Designing and building a remote-controlled 3D printed prototype robot arm implant

M Török[1], T I Erdei[2], Sz Tóth[1], G Husi[1],

[1]Mechatronics Department, Faculty of Engineering, University of Debrecen, Debrecen, Hungary
[2]Doctoral School of Informatics, University of Debrecen, Debrecen, Hungary,

mateka96@gmail.com

Abstract. The basis of this projects are robot arms, and within that topic, implants. This area of science belongs to mechatronics, or more precisely, bionics. The goal of this project was to build and remotely control a 3D printed robot arm implant. The robot arm itself was printed with a custom-built 3D printer using biodegradable materials. The completed implant allows interaction with other physical objects using remote control. This allows to lower direct physical interactions during a pandemic or allow work in an environment where an operator could not stay for a long period of time without health risks.

1. Introduction

Bionics is a field that consists of numerous scientific fields. Its main goal is to implement solutions developed in nature into mechanical creations [1]. Biomechatronics strive to integrate electronics this biological and mechanical design as well. This includes robotics and neurology. Recently, artificial limbs have advanced at a never seen before rate. Nowadays, it is possible for them to precisely reconstruct a real human limb's movements. While these robot arm implants were a great breakthrough, they still have the disadvantage that the movements did not send feedback to the brain, so it was difficult to do precise movements, or to control grip strength [2]. Humanoid robots are a presently active research area. Their goal is to replicate human properties and to reconstruct their movement.
Due to the COVID-19 pandemic, research concerning androids (humanoid robots) has become relevant again. In view of this, a robotic arm was designed and built using additive 3D printing technology, then assembled and made functional using remote control to move it. The robot arm is able to do basic functions, such as grabbing symmetrical objects and push or rotate buttons and knobs, provided that it is fixed to an appropriate mount. In addition, during a pandemic it may be used to lower risk factors, as physical contact with an afflicted person may be avoided, however, cleaning of the surface must still be cleaned periodically with antiviral agents.

2. Robot arm implant design requirements

Planning and implementation were carried out at the Cyber-Physical & Intelligent Robot Systems Laboratory of University of Debrecen, Faculty of Engineering, Department of Mechatronics. Numerous research projects take place in this laboratory because it is possible to test the implementation of these projects in an environment similar to an industrial one [3].
Because designing a robot arm is a complex task, a PhD researcher from the Doctoral School of Pharmaceutical Sciences, University of Debrecen gave us additional support during the project. As multiple Open-Source models were available for research purposes, earlier constructions and designs were re-thought and improved [4]. During the design phase it was vital to pay close attention to the mechanisms responsible for finger movement. The motors responsible for movement were placed in the forearm area, while tendons were replaced with high quality, braided cords. The housing and mounting points of the motors is an original construction. The forearm and the movable wrist are also an original

design. The connection points of the completed fingers and palm also had to be modified. The discs equipped to the motors are likewise an original design.

3. Printing of prototype parts with FDM 3D technology

After designing the robot arm, it had to be 3D printed for prototyping. The model had to be separated into individually printable parts, to allow error-free and efficient additive 3D printing. The work area of the used 3D printer is 200x200x200 [mm]. The extruder head unit is able to move in all three directions of the coordinate system linearly. The model was created in SketchUp [5].
The printing was done using a filament made of PLA, which is a biodegradable, thermoplastic polymer and not soluble in water [6]. The first step of the printing process is separating the model using a specialized program, which process is called splicing. The used program was one called Cura [7]. Using this program, we are able to set numerous printing parameters of a given model. These parameters are layer thickness, fill density 30 [%], printing speed 60 [mm/s], temperature (extruder-210°C, heating bed-60 [°C]. The splicing program and the printed parts are shown on figure 1 and 2.

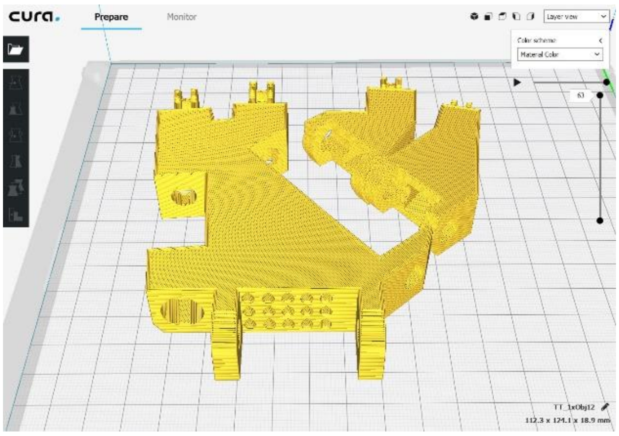

Figure 1. Cura splicer program preview

Figure 2. 3D printed robot arm parts

4. Internal parts and structure of the robot arm

In terms of its construction, the robot arm was modelled after the human arm and hand. The assembly of the printed robot arm began with the fingers. Each finger consists of three parts (phalanges), which were put together, then the assembled fingers were equipped on the hand. Following that, the cords replacing the tendons were lead through the fingers and the palm, responsible for moving the individual fingers. Then the wrist was completed, which is able to rotate in a 90° angle. Later all these cords were connected to the TP MG90S servo motors found in the forearm. The servo motors are responsible for the movement of fingers.

