Modeling Emotion and Temperament on Cognitive Mobile Robots

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Introduction

- Emotions and temperament help animals (including humans) survive and evolve
- Also, groups of animals (including humans) with a diverse set of temperaments are more effective
- Robots that vary their behavior based on their emotions should be very useful
- Although not addressed here, robots with emotions and temperament might be better at interacting with humans also

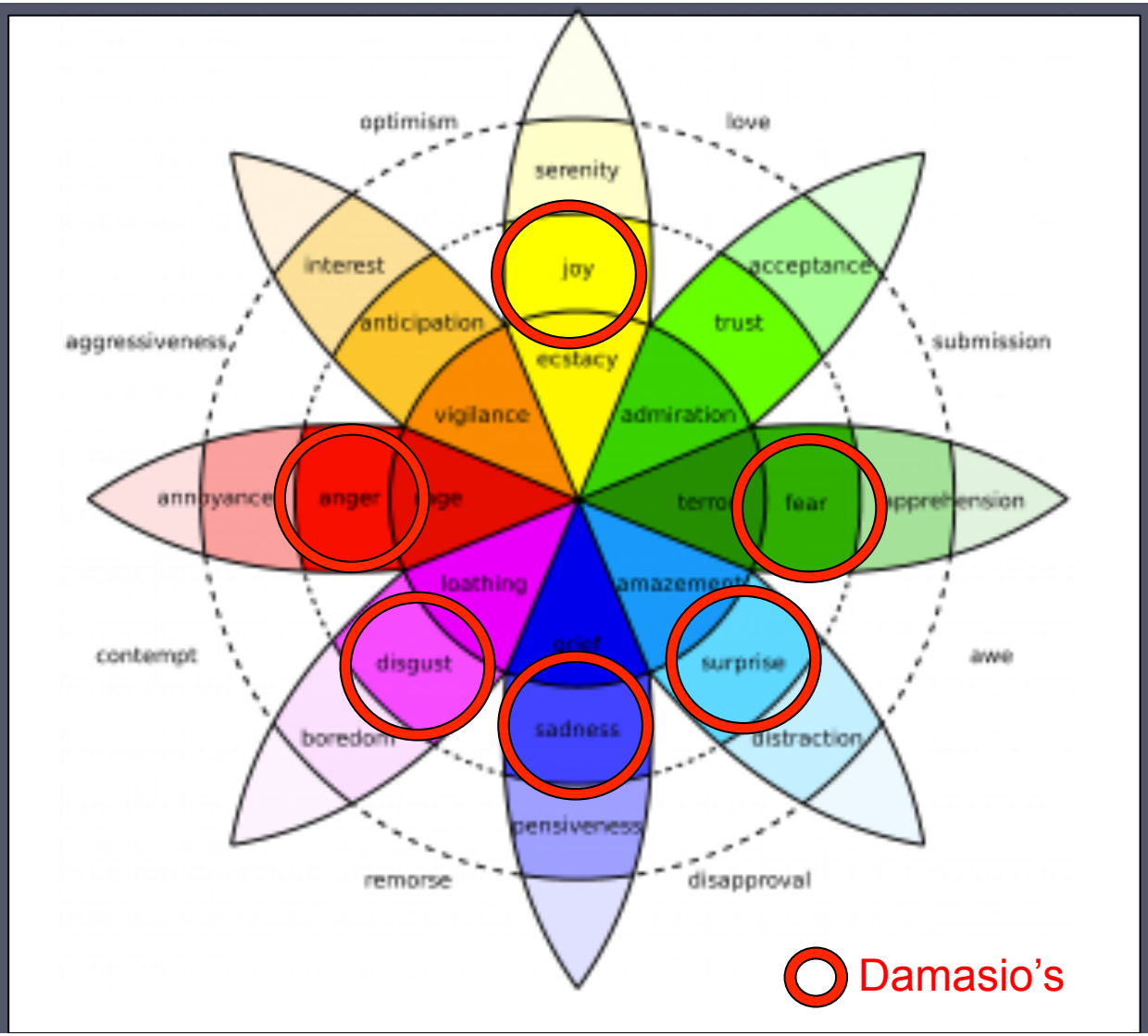
Emotions vs. Temperament

- Emotions vary with time due to rewards and punishments ("reinforcers")
- Temperament (personality) is essentially fixed in each animal, but can vary from animal to animal
- The model presented herein couples emotions and temperaments together into a cognitive architecture on a mobile robot

