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DESIGNING AN ANIMATRONIC HUMANOID ROBOTIC HEAD

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Abstract: *The present work is incorporated in the field of social robots; more precisely does it belong to the category of androids and deals with aspects related to the composition of an animatronic humanoid head. The first part of the paper tackles general aspects about the concepts of robotics and animatronics, followed by the presentation of the design process and the structure of the head in the final part of the paper. All the robot's mechanisms are driven by servomechanisms, which are controlled by a development board equipped with a microprocessor. Their purpose is to contribute to the movement of the eyes, eyelids and jaw.*
Key words: *mechatronics, biomechatronics, social robots, androids, animatronic head.*

1. INTRODUCTION

In our contemporary world, technology has developed in such a way, that it has not only been adapted to the human needs, but it has even adopted human characteristics. The process of achieving technial humanity is strongly related to animatronics. The term “animatronics” is defined as follows: "referring to or involving robotics that realistically mimics living beings" whereas the etymology of the concept is composed of the term "animation" implying "the action of giving life" as well as "electronics" signifying “the science that deals with how electrons behave” [1].

This article proposes aspects regarding the design of an animatronic robot head equipped as to perform autonomous movements similar to those of the human face (moving jaw, eyes and eyelids) so as to achieve a high degree of realism. Another essential aspect is displayed by the functions of the human face which is the most complex form of interacting with the environment and also a highly researched subject nowadays [2-5].

In the course of time, the reaction of our society to android and humanoid robots has developed into an noteworthy topic for science researchers. This fact was probably caused due to the emergence of more and more social robots in everyday life.

The robots called “machines” are part of everyone's life today, infiltrating themselves in many tasks, both regarding social life, as well as the industrial environment. Considering the fact that the world's population is aging, and technology is becoming more accessible and intelligent, social and service robots are advancing towards significant popularity [6].

The android robots, being characterized by: artificial intelligence (A.I.) and animatronics [7], are designed in order to accomplish a predetermined purpose. The essence of this paper is integration of three essential components in the realization of an animatronic humanoid system as follows in Fig. 1.

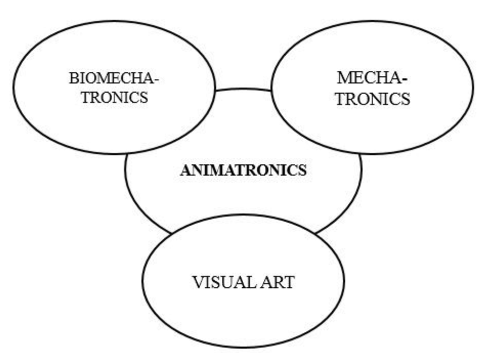

Fig. 1. The components of animatronics

These three areas have been integrated in the paper so that the animatronic system results in acquiring a high degree of accuracy in relation to the human head.

1.2 State of the art

The humanoid robot Eva is a robot that was designed to provide an experimental basis for researchers studying artificial intelligence in the context of robot-human interaction. This robot was conceived from the beginning as open source, being able to express the 6 general emotions, it is also able to move its eyes, eyelids; performs head movement and speech imitation. The control of the humanoid robot Eva is done by *Python* instructions on a plate of *Raspberries Pi*, and the operation of the mechanisms is done with the help of servomechanisms [8].

Chyi-Yeu Lin et al. have developed a robot capable of facial expressions, focusing on reducing and optimizing it as well as creating a good facial expression. They managed to design the robot with fewer servomechanisms and reaching a modularization of the mechanical structure of the robot. The results of their research confirm that the simplification of facial expression mechanisms is possible while maintaining the same expression properties as the most complex ones [9].

Another example of a robot with facial expression capability made by the team Chyi-Yeu Lin et al., which focused on the robot's ability to read and interpret musical notes. This was achieved by inserting webcams in both eyes, and the facial expression of the robot was achieved through 24 servomechanisms. The facial skin was made of silicone together with a coloured pigment for a look as similar as possible to human skin [10].

2. THE ANIMATRONIC HEAD DESIGN

Starting from the previously mentioned idea that the animatronic system is designed as to be as realistic as possible, the entire head is built on a skeleton with a supporting and stiffening role, made of aluminium [11]. The design of the animatronic head commenced with its 3D modelling with the help of a computer-aided design (CAD) program, namely CATIA V5 R20, in which each element of the assembly was modelled and then did their assembly materialize.

