El Greco II: affordable social humanoid for educational use

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***Abstract*—This paper presents the changes in the second version of the humanoid El Greco. El Greco is designed to be used by children in education. It speaks and understands Greek, but it can do the same for more than 160 languages.**

Keywords—Social humanoid, robotics, hardware, software

I. INTRODUCTION

This work concerns the description of the second version of the social humanoid El Greco [1]. Having used El Greco for teaching programming [2] for more than a year and having won the special award in the 8th Industrial Informatics Festival of Kavala [3], as the most complete robot, a second version was decided in order to deal with several problems and keep him up-to-date.

First, a list of the existed problems of El Greco was created to be considered. Then several recent humanoid reviews were studied in order to improve El Greco for his actual use, while preparing him for further future applications [4-6].

In section 2, there is a short presentation of El Greco II, mentioning the maintained characteristics and the desired ones. In Section 3, the changes in design and hardware are presented while in section 4, his programming and the new abilities are detailed. Finally, in sections 5 and 6, evaluation and conclusion are drawn.

II. HUMANOID PRESENTATION

Some of the existed characteristics, that were kept are:

- Small size looking like a child
- Low cost, open source hardware and software
- Easy programming

Characteristics desired to change:

- Less volume but easier access to hardware
- Power increase
- Better communication
- More applications

In order to succeed the low-cost requirement, 3D printing was used again and open source hardware. This kept the cost under 2000 euros per piece and satisfied the easy programming restriction.

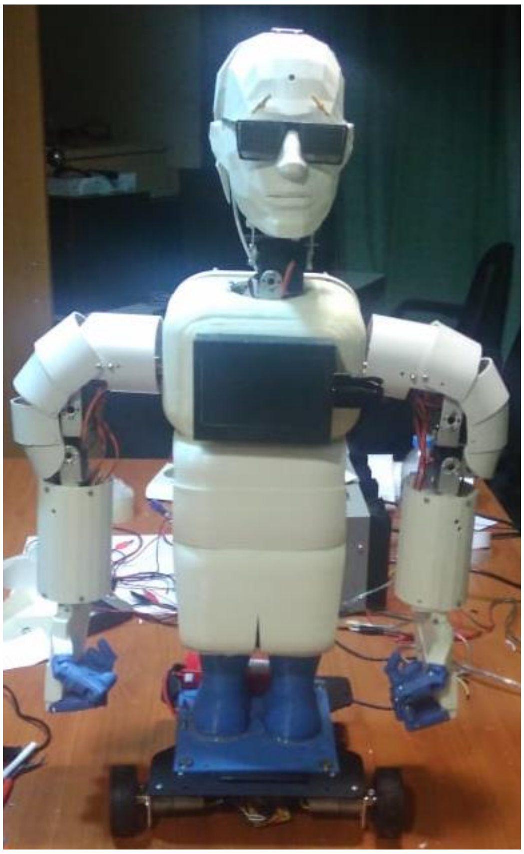

Fig. 1. El Greco II.

On the other hand, it gave us freedom in the design, correcting problematic points, required to be corrected, decreasing the volume and providing easy access to the internal hardware. The power was increased by using an additional Banana Pi, using in total two Single Board Computers, a Banana Pi and a Raspberry Pi 3.

For better communication, Greek language was used as in the first version, but also a touch screen has been introduced, since the voice command understanding can be low in noisy environments e.g. expositions, museums etc. Moreover, using the Google API in our software, it can be easily changed to more than 160 languages.

Last but not least, the existed applications as face recognition and tracking, have been improved, while new ones have been e.g. counting with fingers, emotion expression, rock-paper-scissor game, etc.

III. Building Procedure

The main body of El Greco II (Fig.1) consists of 5 pieces: torso, upper zone, lower zone, trousers. All of these sections were designed and 3D-printed. In the interior of the body, two metallic parallel columns have been placed, aligned with its shoulder contact points. The purpose of this metallic skeleton is to correctly distribute the center of gravity to every move or standing position. In addition, it also gives the possibility of installing the system batteries and the axes that allow movement in space. The armor includes a frame of metal parts to serve in adaptation of the hands and the neck, as well as their connection to the main body. The body sections were connected by silicone, while they were screwed to the internal skeleton.