Damasio (1994 and 2010) Discusses Six "Universal" Emotions

- Fear
- Anger
- Sadness
- Happiness
- Disgust
- Surprise

Plutchik (2001) Emotion Wheel
(eight and they can vary in strength)



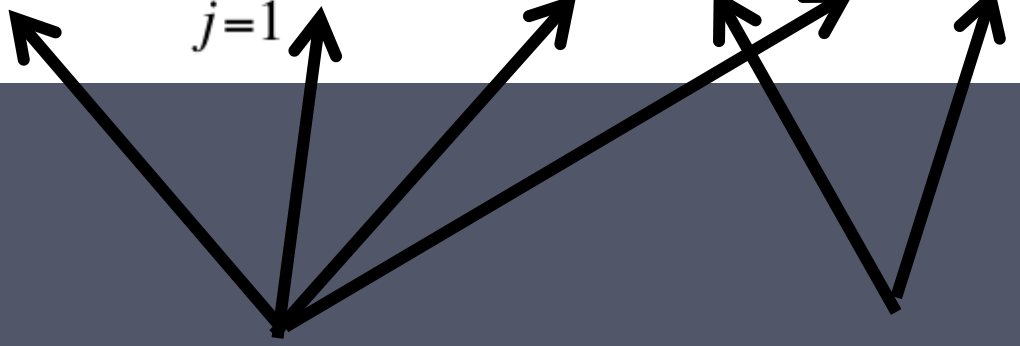
Emotions Used in Simulations

- Fear
- Anger
- Sadness
- Happiness
- Disgust
- Surprise
- Trust
- Surprise

- All those shown in Plutchik color wheel
- Each can vary from 0 to 100
- Largest chosen (winner take all)

Model Created for Emotions

$$Emotion(t)_i = w_{o_i} + \sum_{j=1}^{t} \gamma_i^{(t-j)} \left(w_{1_i} R_{ij}^{+} + w_{2_i} R_{ij}^{-} \right)$$



Eight emotions that vary with time

Fixed coefficients that define temperament

Rewards & Punishments

(Inspired by: Rutledge et al, PNAS 2014)

Five main types of temperament in humans and other animals

- Often called the Big Five (Digman, 1990):
  - Extrovert vs. Introvert
  - Neurotic vs. Rational
  - Conscientious vs. Careless
  - Agreeable vs. Disagreeable
  - Open vs. Reticent

Define a Temperament Matrix

(fixed array of constants to define robot's personality, from emotion equations)

$$T_{ij} = \begin{bmatrix} w_{0_1} & w_{1_1} & w_{2_1} & \gamma_1 \\ w_{0_2} & w_{1_2} & w_{2_2} & \gamma_2 \\ w_{0_3} & w_{1_3} & w_{2_3} & \gamma_3 \\ w_{0_4} & w_{1_4} & w_{2_4} & \gamma_4 \\ w_{0_5} & w_{1_5} & w_{2_5} & \gamma_5 \\ w_{0_6} & w_{1_6} & w_{2_6} & \gamma_6 \end{bmatrix}$$

Fear
Anger
Sadness
Happiness
Disgust
Surprise

Steady state value

Reward factor

Punishment factor

Decay rate

Example Temperament Matrix

$$T_{ij} = \begin{bmatrix} 50 & 0.52 & 0.35 & 0.72 \\ 75 & 0.52 & 0.35 & 0.72 \\ 50 & 0.52 & 0.35 & 0.72 \\ 50 & 0.52 & 0.35 & 0.40 \\ 50 & 0.52 & 0.35 & 0.72 \\ 60 & 0.70 & 0.35 & 0.72 \end{bmatrix}$$

