ТЕХНИЧЕСКИЕ НАУКИ
И ТЕХНОЛОГИИ

ЖАСАНДЫ ИНТЕЛЛЕКТ ЖӘНЕ МАШИНАЛЫҚ ОҚЫТУ
ИСКУССТВЕННЫЙ ИНТЕЛЛЕКТ И МАШИННОЕ ОБУЧЕНИЕ
ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

DOI 10.51885/1561-4212_2023_4_111
IRSTI 20.53.23

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IMPLEMENTATION OF A PROTOTYPE FOR CONTROLLING VARIOUS INFORMATION SYSTEMS AND DEVICES USING GESTURE CONTROL

ҚИМЫЛДАРДЫ БАСҚАРУДЫ ПАЙДАЛАНАТЫН ТҮРЛІ АҚПАРАТТЫҚ ЖҮЙЕЛЕР МЕН ҚҰРЫЛҒЫЛАРДЫ БАСҚАРУ ҮШІН ТӘЖІРИБЕЛІК ЖҮЗЕГЕ АСЫРУ

РЕАЛИЗАЦИЯ ПРОТОТИПА ДЛЯ УПРАВЛЕНИЯ РАЗЛИЧНЫМИ ИНФОРМАЦИОННЫМИ СИСТЕМАМИ И УСТРОЙСТВАМИ С ИСПОЛЬЗОВАНИЕМ ЖЕСТОВОГО УПРАВЛЕНИЯ

***Abstract**. The article provides a brief description of the principles of operation of a prototype device, referred to at the time of development as Glove's Keyboard (GloK), the main function of which is to interact with a wide range of computing equipment (from personal computers to industrial manipulators) and to combine the most common HID devices, such as: mouse, keyboard and joystick. The prototype device is a glove equipped with gyroscope-accelerometer sensors capable of detecting finger positions. The developed cross-platform software provides the ability to conduct communication sessions with devices, obtain data and visualize them using 3D graphics.*

***Keywords:** motion capture; gyroscope-accelerometer, MPU6050, ESP32, microcontrollers, gesture control, gesture recognition, gesture classification, human-computer interaction, HID-devices.*

***Аңдатпа**. Мақалада әзірлеу кезінде Glove's Keyboard (GloK) деп аталған құрылғының прототипінің жұмыс істеу принциптерінің қысқаша сипаттамасы берілген, оның негізгі қызметі есептеу техникасының кең спектрімен (дербес компьютерлерден бастап компьютерге дейін) өзара әрекеттесу болып табылады. өнеркәсіптік манипуляторлар) және ең көп таралған HID құрылғыларын біріктіру үшін, мысалы: тінтуір, пернетақта және джойстик. Құрылғының прототипі - саусақтардың орнын анықтауға қабілетті гироскоп-акселерометр сенсорларымен жабдықталған қолғап. Әзірленген кросс-платформалық бағдарламалық қамтамасыз ету құрылғылармен байланыс сеанстарын жүргізу, деректерді алу және 3D графикасы арқылы оларды визуализациялау мүмкіндігін қамтамасыз етеді.*

***Түйін сөздер**: қозғалысты түсіру; гироскоп-акселерометр, MPU6050, ESP32, микроконтроллерлер, ыммен басқару, қимылдарды тану, қимылдарды жіктеу, адам мен компьютердің өзара әрекеттесуі, HID құрылғылары.*

***Аннотация.** В статье приводится краткое описание принципов работы прототипа устройства, именуемого на момент разработки как Glove’s Keyboard (GloK), основной функцией которого является взаимодействие с широким рядом вычислительной техники (от персональных компьютеров до промышленных манипуляторов) и совмещение наиболее* *распространенных HID устройств, таких как: компьютерная мышь, клавиатура и джойстик. Прототип устройства представляет собой перчатку, оснащенную датчиками гироскопа-акселерометра, способных определять положения пальцев. Разработанное кроссплатформенное программное обеспечение обеспечивает возможность проведения сеансов коммуникации с устройствами, получение данных и их визуализацию с использованием 3D-графики.*

Ключевые слова: *захват движений; гироскоп-акселерометр, MPU6050, ESP32, микроконтроллеры, жестовое управление, распознавание жестов, классификация жестов, человеко-компьютерное взаимодействие, HID-устройства.*

