Robotic Architecture for Experiments on Emotional Behavior

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Abstract: Research in the area of computational approaches to emotions has received increased attention over the last years. The present paper focus two directions: first part investigate emotion from a computational perspective, in order to improve human – robot interaction. The second part presents an experimental approach regarding animatronics design in conjunction with realistic animated motions. The protocol implemented source files are indicated as download files and future project development directions are presented.

Keywords: emotion, social robot, emotional behavior, computational model of emotion, human – robot interaction.

1. INTRODUCTION

In recent years, emotion has increasingly been used in interface and robot design, primarily because of the collective acknowledgement, people tends to treat computers as they treat other people. Moreover, many studies have been performed to integrate emotions into products including toys, electronic games and software agents (Kwon, 2008). However, for robotic field research, emotions are meaningless unless they result in some outward change in the robot, including facial, vocal, or behavioural modifications (Gockley, 2006).

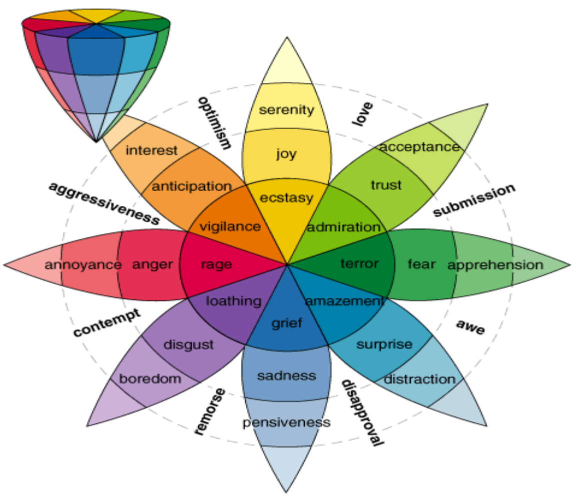

Fig. 1. Plutchik's Diagram of Emotion Wheel (Plutchik, 1980)

Artificial emotions are used in social robots because they facilitate believable human–robot interaction, they can also provide feedback to the user, such as indicating the robot's internal state, goals and intentions. Emotions can act as a control mechanism, driving behavior and reflecting how the robot is affected by, and adapts to, different factors over time (Kwon, 2008).

Emotion can be used to coordinate planning, to determine control precedence between different behavior modes and to trigger learning and adaptation, particularly when the environment is unknown or difficult to predict. One approach is to use computational models of emotions that mimic animal survival instincts, such as look for food, escape from danger, etc. (Breazeal, 2003). Several researchers have investigated the use of emotion in human–robot interaction. Suzuki (Suzuki, 1998) describe an architecture in which interaction leads to changes in the robot's emotional state and modifications in its actions. Breazeal (Breazeal, 2003) presents how emotions influence the operation of Kismet's motivational system and how this affects its interaction with humans. Nourbakhsh (Nourbakhsh, 1999) discusses how mood changes can trigger different behavior in Sage, a museum tour robot (Kwon, 2008).

This paper is organized as follows: Section 2 is dedicated to fundamental issues concerning emotions, Section 3 briefly presents social robots; Section 4 presents our experimental study, Section 5 describes the Voice

Recognition Module and, finally, Section 6 concludes the paper.

2. FUNDAMENTAL ISSUES CONCERNING EMOTIONS

2.1 Towards a generic definition of "emotion"

Emotions play a major role in human interaction. Quite often, emotional reactions are caused by social interactions, influenced by societal and cultural norms, or used to communicate desires to other people. Emotions carry conversational content, allowing conversational partners to form common ground and communicate more effectively (Gockley, 2006).

The ample scope of affective phenomena opens up a definition space that can be explored through many different perspectives, and results in varied descriptions at multiple levels of abstraction. Thus it is difficult to reach consensus in the characterization of affect and emotion (Velasquez, 2007). Kleinginna (Kleinginna, 1981) considers 92 different definitions given by researchers, organized to different categories, ranging from their relation to physiological components or emotional behaviors, to definitions based upon motivational and adaptive views, together with 9 skeptical remarks, regarding that emotion is not such a useful concept.

