Indian journal of
Engineering

A Robo-hand prototype design gripping device within the framework of sustainable development

Yasser Al-Sharo[1], Amer Abu-Jassar[1*], Vyacheslav Lyashenko[2], Vladyslav Yevsieiev[3], Svitlana Maksymova[3]

To Cite:
Al-Sharo Y, Abu-Jassar A, Lyashenko V, Yevsieiev V, Maksymova S. A Robo-hand prototype design gripping device within the framework of sustainable development. *Indian Journal of Engineering*, 2023, 20, e37ije1673
doi: https://doi.org/10.54905/disssi.v20i54.e37ije1673

Author Affiliation:
[1]Faculty of Information Technology, Department of Cyber Security Ajloun National University, Ajloun, Jordan
[2]Department of Media Systems and Technology, Kharkiv National University of Radio Electronics, Kharkiv, Ukraine
[3]Department of Computer-Integrated Technologies, Automation and Robotics, Kharkiv National University of Radio Electronics, Kharkiv, Ukraine

[*]**Corresponding author**
Faculty of Information Technology, Department of Cyber Security Ajloun National University, Ajloun,
Jordan
Email: Amer_abu_jassa@anu.edu.jo

Peer-Review History
Received: 06 October 2023
Reviewed & Revised: 10/October/2023 to 15/December/2023
Accepted: 24 December 2023
Published: 29 December 2023

Peer-Review Model
External peer-review was done through double-blind method.

Indian Journal of Engineering
pISSN 2319–7757; eISSN 2319–7765

ABSTRACT

In the modern world, the rate of science development is far ahead of the rate of latest research results implementation. For research results implementation, it is necessary to develop more and more new engineering solutions. Without them, all scientific developments will remain "on paper". At the first stage of making such solutions, it seems advisable to create prototypes for the systems that are under development. Such prototypes allow you to quickly make a working system with little effort and to test it for its performance, and to identify errors that need to be corrected. In the paper, the authors propose a robo-hand prototype design development. There was selected a necessary equipment and there were developed all the schemes required. In this work, an assembly of a gripping device prototype is presented.

Keywords: Engineering Solutions, Prototype, Robo-Hand, Anthropomorphic Gripping Device

1. INTRODUCTION

In the modern world, a considerable number of scientific minds are engaged in the development of various areas of science. Researchers generate ideas at an incredible rate. However, it is not enough to make ideas; it is necessary to test and further implement them. Scientists firstly have to check ideas functionality, and to implement them. Now, we even see the emergence of a new direction, namely the introduction of science in many areas. For example, the authors consider this direction in medicine (Ahmad et al., 2019; Bauer and Kirchner, 2020; Jacobson et al., 2020; Kilbourne et al., 2020; Orobinskyi et al., 2019; Savanevych et al., 2023). In the technical sciences, an acute problem is the choice or creation of engineering solutions that can fully implement a scientific idea. These solutions help to promote scientific ideas, to set up experiments, and to implement practical solutions.

We can see such solutions in many papers, where authors met some problem, came up with a scientific solution, and then developed an engineering solution to this problem, among them we want to distinguish

DISCOVERY
SCIENTIFIC SOCIETY

(Abu-Jassar et al., 2021; Al-Sharo et al., 2021; Bortnikova et al., 2019). Prototyping is crucial for accelerating of science development because it allows researchers to test ideas in practice, to improve them and to make the basis for new discoveries and innovations or to decide that they are not viable (Arce et al., 2022; Karayannis et al., 2022). Prototyping allows scientists to test hypotheses and ideas in practice, conduct experiments, and study their results. It helps to determine the effectiveness and potential limitations of the concepts.

Prototyping promotes innovation by allowing scientists and engineers to test new ideas, materials, and technologies. This process helps to develop new products, methods, and solutions to scientific problems. Prototyping allows improving and optimizing existing models or technologies based on the experience gained. It contributes to the constant development and improvement of scientific and engineering solutions. The prototyping process promotes exchanging knowledge and experience between scientists and specialists from different fields. It can be helpful for training students and young researchers, helping them understand methods and approaches to solving scientific problems (Zupan and Nabergoj, 2022). Science and engineering are closely related due to the fact that without engineering implementation, scientific ideas will remain useless "on paper".

Scientific research provides knowledge to create new products, technologies, solutions, devices, and systems. The principles that science makes become the basis for developing engineering concepts. Due to the scientific research, it becomes possible to understand physical, chemical, biological, and other principles. Consequently, it becomes possible to create new technologies and improve existing ones. Engineering solutions can generate new questions. And then explore and answer them through scientific research. Modern technologies have reached a high level. This has led to the fact that engineering solutions are very rarely simple and easy to implement. It is often impossible to immediately consider all the factors that affect the implementation of even seemingly simple ideas.

Therefore, the task of creating a prototype becomes urgent. In its "draft" version it helps to understand how the system as a whole works and what changes we need to made. Due to the rapid development of technology, modern engineering solutions face many challenges. There are increased performance requirements, environmental restrictions, etc. (Attar et al., 2022; Kuzomin et al., 2016). First of all, it is necessary to understand that artificial intelligence, quantum computing, biotechnology, and others are pretty complex. Accordingly, new challenges arise in the development, integration, and support of solutions. Many modern projects work with various systems, integrating multiple components, and subsystems. Managing such projects and ensuring compatibility between subsystems are complex tasks. It is also necessary to consider the need to protect information and restrict access. Due to an increase in the amount of data and connected devices, the risk of information leakage increases.

And the measures to provide information themselves will also be quite complex. It is necessary to organize and store this information. In some fields, during something new designing, researchers are faced with the necessity to develop sustainable technologies that consider resource efficiency and environmental impact. Influence on human health, social responsibility, and equal access to technologies are also meaningful. To solve these problems, it is often necessary to use an interdisciplinary approach, collaboration between specialists from different fields, and continuous learning and innovation. Because of this, the engineering solutions themselves are often quite complex. Prototypes are a common feature for many product design and development projects (Coutts et al., 2019). Prototypes are critical to successful products and innovative solutions creation (Lauff et al., 2019). A considerable number of technologies is the base for prototypes development. Among them, we can highlight the following.