Introduction. Currently, there is an acute problem in the complex information systems management. In particular, at the moment in robotics, automated systems have acquired considerable complexity and many degrees of freedom, which has complicated their management using standard peripheral devices [1, 2]. During the tooling of robots, the operator must manually write a code to move to certain positions. This task is simplified by the use of joysticks, but the problem of managing complex systems is not solved [3]. Humanoid robots with a huge number of degrees of freedom are becoming a particular problem, and it becomes obvious to use the capture of human movements for control [4, 5]. During the development, there was a need to expand the functionality, which allowed interaction with a variety of computing equipment and thereby increased the number of potential users who can use this device. To do this, it was planned to use HID (Human Interface Device) standards, which greatly facilitate the task of compatibility with different devices. Thus, the device should emulate the functionality of such devices as a keyboard, a computer mouse and a joystick [6].

Despite the rapid development of the information sphere, keyboards have remained unchanged since their inception. The use of keyboards is not convenient for humans. Many independent engineers offer their solutions to this problem, but they look like exotic products for a regular user. Other authors improve ergonomics by changing the location of the keys and the shape of the device. However, it's still the same keyboard with the same buttons. The device being developed offers a new way of entering information - using gestures.

When using a device using gestures, the intermediate device between the fingers and the computer is eliminated, since we can directly enter data from the fingers.

Thus, the purpose of this study is to design a prototype device for interacting with various computing equipment using gesture fixation, using gyroscope-accelerometer sensors.

Materials and methods of research. The project is divided into three parts: motion capture by reading data from sensors, data classification for gesture detection and association with a specific command, a client application for device configuration [7].

In this case, the device must meet the following conditions: low cost for the end user; speed; compactness; ease of use; the ability to connect to devices without their pre-configuration; scalability by devices (the potential for expanding the functionality of the device should be taken into account); the ability to work with both wired and wireless technologies; device configurability.

During the analysis of the requirements for the project, an overview of existing methods and implemented devices designed to meet these needs was carried out. One of the approaches considered was the computer vision technology used to track movements [8]. However, this technology has a number of significant disadvantages associated with the need to use specialized equipment and equip the room with cameras. As a result, it was decided to abandon the use of this technology. An alternative solution was the development of wearable motion sensors based on gallium thin films [9]. Despite the fact that this technology has high potential, it cannot guarantee stable results, as it is currently at the research stage.

As a result of the analysis, two most suitable options for the implementation of the project were identified. The first concerns the development of a biomechanical anthropomorphic human hand [10], the main purpose of which is to create prosthetic hands. In this case, it is necessary to implement a glove with which it is possible to read the position of the operator's fingers and transmit information to a robotic prosthesis using a cascade of encoders. However, this device has a disadvantage – the lack of compactness, which contradicts one of the key requirements for the device being developed.

The second option is presented by the development of the industrial company Shadow Robotics [11], their solution is the most advanced among those considered. However, similar to the previous example, this project limits its scope of application to remote control of robotic devices and does not provide for the expansion of functionality for a wide range of computing equipment.

Based on the analysis carried out above, it was decided to use gyroscope-accelerometer sensors, since they provide compactness, low cost and ease of implementation of the device. During the development of the project, among other things, the algorithms presented in the research article [12] were used to determine the orientation of sensors based on data received from a magnetometer, gyroscope and accelerometer.

The creation of a prototype can be divided into three main stages. The first stage is the design of a prototype in the form of a glove for further reading of finger movements involves achieving compactness and a large number of possible input combinations.

An ESP32 microcontroller will be used to perform the calculations. The choice was made based on the following factors: ease of operation and dual-core processor, as well as support for wireless technologies at the microcontroller level. Thus, the problems of performance and the ability to work with wired and wireless devices are solved.

To read the data, it was decided to use the module with the MPU6050 gyroscope-accelerometer sensor. The choice was made due to the fact that the module supports the I2C protocol, the ability to change the I2C address. In synthesis, these factors make it possible to connect a large number of sensors.

The second stage is the development of an application that is able to visualize data received from sensors and facilitates the creation of new gestures, thereby simplifying the process of writing a configuration.

The third stage is the implementation of the prototype of the device, which can be conditionally divided into a physical implementation (represents the physical design of the device and includes the electrical circuit of the device) and the design of the appearance of the device, which covers the components used in the device and their location.