The 3d-printed parts of the body, in more detail are:

- Torso: rectangular elliptical shape, printed in two pieces and connected by screws, so that it can be accessed at the rear for possible repairs and access to the body and the included servo control board hat.
- Upper zone: elliptical shape, printed as a single piece with special shaped metal parts for connection to the Lower zone.
- Lower zone: elliptical shape, printed as a single piece with special shaped metal parts for connection to the Upper zone, as well as 2 holes at the bottom for adjusting the legs (trousers). The connection of Upper and Lower zones using metal parts, allows access to the rest of the robotic interior.
- Trousers: two independent designs of a human static foot (i.e., without moving parts) with diameters similar to those of the Lower zone.

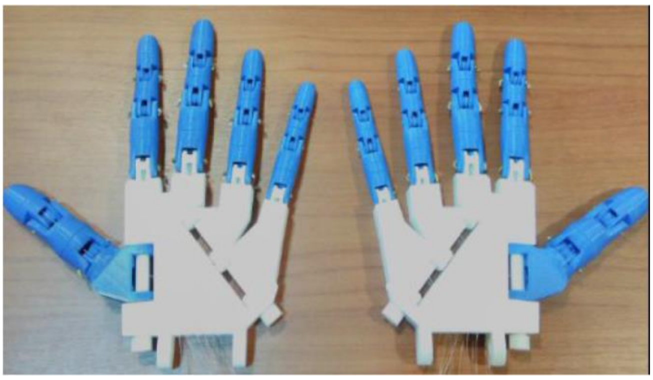

Fig. 2. The palms.

Another novelty is the replacement of the 3-finger hands by more functional, almost human hands. Each palm (Fig.2) requires the 3D-printing of plastic pieces and their assembly using metal connectors. To move, each finger has internal fishing line. Five servo motors have been placed in each hand (Fig.3). This way the movement of the fingers is achieved: by the movement of one motor a fishing line is pulled to direction of the rotation. Thus, at one direction the line is gathered and consequently the finger closes while in the other direction the line is released, and the finger extends. A cylindrical frame was 3D-printed for each hand, to covers the above section and give the appearance of a hand.

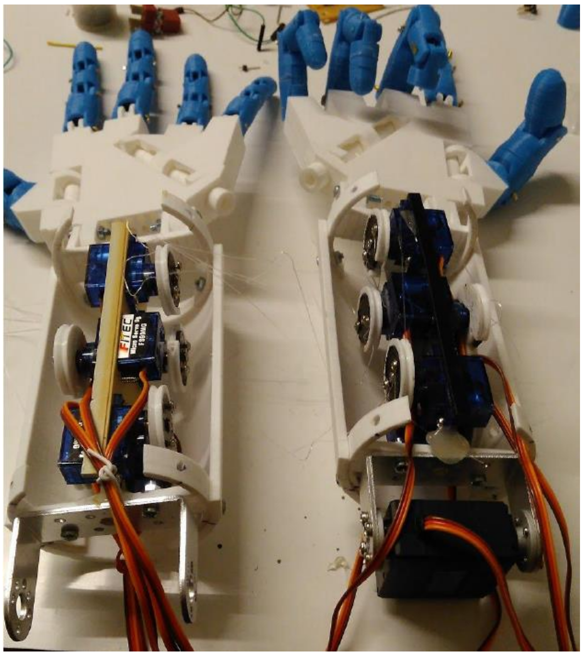

Fig. 3. The hands.

Three motors were used for the arm (Fig.4). One for the shoulder movement, one for the elbow rotation and finally, one for the elbow movement. The linking between them was done by using metal mounts.