In 1984, Scherer defines emotions as feeling states, and measure these states by asking the subjects about the "level" of emotions they are experiencing (Scherer, 1984), while Plutchick in 1962 define emotion as "a patterned bodily reaction of either destruction, reproduction, incorporation, orientation, protection, reintegration, rejection or exploration, or some combination of these, which is brought by a stimulus." (Plutchick, 1962). Scherer (Scherer, 2000), considers the following phenomena important in developing an affective model: emotions, moods and attitudes.

2.2 Modeling Emotion

Recent years have seen a significant expansion in research on computational models of human emotional processes, driven both by their potential for basic research on emotion and cognition as well as their promise for an ever increasing range of applications.

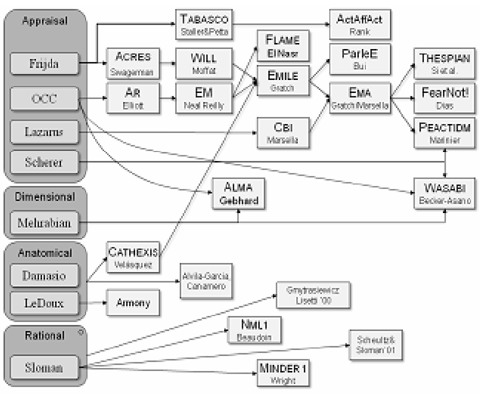

Fig. 2. Several computational models of emotion (Marsella, 2010)

Architectures are being built both to elucidate mechanisms of emotions and to enhance believability and effectiveness of synthetic agents and robots (see Figure 2).

This has led to a truly interdisciplinary and mutually beneficial partnership between emotion research in psychology and computational science (Marsella, 2010).

Key components of emotional processing are the mechanisms that evaluate a current internal and external situation, in terms of an affective state or emotion. This process is referred to as appraisal, (also cognitive appraisal). Appraisal theory develops a catalogue of human emotions and seeks to provide a computational account of the 'appraisals' that lead one emotion to be evoked over another, but without the 'heat' provided by emotion's biological underpinnings in humans. Appraisal theory is therefore a good candidate for algorithms that enable a robot to simulate the appearance of human emotional behavior. However, a good theory of robot emotions must address the fact that many robots will have no human–computer interface, thus a more abstract view of emotion is required (Arbib, 2004).

Dimensional theories of emotion argue that emotion and other affective phenomena should be conceptualized as points in a continuous dimensional space, while anatomic theories stem from an attempt to reconstruct the neural links and processes that underlie organisms' emotional reactions. Rational approaches start from the question of what adaptive function does emotion serve and then attempt to abstract this function away from its "implementation details" in humans and incorporate it into a model of intelligence (Marsella, 2010).

2.3 Basic Elements of Emotional Phenomena

Searching for irreducible elements of emotion, the most important accounts correspond to those that view the range of emotional phenomena as a set of discrete emotions, and those which take on the perspective that emotions can be further reduced into specific dimensions (Velasquez, 2007).

Many researchers argue that any given emotion is reducible to a small number of underlying dimensions.

Earlier approaches take a two-dimensional view of emotion in which the two dimensions correspond to valence (how positive or negative the emotion is) and arousal (the energy or excitation level associated with the emotion) (Velasquez, 2007). Thus, an emotion is considered to be either pleasant or unpleasant (also labeled as positive or negative), either activated or deactivated (also labeled as aroused or sleepy, and engaged or disengaged) (Marsella, 2010).