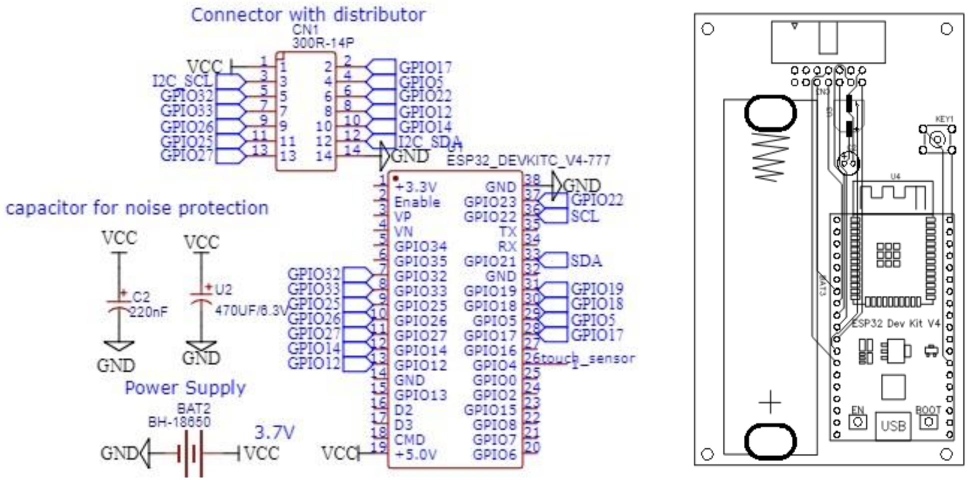
ESP 32 has a dual-core processor [13], as well as support for FreeRTOS [14]. Together, this makes it possible to easily divide the program into tasks and threads. For more stable operation of the device, a printed circuit board was designed. This will reduce possible errors and significantly increases the possibility for reproducibility of the device. The total financial costs amounted to $70.

The main unit is designed for power management and control of the entire device. Accordingly, it is here that all the elements feeding the board and the microcontroller are located. The complete schemes of the block under consideration are shown in Figures 1a, b.

Based on the fact that the architecture of the ESP 32 microcontroller, on the basis of which the device is implemented, has a dual-core architecture [13], it is rational to use the fully available capacities. To do this, the FreeRTOS operating system [14] was used, which implements basic flow and task management in embedded software.

To emulate the keyboard, you will need a classification of gestures and an association of the received data with a specific command.

The gesture classification routine can be integrated both into internal software and placed on an external device. The functionality of this program includes the association of the received data with a gesture and the issuance of a command corresponding to the recognized gesture. It should be noted that commands can be either individual keystrokes, or rather complex combinations, such as automatic login/password insertion, script execution, etc. Accordingly, these gestures must be defined in advance. The configuration specifies a set of gestures.



a *b*

Figure 1. Diagrams of the main unit of the device: a – Basic electrical diagram of the main unit; b – The circuit board of the main unit

Each of the gestures has the following parameters: name; team; a set indicating the sensors used; permissible deviation in time between the execution of the sequence; permissible deviation in coordinates from the specified coordinate points; sequence of points for each sensor; array of pointers to the currently considered elements in each sequence of points.

To implement calculations, you need a device that includes an interface, a data warehouse, a classifier and a visualizer (Figure 2).

The external computing interface is responsible for receiving data from the external environment and their subsequent transfer to the data warehouse. It provides the preparation and transformation of data for further use within the system.

The data warehouse is an intermediate link that receives information from the interface and redirects it to the classifier and visualizer. This ensures centralized storage and management of data, as well as their distribution to other components of the system.

The visualizer takes data from the storage and displays it on the user's screen. This provides a visual representation of the data, transforming abstract information into a form that is understandable and accessible to the user.

The classifier, receiving data from the storage, processes them and sends the recognized commands back to the visualizer and interface. This provides intelligent data processing, allows you to convert input data into information that can then be used to execute commands.

At the end of the work cycle, the interface sends the recognized commands back to the external environment, which completes the cycle.

The client application is written in the C++ programming language using the QT framework. Here we define the ”item” class to work with sensor-related data. This is the base class for objects that can be mapped using OpenGL. The class contains information about the geometry, position and rotation of the object, as well as its hierarchy. In order not to access objects of the item class directly, the adapter_item class is implemented, which acts as an interface and intermediate object for all item objects. That is, the adapter_item class is used to manage a set of objects of the item type.