Fear
Anger
Sadness
Happiness
Disgust
Surprise

Steady state value

Reward factor

Punishment factor

Decay rate

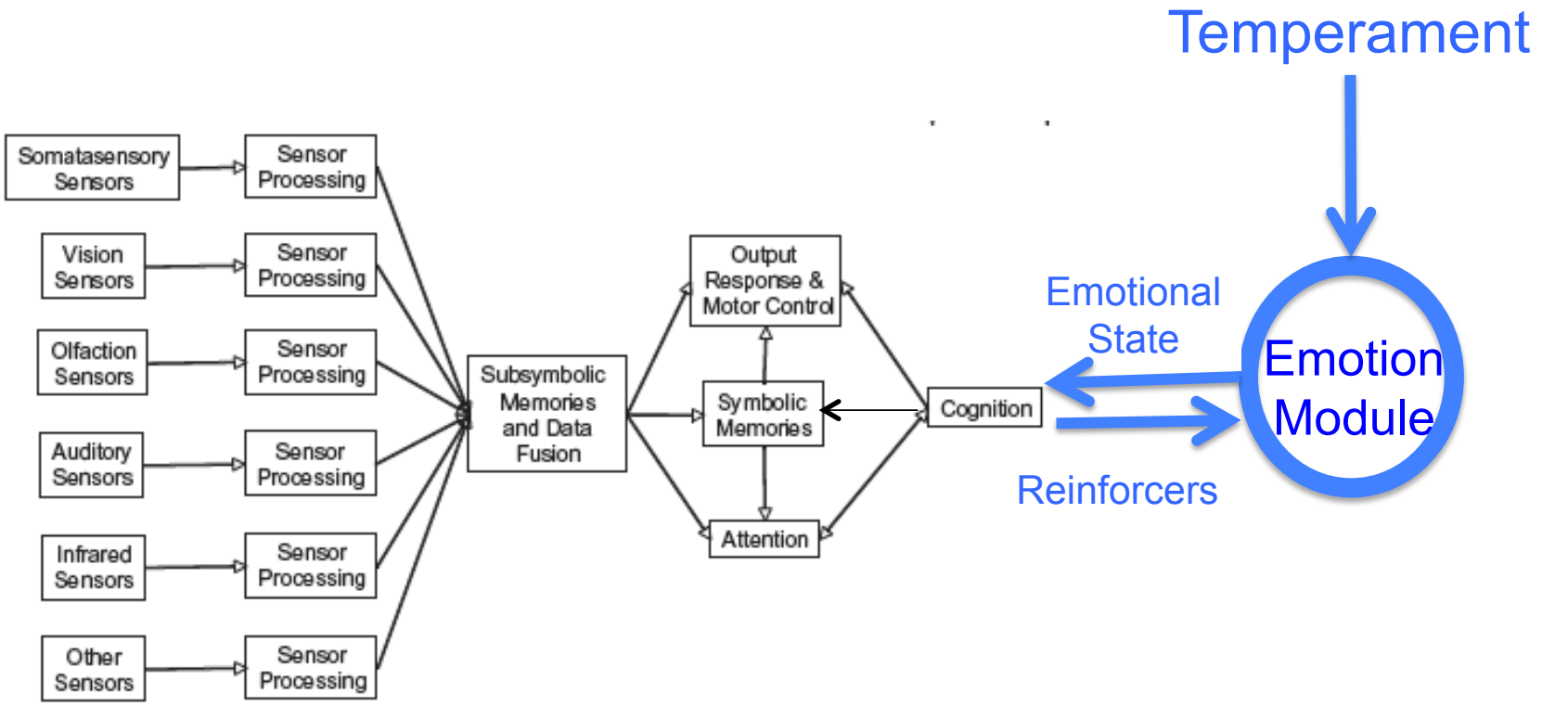
Cognitive Architecture Used

- Symbolic and Subsymbolic Robotic Intelligence Control System (SS-RICS)
- Developed at US Army Research Lab, Aberdeen, MD (Troy Kelley, Eric Avery, and others)
- Inspired by ACT-R
- Lots of libraries for navigation, mapping, visual processing, sensors, and motor control
- Laser range finder, mono camera, stereo camera, wheel encoders, sonar sensors, stereo microphones, stereo speakers, …
- Written mainly in C#