In Figure 3 the Circumplex Model of Affect proposed by Russell (Russell, 2003) was represented, which is one of the major models of emotion The Circumplex Model of Affect is a spatial model based on dimensions of affect and this affective concepts fall in a circle in the following order: pleasure, excitement, arousal, distress, displeasure, depression, sleepiness and relaxation (see Figure 3). According to this model, there are two components of affect that exist: first, pleasure-displeasure, the horizontal dimension of the model, and second arousal-sleep, the vertical dimension of the model. Therefore, it seems that any affect word can be defined in terms of its pleasure and arousal components. The remaining four variables mentioned above do not act as dimensions, but rather help to define the quadrants of the affective space (Altarriba, 2003). It is obvious that this kind of classification is based upon self-reports and introspection and such a model is deeply subjective.

Modeling the emotion computationally implies thinking on a much lower level of abstraction, because at some point it is necessary to be able to relate these emotions and their localization in this two-dimensional space in terms of some measurable feature of the body, or reveal something about the kind of behavior that these emotional experiences result in, such as approach or avoidance (Velasquez, 2007).

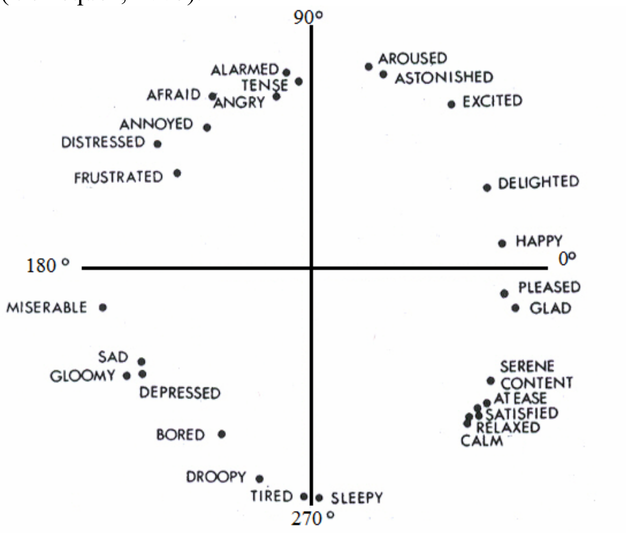

Fig. 3. A circumplex model of affect (Russell, 2003)

Each emotion is characterized by physiological and behavioral qualities, including movement, posture, voice, facial expression, and pulse rate fluctuation.

TABLE I
A SELECTION OF LISTS OF "BASIC" EMOTIONS (ORTONY, 1990)]

Refference	Fundamental emotion	Basis for inclusion
Arnold (1960)	*Anger, aversion, courage, dejection, desire, despair, fear, hate, hope, love, sadness*	Relation to action tendencies
Ekman, Friesen and Ellsworth (1982)	*Anger, disgust, fear, joy, sadness, surprise*	Universal facial expressions
Frijda (1986)	*Desire, happiness, interest, surprise, wonder, sorrow*	Forms of action readiness
Gray (1982)	*Rage and terror, anxiety, joy*	Hardwired
Izard (1971)	*Anger, contempt, disgust, distress, fear, guilt, interest, joy, shame, surprise*	Hardwired
James (1884)	*Fear, grief, love, rage*	Bodily involvement
Mowrer (1960)	*Pain, pleasure*	Unlearned emotional states
Oatley and Johnson-Laird (1987)	*Anger, disgust, anxiety, happiness, sadness*	Do not require propositional content
Panksepp (1982)	*Expectancy, fear, rage, panic*	Hardwired
Plutchik (1994)	*Acceptance, anger, anticipation, disgust, joy, fear, sadness, surprise*	Relation to adaptive biological processes
Tomkins (1984)	*Anger, interest, contempt, disgust, distress, fear, joy, shame, surprise*	Density of neural firing
Watson (1930)	*Fear, love, rage*	Hardwired
Weiner & Graham (1984)	*Happiness, sadness*	Attribution independent

Ekman (Ekman, 1982) and others argue for a set of "basic" emotions that are innate and universal across cultures: anger, disgust, fear, joy, sadness, surprise. All other emotional categories are then built up from combinations of these basic emotions (Gockley, 2006).

