# Development of haptic gloves with vibration feedback as a tool for manipulation in virtual reality based on bend sensors and absolute orientation sensors

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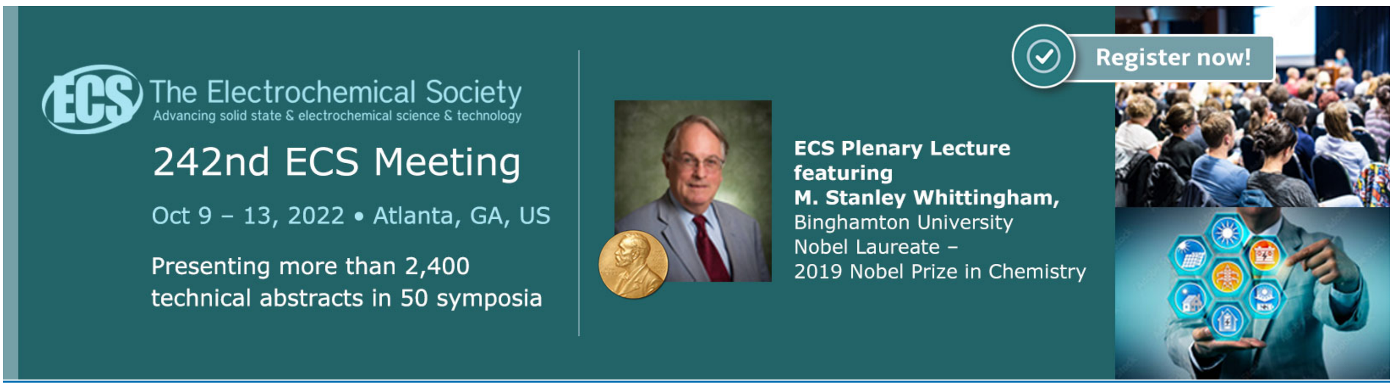

# Development of haptic gloves with vibration feedback as a tool for manipulation in virtual reality based on bend sensors and absolute orientation sensors

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**Abstract.** In the article, the existing developments of haptic gloves were considered, an analysis of scientific publications on this topic, which showed a variety of technical solutions. The main problems of the study area are indicated and two methods for the implementation of haptic gloves, which have a lower cost in comparison with analogues, are proposed. The first method uses nine axial sensors of absolute orientation, which allow to accurately determine the position of the joint in space, and the second method uses bend sensors, which are easier to use but less accurate. To implement the haptic gloves, software was developed, a model was created in the Unity cross-platform development environment.

**Keywords:** haptic glove, virtual reality

## 1. Introduction

It becomes necessary to perform tasks in places where the presence of a person is difficult, risky or even impossible. In such dangerous situations, the use of anthropomorphic manipulators is effective. At this stage of the development of science and technology, only robots that realize the remote presence of an operator by using the copying type of control can completely replace a person when performing complex tasks in a dynamic environment. With copy control, the robot repeats the actions of the operator [1]. The basis of this control method is the simultaneous formation of laws of motion for all degrees of mobility of the anthropomorphic manipulator through a copy type master [2].

For remote control of the manipulator, a haptic glove worn by an operator can be used. Haptic gloves significantly expand the possibilities of plausible immersion, allowing you to feel virtual objects by affecting the tactile sensations of a person for greater dexterity and control during operations. This can be an advantage not only during rescue operations, but also in the energy and construction industries, medicine, and industry.

The aim of this work is to develop haptic gloves. To achieve this goal, literary sources with presented existing haptic gloves were analyzed. Methods for implementing haptic gloves on absolute orientation sensors and bend sensors, as well as software architecture, are proposed.

## 2. Analytical review of current developments of haptic gloves

As part of the work, an analysis has been made of systems and mechanisms developed in recent years that are used in the construction of haptic gloves. There is a general trend for all developments, which consists in the desire to reduce the weight of the structure for the possibility of more comfortable and long-term use, as well as moving towards a cheaper design.