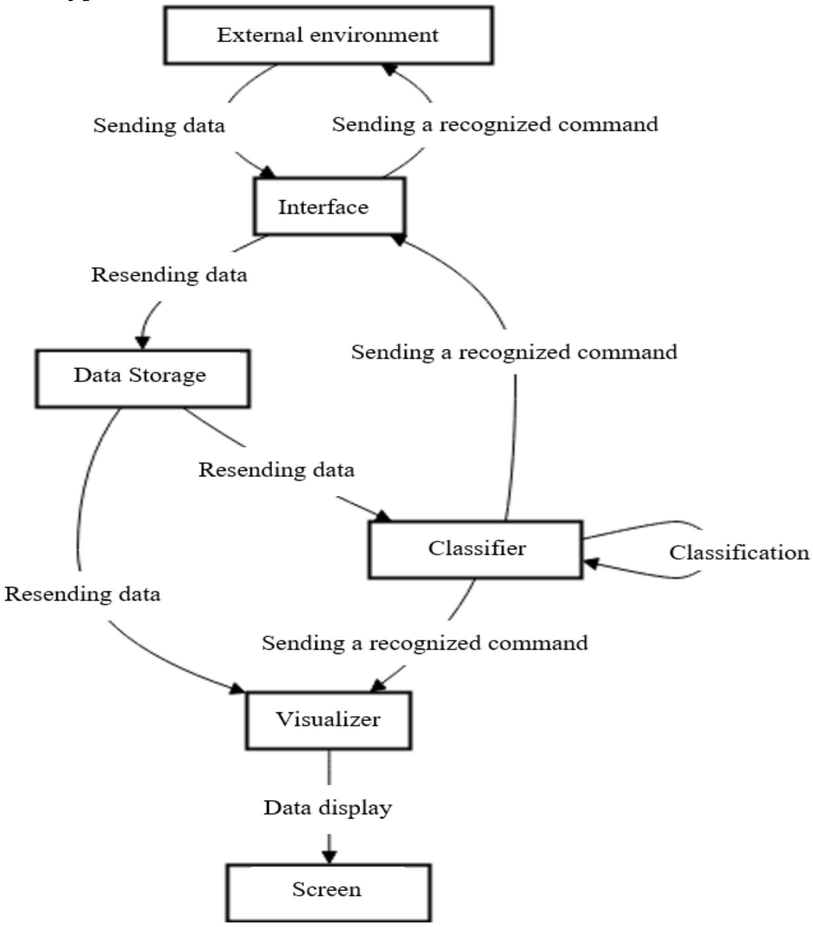


Figure 2. Gesture classification Implementation scheme

Communication with the device was implemented through the base class i_adapter from which any other private implementations of interfaces should inherit. The i_adapter class inherits from QObject, which allows you to use the mechanism of Qt signals and slots to process events and change the states of objects. The class also contains protected methods and fields for managing the adapter and interacting with objects of the item type, as well as methods for processing incoming data and configuration.

For gesture recognition, the algorithm shown in Figure 3 is implemented. It is a gesture recognition system based on a sequence of coordinates of points. There are two main classes in the code: Gesture and GestureManager. The Gesture class represents a separate gesture defined by a sequence of coordinates of points. The GestureManager class manages a set of gestures and processes point coordinate updates for gesture recognition. The system allows you to recognize gestures defined by a sequence of coordinates based on input data representing new points.

The graphical interface of the application consists of various components integrated using the QT framework, which provides a variety of classes for creating a graphical interface, such as

QWidget and its derivatives.

