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на здобуття ступеня бакалавра

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спеціальності 163 «Біомедична інженерія»

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«As a manuscript»

«Approved for defense»
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Graduate work

to obtain a bachelor's degree
under the educational and professional program "Medical Engineering"
specialty 163 "Biomedical engineering"

on the topic: "Complex device for gait analysis"

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Head of Department
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"___"_____________2023 year.

TASK
for a diploma work for a student

Shahrani Malek Mohamed

1. The topic of the work "Complex device for gait analysis", head of the work Larisa Andrii Dubko, associate professor of the faculty BMI, Ph.D., Senior Staff Scientist, approved by order of the university dated May 26, 2023 No. 52/23 si

2. Deadline for student submission of work: 9 June 2023

3. Initial data for work: scientific and technical literature, software

FreeCad, Arduino, Fritzing, Ultimaker Cura.

4. The content of the work: review and analysis of literary data on the study of the peculiarities of human gait; search for existing devices performing similar functions and analysis of engineering solutions that were used in their creation; development of a structural and functional scheme of a complex device; development of an electrical circuit of a complex device; development of appropriate software for setting up the device.

5. A list of illustrative material (with an indication of posters, presentations, etc.): functional scheme of the complex device for gait research, breadboard connecting Arduino to EMG sensor, schematic connecting Arduino to EMG sensor, printed circuit board connecting Arduino to EMG sensor, the body of the

adapter in the FreeCad program, 3D model of the adapter body in the Ultimaker Cura program, schematic of the camera positioning device, printed circuit board of the camera positioning device, presentation.

6. Adviser of work sections

Department	Surname, initials and position adviser	Signature, date	
		task published	task accepted
Labor protection	Kalinchyk V.V . dep. Safety of labor, industrial and of civil security"		

7. Issue date of the assignment____________________

Calendar plan

№ by number	The name of the execution stages thesis	Deadline stages of work	Note
1	Literature review	17.04.2023	
2	Development of the content and structure of bachelor thesis	17-22.04.2023	
3	Development of the structural scheme of the device	24.04.2023	
4	Modeling of the mechanical part of the device	30.04.2023	
5	Writing conclusions on the work	20.05.2023	
6	Completion of the "Labor Protection" section	24.05.2023	
7	Completion of an explanatory note to the thesis	01.06.2023	
8	Submission of work for regulatory control	08.06.2023	
9	Receiving reviews and feedback from the manager	08.06.2023	
10	Submission of a package of documents for the thesis for the defense (Preparation for the defense)	09.06.2023	
11	Defense of the thesis	22.06.2023	

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Supervisor: Andrii Dubko

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ABSTRACT

The volume of work is 54 pages, the number of illustrations – 29, tables – 13, appendices – 1, sources on the list of links – 27.

Rehabilitation, therapy, and sports medicine use gait assessment to detect abnormalities. Parameters used to assess human gait: distribution of pressure on the foot, step length, step width.

The relevance of the thesis lies in the development of an inexpensive complex device for researching the peculiarities of human gait.

The object of research is the parameters of human gait.

The goal of the work is the automation of research on the assessment of human gait.

To achieve the goal, the following research tasks were defined: review of existing analogues of devices; development of a structural diagram of a complex device for gait assessment; modeling of the mechanical part of the complex device; software development.

The structural diagram of the complex device was developed in the work. In the Fritzing software, parts of the layout, electrical circuits, printed circuit boards are developed. The mechanical part of the device was modeled in the FreeCad software. A program for controlling a complex device in the Arduino software was developed.

Keywords: gait analysis, contact and non-contact sensors, complex device, tests.

РЕФЕРАТ

Обсяг дипломної роботи складає 54 сторінки, кількість ілюстрацій – 29, таблиць – 13, додатків – 1, джерел за переліком посилань – 27.

Реабілітація, терапія, спортивна медицина використовують оцінку ходьби для виявлення аномальних відхилень. Параметри, які використовуються для оцінки ходи людини: розподіл тиску на стопу, довжина кроку, ширина кроку.

Актуальність дипломної роботи полягає у розробці недорогого комплексного приладу для дослідження особливостей ходи людини.

Об'єктом дослідження є параметри ходи людини.

Метою роботи є автоматизація досліджень по оцінюванню ходи людини.

Для досягнення поставленої мети, були визначені наступні завдання дослідження: огляд існуючих аналогів приладів; розробка структурної схеми комплексного приладу для оцінювання ходи; моделювання механічної частини комплексного приладу; розробка програмного забезпечення.

У роботі було розроблено структурну схему комплексного пристрою. В програмному забезпеченнні Fritzing розроблені частини макету, електричні схеми, друковані плати. В програмному забезпеченнні FreeCad проведено моделювання механічної частини пристрою. Розроблено програму керування комплексним пристроем в програмному забезпеченні Arduino.

Ключові слова: аналіз ходи, контактні та безконтактні сенсори, комплексний пристрій, випробування.

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LIST OF CONDITIONAL ABBREVIATIONS

MK – Microcontroller

PC - Personal computer

SDK – Software development kit

EMG - Electromyography

USB - Universal Serial Bus

DSP – Digital signal processing

INTRODUCTION

Relevance: the development of an inexpensive complex device that can be used both for the analysis of human gait and for educational purposes.

Purpose: Automation of research on the assessment of human gait is an urgent task, as it allows to correctly describe various parameters related to gait.

The object of the research is computer analysis of human gait parameters.

The subject of the study is a complex device for gait research.

Based on the purpose for this work, the following tasks were set:

1. Review of existing analogues of devices;
2. Development of the structural scheme of the device;
3. Modeling of the mechanical part of the device, software development.

Main results: The structural scheme of the complex device was developed in the work. The working layout of the device is developed. The software of FreeCad simulates the mechanical part of the device. The device control program in the Arduino software has been developed.

SECTION 1
THEORETICAL PART

1.1 Theoretical foundations of human gait analysis

Visual observation of the patient while walking is a typical gait analysis. Such assessment is very important, but it lacks objective data, such as: center of force; step time; swing time; step length; power; weight distribution [1].

Gait is characterized as a quasi-periodic event of loading and unloading of limbs [2, 3].

Gait is analyzed by segmenting time series into several cycles and highlighting the trajectory of movement of the joints of the human body. Quasi-periodicity is used to estimate the gait cycle. Each leg goes through a sequence of repetitive steps while walking. When a person walks normally, the beginning of the cycle begins with the heel strike of the foot and ends with the heel strike of the same foot. Such an event is considered the beginning of the next cycle [4].

Stance and swing are two phases of the gait cycle. The foot of the corresponding limb is on the ground during the stance phase. The foot is no longer in contact with the ground during the swing, so the foot swings to move the body forward. The rack is divided into four phases (see fig. 1.1):

- First double limb support (both feet are on the ground during the starting period of a cycle).
- First single limb support (the starting period of a cycle when one limb is in contact with the ground but the other one is swinging). For example (fig. 1.1), the right limb is swinging, hence this phase is labeled as left single limb support.
- Second double limb support (both feet are on the ground again after the first single limb support).

- Second single limb support (at the end of a cycle with same set of events like the first single limb support but with alternative limbs). For example (fig. 1.1), the left limb is swinging, hence this phase is labeled as right single limb support.