Symbolic and Subsymbolic Robotic Intelligence Control System (SS-RICS)

- Works with variety of robots (Mobile Robots Pioneer robots, the SRV-1 robot, the iRobot PackBot, and Clearpath's Husky A200)
- Easily moved to new ones

SS-RICS with Emotion & Temperament



SS-RICS with Emotion & Temperament

- The Emotion Engine is a sub-symbolic process within SS-RICS
- Written in C++
- Robot is given a temperament matrix to use (personality)
- As robot roams around SS-RICS sends rewards or punishment info to the emotion engine
- The emotion engine keeps track of these and uses the equations shown earlier to predict a numerical value of all emotions as functions of time
- Emotion engine sends current values of emotions (and info on largest one) back to SS-RICS
- Emotions are essentially state variables, so Productions can include info on emotions

Results

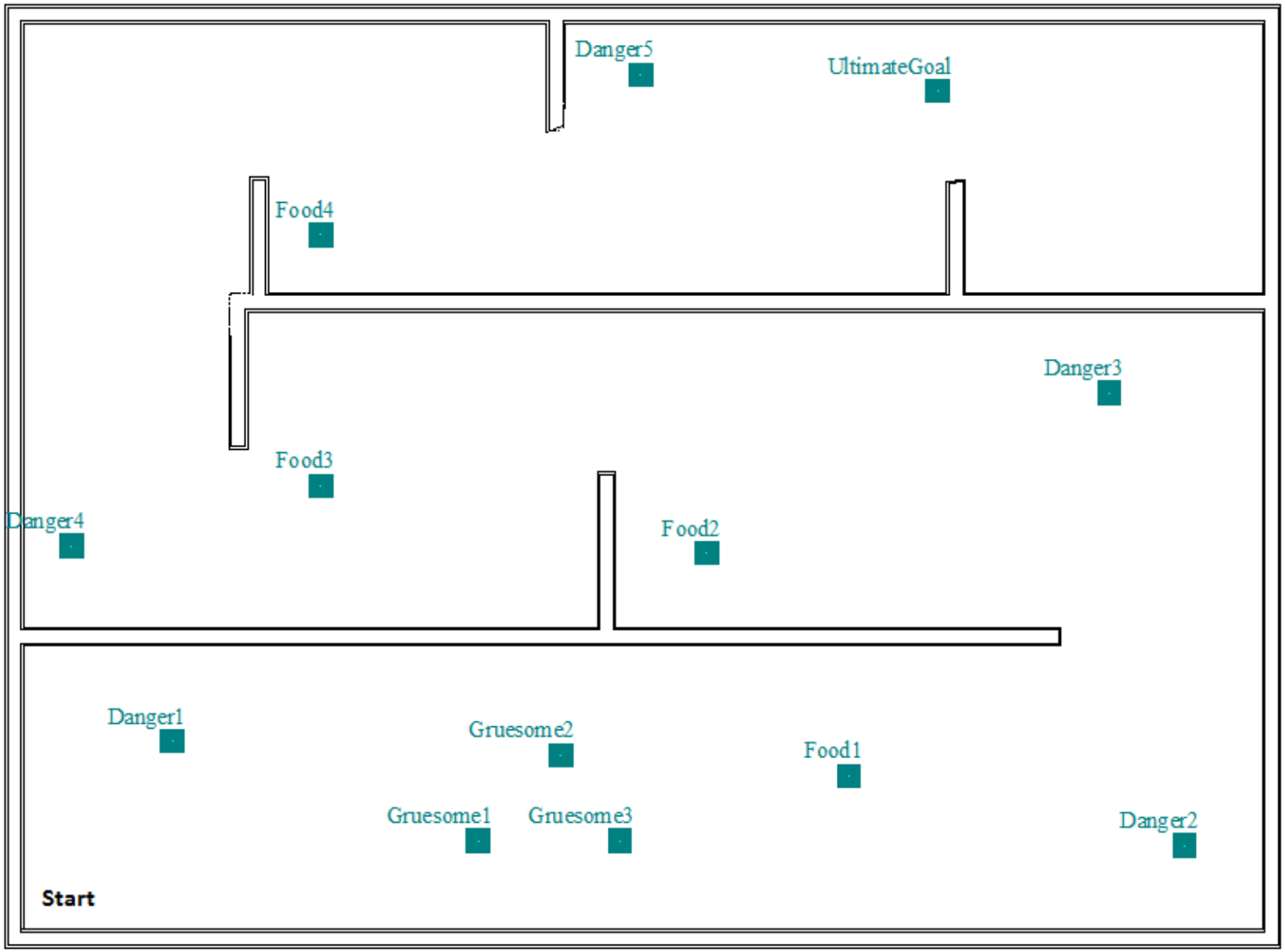
Results from SS-RICS Simulator

(same code as robot code)

SS-RICS Simulation Results

- Simulator is given map of the building with objects that spur emotions distributed around map