There are three main ways in which the notion of basic emotions has been used in the literature (Velasquez, 2007). Ekman (Ekman, 1999) suggests that there are a number of discrete emotions that differ one from another in important ways. For instance, fear, anger, and joy differ in their eliciting conditions, as well as in their usually associated behavioral and physiological characteristics.

Plutchick (Plutchick, 1994) argues that these emotions are fundamental and sufficient elements to describe all emotional phenomena. The term basic applies to them in the sense that they are descriptive of the most common emotional phenomena, and when combined, they can produce other more complex emotions (Velasquez, 2007).

Izard (Izard, 1977) suggests that these discrete emotions have a biological basis, and they are basic for the organism. They evolved due to their adaptive value in helping organisms deal with recurrent, fundamental life- and survival related tasks. Thus, the characteristics shared by these emotions are largely biologically determined (Velasquez, 2007).

Ekman's model (Ekman, 1982), with its six basic emotional states, has been influential in work on emotional expression in robots. The Kismet robot (Breazeal, 2003), for example, can communicate an emotive state and other social cues to a human through facial expressions, gaze, and the quality of the voice. The computations needed to communicate an 'emotional state' to a human might also improve the way robots function in the human environment (Arbib, 2004).

To achieve a translation from emotions into facial expressions, emotions need to be parameterized. In the robot Kismet (Breazeal, 2003), facial expressions are generated using an interpolation-based technique over a three-dimensional, componential affect space (arousal, valence, and stance). Probo (Saldien, 2008) uses two dimensions (valence and arousal) to construct an emotion space, based on the circumplex model of affect defined by Russell (Russell, 2003). In the emotion space a Cartesian coordinate system is used, where the x coordinate represents the valence and the y-coordinate the arousal, consequently each emotion e (v, a) corresponds to a point in the valence-arousal plane (Figure 4). This way, the basic emotions can be specified on a unit circle, placing the neutral emotion e (0, 0) in the origin of the coordinate system. Thus, each emotion can also be represented as a vector with the origin of the coordinate system as initial point and the corresponding valence-arousal values as the terminal point.

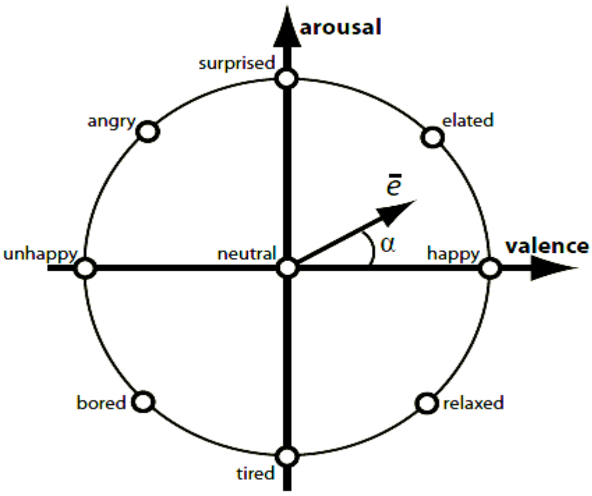

Fig. 4. Probo emotion space (Saldien, 2008)

The direction α of each vector defines the specific emotion, whereas the magnitude defines the intensity of the emotion. The intensity i can vary from 0 to 1, interpolating the existing emotion i = 1 with the neutral emotion i = 0. Each DOF that influences the facial expression is related to the current angle α of the emotion vector.

