

## Simulation of the emotional states using a biomimetic structure

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**Abstract.** This paper presents the control of biomimetic structures, using the PID regulation algorithm and the Arduino ATMEGA microcontroller. By controlling of the Chimpanzee Alive biomimetic structure, the following emotional states can be obtained: joy, sadness and anger. The biomimetic structure has 8 DC motors that control the following elements: eyebrows, eyelids, nose, mouth, eyes and neck. These emotional states are obtained by requiring reference to the position of the eyebrows, eyelids and mouth. An expressive state of the human face is mainly due to the effective position of the eyebrows, eyelids and mouth.

### 1. Introduction

One of the most popular theories of emotion is the Plutchik American psychologist who proposed a detailed classification of emotional responses. He proposed a set of eight basic emotions, which are divided into four pairs of opposite states: joy-sadness, acceptance-disgust, surprise-anticipations, and anger-fear. All these emotions are considered innate. The Plutchik also created a wheel of emotions used to describe the connections between them [1]. His model is the connection between the idea of emotion circle and a colour wheel. Like colours, primary emotions can be expressed at different intensities and can be mixed to form different emotions. Circumplex model is seen as a vertical section of a conical model of emotion [2]. According to Plutchik, people can have opposing emotions at a time. Emotions that are the base of the cone are considered to be the most intense and as the intensity decreases are harder to distinguish [3].

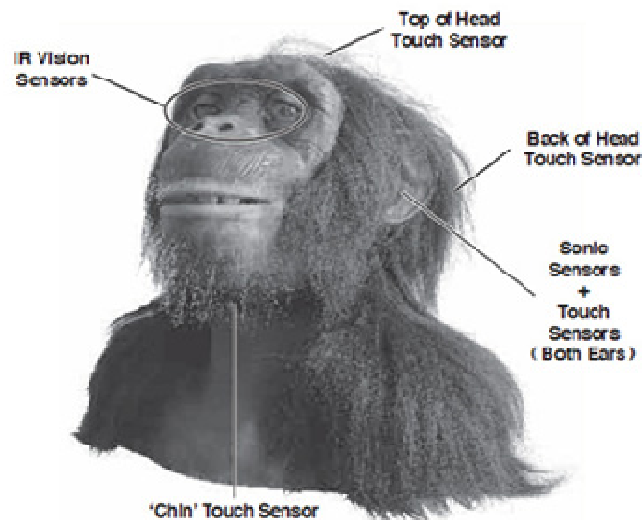
### 2. Experimental Biomimetic structure

In order to experiment implementation of emotional state modified biomimetic architecture based on Wow Wee CHIMPAZEE ALIVE is implemented Figure 1.

The experimental architecture has dc motors for:

- eyebrows movement
- eyelids movement
- mouths movement
- left-right eyes movement
- eyes movement up and down
- left-right head movement
- head-to-head movement
- move nose up and down





**Figure 1.** The robot Chimpanzee Alive [5].

The potentiometer that provides information about the positions of the three s, p, g elements connects to the analogue inputs of the development board. These potentiometers are mechanically coupled to the motor shaft by means of a reductor as in Figure 2. The displacement of the elements causing the change of the s, p and g parameters/positions is limited by the physical / constructive characteristics of the eyebrow, eyelid and mouth, so that for each of them a range / interval of variation comprising a lower maximum limit and a maximum upper limit can be determined. This displacement is proportional to cursor displacement and results in the engagement of each potentiometer cursor attached to the motors. The variation ranges established for each variable are different and necessarily lower than the maximum range of potentiometers, specifying that for each potentiometer the maximum range of variation is between 0 and 5V. All potentiometers are powered from the Arduino MEGA development board from the GND output pins and + 5V.

The determination of variation ranges for each potentiometer is required for the construction of reference blocks for expressive / biomimetic states, since the values prescribed for the s, p and g parameters will take values within the range that belong to these variation domains.