The skeleton has the following mechanisms: one for the jaw, 3 for the eyes and 2 for the eyelids. These are simple *rod-crank* mechanisms. For each drive of the mechanisms, the electric actuators of direct current (DC) are used, through the servomechanisms that generate the necessary moment as to overcome the resisting forces.

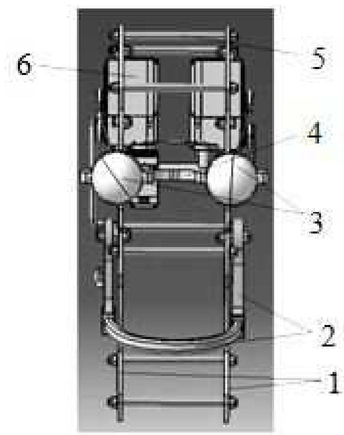

Fig. 2. Robot assembly in CATIA: 1-Skeleton; 2-Mandible; 3-Eyes; 4-Eye support; 5-Spacer; 6-Servomechanism.

For the mechanism of actuation of the mandible, only one servomechanism is used, for actuating the mechanisms of the eyes, there were 3 servomechanisms involved and for actuating the mechanisms of the eyelids, 2 servomechanisms.

In the manufacture of the head, there were used materials with a relatively good strength and relatively low weight. These are: aluminum, polyethylene and steel, the latter being used only for the assembly part of the skeleton and the radial bearings.

2.1 The skeleton

The skeleton represented the first element in the modelling of the humanoid head. It has been designed both technically, functionally and aesthetically. The skeleton consists of two aluminum plates (99.5% Al) with a thickness of 2 mm, which were cut by an unconventional process, namely by means of a laser cutting machine. This method was chosen due to the complexity of the shape of the plates, being similar to the shape of the human head (Fig.3.).

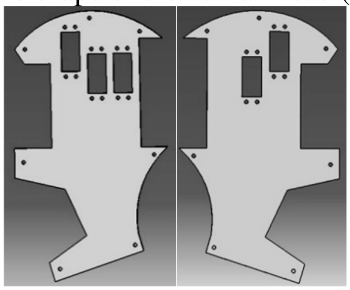

Fig. 3. The two component boards of the skeleton.

The preeminent property of aluminum is that it has a proportionately small mass and a satisfactory resistance in order to achieve the goals in an animatronic system. The two plates are identical as to their exterior shape and size and are positioned in mirror, kept parallel by means of aluminum spacers with an outer diameter of 6mm and the inner one of 4mm. Inside them were introduced steel threaded rods with an external diameter of 4mm, and the two ends were assembled with the help of bolts and nuts.

The two plates are provided with cutouts for the exact positioning of the servomechanisms, as well as their fixing by means of screws and nuts. The entire construction of the skeleton is a "portal" type which has the advantage of providing the entire system a high rigidity (Fig. 4.).

The functional role of the skeleton is to underset all the elements of the robot, static or in motion, such as the servomechanisms, the motion transmission mechanisms, the jaw, the eyes' and eyelids' support.

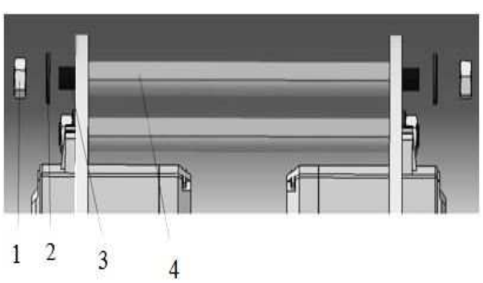

Fig. 4. Components of the skeleton: 1-Nut, 2-Bolt, 3-Threaded rod, 4-Aluminum spacer.

2.2 The mandible

In the composition of the human head the mandible consists of a body and two branches, while between them there is formed an angle of about 120°.

The kinematic component of the mandible is represented by two movements that are considered essential: the movement of rotation with a fixed axis or a "hinge" movement around the temporo-mandibular joint and movements of propulsion and retropulsion [12].

In the case of this robots' mandible, a simplification of movements was achieved by eliminating the two spherical joints represented by the two mandibular condyles and replacing them with two cylindrical joints, more precisely with two radial bearings.

Through the medium of this implementation of the radial bearings, the main rotation movement of the mandible was maintained, as well as the obtaining of a minimum friction (Fig. 5.).

The rotational movement of the mandible is performed by means of an imaginary axis passing through the center of the two radial bearings.