Authors propose to use 3d-printed prototype for their project (Kumar et al., 2022). So, we can use prototyping with Arduino as in (Kondaveeti et al., 2021). In this work, Hari Kishan Kondaveeti and his co-authors present a systematic literature review to intensively analyze and compare existing primary studies on prototyping with Arduino. Let's take a quick look at the benefits of prototyping in robotics. First and foremost is concept validation, which is the ability to evaluate the viability and effectiveness of a robot idea or concept before committing large amounts of time and resources to complete development (Attar et al., 2022; Abu-Jassar et al., 2021; Al-Sharo et al., 2021). Next is that prototyping allows to correct errors at early stages. Prototyping can identify potential problems or errors in a robot's design, software, or mechanics early in development, allowing them to be corrected before they become more severe and costly.

The next advantage is the possibility of testing and improvement, since the prototype can be used for various tests and experiments. We also note the possibility of attracting funding and support. Because having a working prototype makes it more accessible to attract funding and support from investors, clients or other interested parties as it demonstrates the real potential of the project. Prototypes are also often used to facilitate communication between developers, engineers, and customers by visualizing ideas and helping to understand better what is required or expected from a project. Overall, prototyping in robotics helps speed up the development process, reduce risks, improve quality, and even save resources in the long run. That is why the work examines the main issues of prototyping for the developing an anthropomorphic gripping device. It is the primary purpose of this study.

2. MATERIALS AND METHODS

Technical Requirements to Prototype Determining

This paper presents the experience of a robo-hand prototype development (interactive gripping device) based on an Arduino board. We have designed this device to gain knowledge in creating robot manipulators. The device can repeat human movements with the help of a special glove worn by the operator. The device can bend the same fingers that a person turns to grasp and hold objects. The value of robotic hands lies in the possibility of human-like grasping of objects and further manipulating them. If you need to understand how to grasp an object, you need to study the behavior of the wrist. When you design a humanoid wrist, it is crucial to consider many parameters, among them we can distinguish dynamic and kinematic properties, a material choice, interaction with objects, and so on. It is necessary to determine the number of joints and their structure that must move to ensure maximum functionality of the humanoid wrist.

The relevance of this problem is due to the expectation that artificial robotic wrists, when interacting with objects familiar to humans, will be able to use their capabilities in such a way as to manipulate objects as skillfully as a human wrist. The gripping device is a manipulator part. A robot hand can be a single device or a part of a more complex device. The criterion that defines a robotic arm is DOF (Degrees of Freedom) – degrees of freedom, each of which is a movement. DOF indicates the ability of a geometric figure to perform geometric movements in (three-dimensional) space. Directions of movement: forward-backward, up-down, left-right (in the Cartesian coordinate system), including rotations around each of the three mutually perpendicular axes. The number of degrees of freedom determines the number of drives. If their number is higher, then the manipulator functionality is higher. Connections of the manipulator are the links. They will collectively form kinematic pairs, and these pairs form a kinematic chain.

In some cases, close emulation with the human hand is desired, as in robots designed to carry out disarmament and bomb disposal. A microcontroller controls the actuators are; developers usually locate actuators at the base of the lever. The actuators that operate the lever must provide sufficient torque to hold both the grip itself and the objects it holds. In addition, the actuators must provide accurate positioning and maintain their position under load. Numerous studies show that the use of an anthropomorphic robotic hand, which imitates the main features of a human hand, can significantly increase the fields of application of manipulators (Kim et al., 2021; Lopez et al., 2023; Rivera et al., 2021).

The problems of designing such a robotic hand are mainly related to the poor understanding of the human hand mechanics and kinematics and the possibility to reproduce critical biomechanical features with the help of a traditional mechanical design. Despite all the advantages, the main disadvantage of this design is the limited field of application. To clamp a wide range of parts, despite the considerable complexity of the design, anthropomorphic grippers are used, which include three or five movable fingers and thus copy a human hand to a certain extent. Modern mechanical manipulators are very far from being able to convey the complex mobility of the hand. Robot's fingers usually have one degree of freedom (rotate about one axis), but human fingers have two degrees of freedom.

Many authors note that even modern bionic prostheses use hinges with one degree of freedom - simpler and more reliable (Sun et al., 2021; Zhang et al., 2022). In addition, the human palm itself is not rigid. It can bend, change shape, cover, and squeeze the tool in the hand. There are robotic arms that are simple and straightforward to operate, similar to two or three-finger grippers that can reliably perform many tasks (Fan et al., 2021; Liu et al., 2020; Truby et al., 2019). There are also very complex hands with five fingers that are designed to fully repeat human hands (Rosenberger et al., 2020; Simone et al., 2020; Tieck et al., 2020; Wang et al., 2021). If we want the robot to perform as many operations as possible, it needs a hand that is as similar to a human as possible. In automatic control mode, the servo drives move links of the manipulators according to a previously compiled program.

An Anthropomorphic Gripping Device Development and Assembly

We have chosen the model from the personal project of the French sculptor and designer Gael Langevin called in Moov Chinbat and Lin, (2018) as the basis for the prototype of the gripping device. Gael Langevin has created this project in January 2012 as the first prosthetic hand with open access. This model was used in such projects Binotti et al., (2020) and E-Nable (Hawthorn and Ashbrook, 2017; Parry-Hill et al., 2017). A lot of researchers used this project as a basis (Berra et al., 2019; Gong et al., 2022; Paralı et al., 2022). At first, we have developed the functional scheme of our device (Figure 1). The gripper got a 5V and 3A power supply, as these are the characteristics required for the stable operation of the five servos. We have connected the microcontroller and servos to the power supply in parallel, so the integrated converter in the Arduino board steps down the voltage from 5V to 3.3V for stable operation of the microcontroller.

