ANTHROPOMORPHIC ROBOTIC HEAD – THREE PRELIMINARY APPROACHES

Assist. PhD. Eng. Beniamin CHETRAN, Technical University of Cluj-Napoca, e-mail: Beniamin.Chetran@mdm.utcluj.ro
PhD. Stud. Eng. Vasile Sergiu JISA, Technical University of Cluj-Napoca, e-mail: vasile_sergiu_jisa@yahoo.com
Eng. Andras ERLI, Technical University of Cluj-Napoca, e-mail: erliandras@yahoo.com
Prof.Dr.Eng. Dan MANDRU, Technical University of Cluj-Napoca, e-mail: Dan.Mandru@mdm.utcluj.ro

Abstract: The first part of the paper is dedicated to a study regarding the humans’ emotive facial expressions and comparative analysis of representative examples of humanoid robotic heads. The authors’ contribution in this field consists in three different proposals of anthropomorphic robotic head. All technical details that lead to our original design are presented, including the hardware structure, the actuation systems and control of the robotic systems.

Keywords: robotics, anthropomorphic head, emotive facial expressions

1. INTRODUCTION

Usually the service robots operate semi- or fully autonomously to perform services useful to the well-being of humans. They can be classified as professional service robots (for example, professional cleaning, inspection and maintenance, construction, space, defense robots) and personal service robots (companion, entertainment, assistive robots). One functional feature of some of these robotic systems is their permanent interaction with humans. As a consequence, among the factors for their acceptance there are: appearance, humanness, facial dimensions, emotive expressions, [2].

The human face is able to show a large range of emotions due to the movements of eyebrows, eyelids, lips, skin of the face and mouth, like in Fig. 1, [1].

The decisions initiated at the brain and sent through the facial nerve govern the facial expressions that are finally produced by the actions of the facial muscles. By analyzing the different human emotive face expression and facial and head muscles insertion, 13 interest points were found (Fig. 2).

The combination of point’s movement over certain trajectories and with specific amount, gives different face expressions, [1], [6], [10]. For example, by moving the eyebrow points in combination with mouth points can be expressed: positive emotions; fear; sadness; repulsion and so on.
The face skin is playing the role of an elastic membrane that can be easily deformed over the force developed by the face muscles. The opening and closing the lips can be achieved by jaw movements or by contracting the muscles right behind the skin so called skin muscles that are able to move the lips in many more positions than open or closed. Beside mouth the eyebrow and eyelid movements play an important role at the face expressions, [10], [11].

In [1] a collection of humanoid robots some of them with face expressions capabilities are described. Different mechanisms and control systems for anthropomorphic robots are also presented. In [8] is introduced Need Robot a humanoid robot that has 26 DOF at head. It has the ability to communicate with humans by expressing humanoid emotions. In [11] an anthropomorphic head with 12 DOF controlled by a host controller is emphasized. The mechanisms used to move the interest points under the skin material are cable droved. The communication between the host PC and the control system it’s realized with RS 485 protocol. The mechanisms for generating face robot, described in [6], are actuated by McKibben pneumatic artificial muscles. The neck mechanism, for realizing human-like head
motion, is also presented. Paper [7] proposes an innovative actuator based on multiple shape memory alloy wires to enhance facial expressiveness. Using different combination of the action units, the developed robotic systems are able to show ability for expressing six basic facial expressions: surprise, fear, disgust, anger, happiness, sadness.

The research in this field is strongly motivated by the authors’ interest in nest generation of assistive robots for vulnerable persons, like elderly, disabled people – robots that must interact and communicate with their users.

2. PRELIMINARY RESEARCH CONCERNING ANTHROPOMORPHIC ROBOTIC HEAD

The first prototype was developed based on a study of the possibilities for developing three degree-of-freedom (DOF) mechanisms for eye, jaw and head forward/backward projection movements, [9]. The actuators chosen for this prototype were stepper motors controlled by an ATMega 8535 microcontroller through two H bridges as driver, [3].

The human eyes have two movements and both eyes are moving simultaneously. Based on this fact the mechanism used for eye movement is designed to have two DOF for both eyeballs (Fig. 3). The hardware contains two cardanic mechanisms joined by a rood that is moved up/down and left/right by the motors through a nut and screw mechanism.