The work [3] describes the development of a haptic glove with a pneumatic drive to bring closer the sensations of interaction with a virtual person to a natural person. To improve the perception of human skin, a pneumatic drive system with silicone cavities is proposed, they are located at the fingertips and are integrated into the glove in the center of the palm. Air pressure is used to simulate the softness of the skin with different textures. At the moment, the device consists of only three mechanisms: on the thumb and forefinger, as well as in the center of the palm. Wi-Fi support is provided.

In [4], authors proposed a system that recognizes the angle formed by the movement of a human fist to control the Scorbot-Er 4U robotic arm. Technically, this is implemented using an accelerometer in a passive haptic glove that measures the inclination of the hand, then the information is processed by Arduino and transmitted to MATLAB (application package for solving technical computing problems) for further sending the command to the robot.

The article [5] describes the design and optimization of a five-finger mechanism for a tactile glove that uses a worm-geared motor. The glove is a wireless and autonomous mechatronic system that is mounted above the outside of the palm and provides tactile force feedback for each finger. The total weight of all elements of the mechanism is 310 g.

In [6], the ExoTen-Glove haptic glove with integrated force sensors and small-sized DC motors is described. The weight of the glove is 360 g, it is worn on the whole hand, using five fingers.

The RML Glove with a reverse response is put on two fingers (forefinger and middle finger) and weighs 180 g, it also uses a worm motor [7].

The source [8] shows the haptic glove CyberGrasp, driven by a direct current electric motor, worn over the entire wrist and using five fingers. The weight of the device is 450g.

The DEXMO glove, presented in [9], is driven by servos, has a weight of 320 g and is also worn on five fingers.

The article [10-11] describes the development of the haptic gloves and the interface to them The Rutgers Master II. The design works with pneumatic cylinders - these are mechanical devices that use the force of compressed gas to create force in a reciprocating linear motion - weighs 185 g and is worn 4 fingers: thumb, forefinger, middle finger and ring finger.

The Wolverine device described in article [9] consists of a base that is mounted on the thumb and three rods attached to it, each of which has a sliding mount for the tips of the forefinger, middle finger and ring fingers. Each sliding mount has a brake that can lock the corresponding rod. In this way, the braking system can generate motion capture accuracy.

In [12-15], the authors analyze the problems of copying control of robot manipulators using haptic gloves. Which is also an important aspect of glove structure development.

The feedback force for each of the above devices is 80, 35, 12, 29.4, 16, and 106 N, respectively.

**Table 1.** Device comparison

| | Drive unit | Wireless | Number of fingers | Max response force, N | Weight, g |
|---|---|---|---|---|---|
| **ExoTen-Glove** | twisted string system | no | 5 | 80 | 360 |
| **RML Glove** | worm-geared motor | yes | 4 | 35 | 180 |
| **CyberGrasp** | DC electric motor | no | 5 | 12 | 450 |
| **DEXMO** | servos | yes | 5 | 29.4 | 320 |
| **The Rutgers Master II** | pneumatic cylinders | no | | 16 | 185 |
| **Wolverine** [11] | brake gear | yes | 3 | 106 | 55 |