3. SOCIAL ROBOTS

In recent years, the robotics community has seen a gradual increase in social robots, that is, robots that exist primarily to interact with people (Gockley, 2006). Robots are used to entertain humans with an active and affective communication expressing emotions through various communication channels. The robot AIBO is used as an amusement toy, PARO (Shibata, 2003) is a seal-like robot developed to help the healing process of infants in a hospital environment, the Aurora project (Nadel, 1999) created a robot called Robota that deals with children who have psychological or physical learning and communication difficulties and facilitates the emotional development of children by engaging them in interactive games that encourage expressing their affective states while playing with the robot. Another robot developed by NEC called PaPeRo or robots with infant-like abilities of interaction, such as Kismet (Breazeal, 2003), have been used to demonstrate the ability of people to interpret and react appropriately to a robot's displays of emotions. Museum tour-guide robots (Nourbrakhsh, 1999) and robots that interact with the elderly (Montemerlo, 2002) demonstrate not only the benefits of having robots interact with people, but also the need for the interactions to be smooth and natural. Many of these robots have incorporated at least some rudimentary emotional behaviors, but such behaviors are usually ad-hoc and not extensible to other robots (Gockley, 2006).

Thus such social robots could be found in education, in virtual learning situations, in advisory services where it is planned to make information systems more accessible to users when embodied conversational agents to assist them in dealing with specific situations. The area of entertainment is also an important area of application for such systems, as can be seen in the example of various computer games based on avatar technology as well as the success of small robots, which are used as children's toys.

In the framework of the interdisciplinary European research project "Humaine" the key abilities of an emotional embodied conversational agent are defined as follows: first, the ability to co-ordinate different signs such as gestures, facial expression, posture and language; second, articulateness and expressiveness, and third, the generation of affectivity and attentiveness in the communication process.

All robot systems, whether socially interactive or not, must solve a number of common design problems. These include cognition (planning, decision making), perception (navigation, environment sensing), action (mobility, manipulation), human–robot interaction (user interface, input devices, feedback display) and architecture (control, electromechanical, system). Socially interactive robots, however, must also address those issues imposed by social interaction (Kwon, 2008).

4. EXPERIMENTAL STUDY

Wowwee Alive Chimpanzee is an experimental platform for human-robot interaction. It has three touch sensors (one under his chin, one on the back and one on the top of his head), two vibration sensors and two microphones (both ears).

Fig. 5. Woowwee Alive Chimpanzee

The Chimpanzee has four moods which determine his reactions to user interaction: curious (default mood), happy, fearful and angry. The Chimpanzee's emotions change as a direct result of how he is treated.

The Chimpanzee's Infrared Vision System enables him to detect movement in front of him. His vision is on only when he is not moving or making a sound. The Chimpanzee will track objects in front of his face: up, down, left and right. When tracking an object the Chimpanzee will keep his vision locked on it until he loses sight of it. This will not affect his mood. The Chimpanzee has a Stereo Sound Detection System which can detect sharp, loud sounds (like a clap) to his left, his right and directly ahead. He will only listen when he is not moving or making sound.

When he hears a sound, the Chimpanzee will respond with an animation. His hearing and vision is pretty limited to stimuli just 10-20 cm from his face. Responding to sounds will also influence his mood.

In the head there are eight motors (6V DC motor), which are moving the head and the eyes up and down, left and right, moving the mouth and eyelids open and close and the eyebrows and nose up and down.