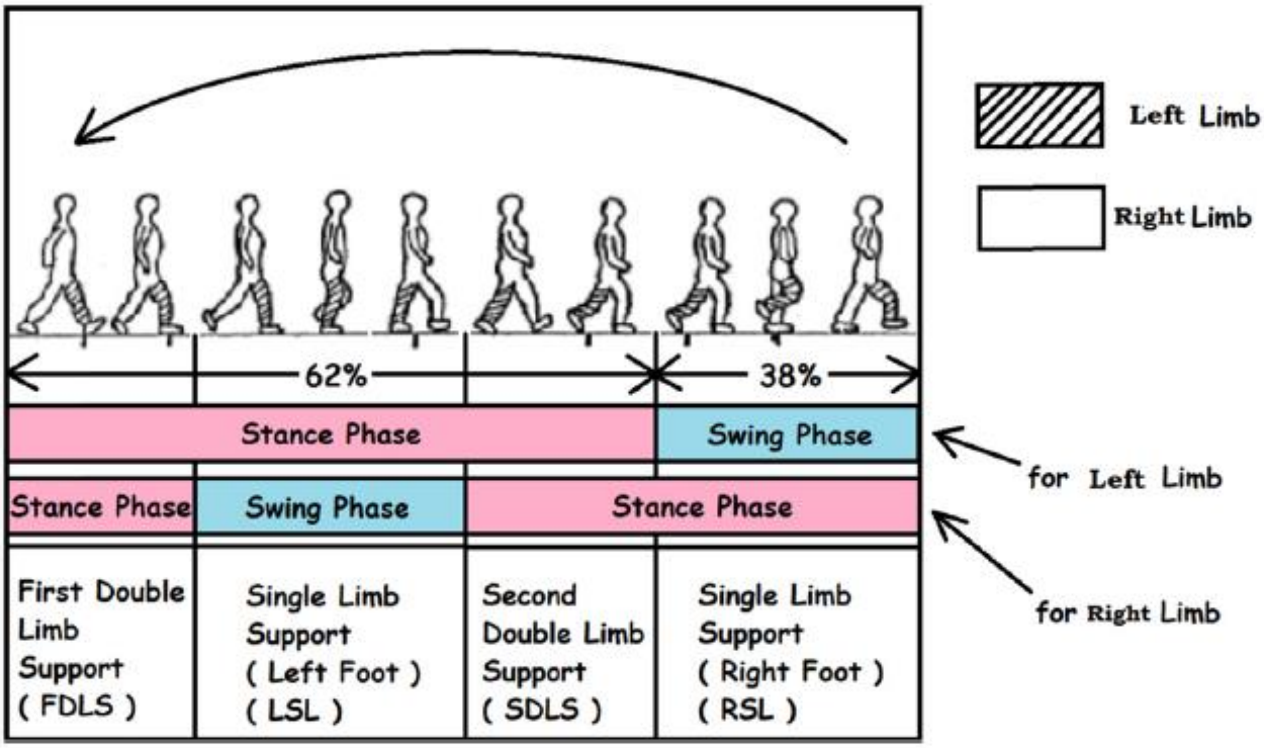

Figure.1.1 - Division of a gait cycle.

Between the two limbs, the phase shift is 50% of the cycle (the swing phase of one limb is superimposed on the mid-stance phase of the other). For a particular limb, the stance phase occupies ≈62% of the cycle, while the swing phase occupies the rest 38% [5].

1.2 Review of existing analogues of devices

Portable sensors for analyzing gait abnormalities are effective tools for outcome assessment and treatment planning. Such clinical tools are used in the preoperative planning of patients with cerebral palsy [6–9] and can change the surgical decision.

Figure 1.2 shows the classification of wearable and non-wearable motion sensors. Such sensors are widely used in clinical practice.

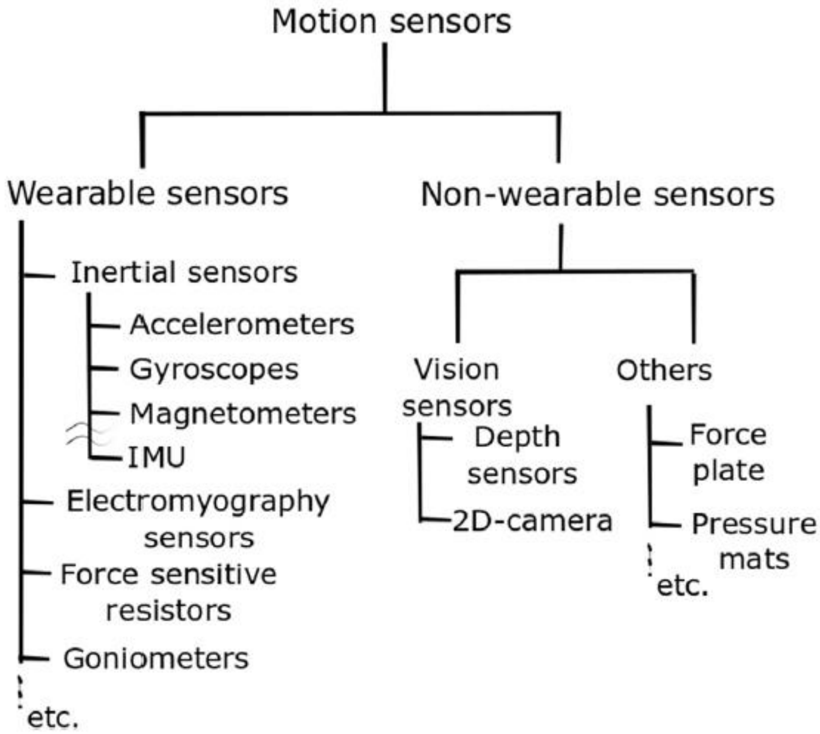

Figure. 1.2 - Classification of wearable and non-wearable motion sensors.

The high accuracy and reliability of the video cameras shown in fig. 1.3, [10, 11].

Vicon (vero v1.3x) **Qualisys (Oqus)**

Figure. 1.3 - Gold standard video cameras.

These video cameras from Vicon and Qualisys companies are considered the gold standard for measuring kinematic and spatio-temporal characteristics in gait analysis. Also, these cameras are used to check the results of other inexpensive sensors.

Well-known companies Kistler, Tekscan produce pressure sensors (pressure mats) [12, 13].

The F-Scan system (fig. 1.4) provides dynamic pressure, force and timing information for foot function and gait analysis. Information obtained from the F-Scan is used in real-world applications, like designing and testing orthotics, offloading diabetic feet and evaluating footwear and techniques in elite athletes [14]. Inexpensive sensors are produced by Sparkfun, WitMotion, which can be used for a cost-effective gait analysis system [15, 16].

Figure. 1.4 - F-Scan system.

Conclusions to section 1

During the analysis of literary data, it was determined that walking is a human behavioral phenomenon.

The cost of high-end motion sensors limits the availability of these clinical services to only a small portion of the general public.

The low-cost, affordable sensors analyzed may be suitable and effective for healthcare applications.

SECTION 2

PRACTICAL PART

2.1 Proposed complex device for gait analysis

To solve this problem, the work process is divided into three main parts: structural, functional-logical and technical.

When designing a device at the structural stage, the principles of construction of such devices are studied, their structure is divided into interconnected blocks, the study of each component is carried out separately.

In fig. 2.1 shows the functional scheme of the complex device for gait research.