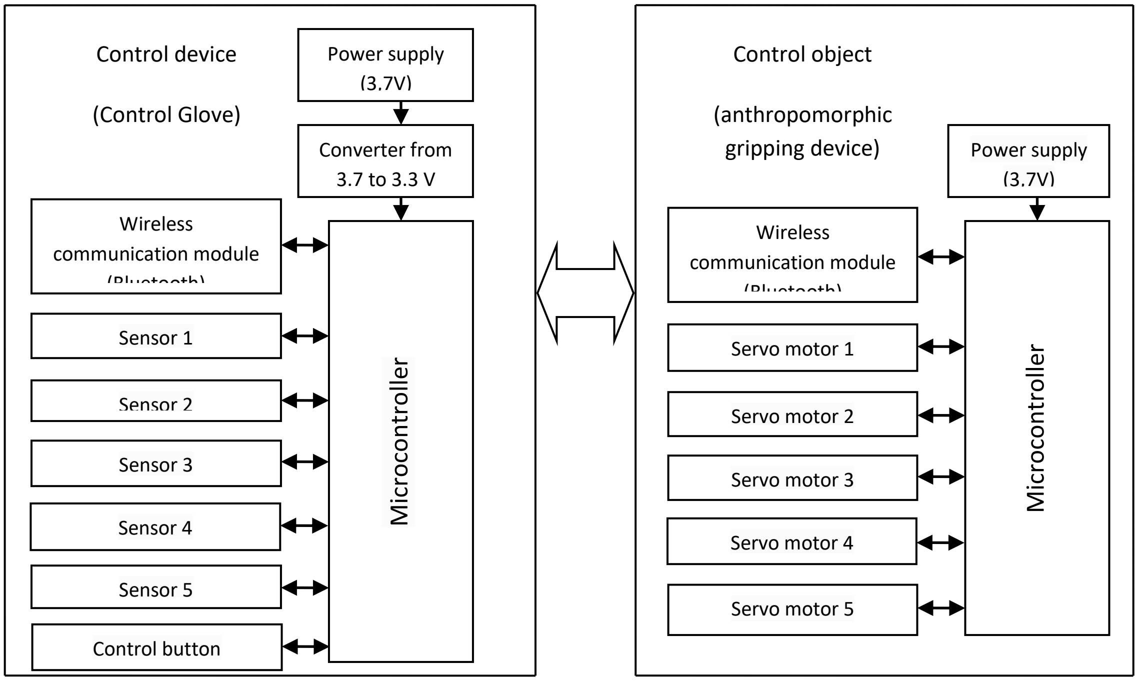

Figure 1 Functional Diagram of an Anthropomorphic Gripping Device

A microcontroller of the same model as for the gripper controls the bend sensor. We used a battery with a capacity of 4000 mAh and a voltage of 3.7 V for this microcontroller powering. Thanks to the integrated converter in the board; the microcontroller will receive a stable 3.3 V. We used this solution because the operating voltage for the bending sensors and the microcontroller is the same. The motor unit contains five servos with feedback to track the current shaft angle. Each servo has a tilt angle of 180°. The main hardware modules include MG995 servo motors, HC05 Bluetooth transmitters, and Arduino Nano microcontroller. We have chosen the Tower Pro MG995 servo because it fully meets the device's speed and torque requirements. In addition, it has metal gears, which are much more reliable.

However, this servo has one significant drawback compared to the Tower Pro SG90 - it is the operating temperature, which, in the case of using the Tower Pro MG995 outdoors, makes it impossible to use the device in the cold season. The HC-05 module is an easy-to-use Bluetooth SPP (Serial Port Protocol) module it is able to transparently set up a wireless serial connection. The serial port Bluetooth module is entirely Bluetooth V2.0+EDR (Extended Data Rate) 3Mbps with a full 2.4GHz baseband radio. It uses CSR Bluecore 04 external single-chip Bluetooth system with CMOS technology and AFH (Adaptive Frequency Switching). Figure 2 shows the HC-05 module and its primary contacts. The HC-05 module operates at a low voltage of 3.0 V and controls I/O from 3.0 V to 4.2 V. It has a built-in antenna, an edge connector, and a UART interface with a programmable data transfer rate.

Figure 2 HC-05 Module

The Arduino Nano is a full-featured miniature device based on the ATmega328 (Arduino Nano 3.0) or ATmega168 (Arduino Nano 2.x), microcontroller, adapted for use with breadboards. In terms of functionality, the device is similar to the Arduino Duemilanove and differs from it in size, lack of a power connector, and a different type (Mini-B) of USB cable. Figure 3 shows the pinout of the Arduino Nano board.

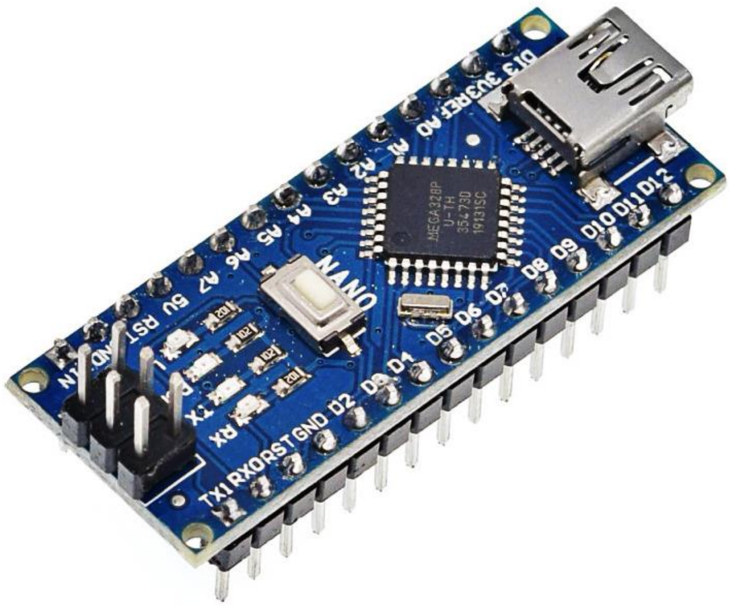

Figure 3 Arduino Nano Board Pinout

We have created the optical flexibility sensor (Figure 4). It consists of a flexible tube with two ends, a reflective inner wall inside the flexible tube, a light source placed at one end, and a photosensitive detector placed at the other end of the flexible tube. When the flexible tube is bent, it detects changes in a direct light rays combination.