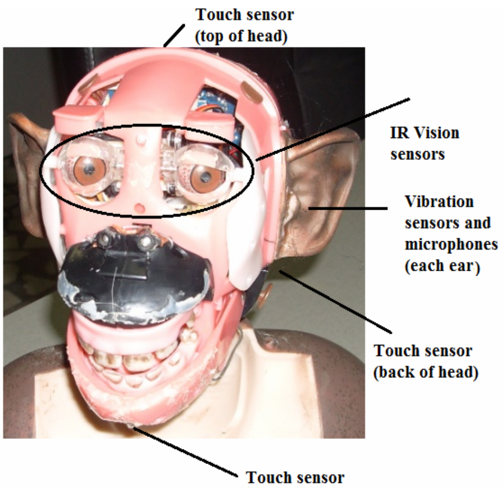

Fig. 1. The Chimpanzee Sensors

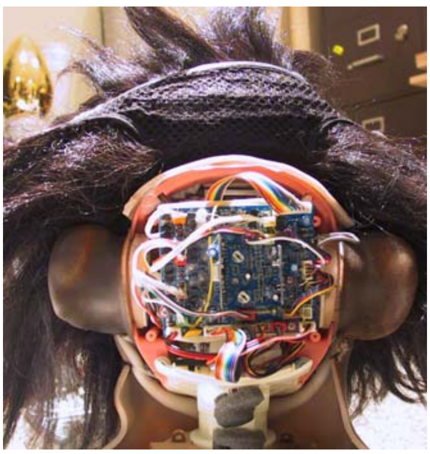

Fig. 2.The Chimpanzee "Anatomy"

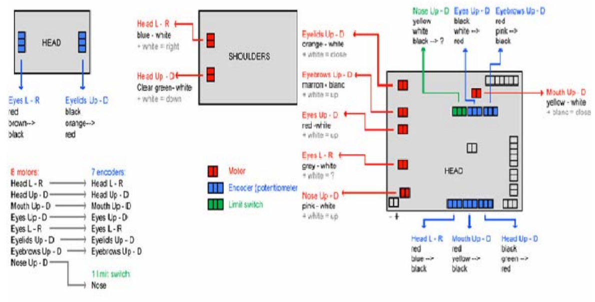

Fig. 3. Initial control board structure

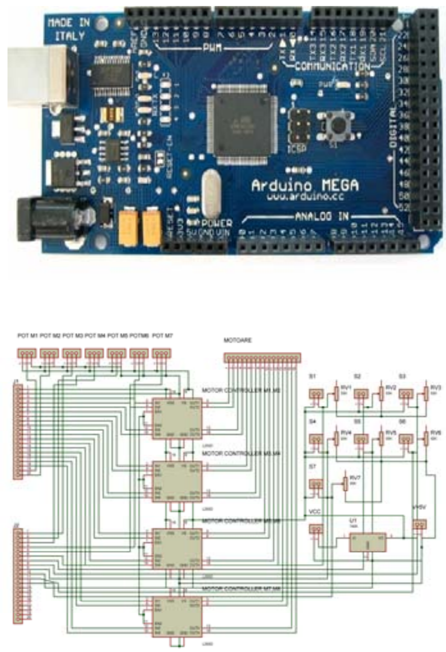

Fig. 4. The Arduino Mega 2560 Board

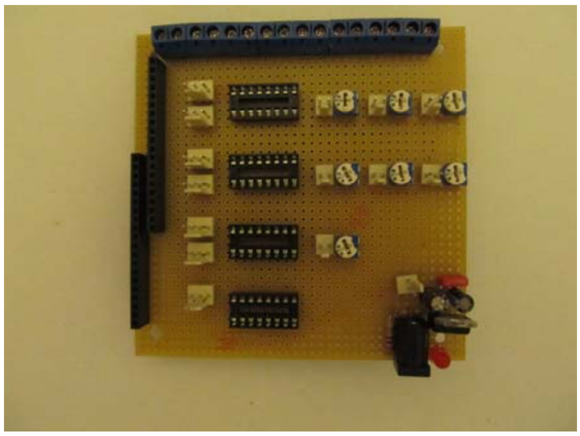

Fig. 5. Motor controls circuit and sensor interface

The original robot was controlled by the remote. For testing and performance enhancement, we have added a "parasitic" microcontroller to the Chimpanzee that allows external control of this device. Arduino Mega 2560 was chosen, a microcontroller board based on the ATmega2560 with a number of facilities for communicating with a computer or other microcontrollers.

The motor control circuit and sensor interface is based on L293D driver structure.

