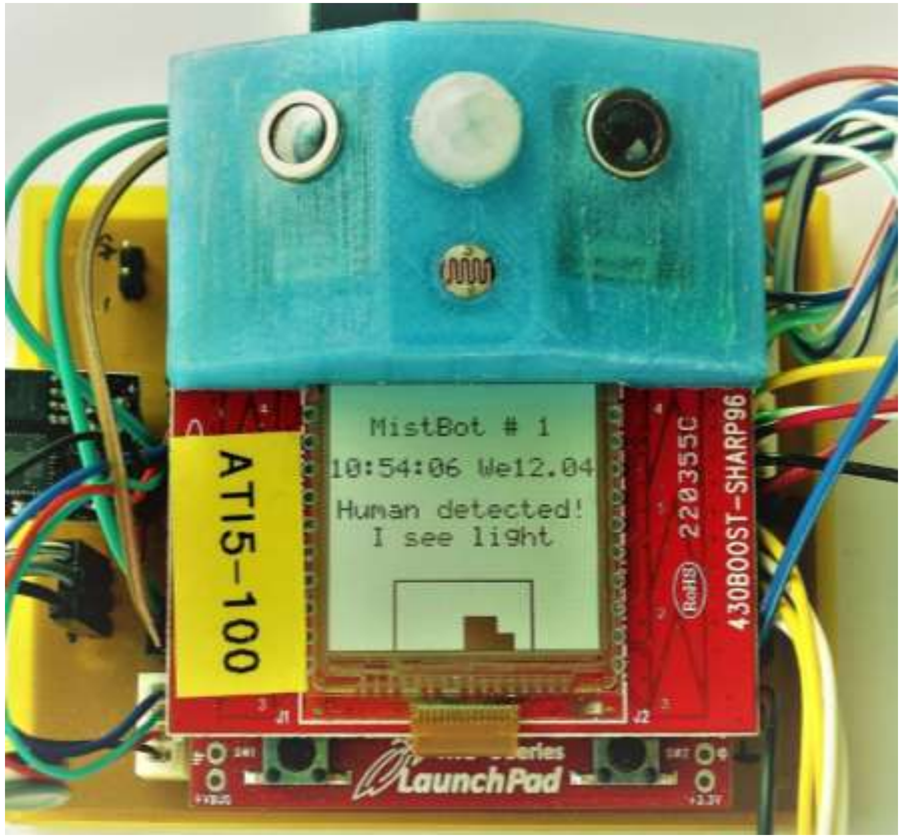
Based on TI TM4C123GXL LaunchPad (ARM Cortex-M4 microcontroller).

Inputs:

- Two Omron MEMS Thermal sensors D6T-44L
- PIR sensor
- Photo resistor (light sensor)
- RTC (DS1307)
- Pushbuttons, microswitch joystick for UI

Outputs:

- Serial interface (USB)
- WiFi ESP8266
- HCI: RGB LED (visual feedback)
- HCI: Mini speaker (audio alert and feedback)
- LCD module 430BOOST-SHARP96
- CMOS switches to control power of sensors
- Service quality history indicator



Predicting activity

Feedback over environment:

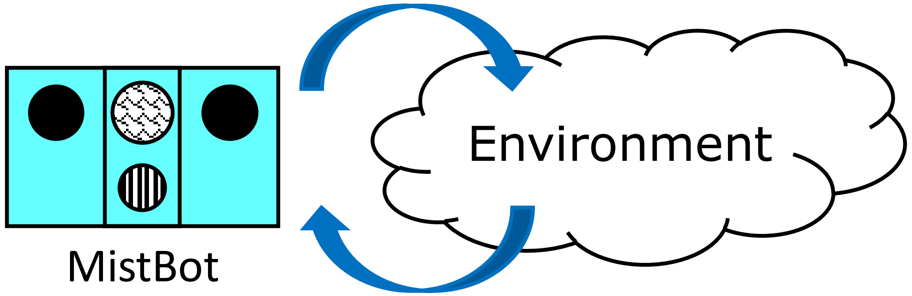
Action1: Alert

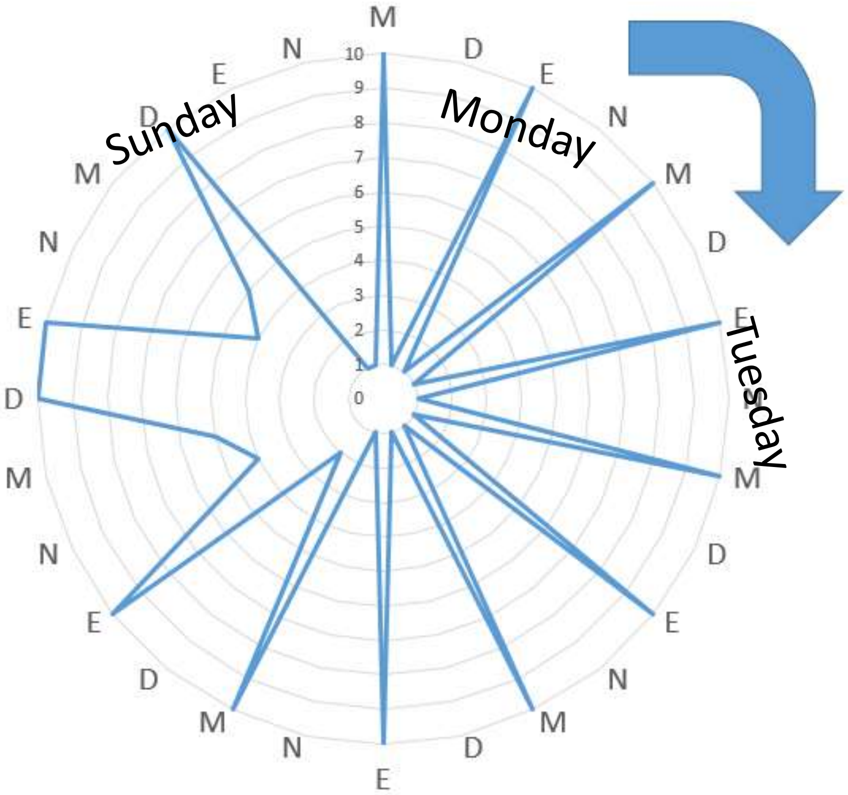
Reaction1: Alert noticed (button pressed)

Action2: Informing Master or peer

Reaction2: Reception of information confirmed

Is it enough to lean feedback about own actions through environment?





Hypothetical weeky activity (seen at home) of a working person. (M – morning, D – day, E – evening, N – night)

Self-awareness

Set of required properties: Semantic Interpretation, Desirability Scale, Semantic Attribution, History of Property, Goals, The Purpose, Expectations on Environment, Expectation on Subject, Inspect Engine … [N.Dutt et.ali. Self-Aware CPS-on-Chip, 2016]

Directly observable self-properties:

- Power consumption (current)
- Battery voltage
- Temperature

Derived self-properties:

- Sensor signal quality
- Communication quality
- Service quality (e.g. number of system failures-resets)

Predicting human behaviour by CPS

- Eventually, every plane will come down
  - Except it is solar powered
  - Except it is piloted by Steve Fossett (record 76 hours non-refuel), etc.
- MIT study in 2015: Data Science Machine – algorithm, which can predict human behavior better than humans*
  - [James Max Kanter and Kalyan Veeramachaneni, “Deep Feature Synthesis:Towards Automating Data Science Endeavors”, ©2015 IEEE]
- … so, don’t give up with CPS’s – they can made predictions too
- Added value of a multitier hierarchical CPS:
  Dynamic Power Management
  - Node activeness depends of **attention** presence and distribution in the system, defining active communication paths and processing need. I.e. proper performance with a minimum energy/cost

Following steps

1. Fog-level node HW/SW design and the whole system assembly
2. Living lab experiments and data collection
3. Data analysis, methodology/approach formalization
4. System refinement and partial re-run of experiments

- Research paper(s) and cooperation

Thanks!