Research Article
Nano Biomed Eng

Control Robotic Hand Depending on Voice Commands and IoT

Aymen Dhafer Abdul-nafa[1]✉, Suha S. Ahmed[2]✉, Yahya Salim Ahmed[3], O. M. Alsaydia[4]
[1] College of Dentistry, Mosul University, Mosul, Iraq
[2] Department of Medical Instrumentation Techniques Engineering, Electrical Engineering Technical College, Middle Technical University, Baghdad, Iraq
[3] College of Medicine, Mosul University, Mosul, Iraq
[4] College of Electronic Engineering, Computer and Information Department, Ninevah University, Mosul, Iraq

✉ Corresponding authors. E-mail: ayman@uomosul.edu.iq; suhasabeh@mtu.edu.iq

Received: Dec. 13, 2022; **Revised:** May 16, 2023; **Accepted:** Jun. 26, 2023
Citation: A.D. Abdul-nafa, S.S. Ahmed, Y.S. Ahmed, et al. Control robotic hand depending on voice commands and IoT. *Nano Biomedicine and Engineering*, 2023, 15(3): 288−295.
http://doi.org/10.26599/NBE.2023.9290028

Abstract

A need for a prosthetic hand device has arisen based on the fact that many people lose one of their upper limbs for various reasons. Many systems are available to control prosthetic hands, such as electromyography (EMG) and mechanomyography (MMG). These systems present many problems, including complexity, high cost, and other issues. Voice commands are among the solutions recommended to address these issues. The proliferation of the Internet, voice recognition technology built into mobile phones, and Internet of Things (IoT) technology has facilitated the use of voice commands to operate prosthetic devices. In this paper, robotic prosthetics were controlled using this technology in the context of five different movement classes. This study involved five participants and reports as accuracy rate of 97%.

Keywords: prosthetic hand; electromyography (EMG); mechanomyography (MMG); Google Assistant; Internet of Things (IoT)

Introduction

According to the World Health Organization, millions of people worldwide have lost limbs, with the majority of amputees in developing countries receiving no rehabilitation or prosthetic devices [1]. Control techniques such as on/off control, proportional control, and finite-state-machine operation have all been used to control prosthetic hands. Moreover, control techniques such as these have been developed for commercially available prosthetic hands. Some control methods, such as electromyography (EMG) and mechanomyography (MMG) [2], rely on biological input from the residual limb. Other control systems, such as Force-sensitive Resistors, capacitive sensors, and ultrasonic technologies, use mechanical signals gathered from the muscles of the residual limb (force-myography, FMG) [2]. However, some amputees are unable to use these procedures because of the condition of the residual limb or high-level amputation; in addition, re-installing sensors at the same spot after periodic usage is difficult. Other control methods, such as voice control, are appropriate for the majority of amputation levels and do not rely on biological impulses from the residual limb [3].

Within the last couple of decades, the evolution of human–machine interactions has experienced increased diversification. It began with the widespread use of the internet in the 2000s, followed by the widespread use of desktop computers, and finally the widespread use of cell phones among the middle and lower classes. Gradually, the use of technology items, such as desktop computers and cell phones, by the general public became a need. In addition to a low cost, technological advancements are competing to build profitable goods that tackle community concerns among all classes of the population. The connection between humans and machines through voice communication is one field that has not been fully studied and developed [4, 5].

As a result, after touchscreen-based interfaces, voice interfaces may represent the future of interfacing technology. Voice recognition is used by numerous interface providers, including Google Assistant, as well as Apple's Siri, Amazon's Alexa, Microsoft's Cortana, and Yandex's Alice, etc.[6].

Google Assistant already uses a combination of Text-to-Speech and Automated Speech Recognition. The dialog flow application programming interface (API) is another option available to third-party application developers, in addition to their projects (API). Because Google Assistant provides an API that may automatically alter it or be customized by developers, and because Google Assistant SDK firmly supports it, developers do not need to develop a method to turn human language into information. This advantage enables developers to focus on the process of creating apps, rather than the translation process [6, 7].