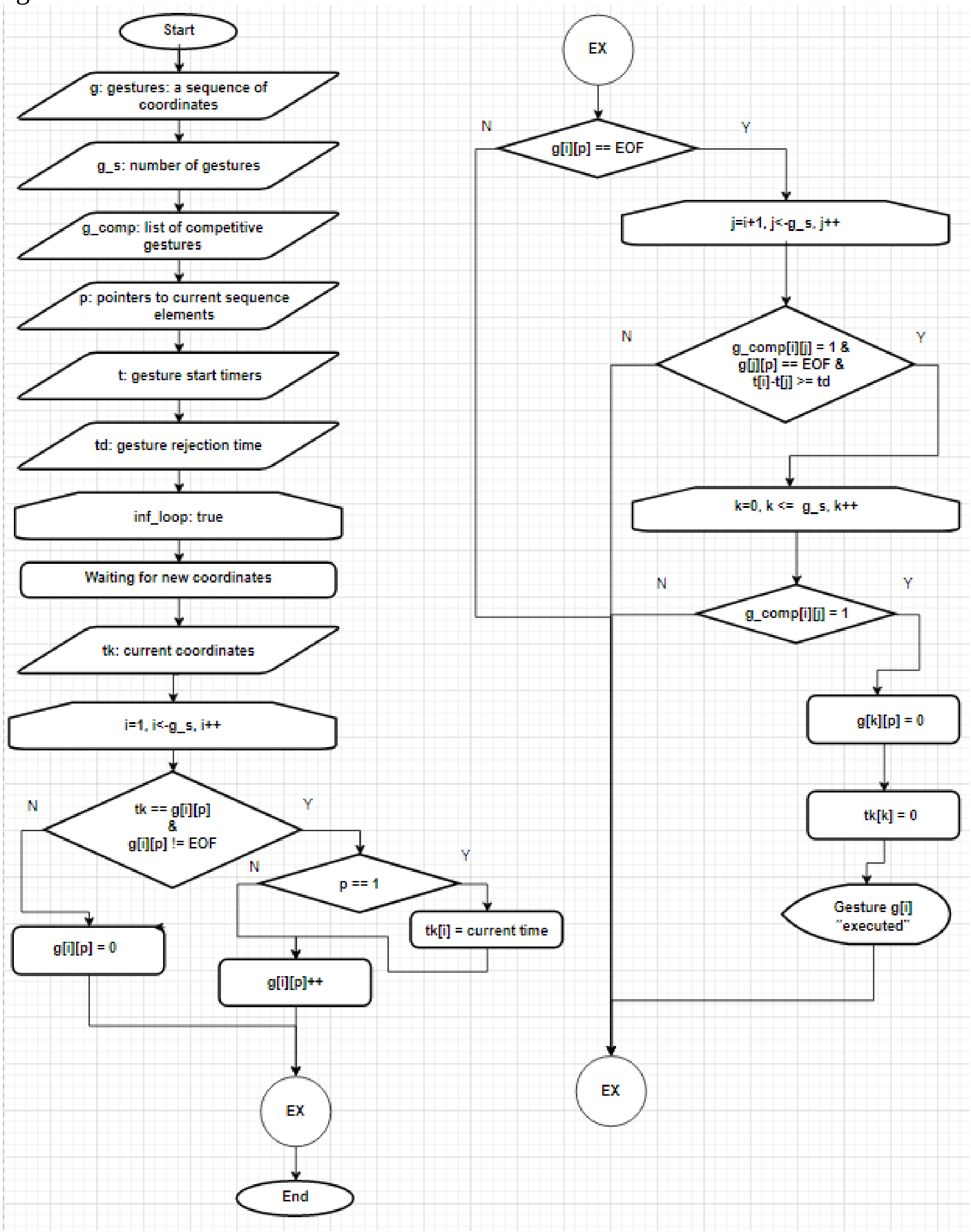


Figure 3. Block diagram of the gesture classification algorithm

When creating configuration data, it is necessary to take into account that each new point is located on a circle from the previous point (example in Figure 4).

When a new sequence of coordinate points is received, they are compared with gesture points according to the pointers to the sequence of passed points in gestures. If the element is not within the acceptable values of the element, then the next element is considered, and if the new point belongs to the next area under consideration, then the pointer is updated to this new element. When all the points in each gesture sequence are passed, the command corresponding to the gesture in question is executed or sent to the device, according to the specified configuration.

