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)

\[ T_{ij} = \begin{bmatrix} w_{01} & w_{11} & w_{21} & \gamma_1 \\ w_{02} & w_{12} & w_{22} & \gamma_2 \\ w_{03} & w_{13} & w_{23} & \gamma_3 \\ w_{04} & w_{14} & w_{24} & \gamma_4 \\ w_{05} & w_{15} & w_{25} & \gamma_5 \\ w_{06} & w_{16} & w_{26} & \gamma_6 \end{bmatrix} \]

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

Steady state value

Reward factor

Punishment factor

Decay rate
Example Temperament Matrix

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

Steady state value
Reward factor
Punishment factor
Decay rate
Fear
Anger
Sadness
Happiness
Disgust
Surprise
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

Temperament

Emotional State

Reinforcers

Emotion Module
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
## Temperament Matrices Used

<table>
<thead>
<tr>
<th>Happy</th>
<th>Fearful</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{ij}$</td>
<td>$T_{ij}$</td>
</tr>
</tbody>
</table>
| \[
\begin{bmatrix}
50 & 0.52 & 0.35 & 0.50 \\
50 & 0.52 & 0.35 & 0.95 \\
50 & 0.52 & 0.35 & 0.95 \\
52 & 0.62 & 0.35 & 0.95 \\
50 & 0.52 & 0.35 & 0.95 \\
50 & 0.52 & 0.35 & 0.30 \\
\end{bmatrix}
\] | \[
\begin{bmatrix}
52 & 0.62 & 0.35 & 0.95 \\
50 & 0.52 & 0.35 & 0.95 \\
50 & 0.52 & 0.35 & 0.95 \\
50 & 0.52 & 0.35 & 0.95 \\
50 & 0.52 & 0.35 & 0.95 \\
50 & 0.52 & 0.35 & 0.30 \\
\end{bmatrix}
\] |

| Angry \[ T_{ij} = \begin{bmatrix} \]
| \[
\begin{bmatrix}
50 & 0.52 & 0.35 & 0.95 \\
52 & 0.52 & 0.35 & 0.95 \\
50 & 0.52 & 0.35 & 0.95 \\
50 & 0.52 & 0.35 & 0.95 \\
50 & 0.52 & 0.35 & 0.30 \\
\end{bmatrix}
\] |
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

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Thank You.  Questions?

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