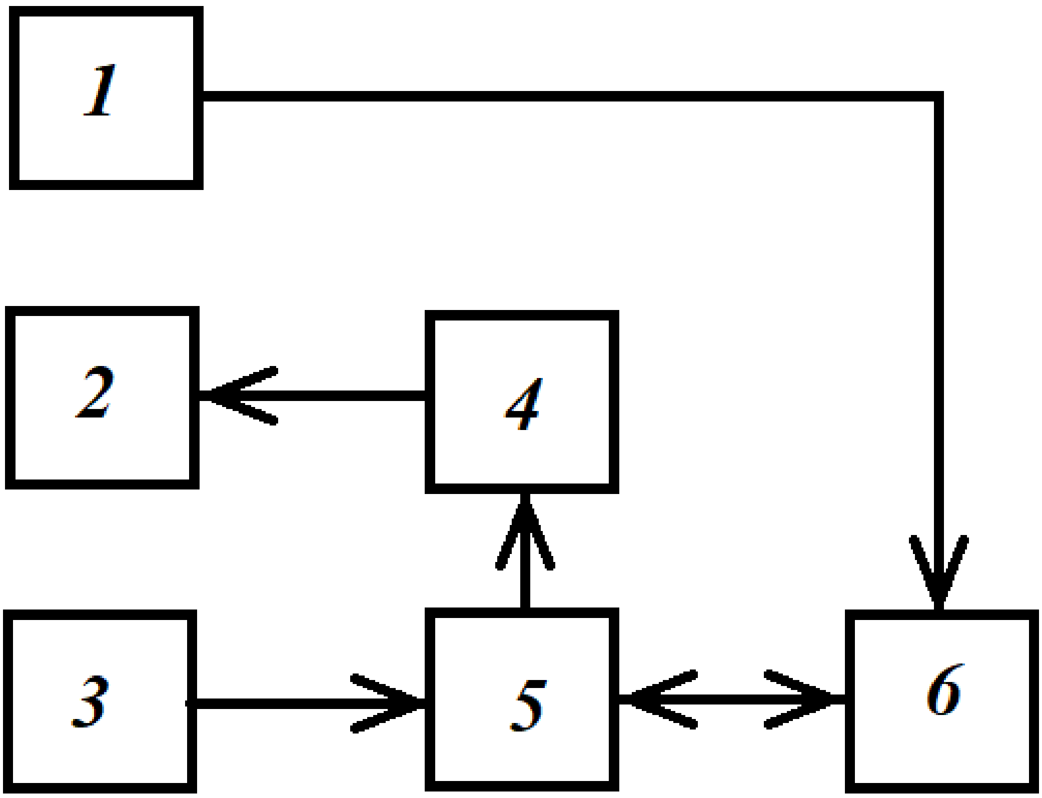

Figure 2.1 – Functional scheme of the complex device for gait research: 1 – Kinect v1 camera; 2 –stepper motor Nema17; 3 – EMG Muscular Signal Sensor; 4 – Stepper Driver; 5 – Arduino microcontroller (MK); 6 – Personal Computer (PC).

Contact and non-contact sensors became the basis for the development of an economical device for assessing human gait.

A muscle signal sensor was chosen for the complex device. Such a contact sensor (fig. 2.2) allows you to control devices using bioelectrical signals generated by human muscles. At the output of such a sensor, the analog signal can be read by the Arduino microcontroller [17].

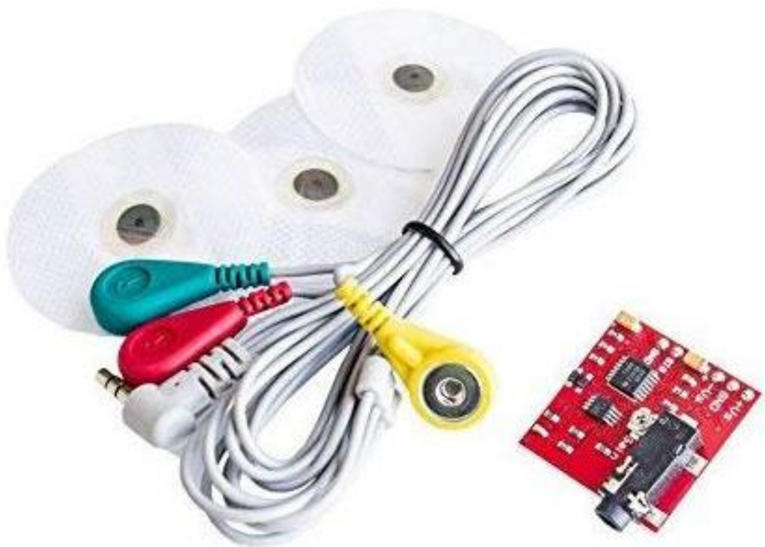

Figure. 2.2 – Contact Sensor.

Selecting a non-contact sensor for the device.

Figures 2.3, 2.4 show the Kinect v1 camera, which is often found for gait analysis [18].

Figure. 2.3 - Camera.

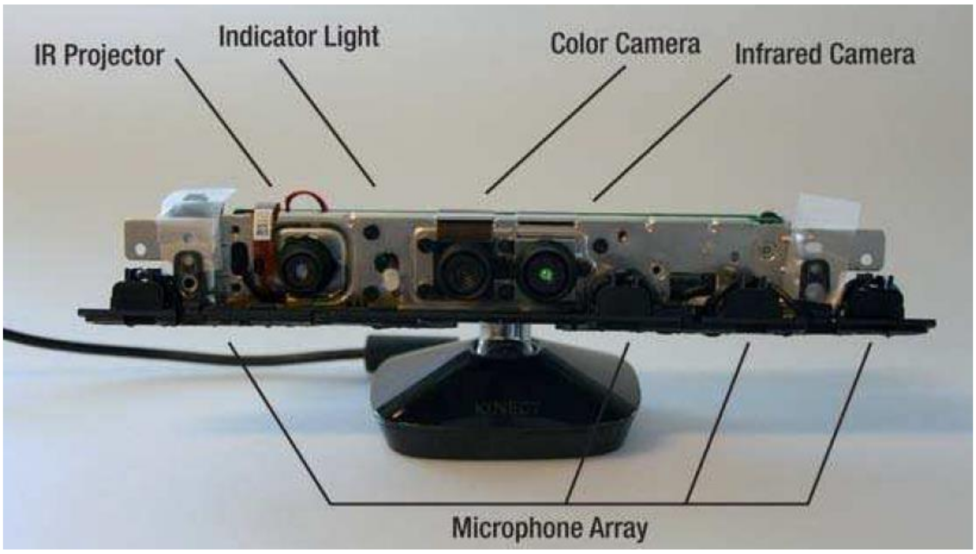

Figure. 2.4 - The components camera.

2.2 Contact sensor of the device

2.2.1. Main characteristics of EMG Sensor

Muscle contraction, activity, and expansion are measured in medical studies using a muscle sensor. The strength of the signal depends on the activity of the selected muscle. Three electrodes (red, green, yellow) are connected to the module for transmitting electrical signals from muscle movement [19].

Features: Adjustable Gain using onboard potentiometer; Specially Designed for Microcontrollers; Small Form Factor; 5mm Connector.

Applications: Medical equipment Robotics;Video games;.

EMG Muscular Signal Sensor Pinout.

This module has 5 pins (fig. 2.5): **SIG:** Analog output; **Vs+:** Positive power supply; **Vs-:** Negative power supply; **GND-BAT:** Ground Battery; **GND:** Ground.

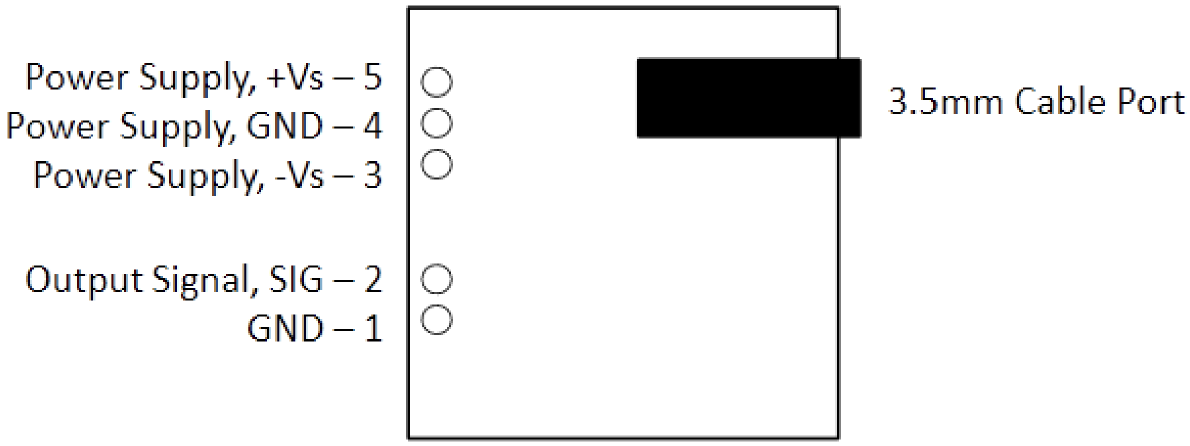

Figure. 2.5 - Pins of the Sensor.

Circuit connections. The sensor board has two sets of pins: A 2-pin set that includes the signal and GND terminals. It’s used to interface the board with the microcontroller; A 3-pin set that includes -+Vs, GND, and -Vs terminals.