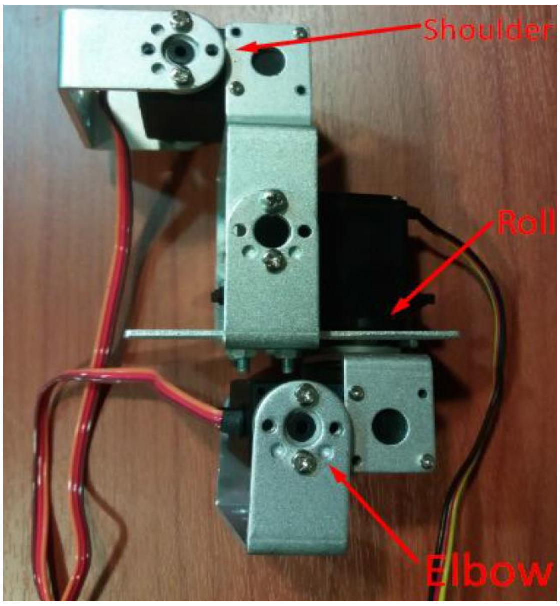

Fig. 4. The arm.

As mentioned before, two Single Board Computers were used: a Banana Pi that took care of all the head functions, except the camera, and a Raspberry Pi 3 for the rest system. In order to cover all the motors, two Servo Pi Hat were connected to Raspberry Pi 3 so it can handle the 23 system motors (except the two eyebrows motors that are connected to banana pi). There was also a touch screen on Raspberry Pi 3 that powered from USB by Raspberry and connected with HDMI.

For the central power supply of the robot, a lithium-ion battery (2 cells) is used with 7.4 volts and 5200 mAh. To distribute current to boards, two step-down converters were used, one at 5V for powering Raspberry and Banana Pi boards and the other at 6V to feed the two hats. Also, a step-up converter at 12V was used to power the two DC motors for the movement of the robot around.

IV. PROGRAMMING EL GRECO II

El Greco's movements are performed by Raspberry Pi 3. The function of the Raspberry is based on 6 files. In more detail:

- *ElGreco2_Core_info file*: In this file, all the connections, done on the two Servo Hat, are registered so that they can be easily called through the corresponding value.
- *ElGreco2_Servo_Limitation file*: It contains the class Limitations that includes the limits for each servo motor, connected to the raspberry Pi 3. More specifically, each motor is corresponded, through an integer matrix, to 3 values, maximum. These values determine the minimum, average and maximum angles that can be reached by themotor. All motors have 3 positions that are necessary for the correct function of the robotic system, except of the finger-motors that currently need only two positions, open or closed. This file makes easy the handling and control of the motors as it only requires the predetermined positions. Moreover, it is easy to add new locations for future use.
- *ServoCurrentState file*: It contains the present position of each motor, giving memory capability in the robotic system for smoother motor movement.
- *StateManager file*: The included functions initialize, update, and retrieve the ServoCurrentState information. So for every movement, the functions are used to recover the current position of the corresponding motors and then to update to the new position. The function *initialize()* is only used in case of system confusion, in order to recover the original position of all motors.
- *ServoManager file*: It contains functions that are responsible for the smooth movement of each motor, using the servo hat library for creating the appropriate pulse signals. The functions receive the above information and give the corresponding signals to the motor, to reach the desired position.
- *Rpi _HatManager file*: El Greco's movements are performed through the Raspberry Pi 3 which is connected to two Servo Hat. The commands are sent using the library Adafruit_PCA9685. The multiple Servo Hat connection with the Raspberry Pi 3 requires the correct addressing of Servo Hat. The whole process of the address initialization and the use of the library is done in this file.

Every movement of the robotic system is included in a separate file for easy call. Concerning calls that require board collaboration, script files are created, which include all the actions that need to be done with the right execution order.

The Banana Pi board handles the facial expressions as well as the vocal system commands. It requires the following files:

- *ClientVoiceRecogn file*: By executing the file, the recording of the user's voice begins and it is converted to text using the Python Speech Recognition library. The text is then compared to the recorded commands in the MySQL database and the corresponding action is performed.
- *VoiceFunctions file*: It includes the Voice Functions class which during the initialization creates a table with the appropriate voice commands.
- *HeadEyebrows file*: It includes the functions for the movement of the two servo motors that correspond to the eyebrows.
- *HeadEyes file*: A file with functions for moving the two led matrices, which correspond to the eyes.