![Eye mechanism front view (a), top view (b) and posterior view (c)](image)

The mouth movements are reduced to the up/down jaw movement, which are realized with a single motor through a single stage 2.56 reduction ratio gearbox (Fig. 4a). The human neck has three anatomical movements; for this prototype, these movements were reduced to the forward/backward projections, realized through a two steps gearbox with 8.4 reduction ratio. Figure 4 presents the first prototype of the anthropomorphic head. The bipolar stepper motors used are produced by the Shinano Company and have the following characteristics: model SST41D0100; step angle 1.8 [deg]; supply voltage 2.3 [VDC]; current 1 [A]; internal impedance 2.3 [Ω]; inductance 3.9 [mH]; torque 0.11 [Nm] (1.2 Kg·cm); rotor inertia 20.3 [gcm²]; number of windings 4; weight: 0.15 kg; the overall dimensions 42x42x22 [mm].
3. THE SECOND PROTOTYPE OF THE ANTHROPOMORPHIC ROBOTIC HEAD

For the second prototype the head structure frame was changed, a mannequin head was used, [4]. It has three DOF, two for the eyes and one for the mandible. The eye mechanism module was preserved from the previously system, (Fig.5a). The stepper motors were changed with servomotors in order to simplify the electronic control module. For the eye up/down movement, a gear box with a 0.96 reduction ratio is used. The gearbox role here is only to minimize the overall head dimension. The goal at this prototype is to simplify the control system and to test the control possibilities of the anthropometric head from a computer. The servomotors that are used (NARO type) have the following characteristics: overall dimensions 22 x 11.24 x 31.35 [mm]; weight 8.8 [g]; supply voltage 4.8 [V]; torque 0.07 [Nm]; angular speed 9.45 [rad/s]. The electronic diagram was simplified because the servomotors are directly connected to the microcontroller through a control wire. For this purpose only three controller ports are needed instead of eight as for stepper motor driver. Between the microcontroller and servo no amplification circuit or driver is needed. The communication between the controller and the PC can be done on serial or USB port. The serial communication was chosen and in this case an additional level conversion circuit is needed. To easily control the robotic head form PC, a simple graphical user interface was developed. This interface allows controlling the servomotors angular position by three scroll bars.
4. THE FINAL PROTOTYPE OF THE ANTHROPOMORPHIC ROBOTIC HEAD

The final prototype is realized by extending the precedent prototype, [5]. The eye mechanism and control is preserved and new mechanisms for jaw, eyelid and eyebrow movements were developed. Servomotors were used as actuators for all movements. Their characteristics are: type AS-100 from ART-Tech Company; overall dimensions 22.5x12x24 [mm]; weight 9 [g]; torque 0.11 [Nm]; angular speed 8.6 [rad/s]. The eyelids are controlled with a single servo placed between them, (Fig. 6a) despite human natural eyelids that have two DOF.

The eyebrows are controlled with two servomotors placed behind them and attached directly on the servo output shaft (Fig. 6b). The jaw is actuated by a single servomotor for opening and closing movements. In order to be able to make more human like face expressions other four servomotors that controls the corners of the mouth were added. These servomotors were placed into the occipital area and the movement is transmitted by cables. These servomotors can make movement like lowering or rising, approaching or stretching the corners of the mouth, (Fig. 6c). Figure 7a shows a picture of the above described subsystems.
The PC graphical user interface was extended with the new features: movement of the eyelid, eyebrow and buttons through which expressions as rejection, bored, sadness, flirt, smile, surprise and neuter can be automatically obtained, (Fig. 7b). The control system is done with an ATMega 8 controller with a 16MHz external oscillator.
All ten servomotors are driven directly by the controller. The communication between microcontroller and a PC is done with serial communication protocol by aid of a MAX 232 level converter, in accordance with Fig. 8.

5. CONCLUSIONS

In the near future, the robots might become to be the humans’ partners in a broad range of activities. Verbal or non-verbal communication and social interaction are significantly important for these robots whose functional feature must be facial expressiveness intuitively understandable to humans. The paper presents three successive improved variants of robotic systems with the capacity of emotional facial expressions. Our future work will be focused on implementation of this type of anthropomorphic robotic head into the structure of assistive robots.

REFERENCES