The AD8226 amplifier needs to be dual powered by two 9V batteries. Connect the positive terminal of the battery to the +VS contact. The negative terminal of this battery is connected to the positive terminal of the second battery. This connection is connected to the GND pin. The negative terminal of the second battery is connected to the -VS contact of the sensor. This connection gives a double supply of the sensor with a voltage of plus/minus 9 V. To connect the sensor to the Arduino UNO microcontroller, it is necessary to connect the GND pin of the sensor to the ground of the microcontroller. The signal contact of the SIG sensor is connected to the analog input of the microcontroller (for example, A1).

The electrodes**.**

A cable (three wires) with a 3.5 mm connector must be connected to the sensor board. The next step is to connect the electrodes to the cable.

We choose a group of muscles for monitoring. Connect the red cable to the electrode located in the middle of the muscle group. We connect the green cable to the electrode located at one end of the muscle group. We connect the yellow connector of the cable to the electrode, which is attached to a bony or non-muscular part of the body.

Signals from such a sensor are amplified. These signals are rectified and smoothed by the AD8226 instrumentation amplifier. The amplifier can amplify the signal up to 1000.

Contraction and relaxation of muscles create an EMG potential if the electrodes are correctly placed on the muscle group. You can amplify the signal by using the potentiometer sensor built into the board. From the sensor board, the output signal is read through the input contact of the microcontroller. The microcontroller reads the analog signal and outputs the reading to the serial port.

2.2.2 EMG Sensor Schematic

The following circuit (fig. 2.6) shows how you should connect Arduino to EMG sensor.

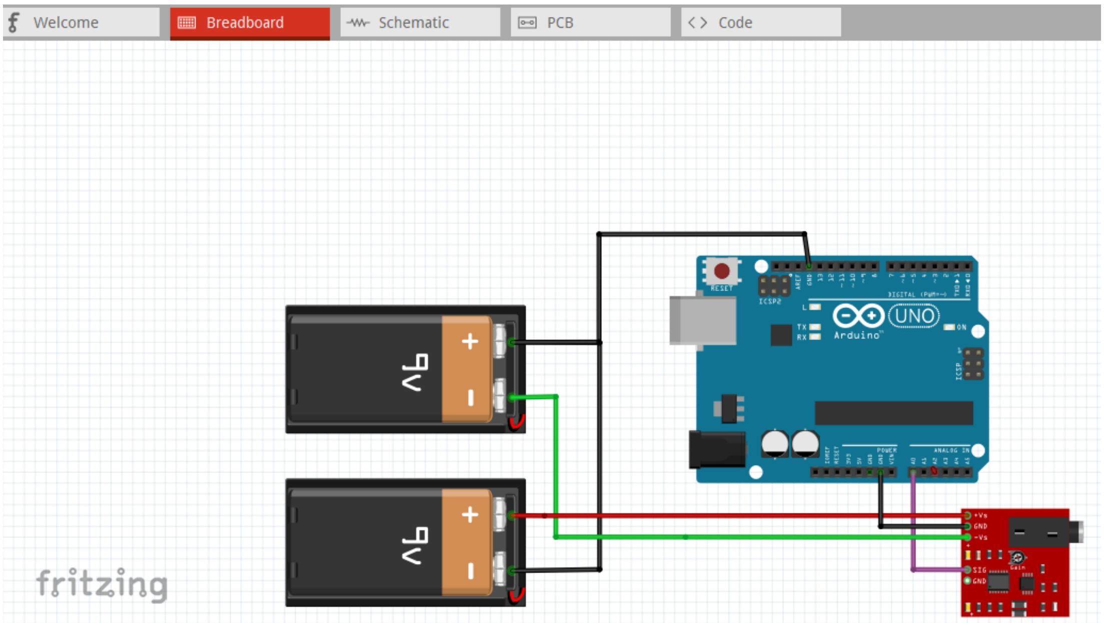

Figure. 2.6 - Breadboard connecting Arduino to EMG sensor.

Figure 2.7 shows Schematic.

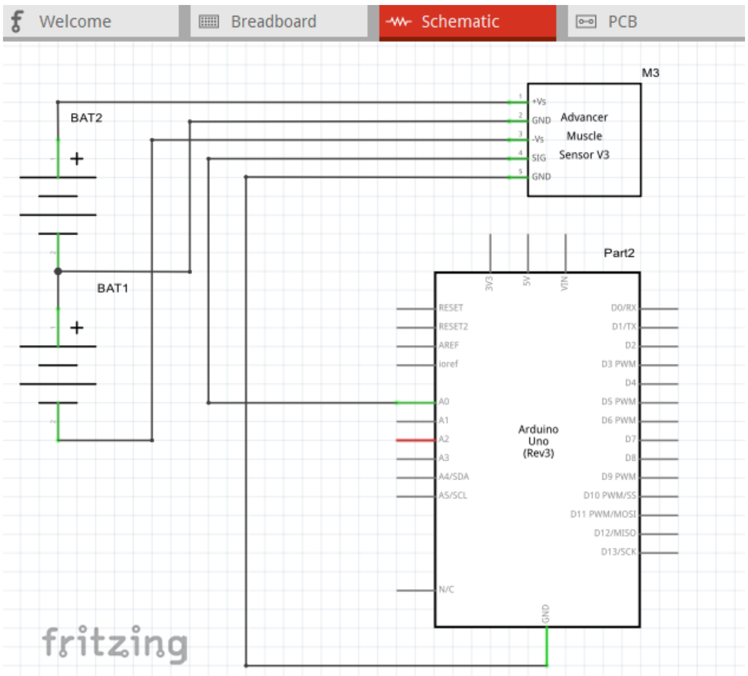

Figure. 2.7 - Schematic connecting Arduino to EMG sensor.

Figure 2.8 shows Printed circuit board.

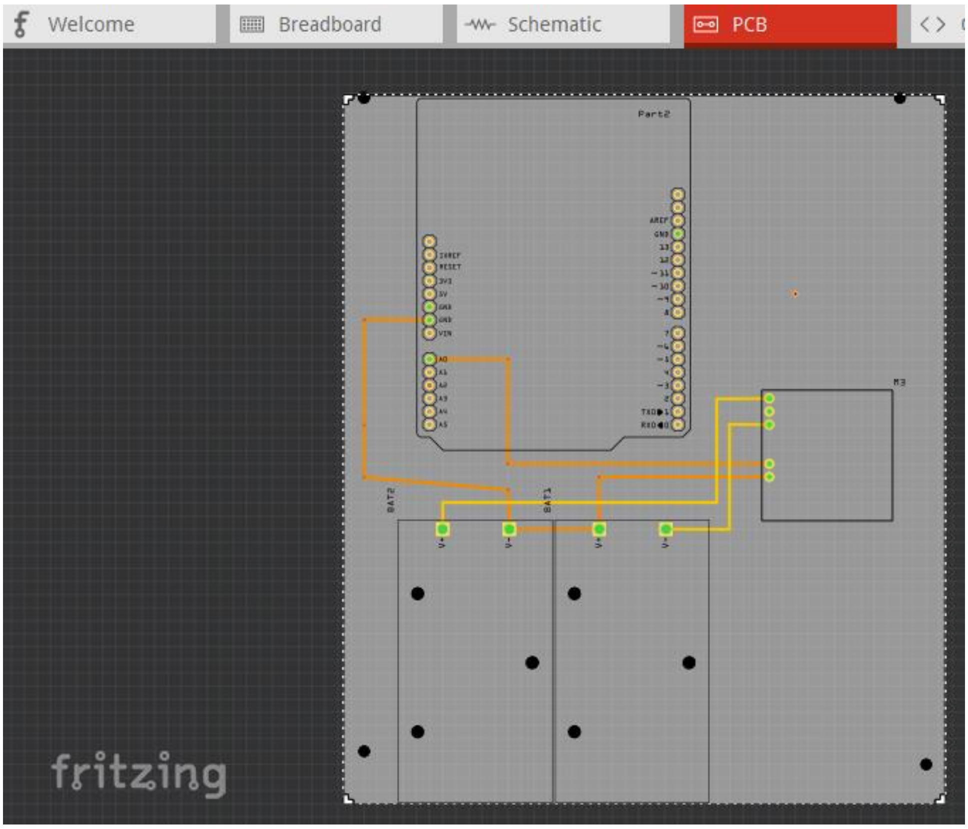

Figure. 2.8 - Printed circuit board connecting Arduino to EMG sensor.