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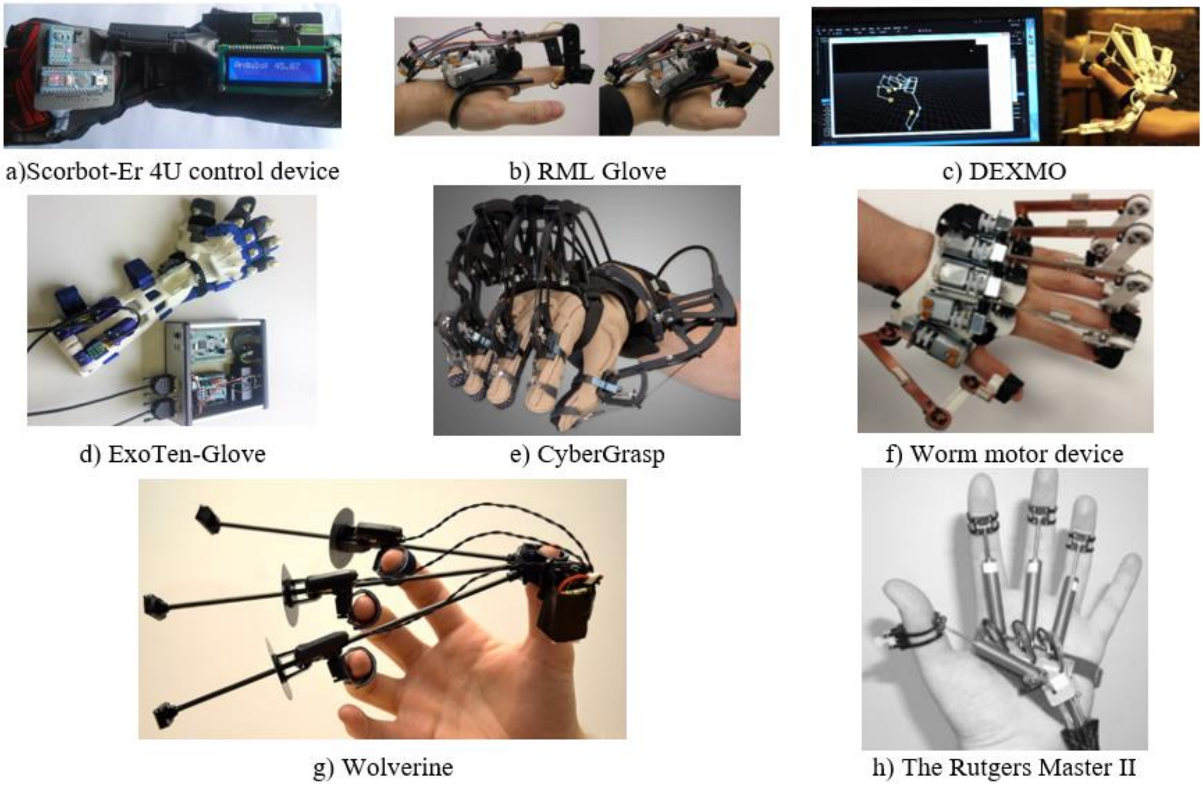


Figure1. Existing Haptic Gloves

As a result of the analysis of haptic gloves, it was revealed that existing solutions have several disadvantages. So, the worm-geared motors used in the RML Glove, cause significant losses in transmitted power, their disadvantages also include the tendency of thread turns and teeth to seize. RML Glove and CyberGrasp are expensive because they use expensive drives. The remaining devices considered are not available for purchase, since they are presented only in laboratory copies.

This article proposes two methods for implementing haptic gloves that are cheap but no less accurate.

## 3. Architecture

Figure 2 shows a block diagram of the software.

Figure 3 shows a diagram of a haptic glove on inertial measuring modules for one finger. The absolute orientation sensor allows to more accurately measure the position of the object in space thanks to three sensors with three axes for simultaneous measurement of tangential acceleration, rotational acceleration and the strength of the local magnetic field, also the built-in microprocessor eliminates a significant amount of mathematical calculations, this will reduce the delay time and increase the accuracy of execution target operations. Each module is located on the phalanx of the finger and fixes its movement in space. To more accurately determine the movement of the hand, one module is installed on the hand. Information about the movement is transmitted to the Arduino, where it is processed and using the Wi-Fi module is transmitted to the computer. The glove is powered by a lithium polymer battery. Using vibration motors, feedback is implemented. The figure shows:

1. Arduino Mega;
2. Lithium polymer battery;
3.ModuleWi-Fi;
4. Logic level converter;
5. Vibration motor;
6. Inertial measuring module.