**Figure 2.** The ensemble motor-reductor-potentiometer

Also, besides position transducers (potentiometers) required to indicate the position of the eyebrows, eyelids and mouth, the chimpanzee robot also has the following transducers and sensors, Figure 1:

- potentiometer for indication of left-right eyes position
- potentiometer to indicate the position of the eyes up and down

- potentiometer to indicate left-right head position
- potentiometer to indicate top-down head position
- switch to indicate nose position up
- touch sensor positioned in the chin
- touch sensor positioned above the head
- touch sensor positioned behind the head
- touch sensors positioned in the two ears
- ultrasonic sensors positioned in the two ears
- infrared sensors positioned in both eyes

In Figure 3a) is presented modified biomimetic structure (chimpanzee ALIVE), and in Figure 3 b1)-b3) the mechanical structure of main emotion expressive states variable s (eyebrows), p (eyelid), g(mouths) are highlighted.



a) The Chimpanzee Alive modified structure



b1) The eyebrow (s variable) action mechanism



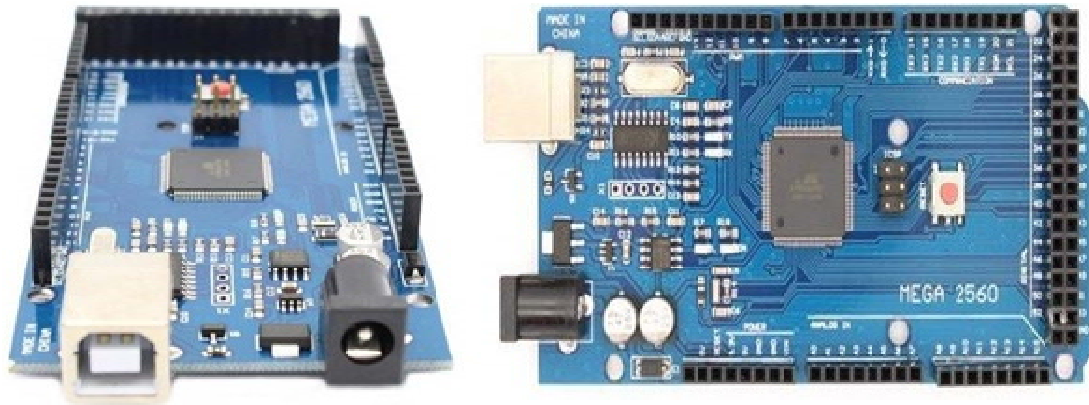
b2) The eyelid (p variable) action mechanism



b3) The mouth (g variable) action mechanism

**Figure 3.** The Chimpanzee Alive structure and its three mechanisms of action.

The connecting sensors to a development board with microcontroller requires the allocation of a large number of inputs, of which seven analog inputs for potentiometer. Therefore, use the ARDUINO MEGA board, Figure 4, which uses the ATmega2560 microcontroller and the ATmega16u2 microcontroller for USB connectivity [6].

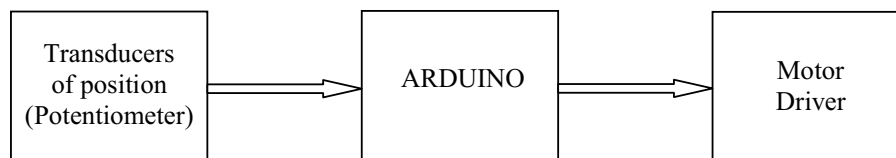


**Figure 4.** The ARDUINO MEGA board [6]

ARDUINO MEGA is an ideal development board for applications that need multiple communication pins, analogs and PWMs. It has the following features:

- 54 digital input / output pins, of which 14 can be PWM
- 16 analog input pins
- recommended input voltage 7-12V
- 5V supply voltage
- frequency 16MHz

In Figure 5 is emphasized the transmission of the information for the realization of expressive states.



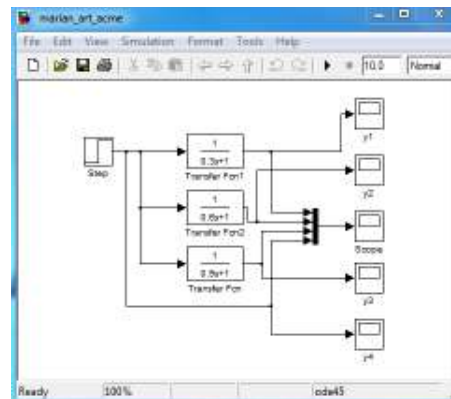
**Figure 5.** Transmission of the information for the realization of expressive state.