2.3 Non-contact sensor of the device

2.3.1 Hardware and software for Kinect v1

Hardware: Kinect v1 can track the human body. Depth mapping is the prime feature of Kinect. Generally, two different types of depth mapping techniques are followed in Kinect: focused and stereo. Focus refers to the fact that when the distance between an object and camera increases, the object becomes blurrier. However, astigmatic lenses help to improve the tracking accuracy of Kinect [20].

Theses lenses use different focal lengths on the x and y axes. Stereo technology helps to compute depth from the disparity [18]. Kinect also has a set of microphones having noise reduction property. The microphones can also track the sound position. Kinect v1 consists of 64 MB DDR2 SDRAM and PrimeSense PS1080-A2 chip to process data [18]. The infrared emitter, having 60 mW laser diode, works on a wavelength of 830 nm. The resolution of the color and depth sensors of Kinect v1 is 640 x 480 pixels and 320 x 240 pixels, respectively.

Software: In 2011, a software development kit (SDK) of Kinect for windows was released which facilitates realtime tracking of body joints. SDK of Kinect uses the depth data to estimate the body parts based on random decision forest. The algorithm was proposed by Shotton et al. [21] where body parts were estimated using a large cohort of training set of depth images.

The skeleton data stream produced by SDK after processing the depth image provides real-time body tracking based on individual joints. Kinect v1 can track up to two users.

2.3.2 Data stream of Kinect v1

Kinect provides five different data streams, i.e.: color (1920 x 1080@30 Hz); - infrared (512 x 424 @ 30 Hz); depth image (512 x 424 @ 30 Hz); body index image (512 x 424 @ 30 Hz); skeleton image (20 joints @ 30 Hz for Kinect v1).

These data streams can be accessed using SDK. Each data frame associates time stamps of local computer. Each Kinect sensor has to be connected to dedicated computer having USB 3.0 connector. SDK can also be used to convert depth image to 3D point cloud.

2.3.3 Wiring an Xbox Kinect for USB

An adapter is required to connect the Kinect v1 camera to a computer. Additionally, the camera needs a 12V, 2A power source [22].

Connecting the camera to the computer and the 12V power source is shown in fig. 2.9.

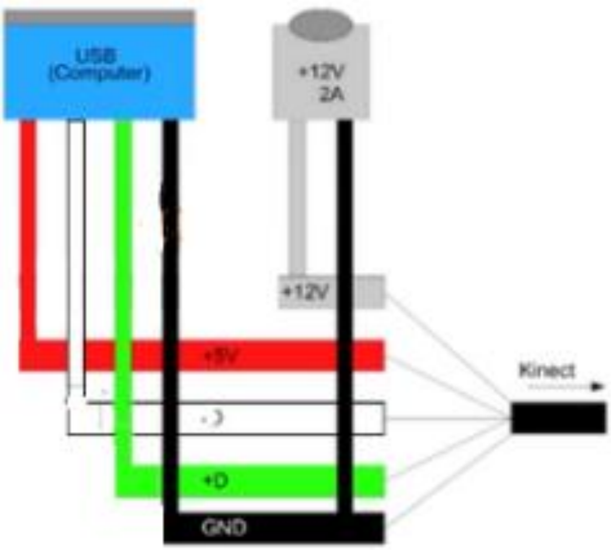

Figure. 2.9 - Connecting the camera to the computer.

Step 1: Cut off the ends of the Kinect, the USB cable and the 12v power supply. Cut the Kinect and power supply close to the plug, but cut the USB with plenty of cable trailing out of the male plug.

Step 2: Solder and heat shrink the four coloured USB wires to their corresponding Kinect wires. Red -> red, green -> green and white -> white. twist up the black wires, but don't solder or heat shrink them just yet. Make sure there is no exposed wire that will cause a short.

Step 3: Solder the brown Kinect wire to the 12v adapter positive, and the 12v adapter negative to the Kinect/USB black. Now you can heat shrink it (fig. 2.10).

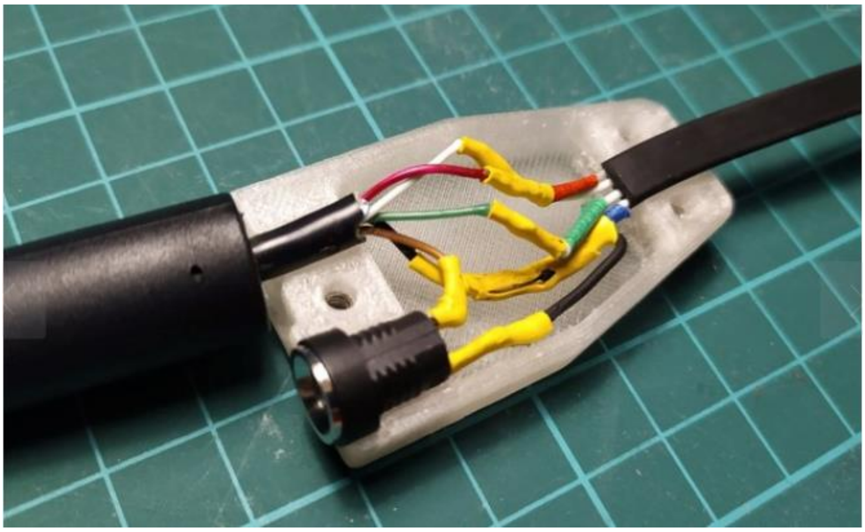

Figure. 2.10 - Kinect Cable Adaptor.

In figure 2.11 shows the body of the adapter in the FreeCad program.

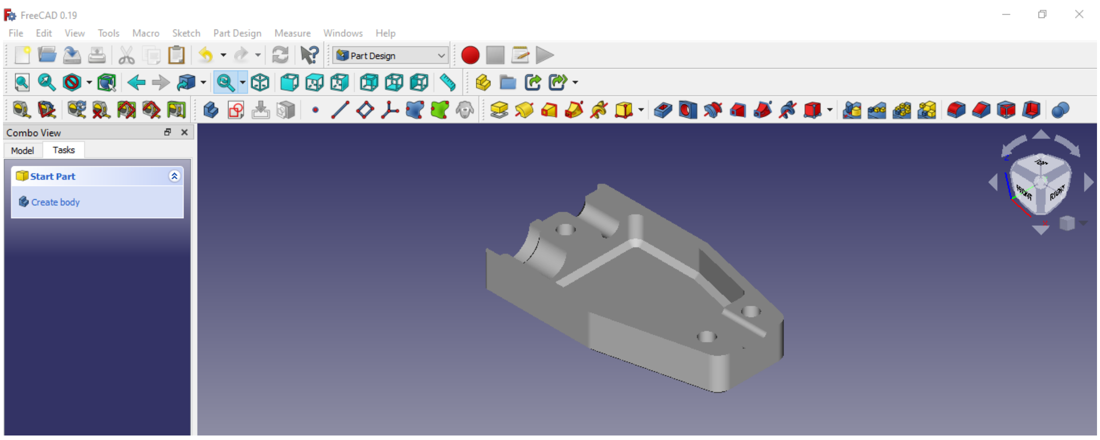

Figure. 2.11 - The body of the adapter.

For 3D printing, the model must be prepared in the Ultimaker Cura program (fig. 2.12).