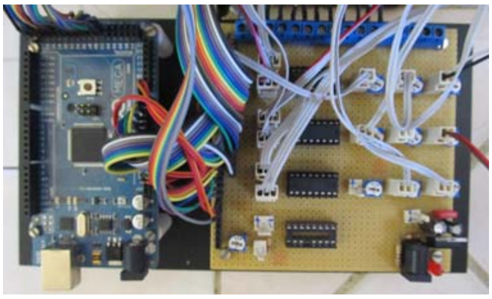

Fig. 6. Arduino based, adapted control architecture

For testing the experimental structure the following protocol was proposed:

1: The robot is waiting for signal from the sensors (the active sensors are the touch sensor under the chin, the force sensor placed on top of the head, the sound sensors and the vibration sensors from the ears and the light sensors)

2: If the force sensor from the chin is activated the light tracking mode is initialized and the biomimetric structure follows the light in a horizontal plane.

3: If the force sensor on top of the head is activated the head's up-down movement sequence is initialized which is repeated 3 times.

4: If the sound sensor in the left ear is activated the chimp reacts by turning its head left.

5: If the sound sensor in the right ear is activated the chimp reacts by turning its head right.

6: If the vibration sensor in the left ear it is stimulated the chimp reacts with a sequence in which it moves its eyes from left to right and blinks.

7: If the vibration sensor in the right ear it is stimulated the chimp reacts with a sequence in which it moves its eyes up and down and moves its eyebrows.

The animatronics architecture reactions where realistic as alive acting. The proposed protocol program can be downloaded from the address: http://ww.robotics.ucv.ro/raluca/experiments/act_1.pdf.

5. ADDING VOICE RECOGNITION MODULE

An usual speech recognition system, installed on a computer identify each word through a complex set of algorithms and display/print them out in order that the words was spooked. But only few computers programs really "understand" what the line of words mean or the context in which they are used.

In the microcontrollers/microprocessor or stand-alone speech recognition board world, the idea of understanding it is more simplified but in the same time more efficient: the words "go right" triggers another line of code to make the left motor (in a differentially driven robot) turn more revolutions than the right motor. The Speech recognition sounds a bit more applicable to a computer understanding commands given to it, as "speech" refers to a series of words that imply an idea, command, or meaning. "Voice" recognition can refer to just the sound of a person's voice or a single word triggering the computer. Of course, in order to interpret vocal command, the usual voice recognition system must to be trained by the user. The most complex system is continuous listening of speech without having to press a button to start a period of listening. The reference speech patterns can be stored on a hard drive for a computer-based program, or static RAM or Flash memory for a stand-alone board. A comparator checks these stored word or phoneme patterns against the output of the A/D converter and makes a determination of what word was spoken into the microphone.

VRBOT offers possibilities of recognizing 30 voice commands, customized by user.

Fig. 7. VRBOT module

A Voice Recognition Module (VRBOT) module was connected to the experimental structure. The VRBot module added to experimental Chimps architecture add voice command functionality to the experiment. The module use for control voice recognition functions for built-in Speaker Independent (SI) commands and up to 32 user-defined commands (Speaker Dependent (SD) trigger or commands, Voice passwords (SV)).

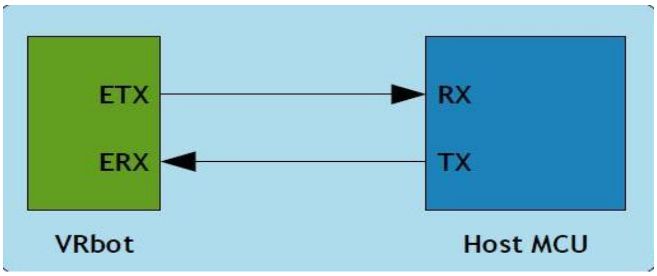

Fig. 8. VRBot communication connections

The communication between this module and microcontroller's board is a serial protocol (9600 8-N-1 default). The VRBot consume typically 12 mA current and use between 3.3 and 5.5V in operation.

