uc3m | Universidad Carlos III de Madrid

HUMAN-ROBOT INTERACTION

Adaptive Emotion and Personality

Bachelor in Robotics Engineering

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INTRODUCTION

Affective expression plays an important role in human-robot interaction since it enables robots to convey their internal states in ways that people can understand. When a robot displays emotions through voice, movement, or facial cues, users find interactions more natural and predictable. This emotional transparency helps build trust, improve engagement, and reduce misunderstandings in collaborative tasks. Clear affective signals also support smoother social dynamics, allowing humans to adjust their behaviour in response. Lastly, expressive robots are better able to connect with users and foster more effective and cooperative interactions.

This practice will guide you through some important concepts of affect generation. Understanding how robots can simulate human-like emotions requires combining models of neurochemistry and personality. The monoamine theory, proposed by Lövheim, provides a framework for linking neurotransmitter activity to emotional states. At the same time, the Big Five personality model offers a structured way to characterise enduring traits that influence behaviour. Integrating these perspectives enables researchers to design robots that not only respond emotionally but also do so in ways consistent with a defined personality, thereby enhancing the naturalness and predictability of human-robot interactions.

LÖVHEIM'S MONOAMINE MODEL

Lövheim's model proposes that three key neurotransmitters—serotonin, dopamine, and noradrenaline—interact to produce basic emotional states. Each emotion is associated with a specific combination of high or low levels of these monoamines. In the middle area, a neutral state is defined to represent an agent not reacting to any situation. The model provides a biochemical perspective on emotion, linking brain chemistry to observable behavioural and affective responses. It allows for a quantitative approach to simulate emotions in artificial agents. By adjusting monoamine levels, it is possible to represent a spectrum of emotional intensities and valences. The simplicity of the model makes it particularly suitable for computational implementations in robotics.

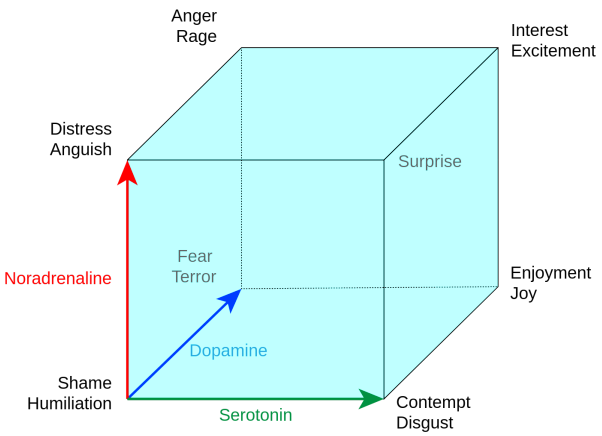

Figure 1. Lovheims' model of affect. Emotions are in the vertices and their activation depends on monoamines dopamine, serotonin, and norepinephrine.

BIG FIVE MODEL OF PERSONALITY

The Big Five model describes human personality through five broad traits: openness, conscientiousness, extraversion, agreeableness, and neuroticism. Each trait represents a continuum, capturing differences in behaviour, emotion, and cognition across individuals. Extraversion and agreeableness, for example, influence sociability and cooperation, while neuroticism relates to emotional reactivity and stress sensitivity. The model is widely validated and provides a framework for predicting behavioural tendencies. In robotics, the Big Five can modulate how a robot perceives stimuli and generates emotional responses. Figure 2 shows the relationship between these factors, whose definition is given below:

- **Openness** reflects how much a person enjoys novelty, creativity, and exploring new ideas or experiences. Open people are curious and comfortable with change, while those low in openness prefer routine and familiarity.
- **Conscientiousness** describes how organised, dependable, and self-disciplined a person is. Highly conscientious individuals plan carefully, meet deadlines, and take responsibility seriously. People low in conscientiousness are more spontaneous, flexible, and sometimes disorganised.
- **Extraversion** refers to the tendency to seek social interaction, stimulation, and positive emotional experiences. Extraverted individuals feel energised around others, while introverted individuals prefer calm environments.
- **Agreeableness** measures how cooperative, compassionate, and considerate a person is. Agreeable people value social harmony and help others. Those low in agreeableness may be more competitive, direct, or sceptical of others.
- **Neuroticism** reflects how often a person experiences negative emotions such as anxiety or sadness. Neurotic people are more sensitive to stress and emotional fluctuations, while those low in neuroticism tend to remain calm.

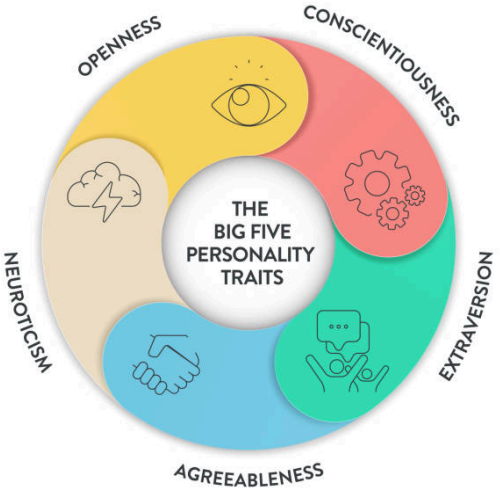

Figure 2. Big five personality traits.