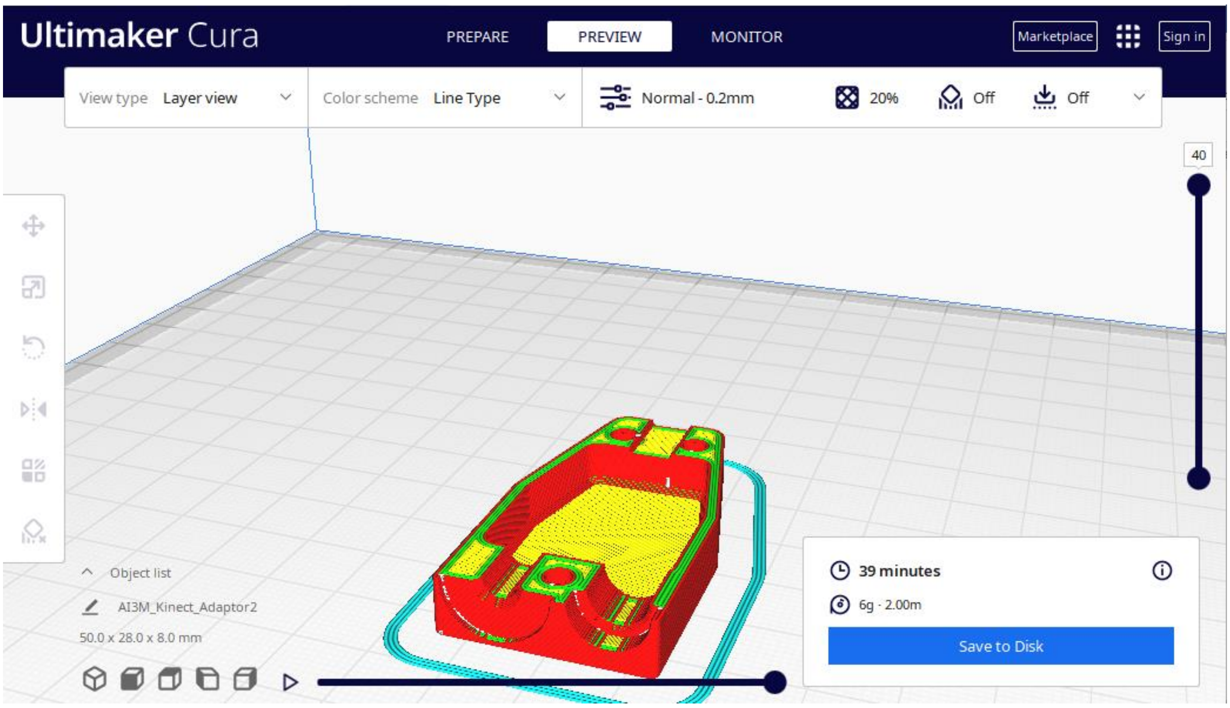

Figure. 2.12 - 3D Model of the adapter body in the Ultimaker Cura program.

2.3.4 Installation

You may want to verify that the drivers installed successfully. This is typically a troubleshooting procedure in case you encounter any problems as you run the SDK samples or begin working through the code in this book. In order to verify that the drivers are installed correctly, open the Control Panel and select Device Manager. As figure 2.13 shows, the Microsoft Kinect node in Device Manager should list three items if the drivers were correctly installed: the Microsoft Kinect Audio Array Control, Microsoft Kinect Camera, and Microsoft Kinect Security Control.

Figure. 2.13 - Kinect drivers.

2.3.5 The composition of the device for moving the kinect camera

Hardware:

Figure. 2.14 shows a device designed for uniaxial movement of a Kinect camera.

Figure. 2.14 - The main components of the device: 1 - vertical guide from profile 30mm x 30mm; 2 - Kinect v1; 3 – mobile cart on which the camera is located; 4 – belt; 5 - stepper motor.

ARDUINO UNO is the ideal board for getting started with electronics, through fun and engaging handson projects (fig. 2.15).

Figure. 2.15 - Arduino Uno.

Arduino Uno is a microcontroller board based on the ATmega328P, an 8-bit microcontroller with 32 KB of Flash memory and 2 KB of RAM. It contains everything needed to support the microcontroller.

Nema 17 Stepper motor. 17HS8401 is a powerful NEMA 17 stepper motor (fig. 2.16). The main purpose is to drive machine tools, 3D printers, plotters and other devices that require a fairly large working force [23].

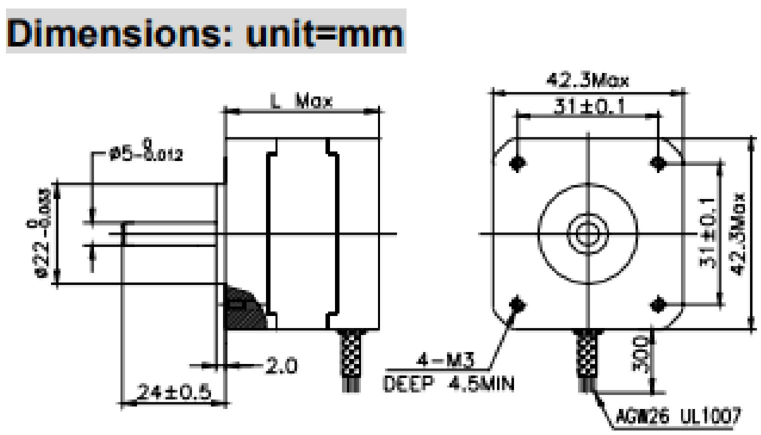

Figure. 2.16 - Nema 17 Stepper motor.

Characteristics: model 17HS8401; rated current 1.7 A; winding resistance 1.8 ohm; winding inductance 3.2 mH; holding moment 5.2 kg/cm; angle of rotation per 1 step 1.8°.

The connection diagram is shown in fig. 2.17.

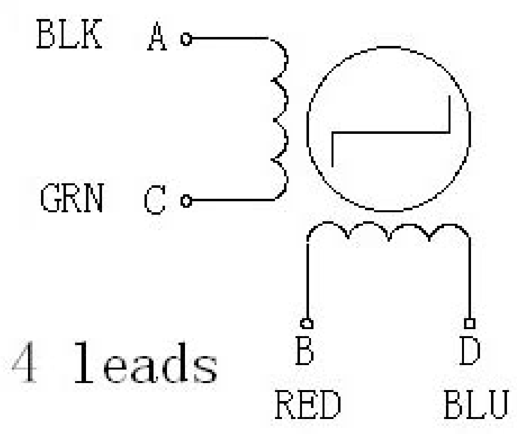

Figure. 2.17 - The connection diagram.

A stepper motor is a synchronous brushless motor with multiple windings in which a current applied to one of the stator windings causes the rotor to lock (fig. 2.18).

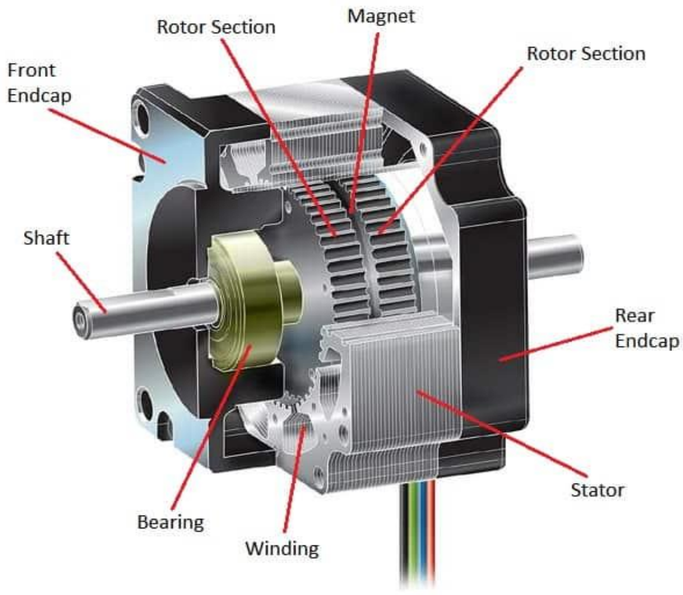

Figure 2.18 – Stepper motor structure.

Ideally in terms of the ratio of parameters and cost suited servo NEMA 17 (fig. 2.18) with the parameters presented in table 2.1.

Table 2.1 – System haracteristics

Dimensions, mm	40x19x43

Torque, kg / cm	15
Operating supply voltage	4.8-7.2 V
Supply current, A	0.5-2.5

Its gear has a radius of 3 mm, so the length of the arc it scrolls will be equal to one third of the perimeter (≈6.28 mm), as the angle of rotation is only 120 degrees. The minimum step corresponding to 1 degree of turn is -0.052 mm. Also, it should be added that all mechanical parts servo NEMA 17 made of metal, which in conditions of high pressure inside the system, will significantly increase the service life.

