CHAPTER 10 - EXPERIMENTS

In this chapter, we present our experiments with our system to evaluate our hypothesis:

Human-like emotion, personality, and physical states can be expressed by a humanoid robot through its motions, encoded as a set of signal transformations.

We test our system with the following approach:

- For all scenarios we assume the following:
  - The system is started: the program is loaded, and the KHR-1 is turned on.
  - The speed parameter for RCB-1 is always set to 6.
  - User is in the view of the camera (Webcam) (optional).
- The test is done in two Scenarios:
  - Scenario 1 – Show Emotions (Joy, Fear, Sadness, Anger) on a Waving-Arm Motion using Reserved Commands.
  - Scenario 2 – Public Evaluation.
  - Scenario 3 – 'Driving' the Emotion of the Robot with the Emotional-Personality model.
- The evaluation is done empirically:
  - Relative qualities such as 'smoother/rougher transitions', 'faster/slower acceleration/deceleration', 'faster/slower duration', 'bigger/smaller range of motion' are compared to the *baseline motion.* We define the *baseline motion* as*:* the basic motion that is interpolated with default interpolation parameter values (*continuity=0, tension=0, bias=0*), without additional interpolation, sampling, or gain adjustments.
  - Whether or not the observer able to identify any resemblence between the modified motion and the original basic motion. For example: will the observer still be able to identify the motion as a Pushup motion after the modifications?

10.1 Scenario 1: Show Emotions (Joy, Fear, Sadness, Anger) on an Waving-Arm Motion using Reserved Commands

10.1.1 Scenario 1 – Goals

The goals of the experiment in Scenario 1 are:

1) to find out if it is *possible* to use the signal processing methods outlined in Chapter 9 in such a way that a simple motion can be modified using those methods into a motion with different emotional expressions. In other words, to investigate if we can represent emotions using a set of values for the parameters of the signal processing methods,
2) to simply observe if a motion (e.g. Waving arm) will be modified when the robot is in an emotional state, and

3) to see if the modifications are appropriate to convey the type of emotion we specified (e.g. is the motion slow enough? Does the slowed motion can be perceived as being sad?).

10.1.2 Scenario 1 – Description

Here, we are not concerned with the context-based response of the robot, the identity of the person, nor the intensity levels of the emotions, and only focused on our goals above. For Scenario 1, we bypassed our Emotional-Personality system using *reserved commands* (Table 10.1). To command the robot to do the Pushup motion, we assign “Wave” to the <action> clause. Using the reserved commands, the Pushup motion will be modified using a set of fixed values for the motion processing parameters for each type of emotion (Table 10.2).

We use the reserved commands in this experiment for the following reason. When the Emotional-Personality system interferes, often the system will not execute the motion because the 'willingness' is not satisfied (see Section 5.5.4) . Specifically, when keywords that trigger Sadness and Anger emotions are found in the input text, the 'willingness' level quickly drops to zero – the robot will not (i.e. 'refuse' to) do the actions we ask the robot to do until the emotion is elevated to somewhat Joy or Fear. Thus, we cannot observe the modified motions if the robot 'refuses' to do the motion we requested. The behavior of the robot's response with interference from the Emotional-Personality system is observed in Scenario 3.

Table 10.1 Reserved Commands for Testing

Reserved Command	Description
“Say (a) happy <action>”	Do <action> with emotion = Joy
“Say (a) scared <action>”	Do <action> with emotion = Fear
“Say (a) sad <action>”	Do <action> with emotion = Sadness
“Say (an) angry <action>”	Do <action> with emotion = Anger

Table 10.2 Emotions vs. Fixed Motion Processing Parameter Values

Motion Processing Parameter	Emotions			
	Joy	Fear	Sadness	Anger
Continuity (c) (default = 0)	3	-1	2	-2
Tension (t) (default = 0)	-2	4	-2	4
Bias (b) (default = 0)	-1	0	1	2

Resampling rate (r) *(default = 1)*	3	1	1	5
High gain (h) *(default = 1)*	1	2	1	1
Medium gain (m) *(default = 1)*	3	-0.5	1	1
Low gain (l) *(default = 1)*	1	1	1	1.5

10.1.3 Scenario 1 – Set Up

The values for the motion processing parameters in Table 10.2 are determined based on the following intuitions (explored in Chapter 9):

1) The intuition gained from the animation theories on the continuity of transitions between joint positions, acceleration/deceleration, speed, and range of motion of an action/movement to convey Joy, Fear, Sadness, and Anger. In this case, we select the following motion characteristics for each emotion:

    1. Joy:
        - smooth/continuous transition from one joint angle position to the next,
        - observable acceleration/deceleration,
        - medium speed of motion (slower than the basic motion, but faster than the 7-points-interpolated version),
        - normal or increased range of motion.
    2. Fear:
        - rough/discontinuous transitions between joint angle positions,
        - very little acceleration/deceleration,
        - slow speed of motion,
        - normal or reduced range of motion.
    3. Sadness:
        - smooth/continuous transitions between joint angle positions,
        - very little acceleration/deceleration,
        - slow speed of motion,
        - normal or reduced range of motion.
    4. Anger:
        - rough/discontinuous transitions between joint angle positions,
        - very high acceleration/deceleration,
        - medium to high speed of motion,

- increased range of motion.

2) The intuition on the effects of different values of the parameters for the motion processing methods (Kochanek-Bartels Interpolation, (Re)Sampling, and Multiresolution Filtering) on a motion signal data:

   1. Kochanek-Bartels Interpolation:

      - *Continuity*: controls the direction (tangent) for the transition from one joint angle position to the next. *Continuity* < 0: more direct, immediate change of direction to the next position (linear, like a military march). *Continuity* >0: smooth, exaggerated motion with sudden change of direction to the next position. *Continuity* = 0: gradual change of direction from one position to the next.

      - *Tension*: controls the smoothness of the transitions between joint angle positions (the sharpness of the curves/corners), and also acceleration and deceleration. *Tension* < 0: rough transitions, more linear interpolation, *Tension* > 0: smooth transitions, more curved interpolation. Tension = 0: neutral/normal interpolation.

      - *Bias:* controls the positions of the *overshoot*. *Bias* < 0: pre-shoot, *Bias* > 0: post-shoot, *Bias* = 0: no overshoots.

   2. (Re)Sampling:

      - *Rate*: controls the duration of the motion. *Rate* = [1,8]. *Rate* = 1: no resampling, slowest motion, *Rate* = 8: restore basic motion (undoing Interpolation), fastest motion where the original motion is preserved.

   3. Multiresolution Filtering:

      - *High gain*: controls the gain of the high frequency components (e.g.: noise) of the motion signal. *High gain* < 1: smoothes the signal, removing noise, *High gain* > 1: accentuate noise, adds to discontinuities in the motion signal. *High gain* = 1: no effect.

      - *Medium gain*: controls the gain of the middle frequency components of the motion signal, affecting the range of motion (amplitude) throughout the motion signal. *Medium gain* < 1: decrease range of motion, *Medium gain* > 1: increase the range of motion, *Medium gain* = 1: no effect.

      - *Low gain*: controls the gain of the low frequency components of the motion signal, affecting the range of motion around *the middle* of the motion signal, and does not affect the range of motion at the beginning and end of the motion signal. *Low gain* < 1: decrease the range of motion, *Low gain* > 1: increase the range of motion, *Low gain* = 1: no effect.

10.1.4 Scenario 1 – Experiment

The experiment of Scenario 1 was done as follows:

1. Enter the text phrase:
   ```
   >> Say a happy wave
   ```

2. The ALICE engine will respond with:
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   >>  "a happy wave"
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3. The Perception system, using Regular Expression will extract the emotion keyword: “happy,” and the verb keyword: “wave”.
4. Evaluate if the executed Waving-arm motion has the characteristics defined for the emotion “happy” with respect to smoothness of transitions, existence of acceleration/deceleration, speed/duration of motion, and the range of motion.
5. Repeat step 1 and 2 by iterating through other emotions: “scared”, “sad”, and “angry.”

10.1.5 Scenario 1 – Results

The results of the experiments using Scenario 1 are as follows:

- The system were able to vary the acceleration, decelration, duration, and range of motion of the Waving-arm motion, but not very well on the continuity of the motion.
- We have confidence that some of our intuition on the relationships between the motion processing method parameters and the motion parameters are valid:
    - Increasing the value of the tension parameter adds acceleration/deceleration, while reducing the value reduces acceleration/deceleration – making the motion more linear/robotic. This property is seen when the movement of the arm gradually speeds up as the arm starts to move (acceleration) and slows down before reaching a stop (deceleration) at different points in the Waving-arm motion.
    - Increasing the rate parameter shorten the duration of the motion – making the motion seems hasted. Decreasing the rate parameter does otherwise. This property is apparent between the emotions: Joy vs. Fear, Joy vs. Sadness, Anger vs. Fear, Anger vs. Sadness, and slightly between Joy vs. Anger (with Anger tends to be faster because of the higher *rate* value than Joy). There is no difference in speed between Fear vs. Sadness as the *rate* values are the same for both emotions.
    - Increasing the medium and high frequency band gains increases the range of motion, and vice versa. The difference between the result from modifying the medium gain and modifying the low gain is seen on where in the motion the range of motion is increased. For the Joy emotion we set the medium gain = 3, while for the Anger emotion, we set the low gain = 1.5. With the Joy emotion, the range of motion was increased when the arm spreads out to the side after fully extended upwards. With the Anger emotion, the arm immediately spreads up and to the side from the rest position, without ever fully extended upwards. Thus the increase of range of motion by the medium gain is in the middle of the motion, while the increase of range of motion by the low gain is throughout the whole motion. This property is useful to realize Exaggeration.
- There are also some unexpected behaviors:
    - The execution of the motion is not entirely consistent. At several instances, the Waving-arm motion with the same emotion type was executed differently. For example, when the emotion is Joy, only 50% of the time the arm was spreaded far to the side (as the effect of the increased medium gain), while in the other times the arm was only extended upwards and immediately moved back down. It appears that the stream of position data was executed without waiting for the current one to be completed. For example: the current shoulder position is at 0. The next position is 60, and the position after that is -10. As the

servo rotates the shoulder to position 60, the second position data (-10) is already received, and the servo immediately changes direction according to this second data before reaching position 60.

10.1.5 Scenario 1 – Conclusions

We achieved Goal #1 and Goal #2 for this Scenario 1, but Goal #3 was only partially satisfied.

Goal #1 was achieved since we have shown that with one basic motion, we can generate four different movements. The four new movements varies with respect to the duration, acceleration/deceleration, and range of motion. The four variations was created only by using different parameter values for our set of motion processing methods (Kochanek-Bartels interpolation, (Re)Sampling, and Multiresolution Filtering).

Goal #2 was achieved by having shown that the Waving-arm motion was executed according to the mapping of the set of parameter values to the four emotion types (Joy, Fear, Sadness, and Anger) as shown in Table 10.2. In addition, this experiment shows that using the simple motion processing methods, we can quickly modify a motion data without having to painstakingly adjust each servo positions anymore. Instead, we can use simple commands, mapped to a small set of parameter values.

Goal #3 was only partially satisfied as the emotional characteristics of the motion was satisfied based on *our own specifications* on what a Joy, Fear, Sad, or Anger movements *should* look like – based on our developed intuition from animation theories. We are fully aware that the observer's perception of emotional expressions are often highly subjective. An untrained observer would have difficulties distinguishing between Joy or Anger, and Fear or Sadness with our specifications. We even doubt they would be able to tell that we 'infused' emotions into the motion. The observer's perception/opinion is investigated further in Scenario 2 and 3.

10.2 Scenario 2: Public Evaluation

10.2.1 Scenario 2 – Goals

The goals of the experiment in Scenario 2 are:

1) to investigate the perception of several observers (excluding the author) to see whether or not the different variations of the movements are perceived by the observers as expressing some kind of emotion.
2) To gain feedback from the observers on what they perceive/expect as the characteristics of Joy, Fear, Sadness, and Anger emotions in a movement.

10.2.2 Scenario 2 – Description

We fully acknowledge the subjective nature of our thesis, and the proving of our thesis is a challenge to achieve objectively. Therefore, we invited several observers to provide their perception and feedback on the variations of the motion of the robot. In this experiment, we would like to investigate the following:

- Does/can the observer recognize the executed modified motion as the same action as the original motion? (For example: does the angry Waving-arm motion still recognized as a Waving-arm action?)
- Do our motion-emotion specifications agree with the observer's motion-emotion specifications?

10.2.3 Scenario 2 - Set Up

10.2.4 Scenario 2 – Experiment

10.2.5 Scenario 2 – Result

10.2.6 Scenario 2 - Conclusions

10.3 Scenario 3: 'Driving' the Emotion of the Robot with the Emotional-Personality model

10.3.1 Scenario 3 – Goals

The goals of the experiment in Scenario 3 are:

1) to examine if context-based motion responses enable observers to more easily identify the emotion expressed by the robot through its motion, and
2) to evaluate the user experience with the human-robot interaction, with the addition of emotionally-expressive motion responses.

10.3.2 Scenario 3 – Description