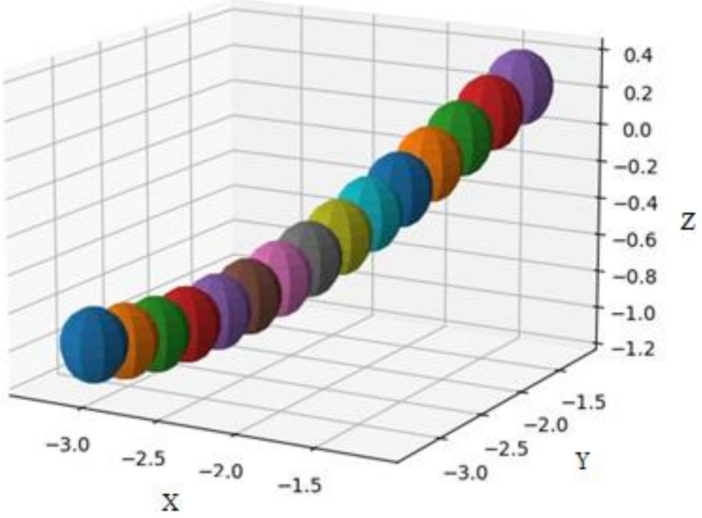


Figure 4. Example of a sequence of points for a single sensor

The external software is designed to simplify the process of creating configurations for the device. Receiving data from the microcontroller, the program visualizes them using 3D graphics (example in Figure 5). In the visualization, each segment is associated with a separate sensor, and its position is determined by the data received from the corresponding sensor.

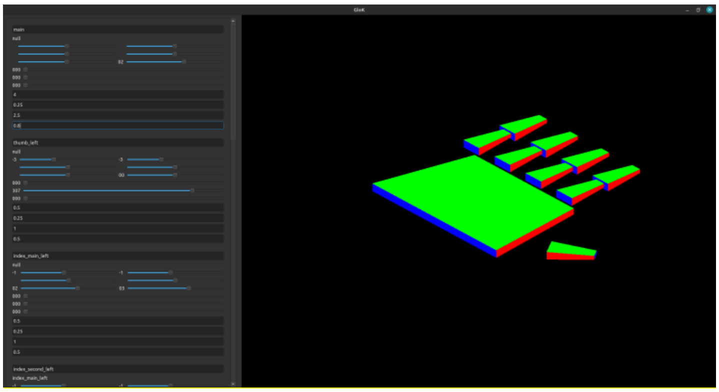


Figure 5. Example of data visualization with the possibility of configuration

Results. The result is a developed prototype device, which is a glove equipped with gyroscope-accelerometer sensors capable of detecting finger positions. The device provides the ability to transmit finger position data to external devices via serial port interfaces and/or a wireless connection using Bluetooth technology.

The prototype contains functionality for classifying the data received from sensors in order to recognize certain gestures, as well as the subsequent receipt of commands associated with these gestures. The device interacts with the target device as a HID (Human Interface Device) without the need for additional drivers.

In addition, cross-platform software has been developed that provides the ability to conduct communication sessions with the device, receive data from it and visualize them using 3D graphics. This software greatly simplifies the process of creating new configurations and defining new gestures for controlling devices.

Thus, the developed prototype is a promising device for interacting with target devices, providing gesture recognition, replacing a wide range of peripheral devices. The cross-platform software developed within the framework of this project contributes to convenient user interaction with the device and the expansion of the functionality of gesture control.

Conclusion. The created prototype performs its functions quite successfully. Nevertheless, there are positions where it is possible to further optimize the work and structure of the prototype. First of all, this is to increase the ergonomics of the device by reducing the size of its functional components and placing them more compactly inside the case. The second direction of optimization may be the installation of alternative sensors that can replace the MPU6050-based gyroscope-accelerometer modules. The main problem is the limitations of the I2C protocol, which affects the speed of data collection. Presumably, wearable gallium sensors [9] will solve this problem, but at the time of writing they are still under development. The third direction of optimization is to improve the gesture classification process by searching for more efficient algorithms, which should increase the speed of the software. The fourth aspect of optimization is related to the possibility of using TCP/IP protocols to connect the device to the Internet and integrate with cloud computing, which should expand the functionality of the device. The fifth aspect of optimization is the replacement of the used microcontroller with a more productive analog, which will undoubtedly improve the characteristics of the device.

All of the above optimization methods are aimed at making the developed prototype more efficient and user-friendly, which in turn will contribute to the widespread use of this technology in various fields, such as virtual and augmented reality, rehabilitation, telemedicine, robotics and other areas where precision and ease of gesture control are important.

Thus, in order to maximize the potential of the developed prototype and ensure its successful integration with various applications and areas, it is necessary to continue research and optimization of the device, taking into account the identified shortcomings and the needs of end users. This will improve the characteristics of the device, make it more convenient and efficient, as well as expand its application areas and opportunities for innovation and development of gesture control technology.

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