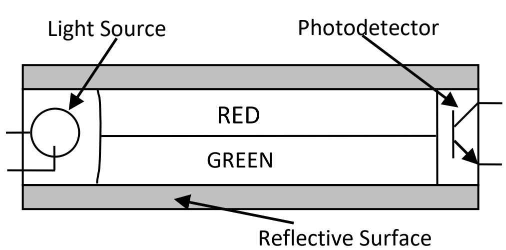

Figure 4 Optical flexibility sensor

The light flux from the LED enters the photoresistor through the silicon tube, and when it is bent, the light flux will fall smaller. Accordingly, the resistance at the output of the photoresistor will change. The silicone tube is elastic and resistant to moderate physical stress (for example, accidental impacts). The advantages of use include the ease of manufacturing a sensor of different lengths depending on the need, its low cost, arbitrary bending radius, relatively good linearity of readings, and a simple thermal method of restoring mechanical characteristics. Weak mechanical stability due to the absence of elastic elements is one of the disadvantages. You can use this sensor to study the basics of robotics and to build automation systems. Figure 5 presents the electrical components connection diagram.

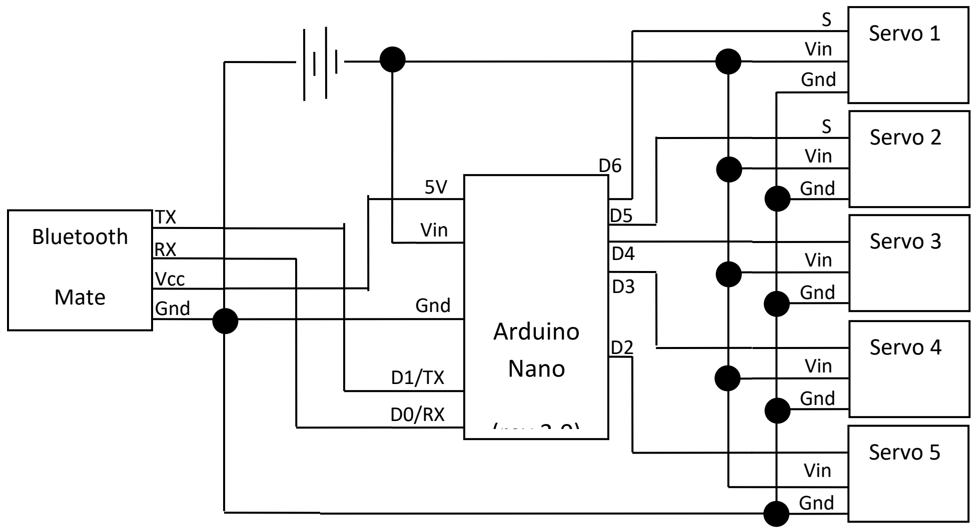

Figure 5 The Electrical Components Connection Diagram

Let us denote:

I_o – Initial level of the light signal reaching the optocoupler photodetector;

I – Current level of the light signal reaching the optocoupler photodetector;

S – A bend in the optical wire that changes the amount of light reaching the photodetector.

The signal level difference (ΔI) in this case is used to measure the changes in the optical signal that occur when the optical wire is bent. In the context of our optical sensor, bending the optical wire changes the amount of light reaching the optocoupler's photodetector. When the wire is fully straightened ($S = 0$), the initial level of the light signal (I_o) is fixed. When the wire is bent, the difference in light signal levels (ΔI) is measured. This difference is a quantitative indicator of the wire bending.

Calculating the signal level difference is important because it allows you to quantify the degree of optical wire bending. By analyzing (ΔI) and using appropriate calibration data or coefficients, we can determine the degree of bend and therefore the position or movement that you want to measure or control.

$$\Delta I = I - I_o, \quad (1)$$

where ΔI – signal level difference.

Let us represent ΔI in next way:

$$\Delta I = f(S) = k \cdot S, \quad (2)$$

where $f(S)$ – a function that describes the dependence of changes in the light signal level on the wire bend;

k – a coefficient that presents the sensitivity of our optical sensor to bending.

Based on the above formula, in the framework of these studies, the function represents a linear relationship between the change in the light signal and the degree of the wire bending. This assumption can be adapted depending on the specific characteristics of our sensor.

Let us give an example of a primary calculation. Let us say we have a sensor, and we have calibrated it to determine that with a fully straightened wire $S = 0$, the value of the initial light signal level is $I_o = 100$, and with a completely bent wire $S = S_{\max}$, the value of the light signal level is $I = 50$.

Then the difference in light signal levels will be:

$$\Delta I = I - I_o = 50 - 100 = -50. \quad (3)$$

Now, to convert this value to physical bend S, we can use the equation:

$$\Delta I = k \cdot S. \quad (4)$$

where k – coefficient that is determined during the sensor calibration process.

Substituting known values:

$$-50 = k \cdot S_{\max}. \quad (5)$$

Let's assume in the first calculation that the coefficient is $k = 2$, then:

$$-50 = 2 \cdot S_{max} . \quad (6)$$

Based on this, we can find the bend value S_{max}:

$$S_{max} = \frac{-50}{2} = -25 . \quad (7)$$

Note that the bend value S can be negative depending on the bend direction and the orientation of the designed sensor. When setting up an experimental layout, the values and coefficients will depend on the specific design and calibration of the proposed optical sensor. The obtained experimental values are shown further in the graphics. Figure 6 shows a prototype of a fully assembled anthropomorphic gripping device.

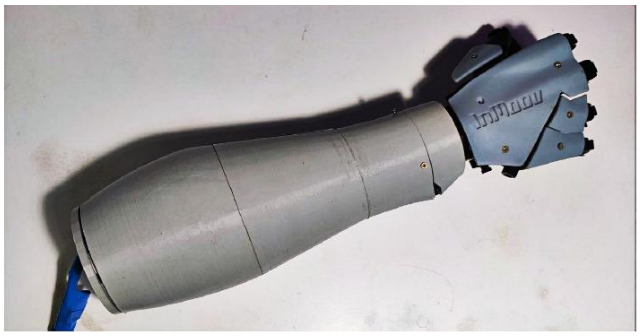

Figure 6 Assembled Prototype of An Anthropomorphic Gripping Device

This prototype comprises 21 3D printed parts, five servos, an Arduino Nano board, an HC-05 Bluetooth module, and a 5V power supply. Figure 7 shows this prototype fully disassembled.