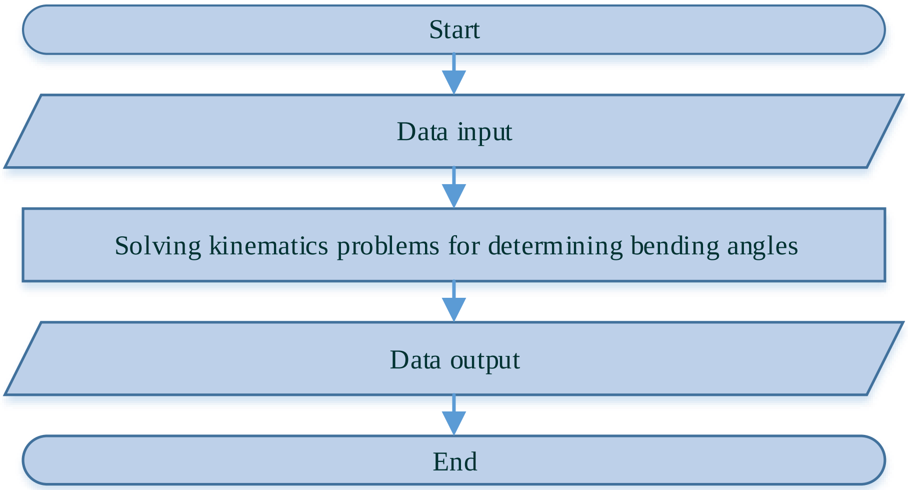


Figure 2. Software block diagram

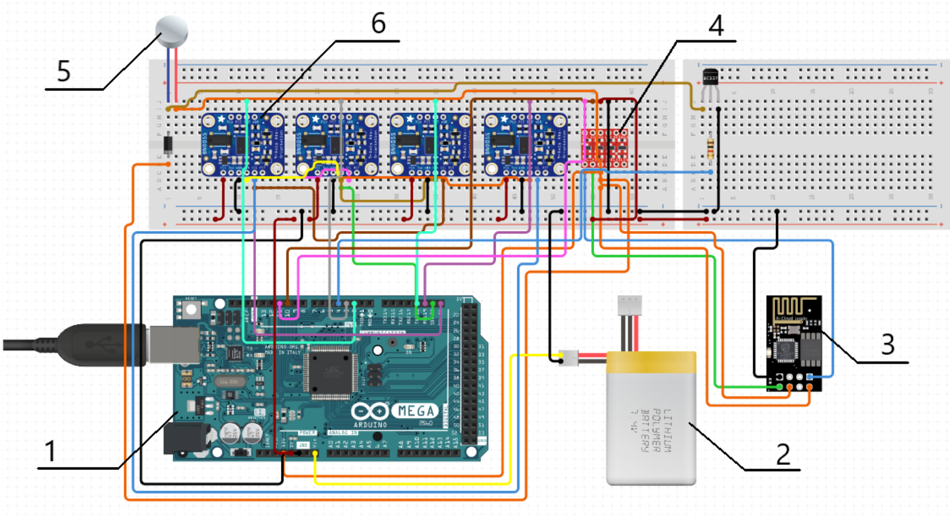


Figure 3. The electrical circuit of the haptic gloves with absolute orientation sensors

Figure 4 shows a diagram of a haptic glove on bend sensors for five fingers. The difference from the first option is the use of bend sensors to determine the movement and bend angles of the operator's fingers. Depending on the degree of bending, the sensor returns a number from 0 to 1023. An inertial measuring module helps determine the movement of the operator's hand. The figure shows:

1. Arduino Mega;
2. Lithium polymer battery;
3. Module Wi-Fi;
4. Logic level converter;
5. Vibration motor;
6. Inertial measuring module;
7. Bend sensor.