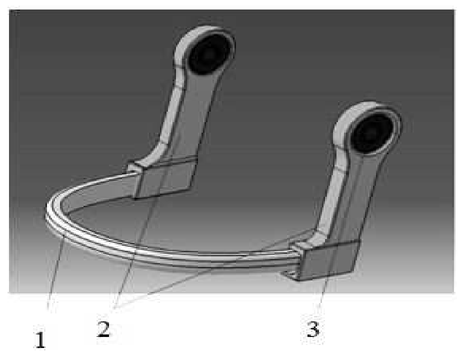

Fig. 5. The Jaw; 1-Body; 2-Branches; 3-Bearings

The constructive method of fixing the mandible to the skeleton was made by means of threaded rods and aluminum bores. The tightening of these bores was executed by means of the nut (Fig. 6.).

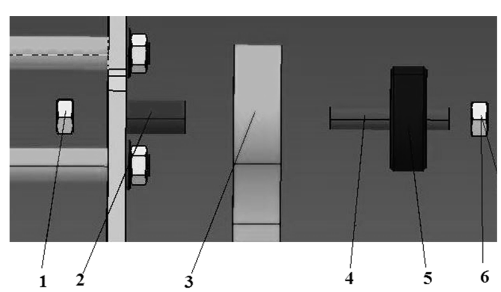

Fig.6. Attaching the mandible to the skeleton: 1-Nut,

2-Bore, 3-Mandibular branch, 4-Threaded rod, 5-Radial bearing, 6-Nut.

The mandible body and the two branches were fabricated of polyethylene on the 3D printer. On the body of the mandible and on the jaw, there was assembled the denture that was made of white pottery plaster, followed by its casting in silicone molds.

2.3 The ocular system and the eyelids

In the case of the ocular system, there was raised the problem of supporting the eyes, as well as the possibility of moving them.

In the human eye system, the eyes are held in orbit by means of 6 muscles that act on them, creating the torque needed as to move the eyeball in the direction of the sight [13]. Therefore, according to the two rotational movements of the eyes on the two axes (x, y), it was necessary to impose a cardan mechanism that allows these movements to be performed.

The construction of the eyes was done on the 3D printer, produced out of polyethylene, and the cardan mechanism was fixed to them with an adhesive. The eyes have a spherical shape and posteriorly they are provided with a cut-out in which a part of the cardan mechanism is introduced, and previously they were painted in a notably realistic way, similar to the human eye. In order to give the eyes a better resemblance to that of the human ones, over their painting was chosen the application of a layer of epoxy paint. Another advantage is the fact that it offers them a longer resistance.

The present part of the paper, regarding the eyes, is an item belonging to the third component that was used to make the animatronic head, namely the visual arts. (Fig. 1.).

The eye bracket is made of polyethylene on the 3D printer and has a cut-out for the insertion of a servomotor that has the role of producing the left-right (y) rotation motion (Fig. 7.).

The left-right rotation could be achieved with a single servomechanism due to the fact that both eyes have a synchronous movement. This was accomplished by implementing a support that allows synchronous movement of the eyes. Through this process, it has been achieved the reduction of the servomechanisms and implicitly the increase of the operating life of the robotic head.

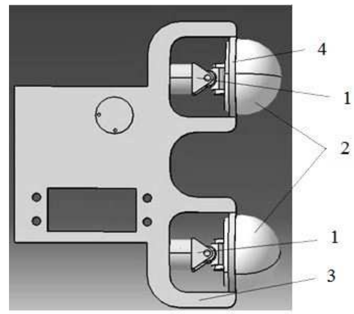

Fig.7. Eye assembly: 1- Cardan mechanism, 2- The two eyes, 3- Eye support, 4- Eyelids.

The motion transmission mechanisms of the eyes is a one of the *rod-crank* type and the connecting rod is composed of steel levers. The bumps are made of aluminum, they are individually actuated by two servomechanisms through two steel levers.

3. THE DRIVING SYSTEM

The electronic diagram of the control system is shown in Fig. 9. It is realized in the EAGLE program and contains the component elements of the control and drive system. The control system contatins an Arduino Mega 2560 development board equipped with the Atmega2560 AVR microprocessor, which also has a 16MHz quartz oscillator through which all the servomechanisms are controlled.

As actuators, the MG 996R DC servomechanisms were used, which have a torque of 1.07 [Nm] at the supply voltage of 6 Volts (V) and 0.92 [Nm] at the voltage of 4.8 Volts (V), which manage to defeat the resistant forces. These actuators have a rotation angle of 120°, 60° in one direction and 60° in the other one [14]. The servomechanisms are connected to the Arduino Mega 2560 board at PWM outputs on the A2-A7 pins.