The RS-15-5 power supply shown in fig. 2.19.

Figure 2.19 – Power supply RS-15-5.

This power supply well combines high electrical parameters (table 2.2) at small sizes. It has a high efficiency of up to 91.5% and low power consumption without load less than 0.5 watts.

Table 2.2 – Technical parameters of RS-15-5

Temperature mode, °C	-20… 70
Output voltage, B	5
Load current, A	3
Input voltage, B	88… 264
Protection	from a short circuit, overload, temperature difference, supply voltage drop

The power supply was selected according to the needs of the stepper motor and taking into account the highest possible level of protection.

A3967 EasyDriver - Stepper Motor Driver (fig. 2.20). The A3967SLB is a complete microstepping motor driver with built-in translator [24].

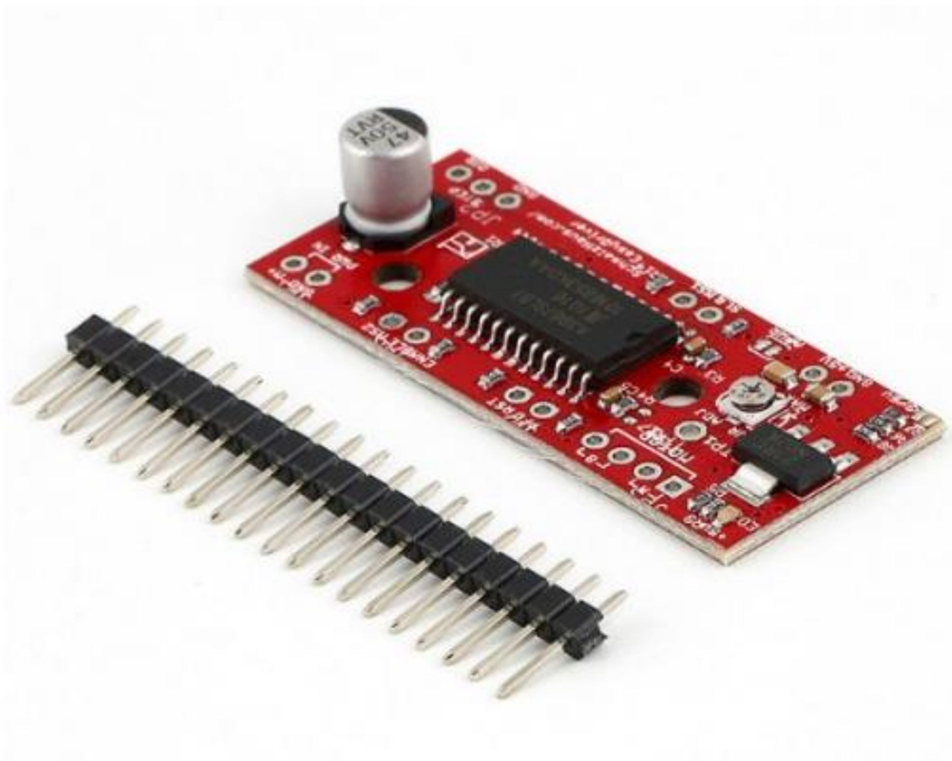

Figure. 2.20 - Stepper Motor Driver.

The A3967SLB includes a fixed off-time current regulator that has the ability to operate in slow, fast, or mixed current-decay modes.

FEATURES: ±750 mA, 30 V Output Rating; Satlington® Sink Drivers; Automatic Current-Decay Mode Detection/Selection; 3.0 V to 5.5 V Logic Supply Voltage Range; Mixed, Fast, and Slow Current-Decay Modes; Crossover-Current Protection.

Joystick KY-023. Dual axis control module XY (fig. 2.21) [25].

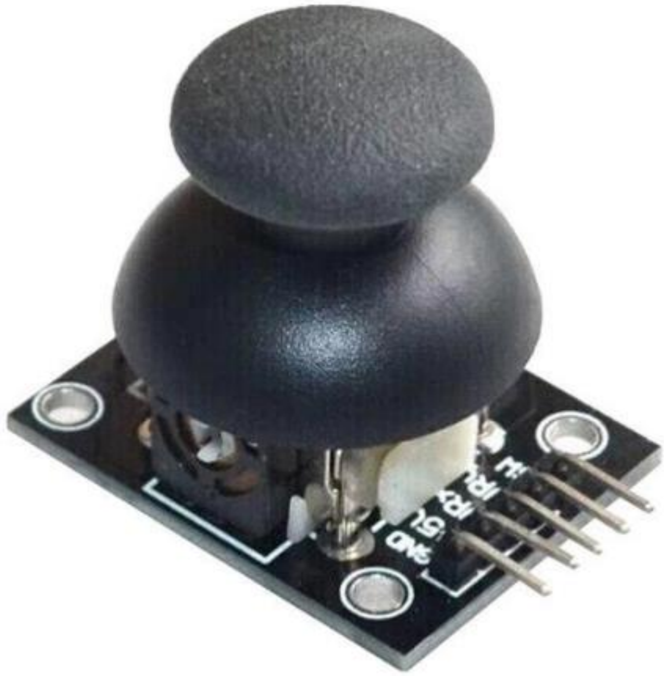

Figure. 2.21 - Joystick KY-023.

<u>Circuit model of the device.</u>

The software, called Fritzing, developed a breadboard, electrical circuit and printed circuit board for the circuit that controls the movement of the platform on which the Kinect camera is located. Fritzing is an open-source hardware initiative that makes electronics accessible as a creative material for anyone. This program allows users to document their prototypes, share them with others. Fritzing helps teach electronics, design and build professional printed circuit boards.

The power supply of the Easy Driver is connected to the 12V of a separate power supply.

Arduino and driver power separated by Easy Driver.

Figure 2.22 shows the Breadboard of the camera positioning device.

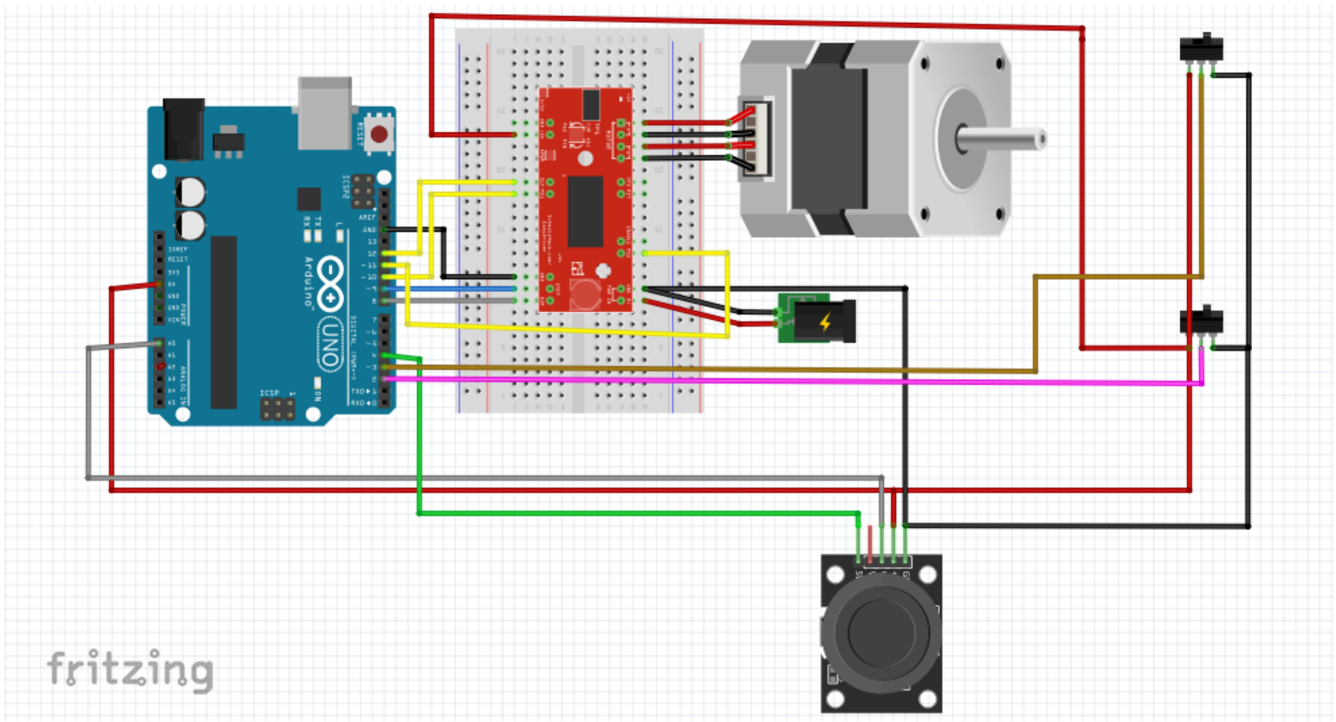

Figure. 2.22 - Breadboard of the camera positioning device.