Related Work

Voice control is considered one of the methods that can be used to control prosthetic hands, as reported previously by many authors. Oppus et al. designed a system for controlling a three-dimensional (3D)-printed hand that depended on the mind wave and voice command using a voice recognition module (VRM) [7]. The system tested five hand gestures using voice commands, with 25 trials performed for each gesture. Samant et al. designed and applied a prosthetic arm that was controlled by a VRM and tested it by picking up an object and transferring it from one place to another [8]. Fang et al. designed a hybrid control system by combining EMG and speech signals to move a prosthetic arm by 3 degrees of freedom. The control system was tested on three groups of one subject. The speech signal was used to move the arm joint and the EMG signal was used to move the wrist joint [9]. Keerthi et al. designed a hybrid method for controlling the robotic prosthetic and speech signals used to control two classes of motion. Viniegra and Ierache developed an experimental system to control an upper-limp prosthetic hand with five classes of movement. This experiment was based on a brain–computer interface (BCI) depending on EEG signals and voice commands from the VRM; the command had to be voiced twice to be executed [10]. Jafarzadeh and Tadesse proposed a system to control a prosthetic-hand-based end-to-end convolutional neural network (CNN) using a digital microphone and an analog-to-digital converter. The microphone was used to read the speech signal that enters the neural network, to train it; 8-word commands were used to train the network [11]. Venkatagiri et al. designed a voice command to control a bionic hand. The speech order was delivered by the Bluecontrol app in an Android phone that sent to Arduino NANO, which controlled the robotic hand. Ten voice commands were used to control the hand via Bluetooth. This system did not use any type of intelligent process for voice commands [12].

These researchers used some types of unintelligent control systems of voice recognition and had to store each voice command, as it must be used precisely by the subject. These systems must train the user of the prosthetic hand regarding each command. Moreover, each move must be executed with one precise command, and each word must be spoken correctly. Many orders may have to be repeated for proper execution of the movement.

The Internet of Things (IoT) has been hailed as the most cutting-edge technology for the operation of numerous devices [13]. Google Assistant was regarded as a smart technology built on deep learning that has been integrated into numerous smart devices, including smartphones. Its voice recognition was proposed in this study. A robotic arm of amputee is controlled by Google Assistant that has emerged as a voice recognition technology by using Android mobile phones without any training process.

Methodology

The functionality of the system reported here was depended on the voice command that was sent through Google Assistant to the internet cloud, and then on to Arduino, which controlled the robotic hand, as shown in Fig. 1.

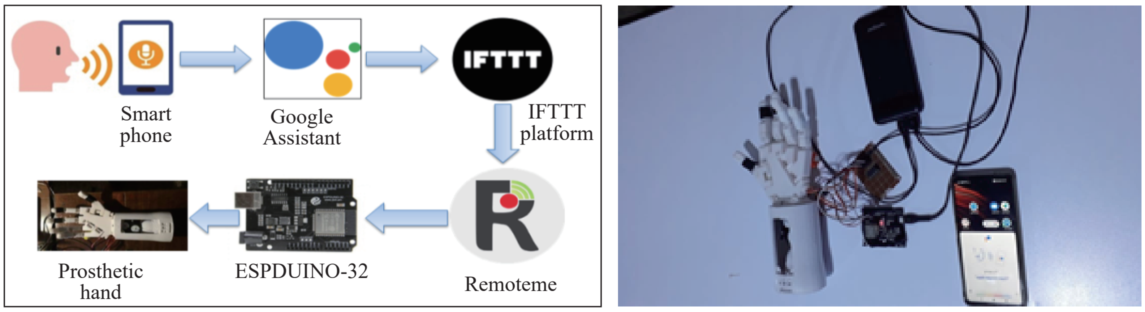

Fig. 1 Block diagram of the control system and the tools used in the present study.