Figure 7 All Hardware Parts of the Gripper Prototype

We can conditionally divide the assembly process into two stages. The first step is the hand wrist assembling, and the second step is the servo unit assembling. In the first stage, with the help of glue and pins, we collect each finger and push the fishing line through them. The fishing line must be fixed with a knot at the ends of the fingers so that it does not scroll while turning the servo. Next, we passed the fishing line through the holes in the palm, and then the fingers are attached to the palm and secured with large pins. At the end, we connected decorative overlays to the wrist. Figure 8 shows a photo of the finished gripper wrist.

The second stage begins with attaching the carriage for the servo drives to the inside of the case. We mounted five servo drives on this carriage with self-tapping screws. A pulley is attached to each servo, to which the fishing line is tied. All wires pass through technical holes to the outside for convenient connection to the control board. Figure 9 presents a fully assembled servo unit. After completing the assembly of the first and second stages, these parts are combined and connected to a microcontroller with a Bluetooth module and a power supply, and we get a gripper.

Figure 8 Gripper Wrist

Figure 9 Servo unit

3. RESULTS

In accordance with formulas (1), (2), we calibrated the sensors for each of the five fingers. First, we calibrated the sensors for the hand in a "relaxed" state, that is, when the bend S= 0 (Figure 10). And then we calibrated the sensors for sudden changes in bending (Figure 11). Next, we conducted an experiment to select the bending force of the sensors. After connecting the control device to the control unit, thanks to the Arduino IDE interface, we can to draw a graph of the resistance of the photoresistor against time. With this data, we can see the difference between the resistances on the different bend sensors. Figure 10 shows a graph where we can see this difference.

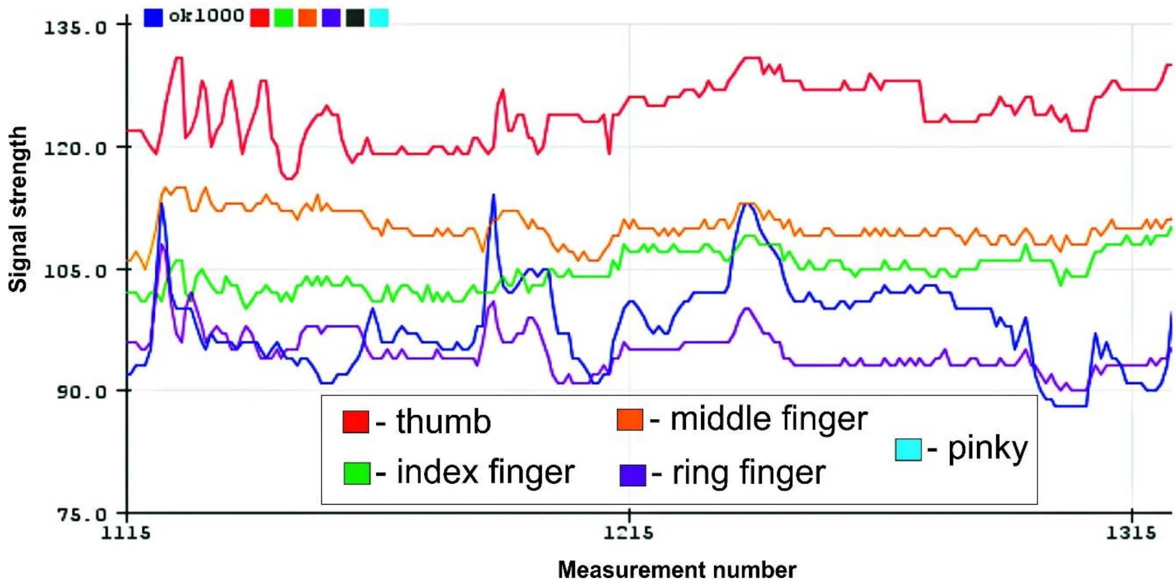

Figure 10 Graph of Resistance Versus Time for Five Photoresistors

In this figure, the hand is in a relaxed state. Calibration corrects the difference in resistance and does not prevent the gripper from working. Small fluctuations occur within the limits of a small error. we can observe the range in which the photoresistors work - from 60 ohms to 180 ohms by clenching and unclenching the hand with the control device on. Figure 11 presents this range.

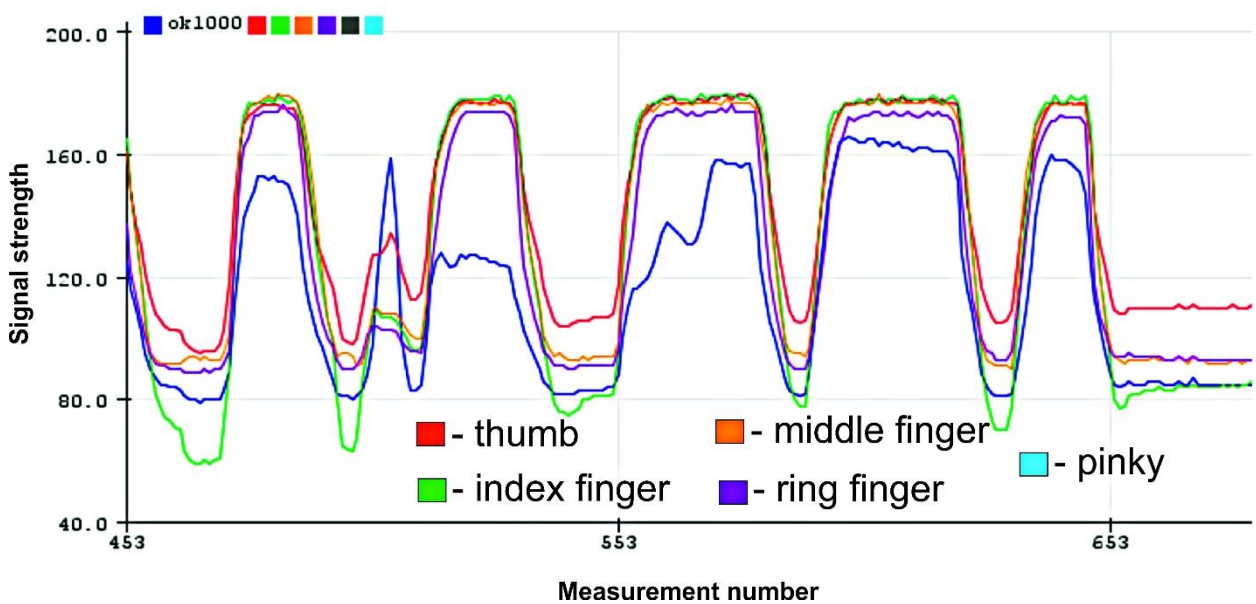

Figure 11 Graph of Dependence of Resistance on Time with Sudden Changes in Indicators

When manually entering these values into the program code, the gripping device works stably, so the experiment with the manual selection of values was successful. When the calibration mode is on, the program records all lower and upper threshold values for each photoresistor and converts these values for each servo on the gripper to an angle range of (0 – 180)°.

