



# Implementing Emotions in Cognitive Robots

**Lyle N. Long**
Aerospace Engineering, Mathematics, and Computational Science
The Pennsylvania State University

**Troy D. Kelley**
U.S. Army Research Lab
Aberdeen, Maryland

# Introduction

- Emotions and temperament help animals (including humans) survive
- Emotions are important memory triggers. Emotional events are remembered well
- Robots that vary their behavior based on their emotions should be more effective
- 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 reward and punishment
- Temperament (personality) is essentially fixed, but can vary across individuals
- The model presented herein couples emotions and temperament together into a cognitive architecture on a mobile robot using the Symbolic and Sub-symbolic Robotics Intelligence Control System (SS-RICS)

# Emotions Used in Simulations

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

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

( could also model Trust, and others)

# 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)

Note: There are similarities between cognitive models of memory and the above equation

# Five main types of temperament in humans and other animals



Often called the Big Five Temperaments (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

These values, so far, have been chosen to be near the values in Rutledge et al, PNAS 2014.
More work needs to be done in tuning tehse parameters.

# Cognitive Architecture Used

- Symbolic and Sub-symbolic Robotic Intelligence Control System (SS-RICS)
- Developed at US Army Research Lab, Aberdeen, MD (Troy Kelley, Eric Avery, Sean McGhee, and others)
- Inspired by ACT-R (Carnegie Mellon)
- 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 Sub-symbolic 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

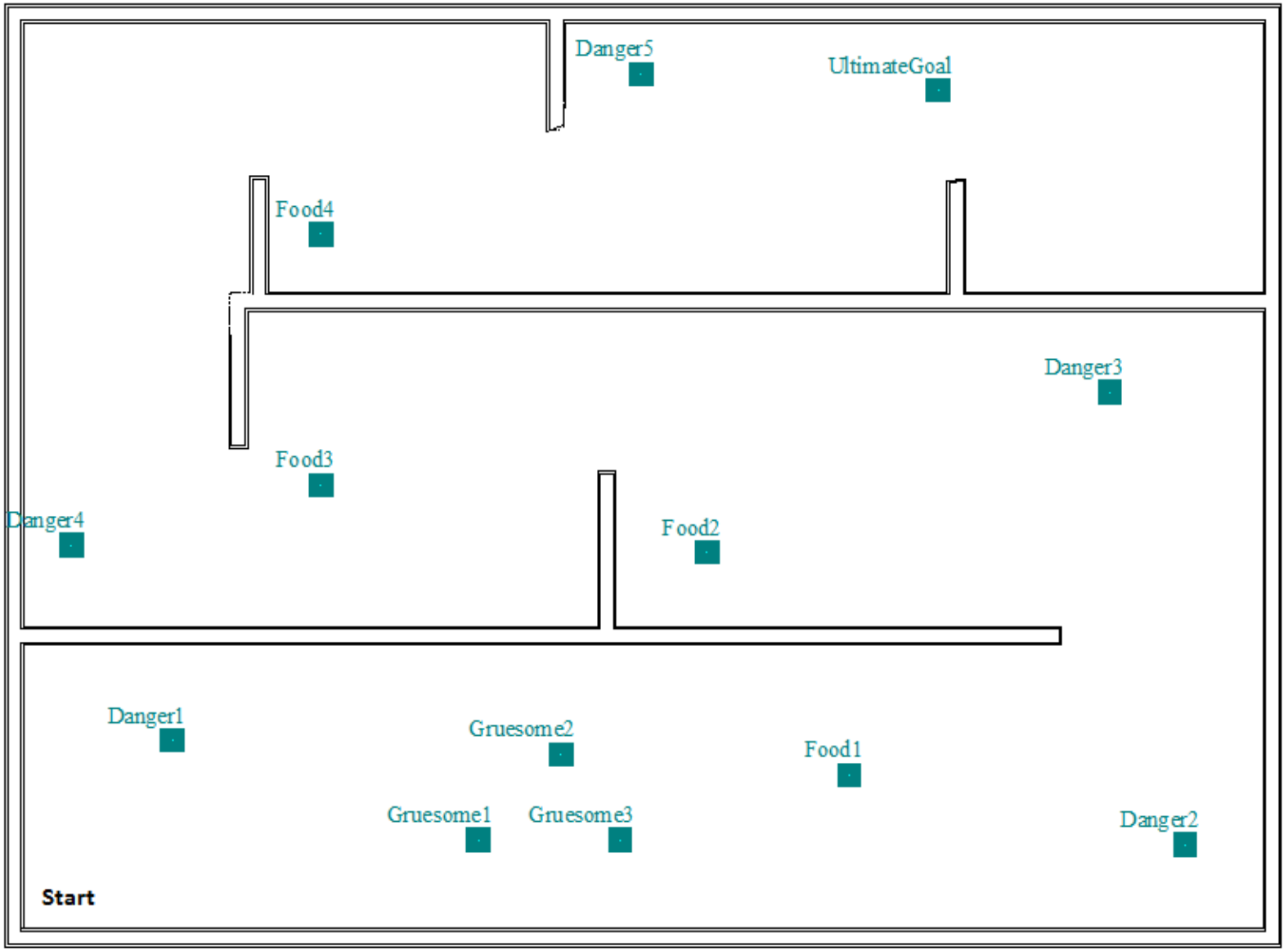
- The Emotion Engine is a sub-symbolic process (unconscious) within SS-RICS
- Written in C++
- Robot is given a temperament matrix to use (personality)
- As robot roams around SS-RICS sends rewards or punishment info to the emotion engine
- The emotion engine keeps track of these and uses the equations 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