- It roams around the building searching for one object
- Robot speaks when it is near the objects ("I see danger"), and these objects can change its emotion
- Robot also periodically states what emotion it is "feeling" (e.g. "I feel happy")
- Depending on emotion it is feeling, its behavior is modified via SS-RICS productions

Map Used for Tests



Temperament Matrices Used

Happy

$$T_{ij} = \begin{bmatrix} 50 & 0.52 & 0.35 & 0.50 \\ 50 & 0.52 & 0.35 & 0.95 \\ 50 & 0.52 & 0.35 & 0.95 \\ 52 & 0.62 & 0.35 & 0.95 \\ 50 & 0.52 & 0.35 & 0.95 \\ 50 & 0.52 & 0.35 & 0.30 \end{bmatrix}$$

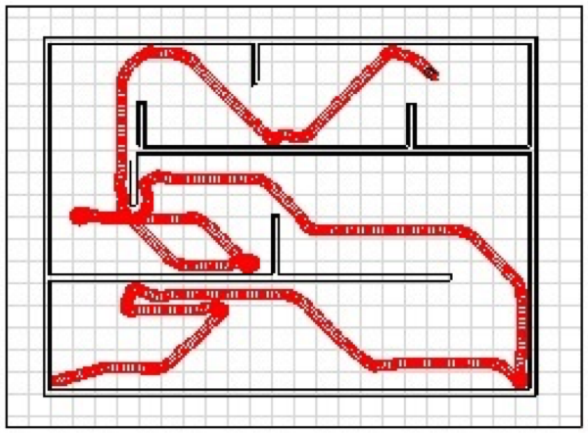
Fearful

$$T_{ij} = \begin{bmatrix} 52 & 0.62 & 0.35 & 0.95 \\ 50 & 0.52 & 0.35 & 0.95 \\ 50 & 0.52 & 0.35 & 0.95 \\ 50 & 0.52 & 0.35 & 0.95 \\ 50 & 0.52 & 0.35 & 0.95 \\ 50 & 0.52 & 0.35 & 0.30 \end{bmatrix}$$

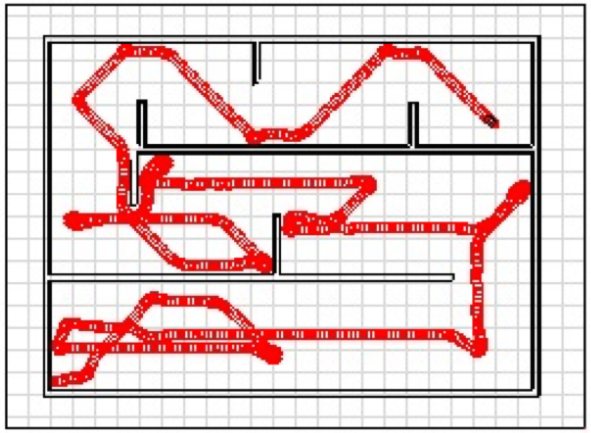
Angry

$$T_{ij} = \begin{bmatrix} 50 & 0.52 & 0.35 & 0.95 \\ 52 & 0.52 & 0.35 & 0.95 \\ 50 & 0.52 & 0.35 & 0.95 \\ 50 & 0.52 & 0.35 & 0.95 \\ 50 & 0.52 & 0.35 & 0.95 \\ 50 & 0.52 & 0.35 & 0.30 \end{bmatrix}$$