4. DISCUSSION

E. Morozova and co-authors propose a robotic glove prototype. It is based on sensors. It can control the robotic fingers to the remote processing of usual laboratory test benches (Morozova et al., 2021). They developed a prototype robotic glove. They used an Arduino board as the basis. They also used an additional low-pass filter to suppress noise from remote measurements. At the same time, the authors claim that the approach described in this paper can be used to remotely control such devices. They also developed a series of mathematical models that allowed them to create their device. Scientists note that a bionic hand can replace human hand during different operation performing. But in this case, it is necessary to equip it with fine motor ability (Shi et al., 2018). They also write that myoelectric control has been widely used to recognize hand movements. They propose a prototype system to identify hand postures.

They want to control a bionic hand by analyzing surface electromyography signals. That they measure at the flexor digitorum superficialis and extensor digitorum muscles. They also used Arduino microprocessor to control the bionic hand. The signals were received from the classification process. The microprocessor converted these signals. And they were fed to the servo motors controlling the bionic fingers. Authors developed a two-channel surface electromyography pattern-recognition system. This system can recognize human hand postures. And on the bases of this recognition the developed system controls a bionic hand to make the same hand postures. A soft robotic glove system based on surface electromyogram sensors is presented in paper (Zhao et al., 2021). This system can identify the finger activities. And then it performs the same actions via the bionic glove.

Authors proposed to identify finger activities by using electrodes sensors. These sensors allow monitoring the electric potential variations on different parts of hand. As the result, scientists developed bionic soft robotic glove. And this glove successfully demonstrated the finger action identification. Researchers turn our attention to the fact that we can use gesture-sensing gloves to control mechanical arm (Lili et al., 2019). They use the STM32 microcontroller as the core controller of the robotic arm. Also, they transplanted Linux operating system to the S3C2440 development board and established the LAN server. They also use the signet to control the robot's arm. Scientists introduced a new control-centric approach for the characteristics modeling for flex sensors on a goniometric glove (Syed et al., 2019). It was is designed to notice and to recognize the user hand gesture and then to wirelessly control a bionic hand. Authors used a black-box identification and the inverse dynamic model strategy to design the compensator.

This compensator provides an approximate linear mapping between the sensor output and the dynamic finger operations. This compensator is restructured into a Hammerstein–Wiener model to smoothly recover the goniometry on the bionic hand’s side when the wireless transmission. There is noted that current myoelectric interfaces based on surface electromyography often fail to achieve requirements by demanding multiple sensors and exhibiting unreliable performance under limb posture changes (Cheon et al., 2020). In this study, authors show that a myoelectric interface on the musculotendinous junctions (MTJs) of the flexor digitorum superficialis enables reliable control of a robotic glove with a single electromyography sensor by identifying power grasp intentions. They developed two myoelectric control methods for a mechanical glove-Dual-threshold control and Morse-code control. Further authors showed their performances in practical operations.

The complex research in the field of wearable gesture recognition devices development is presented in study (Ji et al., 2023). First of all, scientists analyze the benefits and flaws of four different approaches in designing interactive gloves. These approaches are based on the flexible strain sensors, inertial and magnetic sensors, vision sensors, and myoelectric sensors. Then the authors demonstrate the advantages of the flexible data glove based on strain sensor. Based on the analysis of all the literature above, we can identify one common drawback. These gloves usually use resistive flex sensors, which are pretty expensive (a minimum of 15$). Creating a bionic glove requires at least five such sensors. This fact leads to a significant increase in the cost of such a device. Further, we must not that with constant use of bend sensors, they become deformed over time, the accuracy of the readings decreases, and they “float”.

Therefore, regular reconfiguration of such sensors is required. To create such a glove, we developed our sensor based on an optocoupler. Next, we assembled a prototype and conducted an experiment to configure this sensor. The graphs above show the setup process, that is, selecting the signal level for the control system. Our sensor price does not exceed $2. This fact is a significant advantage over usually used sensors to solve similar problems. The main advantage of the developed robo-hand is the developed bending sensor. This sensor, based on an optocoupler, is more accurate and wear-resistant than its analogues in the above works. The simplicity of the sensor's operation ensures its reliability. Since the simpler the device, the more clearly it works. The physical processes underlying the basic operating principle of the developed sensor are described above. The experiments carried out showed the adequacy of the work of a robotic hand created using such sensors. Moreover, the cost of this sensor allows it to be replaced with even the smallest deviations from a given confidence interval of accuracy.

5. CONCLUSION

In the paper, a robo-hand prototype design development is proposed. We presented a general functional scheme, reflecting the functions of individual elements of the system and the connections between them. We analyzed the hardware modules. We selected MG995 servo motor, HC-05 Bluetooth transmitters and Arduino microcontroller. We also created a custom bending sensor. It meets all the project's requirements. Based on the developed wiring diagrams of the hardware modules of the control system and the wiring diagram of the hardware modules of the gripping device, we carried out the assembly of the prototype of the gripping device. We conducted an experiment to select the bending force of the sensors. This experiment showed that when we enter values manually into the program code, the gripping device works stably. In the future, we plan to develop a control system for the developed prototype and conduct several of experiments.

Author Contributions

Yasser Al-Sharo: Conceptualization, Writing Draft, Review; Amer Abu-Jassar: Formal analysis, Methodology, Writing – original draft; Vyacheslav Lyashenko: Writing Draft, Review and Editing; Vladyslav Yevsieiev: Conceptualization and Implementation, Writing Draft and Editing, Writing – original draft; Svitlana Maksymova: Writing Draft, Methodology and Implementation, Review and Editing. All the authors read and approved the final version of the manuscript.