Google Assistant

As shown in Fig. 2, Google Assistant is a smart personal assistant created by Google. It was created for use in a conversational setting [8]. Google Now is Google Assistant's forerunner. Google Home, which is a voice-activated speaker, is linked to Google Assistant. Google Now answers questions, makes recommendations, and performs actions by delegating requests to a variety of services via a natural-language-user interface. Furthermore, it predicts users' needs and presents information to them. Google Assistant is now provided in all Android smartphones [14].

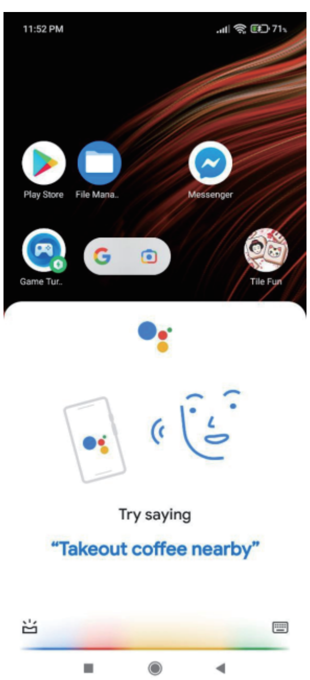

Fig. 2 Google Assistant application on an Android smartphone.

If This Then That (IFTTT) platform service

If This Then That (IFTTT) is a public-service platform that has received significant industry traction and acceptance. IFTTT provides a rational framework for service control. Users sign-up to the IFTTT platform and configure their accessible gadgets for activation by a wide range of triggers. The IFTTT platform enables the connection of Easy Control to many smart products or services. "Applets" can be generated by using the IFTTT approach. These applets are made up of a trigger (if this,...) and a related action (..., then that). If a trigger happens in one product or service (e.g., if "close hand"), IFTTT will perform the related action/s (e.g., the hand will close)[13, 14].

Five applets were created to control the robotic arm, as shown in Fig. 3, in which each applet represents one order that would be spoken to Google Assistant. These orders were as follows: (1) close hand; (2) open hand; (3) hand pinch; (4) hand index; and (5) hand thump. These orders are sent to the Remoteme cloud, which will translate these commands and send them to Arduino.

Remoteme

A system called Remoteme.org provides assistance by communicating with the microcontroller. Moreover, as shown in Fig. 4, Remoteme offers a library set for Arduino that may be used to communicate with the system itself. Any ESP8266 or ESP32 connected to the Remoteme cloud must have a device ID that is distinct and a device address in remoteme.org. Most frequently, the ESP Device is linked to the system using the plain socket protocol.