### 3. The simulation of the biomimetic states

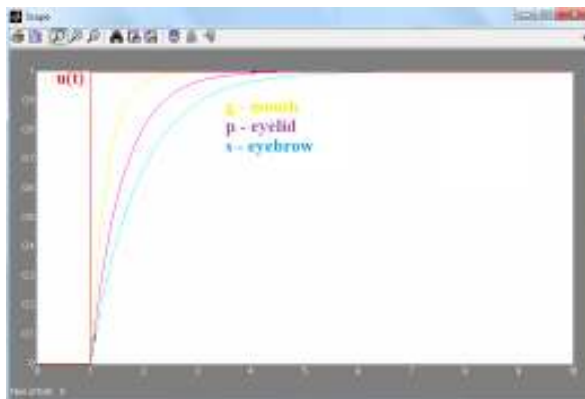
Simulation of the control structure for studied biomimetic architecture was performed in Matlab / Simulink environment. In the Figure 6 shows the simulation scheme in the matlab environment for the control architecture with PID regulation algorithm and implemented with a P type regulator.

Figure 7 shows the results of the simulation in the matlab environment of the variation of the output values (positions of the variables s, p, g) at a step variation of a reference value for a certain biomimetic state. The variation of the robot output s, p, and g, which shows that they do not show over-regulation, as their evolution is of the aperiodic type.

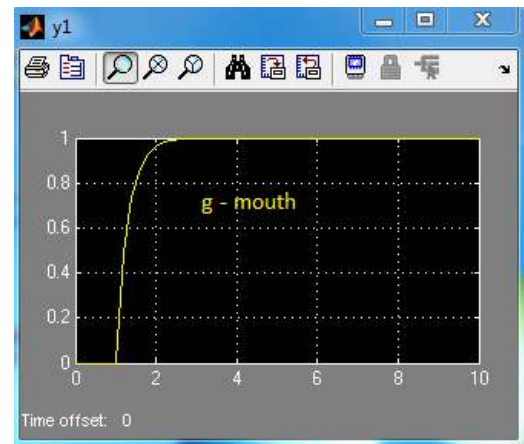
Since the potentiometers from the actuating mechanisms of the three elements of the biomimetic structure that determine a certain expressive state have a low regulation curve, the regulator parameters of the P-type regulator have been chosen so as to have a slow variation of the motors.



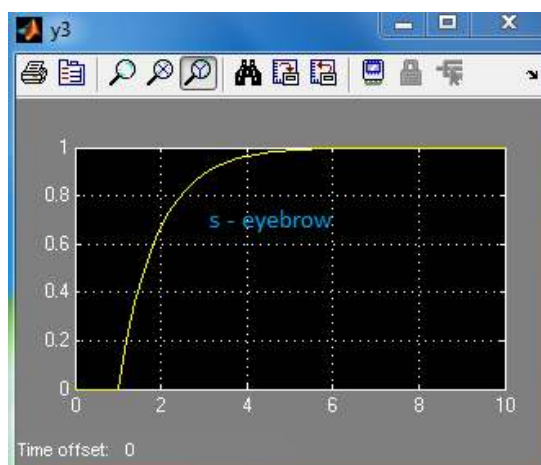
**Figure 6.** Simulation scheme in simulink for the control biomimetic structure.



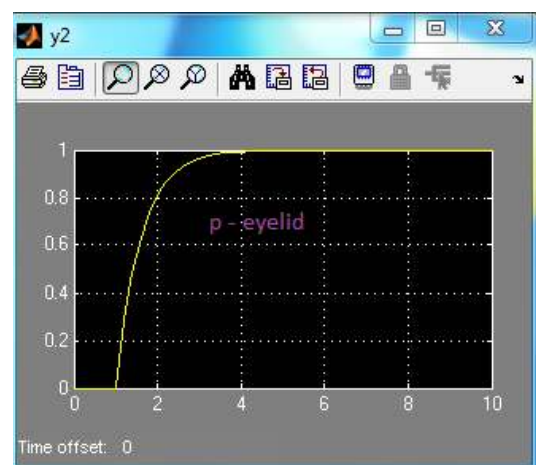
Simulation of the variation of the output values ( the variable s, p, g)