PRACTICE

Objective

The aim of this practical session is to explore how robots can simulate human-like emotional responses influenced by personality and neurochemistry. Students will interact with a two-program system where they can define and send stimuli to a robot and observe how these stimuli affect its internal emotional state. This exercise demonstrates the interplay between external events, personality traits, and emotional responses, providing insight into the design of socially intelligent robots.

System Overview

The practice uses two interconnected programs:

Stimulus Manager: This program allows students to define custom stimuli and select which ones to send to the robot. Stimuli are transmitted using **ZeroMQ** and encoded in **JSON**, enabling real-time communication between the two programs.

Each stimulus has the following characteristics:

- Name: name given to the the stimulus
- Dop: effect on dopamine
- Ser: effect on serotonin
- Ne: Effect on norepinephrine
- Intensity: Value from 100 to 0 after activation
- Decay rate: Intensity decay each time step

The stimuli manager allows activating more than one stimulus from the keyboard. Each time you activate a stimulus, it will automatically get the intensity of 100. Then, its intensity will decay at a speed equal to the decay rate parameter (the default value is 5) until reaching 0 units. Then, it will become deactivated.

The stimuli manager publishes the intensity and effects on monoamines of each active stimulus on every time step. These values are automatically received in the affective manager to update the robot's emotion.

Affective Manager: This program represents the robot's internal emotional system. It receives active stimuli, updates the robot's **monoamine levels** (serotonin, dopamine, norepinephrine), and computes the resulting emotion using **Lövheim's monoamine model**. The program also allows you to define the robot's personality using the **Big Five model** (openness, conscientiousness, extraversion, agreeableness, neuroticism), with values ranging from 0 to 1. Personality influences both how stimuli are perceived and the tendency to express specific emotions.

Monoamines levels affect which emotions are triggered using thresholds as limits. Each emotion depends on different levels of dopamine, serotonin, and norepinephrine. Each emotion has an unique colour that must light up when the emotion is active.

Besides, the robot's personality can affect how easily emotions appear, affecting the monoamine levels. For example, neurotic people will experience sadness more easily because their serotonin and dopamine levels get impaired.

Monoamines and Emotions

The robot's emotional state is governed by the levels of three monoamines: serotonin,

dopamine, and norepinephrine. Each stimulus affects these levels, which by default start at 0.5. Changes in monoamine levels are mapped to basic emotions using Lövheim's model, allowing students to observe how combinations of neurochemical changes produce distinct affective responses. For example, high dopamine, low norepinephrine, and high serotonin may result in joy, whereas elevated norepinephrine with low serotonin may produce fear or anger.

Personality Effects

Personality traits modulate both perception and emotional expression. For instance:

- **High neuroticism** increases sensitivity to negative stimuli, making the robot more prone to sadness or fear.
- **High extraversion** enhances positive responses, making joy more easily expressed.
- **Other traits** such as openness, agreeableness, and conscientiousness can subtly influence emotional intensity and the way stimuli are weighted.

Through this mechanism, students can explore how individual differences in personality shape emotional reactions, illustrating the complexity of human-like affective behaviour.

ACTIVITIES

IMPORTANT! Complete the following activities and submit the requested files. You have 2 weeks from the date of the lab session

1. Install the necessary libraries to run the scripts in two different terminals.

```shell
pip install json
pip install zmq
pip install queue
pip install matplotlib
```

2. Explore the provided code and notice that there is one stimulus already defined (touch) with one emotion associated (joy).
3. Run the code and see the output. Is it working correctly?
4. As you may notice, there is only one emotion defined. Use the Lovheim's model of affect to update the `lovheim_emotion()` including the other emotions. They should activate with the appropriate monoamines levels. Assign an appropriate colour to each emotion using the `EMOTION_COLOURS` variable.
5. Move back to the stimuli_manager.py and add new stimuli with other effects using the `STIMULI` variable. Make that each of your new stimuli trigger a different emotional response playing with the monoamine effects.
6. As you may notice, if more than one stimuli are active simultaneously, the system only applies the effects of the last one received. Update the `main()` function of the

affective_manager.py file (line 122 in the template) to make the system consider all active stimuli. The final value of the monoamines should sum all the stimuli effects. Therefore, if there is one stimulus that triggers joy and another sadness, the robot should remain in a neutral state.

7. The variable `PERSONALITY` in the affective_manager.py file allows you to define the robot's personality using the Big Five Factor model (openness, conscientiousness, extraversion, agreeableness, and neuroticism).

   Update the method `modulate_substances()` to regulate the robot's emotions based on the robot's personality. Define at least two different personality profiles different from the following example to allow the robot to experience some emotions more easily.

   For example:

   An extraverted robot will experience positive emotions such as joy more easily. Therefore, stimuli with moderate effect on dopamine and serotonin will be amplified. Define one positive stimuli such as receiving a caress with moderate effects and make the extraversion factor to amplify the effects to elicit joy.

8. Upload to AulaGlobal a compressed *ZIP folder* with the following items: the report, the code files, and a short video. **IMPORTANT: THE NAMES OF ALL MEMBERS OF THE GROUP NEED TO BE PRESENT ON THE REPORT, AND AS COMMENTS AT THE TOP OF BOTH PYTHON FILES. FAILING TO DO SO WILL RESULT ON FAILING THIS ASSIGNMENT**