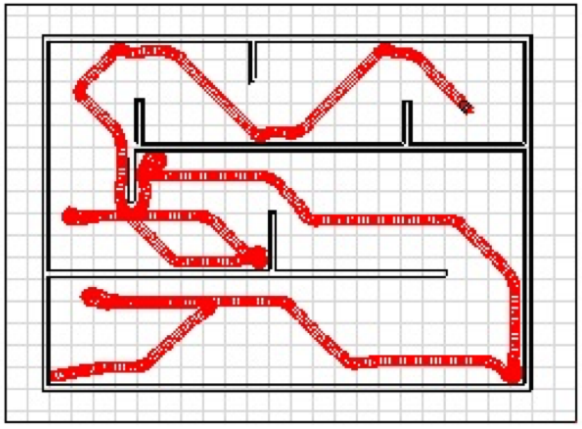
Routes Taken by Robots



Angry

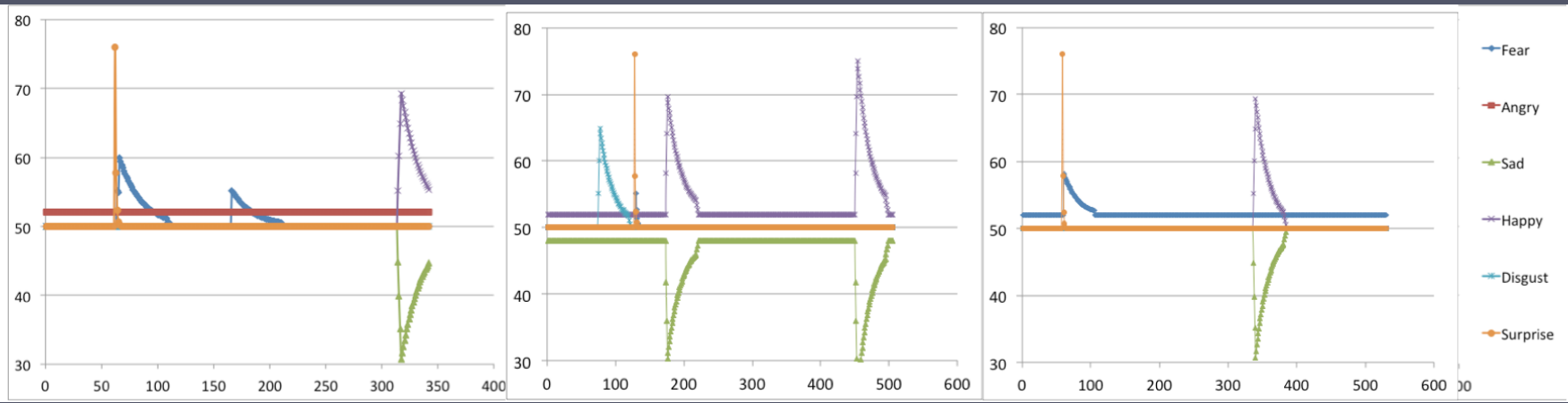


Happy



Fearful