5. ESP NodeMCU-32S & servos

An ESP NodeMCU-32S microcontroller is used for controlling the motors. It should be noted that only the prototype uses this controller for testing purposes, the final design may use an industrial solution. The PWM cycle of the TP MG90S micro servo can be seen on the 3rd figure [8].
The ESP NodeMCU32S module also has the advantage of an on-board Wi-Fi and Bluetooth connection on its PCB. The module itself is shown on figure 4 [9] [10].

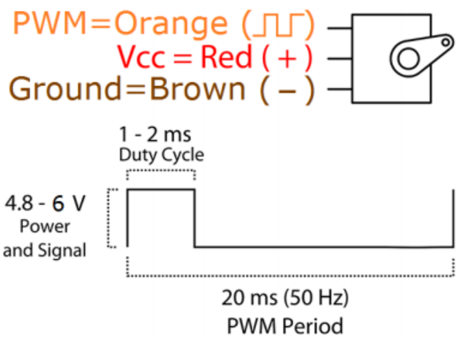

Figure 3. TP MG90S Servo PWM cycle [8]

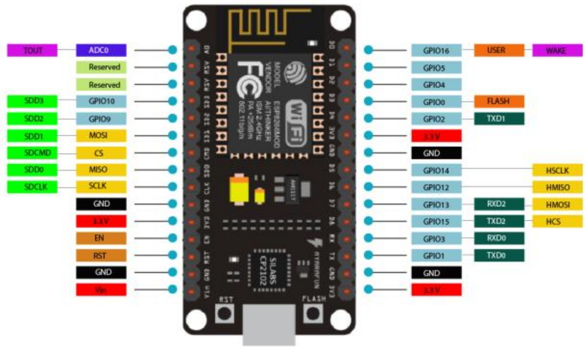

Figure 4. ESP NodeMCU32S pinout diagram [9]

6. ESP NodeMCU32S based remote control

The servos are connected to the ESP32 module, where the finger moving motors are connected to pins 4, 5, 12, 13, 14, while the wrist moving motor to pin 15. The 5V logic power is supplied to the module via the USB connection using an ADATA P20000D Li-Ion power bank with a maximum capacity of 20000mAh [11]. These connections can be observed on figure 5 made by Fritzing [12].

In order to move the fingers individually to a desired position, a GUI (Graphical User Interface) had to be created, which was done in HTML. This interface contains seven sliders: one for each of the five fingers, one for the wrist, and a final slider to move all five fingers at once. Figure 6 shows three states of the hand.

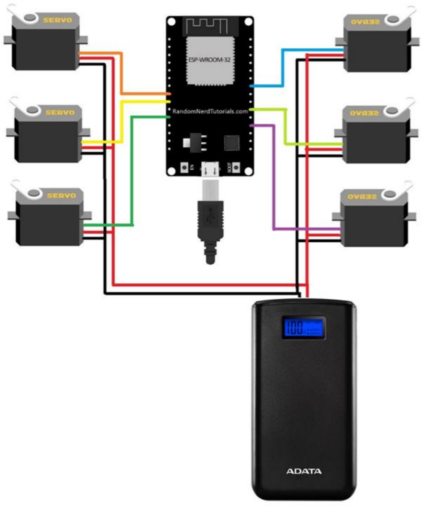

Figure 5. connection diagram

Figure 6. states of the robot arm

This solution allows more precise movement, as the fingers are able to move to and hold any position, not just the end states. The program's flowchart is shown on figure 7. During programming, we first had to load the <Wifi.h> library. Following this, the Wi-Fi network's name and password were configured. Thus, the ESP is able to connect to the existing Wi-Fi network. Following that, the servo motor outputs were declared. Lastly, the HTML page was created. After creating every slider, their respective motors were assigned to them to move the fingers to the desired position at the given angle.

The ESP NodeMCU32S supports the 802.11n Wi-Fi standard, but power-up and reset timing must be considered, which parameters are shown on Fig. 8.

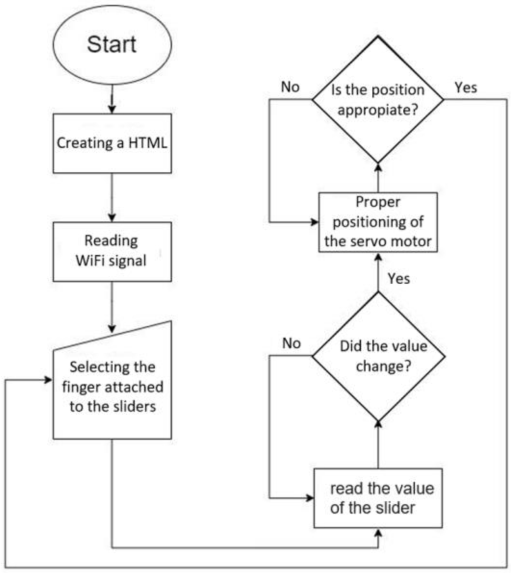

Figure 7. Robot arm program flowchart

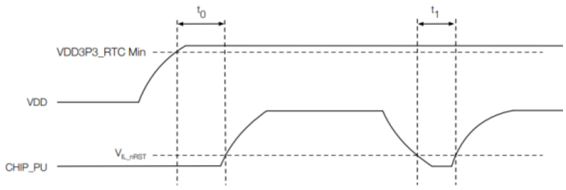

Figure 8. Power-up and Reset Timing [13]