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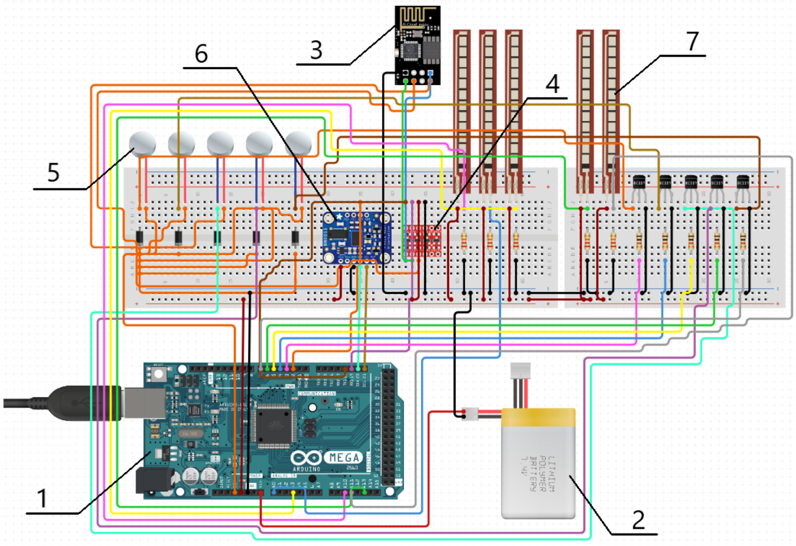


Figure 4. Haptic glove wiring diagram with bend sensors

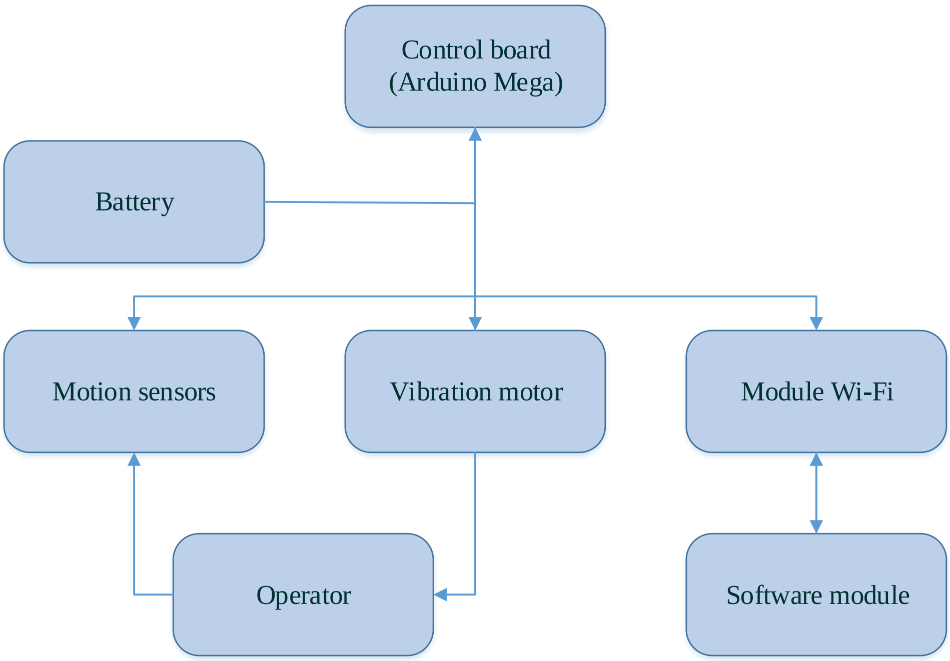


Figure 5. Functional diagram of the haptic glove

Advantages relative to analogues are light weight, ergonomics and ease of implementation. The approximate price is 11 thousand rubles.

The disadvantage is the impossibility of tracking the movement of the elbow.

## 4. Software

To implement the presented haptic gloves, software was developed and a model was created in the Unity cross-platform development environment (figure 6). Scripts are written in C #. Hand model rigging was done in Blender v2.81. The software allows you to display in real time each registered movement of the fingers and hands of the operator.