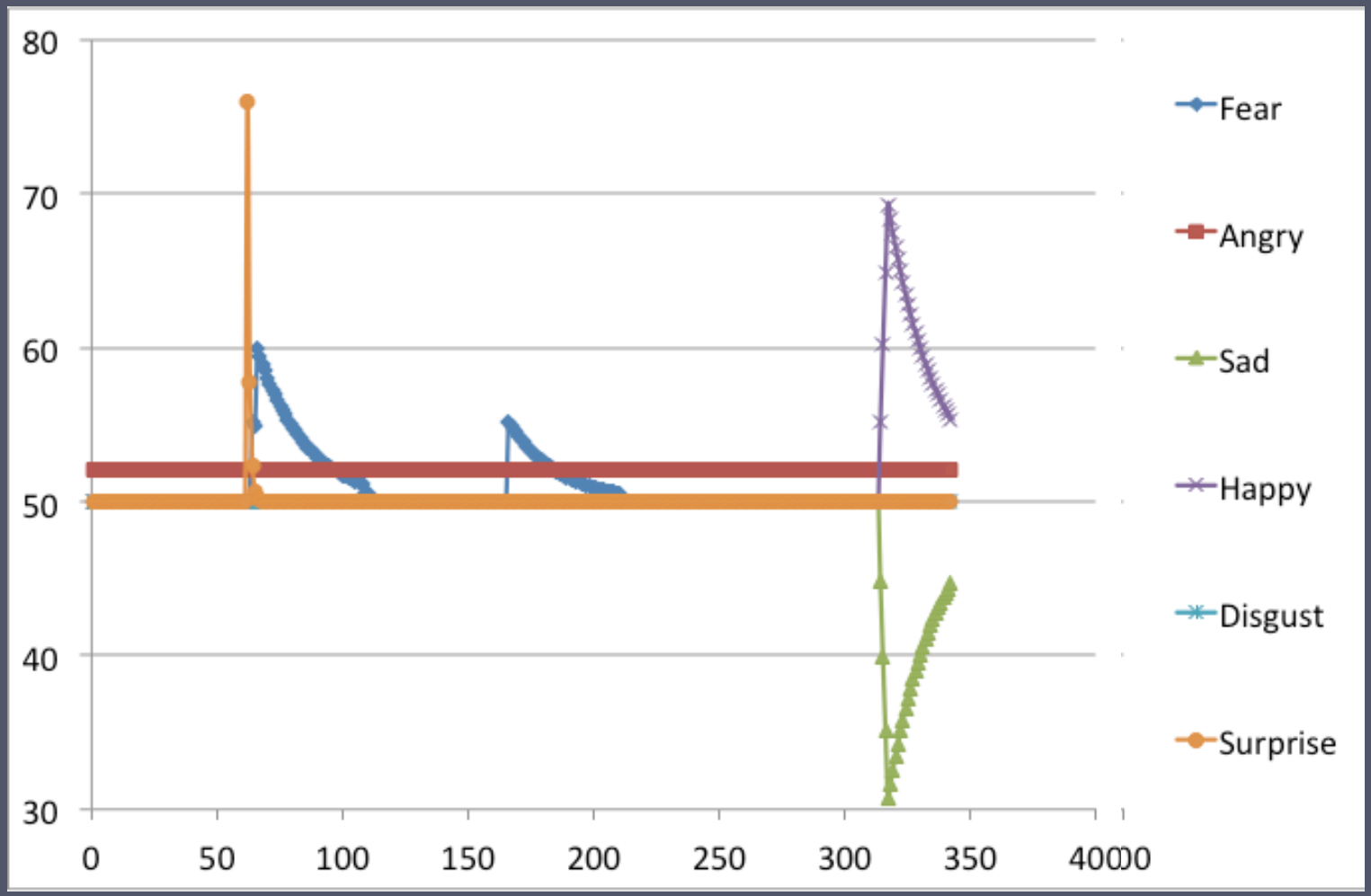
Emotion Time Histories



Angry **Happy** **Fearful**

Example Emotion Time History

("Angry" Temperament)