These elements of the driving system take their energy source from two lithium ion batteries: one with a voltage of 9V and the other of 6V. Starting and stopping the entire system is done through two switches.

4. CONCLUSION

The project was completed with the construction of the animatronic head found in

Fig. 8., offering an innovative and faithful variant of the human head.

Due to the servomechanisms and the aesthetics, the physical tests conducted have shown the robot's similarity in performing the characteristic human movement functions.

By integrating these three categories (Fig. 1.), the realisation of the animatronic humanoid robot was successful, as it consists of innovative elements that are important in the construction of a new robotic system. These elements are: the realisation of complex movements with a relatively small amount of servomechanisms and the usage of resistant and light materials and ingenious methods.

Given the continuous evolution of materials, mechanisms and visual arts, this paper presents the possibility of improvement in the future. Future contributions to the existing animatronic system focus on equipping it with artificial intelligence, offering the possibility to assign more complex tasks. Another improvement can be made from an aesthetic point of view, by equipping the robot with materials similar to human skin, these being part of the main future aspects of the development of the animatronic system.

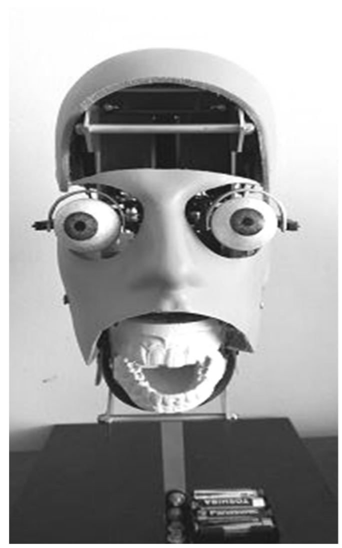

Fig. 8. The final result

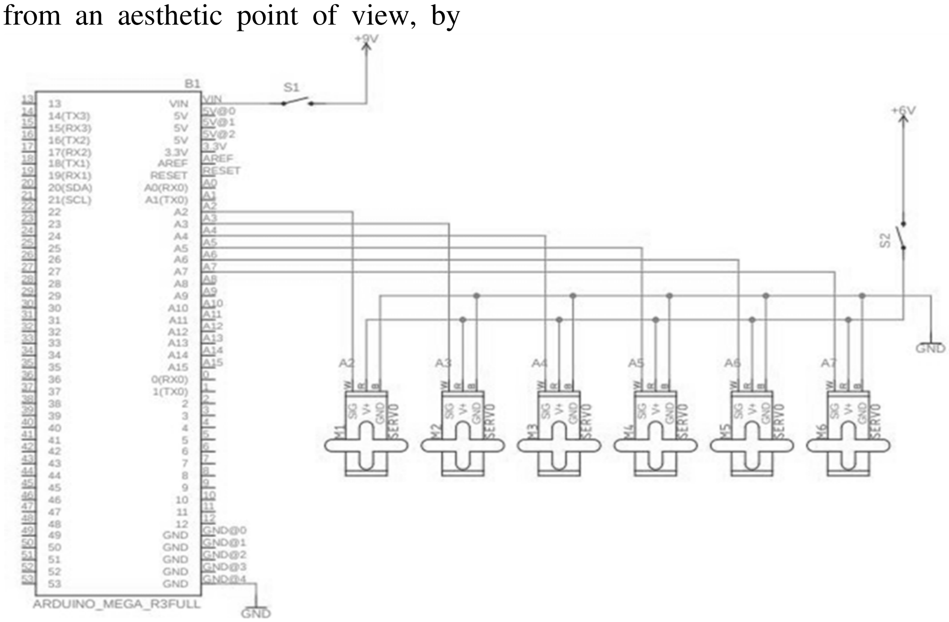

Fig. 9. Electronic scheme of the driving system

5. ACKNOWLEDGEMENT

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Proiectarea unui cap robotic umanoid

Rezumat: Lucrarea de faţă face parte din domeniul roboţilor sociali, mai exact din categoria androizilor şi tratează aspecte referitoare la componenţa unui cap umanoid animatronic. Prima parte a lucrării tratează aspecte generale despre conceptele de robotică şi animatronică, urmând apoi prezentarea procesului de proiectare şi a structurii capului în cea de-a doua parte a lucrării. Toate mecanismele robotului sunt antrenate de către servomecanisme, care sunt controlate de către o placă de dezvoltare dotată cu microprocesor. Scopul acestora este de a contribui la mişcarea ochilor,a pleoapelor şi a maxilarului.

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