Ethical issues

Not applicable.

Informed consent

Not applicable.

Funding

This study has not received any external funding.

Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Abu-Jassar AT, Al-Sharo YM, Lyashenko V, Sotnik S. Some Features of Classifiers Implementation for Object Recognition in Specialized Computer systems. TEM J 2021; 10(4):1645-1654. doi: 10.18421/TEM104-21
2. Ahmad MA, Baker JH, Tvoroshenko I, Lyashenko V. Modeling the structure of intellectual means of decision-making using a system-oriented NFO approach. Int J Emerg Trends Eng Res 2019; 7(11):460-465. doi: 10.30534/ijeter/2019/107112019
3. Al-Sharo YM, Abu-Jassar AT, Sotnik S, Lyashenko V. Neural Networks as A Tool for Pattern Recognition of Fasteners. Int J Eng Trends Tech 2021; 69(10):151-160. doi: 10.14445/22315381/IJETT-V69I10P219
4. Arce E, Suárez-García A, López-Vázquez JA, Fernández-Ibáñez MI. Design Sprint: Enhancing STEAM and engineering education through agile prototyping and testing ideas. Think Skills Creat 2022; 44(1):101039. doi: 10.1016/j.tsc.2022.101039
5. Attar H, Abu-Jassar AT, Yevsieiev V, Nevliudov I, Lyashenko V, Luhach AK. Zoomorphic Mobile Robot Development for Vertical Movement Based on the Geometrical Family Caterpillar. Comput Intel Neurosc 2022; 2022:3046116. doi: 10.1155/2022/3046116
6. Bauer MS, Kirchner J. Implementation science: What is it and why should I care? Psychiatatry Res 2020; 283:112376. doi: 10.1016/j.psychres.2019.04.025
7. Berra R, Setti F, Cristani M. Berrick: a low-cost robotic head platform for human-robot interaction. In 2019 IEEE International Conference on Systems, Man and Cybernetics (SMC) 2019; 559-566. doi: 10.1109/SMC.2019.8913932
8. Binotti M, Di-Marcoberardino G, Manzolini G. BIONICO-Biogas membrane reformer for decentralized hydrogen production. Impact 2020; 2020(4):46-48. doi: 10.21820/23987073.2020.4.46
9. Bortnikova V, Yevsieiev V, Beskorovainyi V, Nevliudov I, Botsman I, Maksymova S. Structural parameters influence on a soft robotic manipulator finger bend angle simulation. In 2019 IEEE 15th International Conference on the Experience of Designing and Application of CAD Systems (CADSM), Polyana, Ukraine 2019; 35-38. doi: 10.1109/CADSM.2019.8779300
10. Cheon S, Kim D, Kim S, Kang BB, Lee J, Gong HS, Jo S, Cho KJ, Ahn J. Single EMG sensor-driven robotic glove control for reliable augmentation of power grasping. IEEE Trans Med Robot Bionics 2020; 3(1):179-189. doi: 10.1109/TMRB.2020.3046847

11. Chinbat O, Lin JS. Prosthetic arm control by human brain. In 2018 International Symposium on Computer, Consumer and Control (IS3C) 2018; 54-57. doi: 10.1109/IS3C.2018.00022
12. Coutts ER, Wodehouse A, Robertson J. A comparison of contemporary prototyping methods. In Proceedings of the design society: international conference on engineering design 2019; 1(1):1313-1322. doi: 10.1017/dsi.2019.137
13. Fan P, Yan B, Wang M, Lei X, Liu Z, Yang F. Three-finger grasp planning and experimental analysis of picking patterns for robotic apple harvesting. Comput Electron Agr 2021; 188:106353. doi: 10.1016/j.compag.2021.106353
14. Gong L, Chen B, Xu W, Liu C, Li X, Zhao Z, Zhao L. Motion similarity evaluation between human and a tri-co robot during real-time imitation with a trajectory dynamic time warping model. Sens (Basel) 2022; 22(5):1968. doi: 10.3390/s22051968
15. Hawthorn P, Ashbrook D. Cyborg pride: Self-design in e-NABLE. In Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility 2017; 422-426. doi: 10.1145/3132525.3134780
16. Jacobson TA, Smith LE, Hirschhorn LR, Huffman MD. Using implementation science to mitigate worsening health inequities in the United States during the COVID-19 pandemic. Int J Equity Health 2020; 19:1-6. doi: 10.1186/s12939-020-01293-2
17. Ji B, Wang X, Liang Z, Zhang H, Xia Q, Xie L, Yan H, Sun F, Feng H, Tao K, Shen Q, Yin E. Flexible Strain Sensor-Based Data Glove for Gesture Interaction in the Metaverse: A Review. Int J Hum Compu Interact 2023; 1-20. doi: 10.1080/10447318.2023.2212232
18. Karayannis P, Saliakas S, Kokkinopoulos I, Damilos S, Koumoulos EP, Gkartzou E, Gomez J, Charitidis C. Facilitating Safe FFF 3D Printing: A Prototype Material Case Study. Sustain 2022; 14(5):3046. doi: 10.3390/su14053046
19. Kilbourne AM, Glasgow RE, Chambers DA. What can implementation science do for you? Key success stories from the field. J Gen Intern Med 2020; 35(Suppl 2):783-787. doi: 10.1007/s11606-020-06174-6
20. Kim U, Jung D, Jeong H, Park J, Jung HM, Cheong J, Choi HR, Do H, Park C. Integrated linkage-driven dexterous anthropomorphic robotic hand. Nat Commun 2021; 12(1):7177. doi: 10.1038/s41467-021-27261-0
21. Kondaveeti HK, Kumaravelu NK, Vanambathina SD, Mathe SE, Vappangi S. A systematic literature review on prototyping with Arduino: Applications, challenges, advantages, and limitations. Compu Sci Rev 2021; 40(38):100364. doi: 10.1016/j.cosrev.2021.100364
22. Kumar V, Singh R, Ahuja IS. On 3D printed meta-structure-based functional prototype as an innovative solution for repair and online health monitoring of heritage structures. Mater Lett 2022; 326:132950. doi: 10.1016/j.matlet.2022.132950
23. Kuzomin O, Lyashenko V, Tkachenko M, Ahmad MA, Kots H. Preventing of technogenic risks in the functioning of an industrial enterprise. Int J Civ Eng Technol 2016; 7(3):262-270.
24. Lauff C, Menold J, Wood KL. Prototyping canvas: Design tool for planning purposeful prototypes. In Proceedings of the design society: international conference on engineering design 2019; 1(1):1563-1572. doi: 10.1017/dsi.2019.162
25. Lili T, Qijun H, Wei H. IoT Multi-Control Bionic Manipulator's Design. In 2019 3rd International Conference on Circuits, System and Simulation (ICCSS) 2019; 1-4. doi: 10.1109/CIRSYSSIM.2019.8935609
26. Liu CH, Chung FM, Chen Y, Chiu CH, Chen TL. Optimal design of a motor-driven three-finger soft robotic gripper. IEEE/ASME Transactions on Mechatronics 2020; 25(4):1830-1840. doi: 10.1109/TMECH.2020.2997743
27. Lopez PR, Oh JH, Jeong JG, Jung H, Lee JH, Jaramillo IE, Chola C, Lee WH, Kim TS. Dexterous Object Manipulation with an Anthropomorphic Robot Hand via Natural Hand Pose Transformer and Deep Reinforcement Learning. Appl Sci 2023; 13(1):379. doi: 10.3390/app13010379
28. Morozova E, Demidova G, Rassolkin A. Robotic glove prototype: Development and simulation. In 2021 IEEE 62nd International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON) 2021; 1-5. doi: 10.1109/RTUCON53541.2021.9711744
29. Orobinskyi P, Petrenko D, Lyashenko V. Novel Approach to Computer-Aided Detection of Lung Nodules of Difficult Location with Use of Multifactorial Models and Deep Neural Networks. In 2019 IEEE 15th International Conference on the Experience of Designing and Application of CAD Systems (CADSM) 2019; 1-5. doi: 10.1109/CADSM.2019.8779340
30. Paralı L, Ali S, Mehmet E. Design of a 3D Printed Open-Source Humanoid Robot. Bitlis Eren Üniversitesi Fen Bilimleri Dergisi 2022; 11(2):411-420. doi: 10.17798/bitlisfen.998006
31. Parry-Hill J, Shih PC, Mankoff J, Ashbrook D. Understanding volunteer at fabricators: opportunities and challenges in diy-at for others in e-nable. In Proceedings of the 2017 CHI conference on human factors in computing systems 2017; 6184-6194. doi: 10.1145/3025453.3026045
32. Rivera P, Valarezo Añazco E, Kim TS. Object manipulation with an anthropomorphic robotic hand via deep reinforcement learning with a synergy space of natural hand poses. Sens (Basel) 2021; 21(16):5301. doi: 10.3390/s21165 301
33. Rosenberger P, Cosgun A, Newbury R, Kwan J, Ortenzi V, Corke P, Grafinger M. Object-independent human-to-robot