# 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

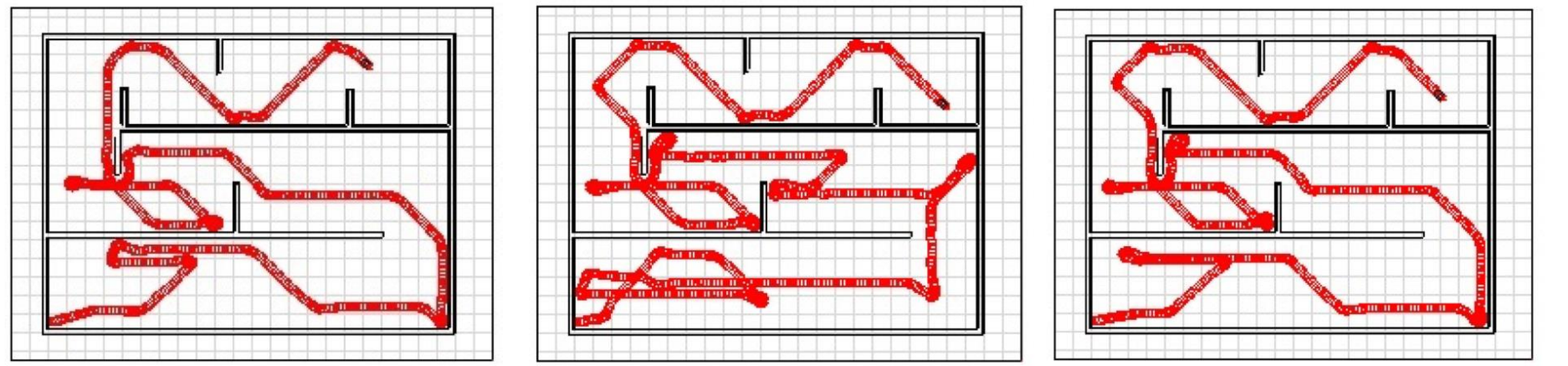
# Map Used for Tests






for Land Forces

# Routes Taken by Robots



**Angry** **Happy** **Fearful**

**Robots travel thru maze and experience items that effect their emotions. All robots go thru same maze and experience same items. Robots with different temperaments behave differently.**

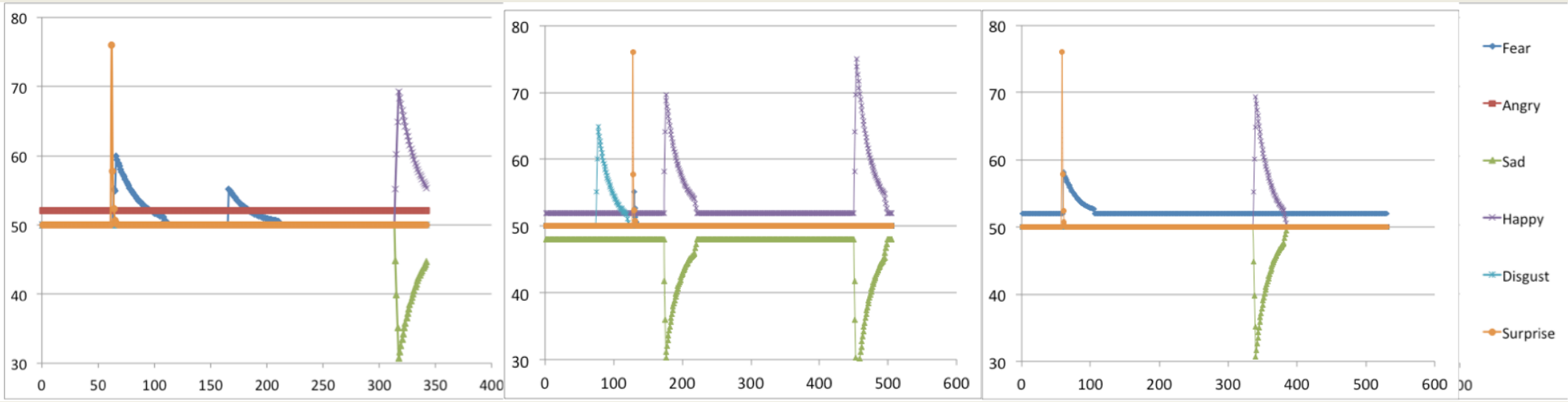
# Emotion Time Histories

## Angry

## Happy

## Fearful

Emotion Values




Time

Time

Time

**Robots travel thru maze and experience items that effect their emotions. Robots with different temperaments have different emotion time histories.**

# 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

# Conclusions

- Emotion and temperament model has been developed
- It has been incorporated into a cognitive mobile robot
- Will run more extensive tests in future
- Will also work to evaluate the emotion/temperament model and the temperament matrix
- It would also be interesting to couple memories and storage. Emotions can influence memories.
- More Details in:

Long L.N., "A Model for Temperament and Emotions on Robots. In: Chen J. (eds), Advances in Human Factors in Robots and Unmanned Systems. AHFE 2017. Advances in Intelligent Systems and Computing, vol 595. Springer, 2018.

# Thank You. Questions?

**Lyle N. Long**

www.personal.psu.edu/lnl

LNL@psu.edu

**Troy D. Kelley**

troy.d.kelley6.civ@mail.mil

**SS-RICS:** https://www.arl.army.mil/www/default.cfm?page=3236