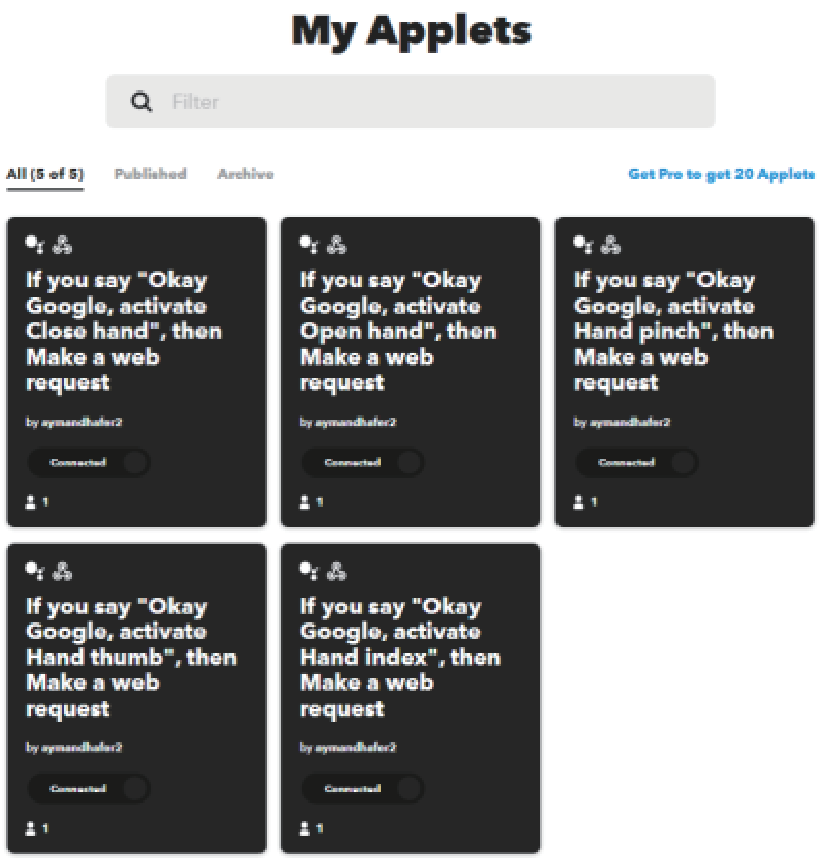

Fig. 3 The applets that were created to control the robotic arm.

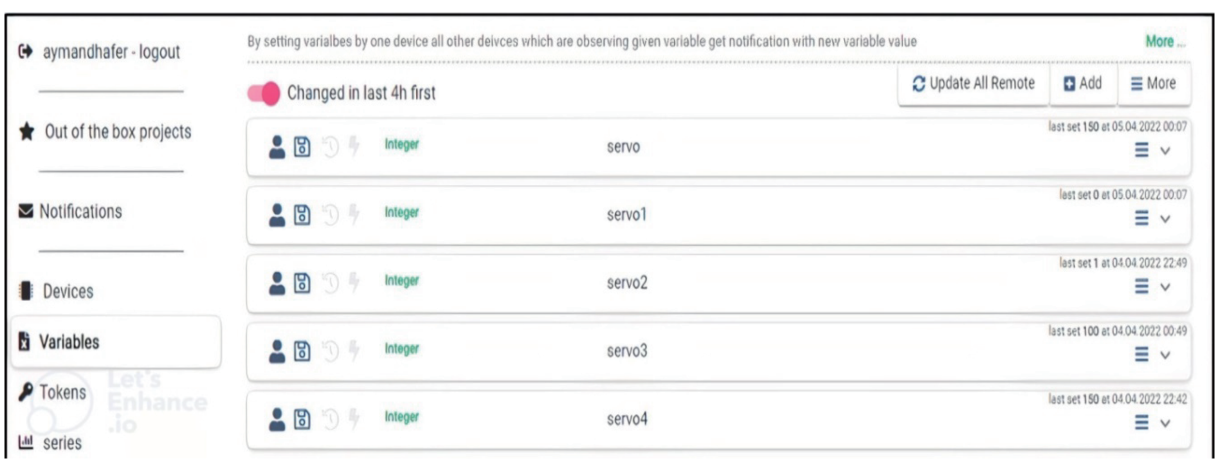

Fig. 4 The Remoteme cloud server connects with Arduino.

In the beginning, five integer variables must be set to add the servo motors of the prosthetic hand, followed by the addition of the WiFi network and its password and the generation of a code, which in then pasted into the Arduino IDE [15].

Microcontroller

As shown in Fig. 5, ESPDUINO-32 is a potent and universal WiFi+BT+BLE MCU module that is intended for use in a wide range of applications, from voice encoding to low-power sensor networks. The

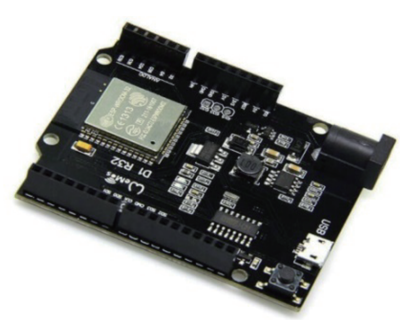

Fig. 5 Arduino ESPDUINO-32 which was used to control the robotic hand.

module is future-proof because of the combination of Bluetooth and WiFi; WiFi enables a wide physical range and a direct connection to the internet via a WiFi router, making it suitable for a variety of applications [16].