Using the above-mentioned abilities several new applications can be performed by El Greco II:

- *News release*: The process starts with El Greco appealing the categories of the news (economic, sports, entertainment, health, science, technology) and the user is asked to select one of the mentioned categories. Finally, El Greco speaks out the titles of the most popular news articles in the category.
- *Count demo*: By executing the command the robotic system initializes the right hand (palm closed). Throughout the movements the motions are being addressed.
- *Learn face*: Learning a new face is done through a simple photo and the use of the camera. After performing the learning process correctly facial features are stored in a .pkl file.
- *Face Recogniton*: The system keeps a list of pickle files containing the facial features. At the start of the recognition process the system loads all the known faces into memory. Then holds a frame from the camera and looks for faces in the frame. For each found face, the files in the memory are checked if match the collected data. If no person is found for 20 seconds, it stops searching.
- *Face Tracking*: Through the camera, El Greco receives a frame of size 320x240 pixels. Using the Haar Feature-based Cascade a frame of 30x30 pixels is created in the frame area where the face is. For each subsequent frame the robot tries to bring as much as possible closer to the center of the original frame the smallest one.

- *Emotion demo*: The system performs a brief presentation describing the simulation of emotions with the use of the led matrices and the eyebrows.
- *Rock Paper Scissor Game*: The game starts by initializing the position of the right hand. Then, El Greco picks up a random move and waits for the move response of the opposite player. Through a voice command the second player gives his move. Then the robotic system compares its movement to that of the player and speaks out the result and the score.

V. Evaluation

In order to evaluate El Greco's response, we experimented repeating 20 times the above mentioning tasks and applications. In Table 1, the corresponding success rates are presented, while in Fig.5, several frames from the Count demo are pictured.

TABLE I. Task & Application Succes Rates

Task or application	***Success rate***
Self-presentation	90%
Count demo	85%
News release	75%
Learn Face	90%
Face Regocniton	90%
Face Tracking	65%
Emotion demo	80%
Rock-Paper-Scissor Game	75%
Voice Commands (in private place)	80%
Voice Commands (in public place)	20%

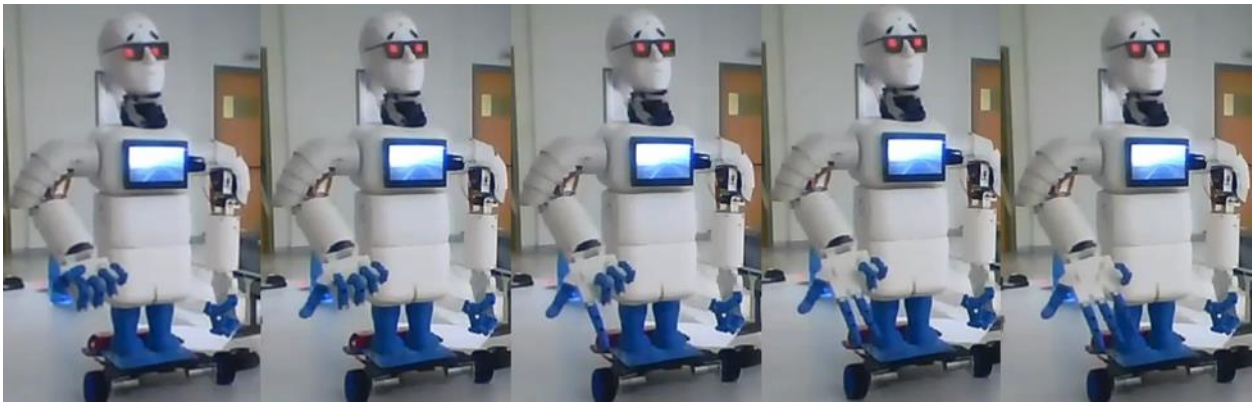

Fig. 5. Frames of Count demo.

VI. Conclusion

In this paper, the updates for El Greco II have been presented. The selected updates have been a result of the current demands in education of young children, while our mention concern was to keep low the total cost of the humanoid. Open source hardware and software have been totally used. Our intention is to use the new robot for the new version of our programming playroom [2] and other educational tasks.

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