Simulation of the variation of the the variable g – mouth to step input



Simulation of the variation of the the variable s – eyebrow to step input



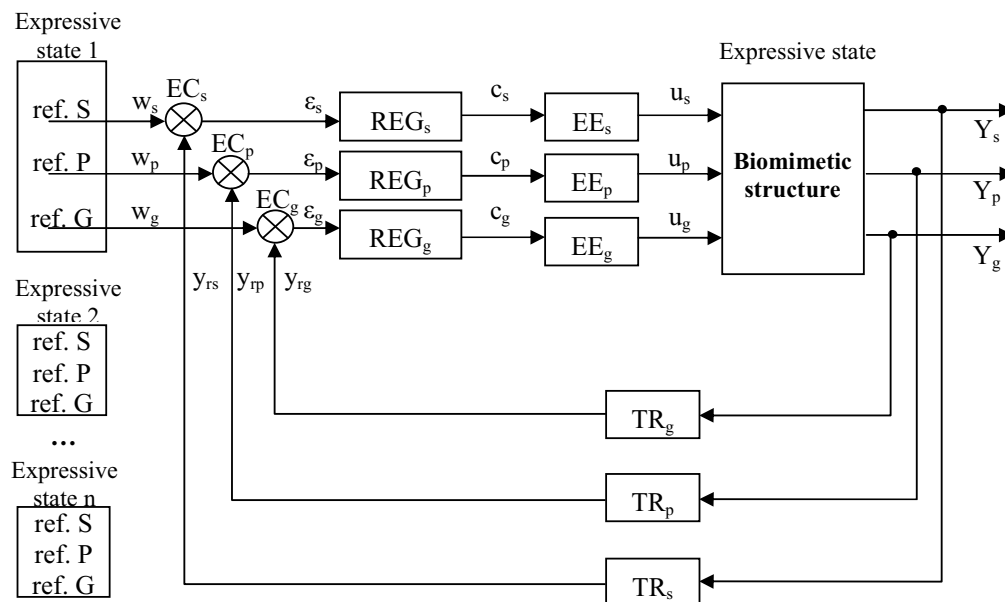
Simulation of the variation of the the variable – eyelid to step input

**Figure 7.** The simulation of the variation of the output values ( the variable s, p, g)

#### 4. Description of the control architecture for command of biomimetic structure

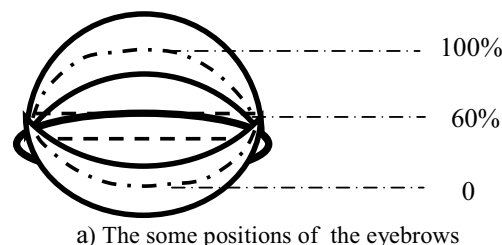
Using the experimental biomimetic platform, based on the simulation results, the basic emotional states (or expression states) are implemented. These states can be obtained within the control architecture by imposing references to the actual positions of the eyebrows, eyelids and mouths. It can be considered that the expressive state of a primate (chimpanzee in this case) or of a human face is mainly given by the actual positions of the eyebrows, eyelids and mouth. The actual positions of these elements were obtained for each base expression state using an experimental analysis of these by comparison.

The control of this structure is achieved by three regulators with regulation algorithms proportional-integrator-derivative, three EEs on the direct path and three position transducers (TR) located on the reaction path with the possibility of changing the reference quantities for each emotional state in part, as in Figure 8.



**Figure 8 .** Block diagram of the command and control of emotional states.

As stated, an expressive state of the human face (or primate) is mainly given by the effective position of eyebrows (s), eyelids (p) and mouth (g). From the analysis of the actual positions of the eyebrows (s), the eyelids (p) and the mouth (g), corresponding to the underlying expressive states, the variation domains for these variables can be defined. In the Figure 9 a) [4] is presented the s variable for the eyebrows that has the variation range:  $s \in [0, 100]$  [%] and in the Figure 9 b1)-b3) are presented the some positions (maxim, minim and neutral) of the eyebrows.



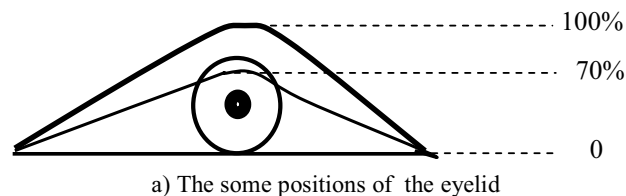




**Figure 9.** The range of the eyebrows [4].

The eyebrows for the neutral facial expression has the position '60' [%], for the high position (maximum) is '100' and for the low (minimum) position '0' [%].