Results from Robot

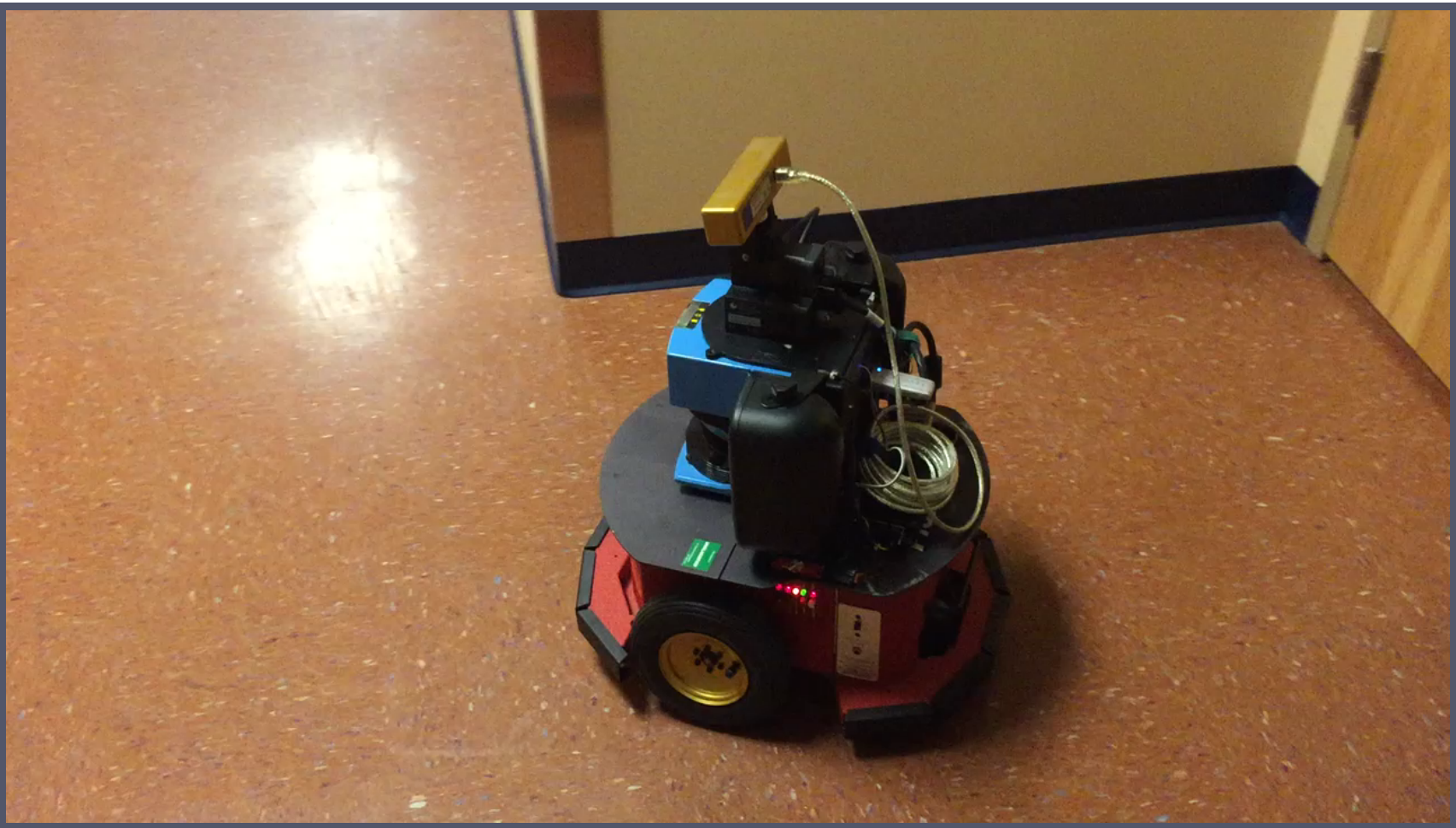
(same code as robot code)

Robot Test Cases

Robot Results

- Ran the same tests as ran in simulator but on mobile robot (results were essentially the same qualitatively)
- Objects were stored in map
- Robot speaks when it sees these things (“I see danger”)
- Robot also periodically states what emotion it is “feeling” (e.g. “I feel happy”, “I’m afraid”, “I’m very afraid”)
- Depending on emotion it is feeling, its behavior is modified
- It roams around the building looking for a particular object while it builds a map of the building

Robot Video



Robot Results

- Have also incorporated object recognition code (Local Binary Patterns (LBP))
- Have trained it to recognize objects that might stir emotions (food, guns, snakes, soldier uniforms, mannequins, …)
- It now does not have the items stored in the map, it "sees" them with the camera

Conclusions

- Emotion and temperament model has been developed
- It has been incorporated into a cognitive mobile robot
- Will run more extensive tests in the next few months
- Will also work to evaluate the emotion/temperament model and the temperament matrix
- More Details in: Long, Lyle N., Kelley, Troy D., and Avery, Eric S., "An Emotion and Temperament Model for Cognitive Mobile Robots," 24th Conference on Behavior Representation in Modeling and Simulation (BRIMS), March 31-April 3, 2015, Washington, DC

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Thank You. Questions?

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