Algorithm used in the experiment

When the user talks to Google Assistant through the mobile microphone, Google sends the command (which is called a trigger) to the IFTTT platform. The command sends the order from IFTTT, which will call the http query to change the variable in the Remoteme cloud that sent the signal to Arduino, to control the prosthetic hand. The IFTTT platform can be programmed to perform moves executed by more than one possible word, thus giving the user more options to move the robotic hand. Google Assistant can be set to execute the command at the subject's voice imprint. This will trigger the assistant to execute the command according to the user's speech signals. The following flow chart explains the algorithm used in this experiment (Fig. 6).

Results and Discussion

This study included five subjects (three men and two women). Each subject gave five types of orders, as follows: (1) close hand; (2) open hand; (3) hand pinch; (4) hand index; and (5) hand thump. Each order represented a robotic hand movement. Each order is repeated twenty times. The purpose of repeating orders is to determine the types of command words that yield the highest level of response. The purpose of this verification step is to examine how voices are pronounced. When using the Google Assistant application on an Android smartphone, voice pronunciation must be accurate and precise. In turn, the Google Assistant application will reject a voice that has an improper and confusing pronunciation. The results are shown in the confusion matrix that was calculated by Eq. (1), which represents the accuracy of the response to the command words (Fig. 7). The average accuracy obtained for the five subjects was 97%; that was compared with the results of research performed by others, as shown in Table 1. The analysis of word responses revealed that the orders "close hand" and "open hand" exhibited the best acceptance, whereas the order "hand thump" yielded the weakest response among the five orders, as shown in Fig. 8. Speeches and types of words that are close in pronunciation to other words were poorly understood by the system.

$$\text{Accuracy} = \frac{\text{Truepositive} + \text{truenegative}}{\text{Truepositive} + \text{truenegative} + \text{falsepositive} + \text{falsenegative}} \quad (1)$$