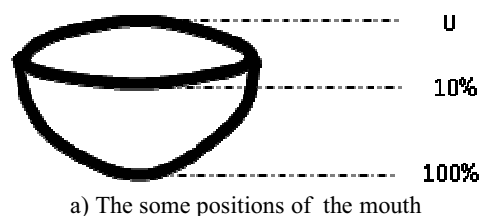
In the Figure 10 a) [4] is presented the  $p$  variable for the eyelid that has the variation range:  $p \in [0,100]$  [%] and in the Figure 10 b1)-b3) are presented the some positions (maxim, minim and neutral) of the eyelid.



**Figure 10.** The range of eyelid variation [4].

The eyelid for the neutral facial expression has the position '70' [%], for the closed position (minimum) it has '0' [%] and for the high position (max) '100' [%].

In the Figure 11 a) [4] is presented the  $g$  variable for the mouth that has the variation range:  $g \in [0,100]$  [%] and in the Figure 11 b1)-b3) are presented the some positions (maxim, minim and neutral) of the mouth.





**Figure 11.** The variation range of the mouth [4].

The mouth is relaxed (neutral facial expression) for position '10' [%], opened to maximum at '100' [%] and tightens (minimum) to '0' [%].

Through a study and observation of the positions of the three variables  $s$ ,  $p$ , and  $g$ , based on the variation domains established for them, for each elementary expression / biomimetic state are determined the minimum, maximum and intermediate values of variables  $s$ ,  $p$ ,  $g$ , as percentage of the extreme values of the variation domains.

Table 1 defines the range of variations of the quantified values of the analog-to-digital converter for the analog signals sent from the potentiometers (the reaction transducers) and their association with the elementary biomimetic states.

For biomimetic structures of the same type, the ranges of variations of the quantified values are different, because the potentiometer mounting positions are different for each biomimetic structure. For example, if two identical biomimetic structures are available, different values will result for the  $s$ ,  $p$ ,  $g$  parameters.

By powering the motors in both directions to the end of course, they will cause the  $s$ ,  $p$ ,  $g$  to change, and will determine the variation ranges of these parameters (from the minimum value to the maximum value).

For each parameter, the minimum and maximum values are in the range  $[0; 1024]$ . The maximum value 1024 corresponds to the situation when the potentiometer cursor has a maximum trip (up to the potentiometer end of the maximum potential) and provides the maximum value of 5V (corresponding to the maximum value / reference for the 10-bit numeric analog converter for which  $2^{10} = 1024$ ). The ends of race of the mechanisms (mechanism which help to change the parameters  $s$ ,  $p$  and  $g$ , i.e. the actual heads of the eyebrows, eyelids and mouth) do not coincide with the potentiometer's displacement ends.

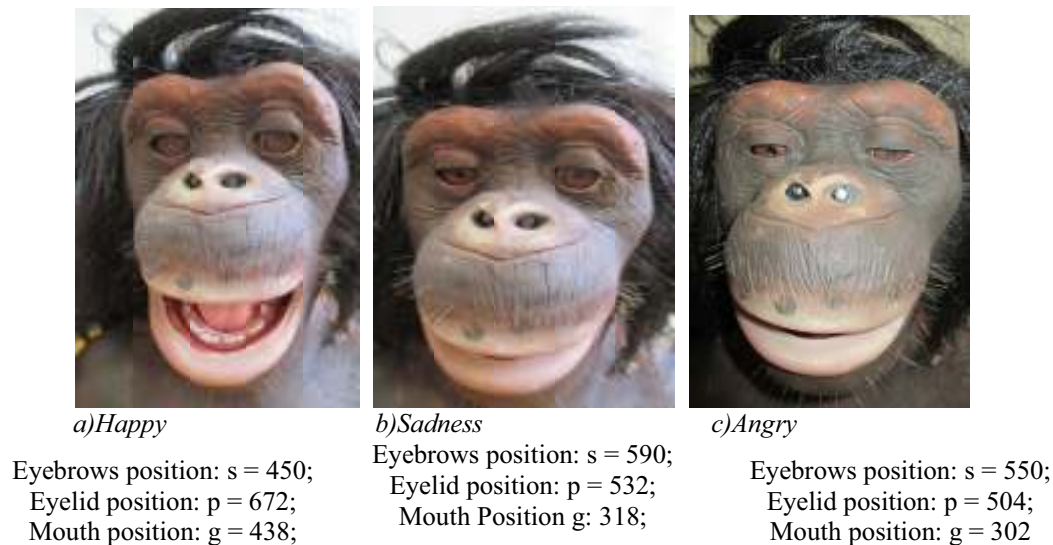
- For the eyebrow, the values provided by the potentiometer (corresponding to parameter  $s$ ) are:
  - Minimum value for eyebrow position upwards: 450
  - Maximum value for eyebrow position down: 650
- For the eyelid, the values provided by the potentiometer (corresponding to parameter  $p$ ) are:
  - Minimum eyelid position down: 420
  - Maximum value for eyelid position upwards: 700
- For the mouth, the values provided by the potentiometer (corresponding to parameter  $g$ ) are:
  - Minimum position for mouth up (closed): 270
  - Maximum position for mouth position down (open): 510.