The main function of VRBOT are:

• A host of built-in speaker independent (SI) commands (available in US English, German, Italian and Japanese) for ready to run basic controls.

• Supports up to 32 user-defined Speaker Dependent (SD) triggers or commands (any language) as well as Voice Passwords.

• Easy-to-use and simple Graphical User Interface to program Voice Commands to your robot.

• Languages currently supported for SI commands: English U.S., Italian, Japanese and German. More languages available in the near future.

• Module can be used with any host with an UART interface (powered at 3.3V - 5V) .

• Simple and robust serial protocol to access and program the module through the host board.

There are four kinds of commands :

- Trigger - is a special group where it is defined SI trigger word (default word it is "ROBOT"). The user can add one user-defined SD trigger word. Trigger words are used to start the recognition process

- Group - where user can add user-defined SD commands

- Password - a special group for "vocal passwords" (up to five), using Speaker Verification (SV) technology

- Word set - built-in set of SI commands

The user can define groups of SD commands or passwords and generate a basic code template to handle them. The recognition function of VRbot works on a single group at a time, so that users need to group together all the commands that they want to be able to use at the same time.

When VRbotGUI connects to the robot, it reads back all the user-defined commands and groups, which are stored into the VRbot module non-volatile memory.

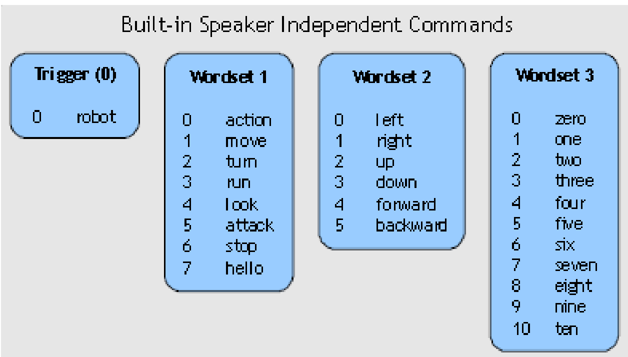

Fig. 9. Built-in speaker independent commands

The experiments with modified animatronics architecture was successful, but the commands used for the begin was imitated only to built-in speaker independent commands.

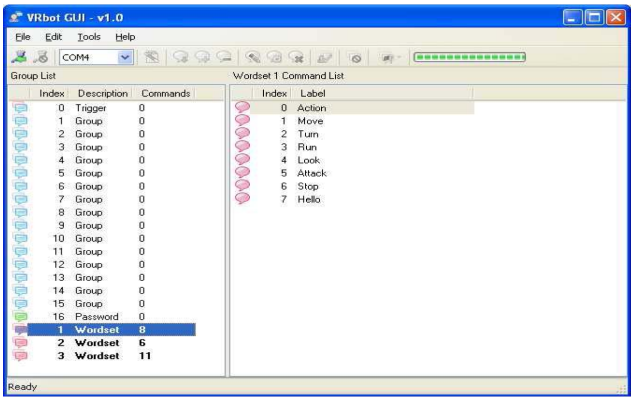

Fig. 10. GUI for VRBot : sample programming

One can download program sample from the address: http://www.robotics.ucv.ro/raluca/experiments/act_2.pdf.

6. CONCLUSIONS

In the last few years there has been an increased interest for research in the area of computational approaches to emotions.

The idea of our experimental project is the design and implementation of an emotional architecture which allows an easy integration of new drives, sensors, actors and behaviors. In the future, we intend to implement with the existing equipment a robot affective system that will produce the robot's emotional states in accordance with the internal and external stimuli such as interactions between the user and the Chimpanzee. Human – robot interaction will be enhanced by implementing a communication module which consists of a MP3 Trigger, thus giving the robot the ability to play MP3s file (pre-recorded answers) as response.

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