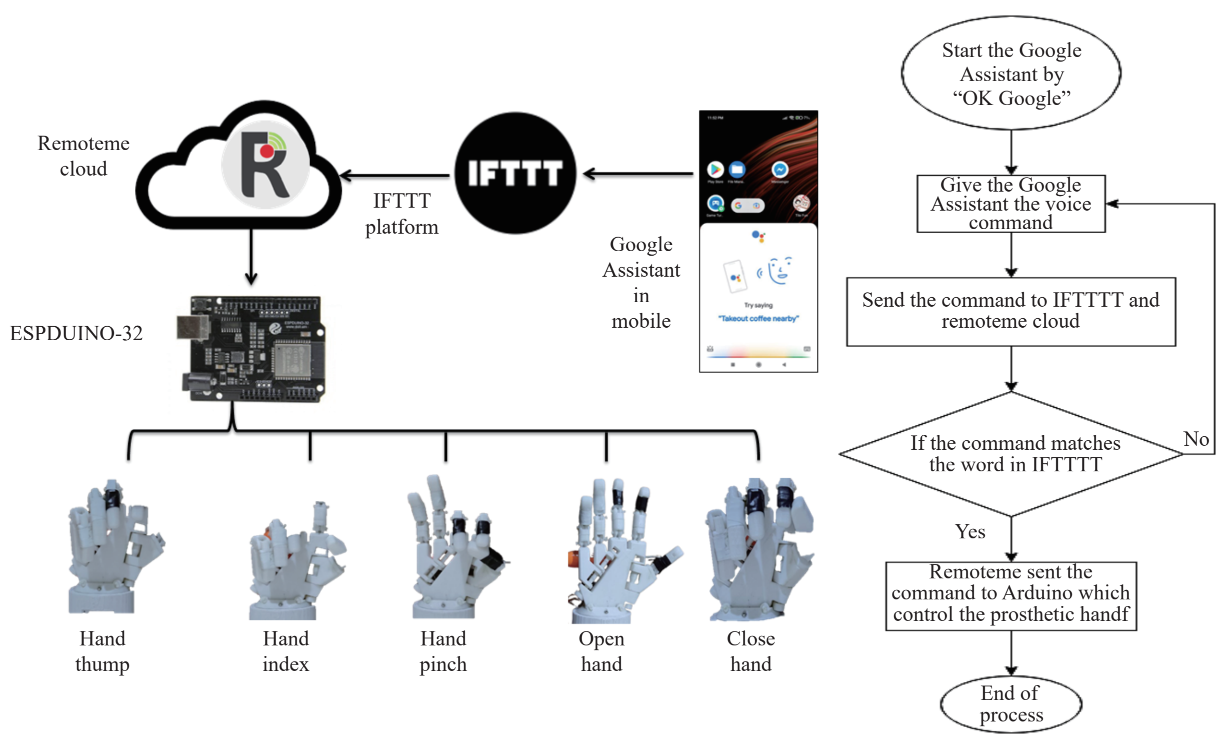

Fig. 6 Schematic diagram and flow chart of the algorithm process used in the experiment.

Fig. 7 Confusion matrix used for command response in the five subjects.

Table 1 Comparison of the accuracy obtained in this article with those reported by previous research

Source	Method	Accuracy
Oppus et al. [7]	VRM	89%
Samant and Agarwal [8]	VRM	88%
Jafarzadeh and Tadesse [11]	Convolutional neural network	88.1%
This article	Google Assistant and IoT	97%

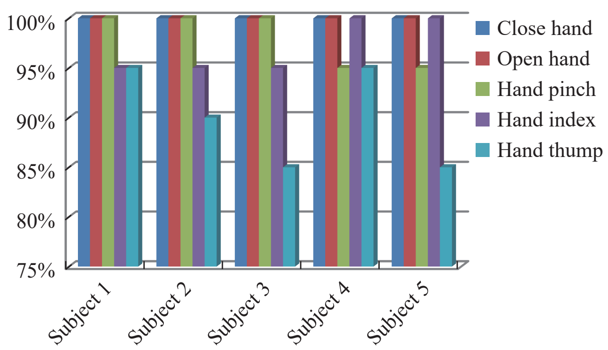

Fig. 8 Accuracy of the response to each spoken command.

Conclusion

This system showed a promising capability for controlling robotic prosthetic hands. The average accuracy of about 97% obtained here provides an optimal solution for controlling robotic hands. The accuracy of the system was calculated according to the equation of the confusion matrix. The system differed from other surveyed research in that it included a type of intelligent control. Moreover, the system did not require any type of training, which rendered it a simple system. The only requirements were writing the word to be used to move the robotic hand and voicing it to Google Assistant. The control system could consider an embedded independent system that the users can carry with them. All system parts are available and do not entail a high cost. In the future, this system can be used independently or in combination with another control system to move a prosthetic device.

CRediT Author Statement

Aymen Dhafer Abdul-nafa and **Suha S. Ahmed** conceived of the presented idea, developed the theory, performed the computations, and carried out the experiment. **Yahya Salim Ahmed** and **O. M. Alsaydia** wrote and reviewed the manuscript.

Acknowledgment

This work was supported by College of Dentistry and College of medicine of Mosul University, as well as Department of Medical Instrumentation Techniques Engineering, Electrical Engineering Technical College, Middle Technical University,

Conflict of Interest

The authors declare that no competing interest exists.