handovers using real time robotic vision. IEEE Robot Autom Lett 2020; 6(1):17-23. doi: 10.1109/LRA.2020.3026970
34. Savanevych V, Khlamov S, Briukhovetskyi O, Trunova T, Tabakova I. Mathematical Methods for an Accurate Navigation of the Robotic Telescopes. Mathematics 2023; 11 (10):2246. doi: 10.3390/math11102246
35. Shi WT, Lyu ZJ, Tang ST, Chia TL, Yang CY. A bionic hand controlled by hand gesture recognition based on surface EMG signals: A preliminary study. Biocybern Biomed Eng 2018; 38(1):126-135. doi: 10.1016/j.bbe.2017.11.001
36. Simone F, Rizzello G, Seelecke S, Motzki P. A soft five-fingered hand actuated by Shape Memory Alloy wires: design, manufacturing, and evaluation. Front Robot AI 202 0; 7:608841. doi: 10.3389/frobt.2020.608841
37. Sun Y, Tang H, Tang Y, Zheng J, Dong D, Chen X, Liu F, Bai L, Ge W, Xin L, Pu H, Peng Y, Luo J. Review of recent progress in robotic knee prosthesis related techniques: Structure, actuation and control. J Bionic Eng 2021; 18(4):764 -785. doi: 10.1007/s42235-021-0065-4
38. Syed SAA, Ahmad NS, Goh P. Flex sensor compensator via Hammerstein–Wiener modeling approach for improved dynamic goniometry and constrained control of a bionic hand. Sens (Basel) 2019; 19(18):3896. doi: 10.3390/s19183896
39. Tieck JCV, Weber S, Stewart TC, Kaiser J, Roennau A, Dillmann R. A spiking network classifies human sEMG signals and triggers finger reflexes on a robotic hand. Robot Auton Syst 2020; 131:103566. doi: 10.1016/j.robot.2020.103566
40. Truby RL, Katzschmann RK, Lewis JA, Rus D. Soft robotic fingers with embedded ionogel sensors and discrete actuation modes for somatosensitive manipulation. In 2019 2nd IEEE international conference on soft robotics (RoboSoft) 2019; 322-329. doi: 10.1109/ROBOSOFT.2019.872 2722
41. Wang Y, Li W, Togo S, Yokoi H, Jiang Y. Survey on Main Drive Methods Used in Humanoid Robotic Upper Limbs. Cyborg Bionic Systems 2021; 2021:9817487. doi: 10.34133/20 21/9817487
42. Zhang Z, Zhang Y, Zhao J, Zhou Z. Design method of a single degree-of-freedom planar linkage bionic mechanism based on continuous position constraints. Mech Mach Theory 2022; 170:104730. doi: 10.1016/j.mechmachtheory.20 22.104730
43. Zhao S, Wang Z, Lei Y, Huang S, Zhang J, Liu J, Gong Z. A bionic soft robotic glove mimicking finger actions based on sEMG recognition. Preprint (Version 1) 2021. doi: 10.21203/r s.3.rs-418019/v1
44. Zupan B, Nabergoj AS. Design thinking as a course design methodology. Design Thinking 2022; 17-39. doi: 10.1201/978 1003189923