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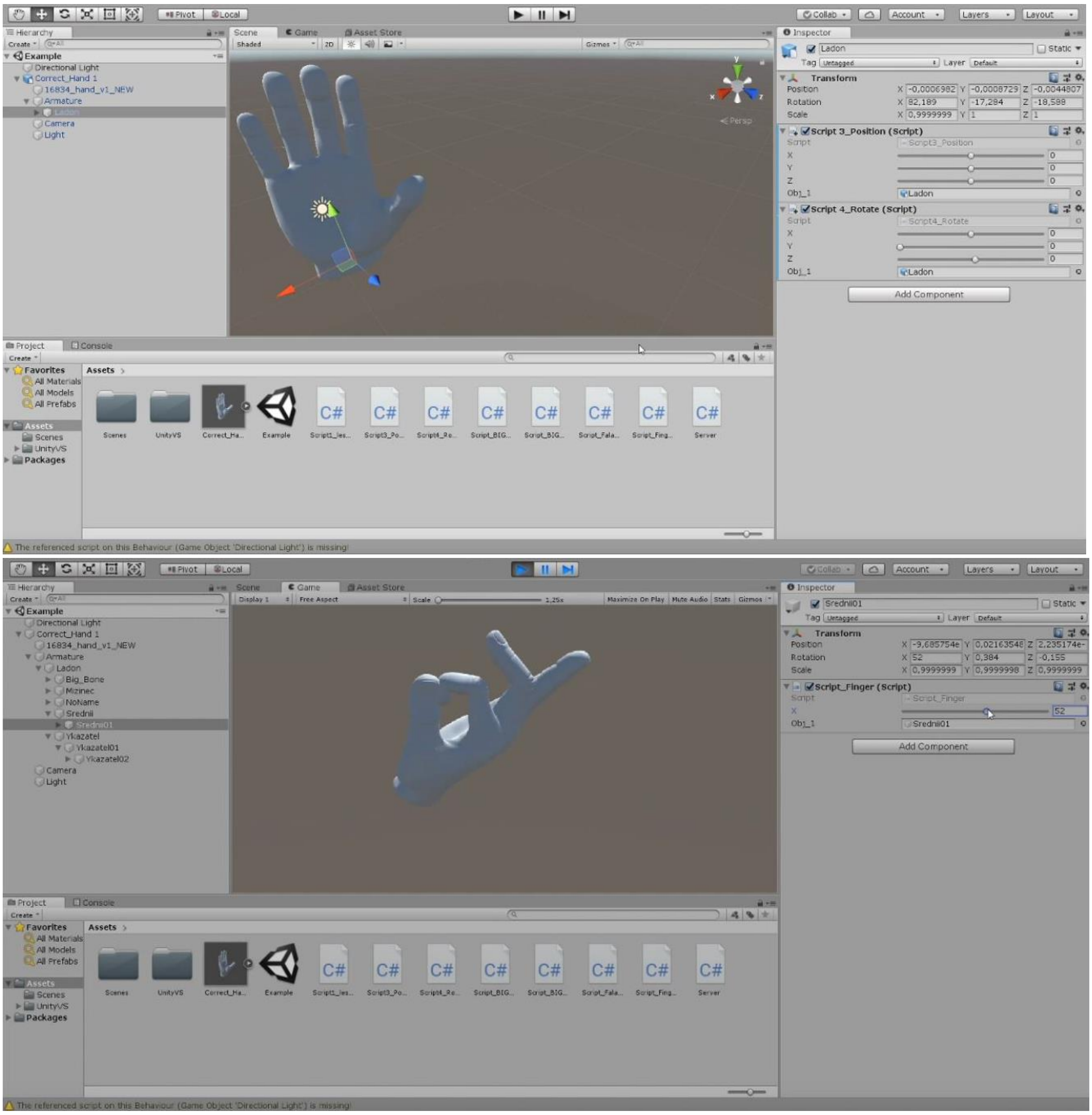


Figure 6. Virtual model

Using the Wi-Fi module, the haptic glove connects to the computer on which the software is installed. Absolute orientation sensors transmit measurements of tangential acceleration, rotational acceleration, and local magnetic field strength, and bend sensors transmit values from 0 to 1023, depending on the degree of bending.

## 5. Conclusion

Based on the results of the analysis of current developments of haptic gloves, problems such as high cost and significant losses in transmitted power were identified. It is also noted that most of the devices examined are presented exclusively as laboratory specimens and are not available for purchase.

As possible solutions to the above problems, two methods for the implementation of haptic gloves based on bend sensors and absolute orientation sensors and software developed for them were proposed.

These developments additionally solve the issue of reducing the weight of the structure and increase the ergonomics of the device.

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