References

[1] F. Cordella, A.L. Ciancio, R. Sacchetti, et al. Literature review on needs of upper limb prosthesis users. *Frontiers in Neuroscience*, 2016, 10: 209. https://doi.org/10.3389/fnins.2016.00209

[2] Y.F. Fang, N. Hettiarachchi, D.L. Zhou, et al. Multi-modal sensing techniques for interfacing hand prostheses: A review. *IEEE Sensors Journal*, 2015, 15(11): 6065−6076. https://doi.org/10.1109/JSEN.2015.2450211

[3] T. Triwiyanto, A.M. Maghfiroh, S.D. Musvika, et al. State of the Art Methods of Machine Learning for Prosthetic Hand Development: A Review. In: Proceeding of the 3rd International Conference on Electronics, Biomedical Engineering, and Health Informatics, 2023: 555–574. https://doi.org/10.1007/978-981-99-0248-4_37

[4] M.S.H. Talpur, M.Z.A. Bhuiyan, G.J. Wang. Energy-efficient healthcare monitoring with smartphones and IoT technologies. *International Journal of High Performance Computing and Networking*, 2015, 8(2): 186−194. https://doi.org/10.1504/IJHPCN.2015.070019

[5] M.M. Islam, A. Rahaman, M.R. Islam. Development of smart healthcare monitoring system in IoT environment. *SN Computer Science*, 2020, 1(3): 185. https://doi.org/10.1007/s42979-020-00195-y

[6] E.V. Polyakov, M.S. Mazhanov, A.Y. Rolich, et al. Investigation and development of the intelligent voice assistant for the Internet of Things using machine learning. In: Proceedings of 2018 Moscow Workshop on Electronic and Networking Technologies (MWENT), 2018: 1−5. https://doi.org/10.1109/MWENT.2018.8337236

[7] C.M. Oppus, J.R.R. Prado, J.C. Escobar, et al. Brain-computer interface and voice-controlled 3D printed prosthetic hand. In: Proceedings of 2016 IEEE Region 10 Conference (TENCON), 2017: 2689–2693. https://doi.org/10.1109/TENCON.2016.7848527

[8] P. Samant, R. Agarwal. Real-time speech recognition system for prosthetic arm control. *International Journal of Sensing, Computing & Control*, 2015, 5(1): 39−46.

[9] P. Fang, Y.J. Geng, Z. Wei, et al. New control strategies for multifunctional prostheses that combine electromyographic and speech signals. *IEEE Intelligent Systems*, 2015, 30(4): 47−53. https://doi.org/10.1109/MIS.2015.40

[10] N. Viniegra, J. Ierache. Control of a robotic hand through voice commands and biosignals. In: Iberoamerican

Workshop on Human-Computer Interaction. Cham: Springer, 2021: 32–43. https://doi.org/10.1007/978-3-030-92325-9_3

[11] M. Jafarzadeh, Y. Tadesse. End-to-end learning of speech 2D feature-trajectory for prosthetic hands. In: Proceedings of 2020 Second International Conference on Transdisciplinary AI (TransAI), 2020: 25–33. https://doi.org/10.1109/TransAI49837.2020.00010

[12] R. Venkatagiri, A. Anish, S. Sujan, et al. Design and development of bionic hand using voice control. *International Journal of Innovative Science and Research Technology*, 2017, 2(5): 526−530.

[13] A. Agosti. Una religione afferrabile e terrena: due inediti di Franco Venturi sull’idea comunista. *Passato e Presente*, 2015, 33(95): 121−131.

[14] X. Mi, F. Qian, Y. Zhang, et al. An empirical characterization of IFTTT: ecosystem, usage, and performance. In: Proceedings of ACM Internet Measurement Conference, 2017: 398–404, 2017.

[15] H. Isyanto, A.S. Arifin, M. Suryanegara. Design and implementation of IoT-based smart home voice commands for disabled people using google assistant. In: Proceedings of 2020 International Conference on Smart Technology and Applications (ICoSTA), 2020: 1–6. https://doi.org/10.1109/ICoSTA48221.2020.1570613925

[16] ESP. ESP32 Series Datasheet. 2021.