7. Movement of prototype arm phalanges

The method of movement described at the early parts of this article are satisfactory if we only want to control the fingers, and the wrist, however, it was unable to move the phalanges individually. To make this possible, we also used an ESP NodeMCU32S like before. Similarly, an HTML page consisting of sliders was created, to remotely control the finger's phalanges individually. On the 9th figure this new GUI can be seen, where each slider is labelled with the anatomically [14] correct name of the discussed finger parts.

The created prototype is able to grab and hold lightweight symmetrical objects, as seen on figure 10.

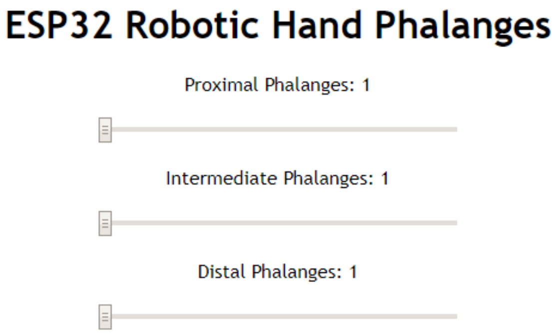

Figure 9. Graphical user interface

Figure 10. Robot arm prototype holding a light spherical object

Conclusion

The goal of this project was to design, assemble, and remotely control a 3D printed humanoid robot arm. The required parts of the prototype were made locally using a custom-built 3D printer. To control a prototype, the NodeMCU32S developer board was used, which allows the fine control of individual fingers using a GUI. In summary, we achieved our goals further upgrades also could be done.

References

[1] Bionika fogalma [Online]. Available: https://www.wisegeek.com/what-is-biomimicry.htm [Accessed: 09.10.2019.]

[2] C. Quinayas, Doyra Mariela Muñoz-Añasco, Andres Vivas, Carlos Alberto Gaviria Lopez, Design and Construction of the Robotic Hand Prosthesis UC-1 - July 2010Ingenieria y Universidad 14(2):223-237.

[3] T. I. Erdei, G. Husi, „Singularity measurement in the Cyber-physical and intelligent robot systems laboratory," IRASE (International Review of Applied Sciences and Engineering) 2020.

[4] Hand models (COVID-19) pandemic [Online] Available: https://www.thingiverse.com/thing:17773 [Accessed: 12.11.2020]

[5] SketchUp [Online] Available: http://www.sketchup.hu/ [Accessed: 20.10.2019.]

[6] PLA Filament parameters [Online] Available: https://www.simplify3d.com/support/materials-guide/properties-table/ [Accessed: 09.18.2020]

[7] Ultimaker Cura [Online] Available: https://ultimaker.com/software/ultimaker-cura [Accessed: 22.10.2019.]

[8] Szervo motor adalapja [Online] Available: http://www.electronicoscaldas.com/datasheet/MG90S_Tower-Pro.pdf [Accessed: 20.10.2019.]

[9] ESP NodeMCU32S pin kiosztása [Online] Available: https://www.theengineeringprojects.com/2018/10/introduction-to-nodemcu-v3.html [Accessed: 09.16.2020]

[10] Bluetooth Modul HC-05 [Online] Available: https://opencircuit.shop/resources/content/5baa51029ff43/crop/900-600/HC-05-Bluetooth-module.jpg [Accessed: 01.11.2020]

[11] ADATA 20000mAh P20000D [Online] Available: https://www.adata.com/us/feature/425 [Accessed: 12.11.2020]

[12] Frizing [Online] Available: https://fritzing.org/ [Accessed: 20.10.2019.]

[13] VI. ESP NODEMCU32S Datasheet [Online] Available: https://www.espressif.com/sites/default/files/documentation/esp32-wroom-32_datasheet_en.pdf [Accessed: 10.11.2020]

[14] Kézfej izmok [Online] Available: https://www.assh.org/handcare/Anatomy/Tendons?fbclid=IwAR1hXIEttKRtWCkVE1TfC01QC3payzJrFnxBhsCWIyodr9w7bXsypYmqqFM#Finger%20Flexor [Accessed: 20.10.2019.]

Acknowledgements

The project was supported by the cyber-physical & intelligent robot systems laboratory, Special thanks to Petra Arany. Produced in the framework of the EFOP-3.6.1-16-2016-00022 "Debrecen Venture Catapult program".