**Table 1.** The variation domains of the quantified values of the analog-numeric converter and their association with elementary biomimetic expression states.

Expressive state	Variables	The percentage values of the s, p, and g variables in order to achieve of the expressive / biomimetic elementary state.				
		Achieve 100% from biomimetic state	75% biomimetic state	50% biomimetic state	25% biomimetic state	(neutral) biomimetic state
Happy	s	100% (450)	90% (470)	80% (490)	70% (510)	60% (530)
	p	90% (672)	85% (658)	80% (644)	75% (630)	70% (616)
	g	70% (438)	55% (402)	40% (366)	25% (330)	10% (294)
Angry	s	50% (550)	52,5% (545)	55% (540)	57,5% (535)	60% (530)
	p	30% (504)	40% (532)	50% (560)	60% (588)	70% (616)
	g	6% (302)	7% (300)	8% (298)	9% (296)	10% (294)
Surprised	s	100% (450)	90% (470)	80% (490)	70% (510)	60% (530)
	p	100% (700)	92,5% (679)	85% (658)	77,5% (637)	70% (616)
	g	90% (486)	70% (438)	50% (390)	30% (342)	10% (294)
Disgust	s	40% (570)	45% (560)	50% (550)	55% (540)	60% (530)
	p	50% (560)	55% (574)	60% (588)	65% (602)	70% (616)
	g	30% (342)	25% (330)	20% (318)	15% (306)	10% (294)
Sadness	s	30% (590)	37,5% (575)	45% (560)	52,5% (545)	60% (530)
	p	40% (532)	47,5% (553)	55% (574)	62,5% (595)	70% (616)
	g	20% (318)	17,5% (312)	15% (306)	12,5% (300)	10% (294)
Fearful	s	10% (630 )	22.5% (605)	35% (580)	47.5% (555)	60% (530)
	p	90% (672)	85% (658)	80% (644)	75% (630)	70% (616)
	g	50% (390)	40% (366)	30% (342)	20% (318)	10% (294)

Next, we will examine three basic emotional states of a chimpanzee robot, namely: happy, sadness and angry. In Figure 12 these states are presented. The references for the 3 states have the values showed in the figure.



**Figure 12.** The emotional states of a chimpanzee robot: happy, sadness and angry.

## 5. Conclusions

The article presents the implementation of a biomimetic primate emotional states using a P-type regulation law, implemented using ARDUINO board. Since the analyzed biomimetic structure behaves as a slow process, the regulation law of the regulators was chosen by the proportional type for the regulation of the three parameters  $s$ ,  $p$ ,  $g$ . The proportional regulation law also has the advantage of a high value command signal for the drive motor that it develops sufficient torque to overcome the resistant torque. Even if a P regulation law was used as a slow process, the transient performances were not affected. In future it will develop the complete emotional state and especially the natural evolution of the biomimetic architecture from one emotional state to other. Other future direction will be the voice command of the biomimetic structure, in order to develop an interactive communication through a mobile phone (bluetooth based communication).

## 6. References

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