Figure 2.23 shows the Schematic of the camera positioning device.

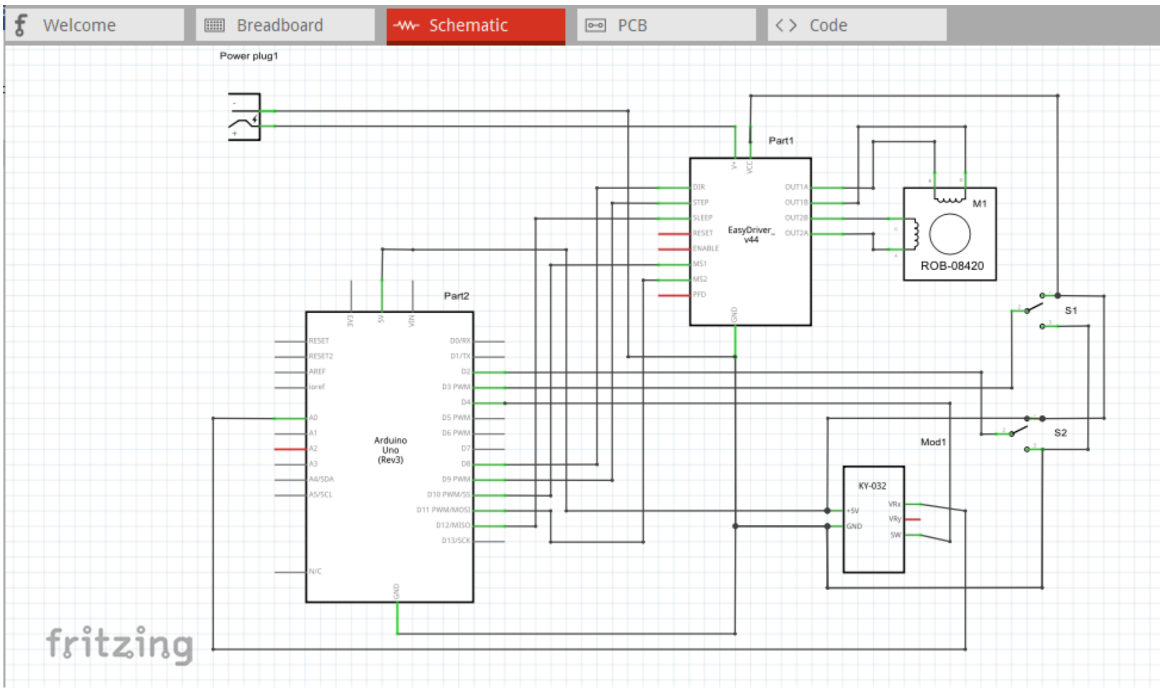

Figure. 2.23 - Schematic of the camera positioning device.

Figure 2.24 shows the Printed Circuit Board of the camera positioning device.

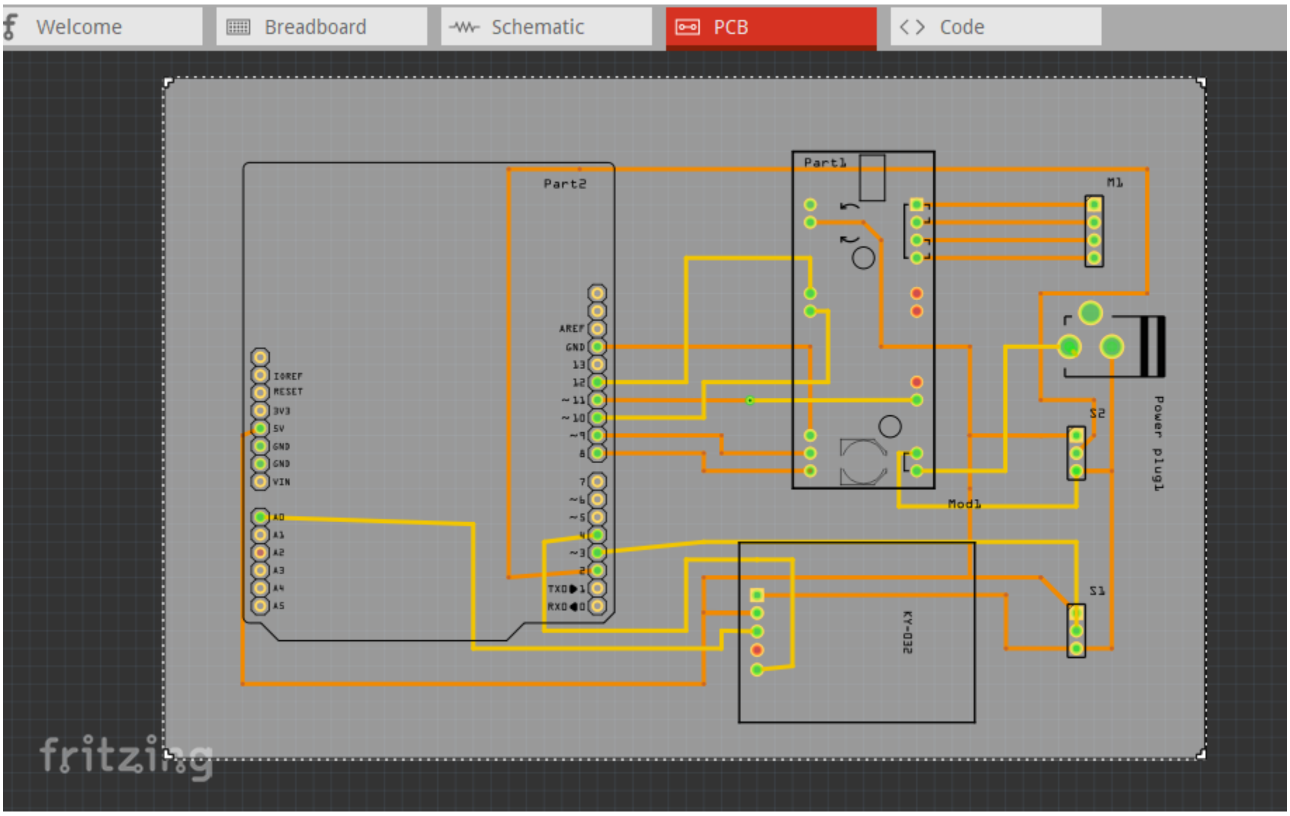

Figure. 2.24 - Printed Circuit Board of the camera positioning device.

Conclusions to section 2

During the practical part, based on the analyzed analogues, a design scheme of a complex device for assessing human gait was developed. The principle of operation of each element of the scheme was considered separately.

Based on the received data, the element base of the installation was selected. 3D printing parts were developed.

The software necessary for the operation of the complex device has been developed. Electrical circuits and printed circuit boards of the device have also been developed.

SECTION 3
OCCUPATIONAL HEALTH

Thesis was performed on the basis of the National Technical University of Ukraine "Kyiv Polytechnic Institute named after Igor Sikorsky" (Faculty of Biomedical Engineering).

In this thesis on the topic, a complex device for gait research was developed, which is the subject of research in this section. This device is intended for research and educational work, therefore the identification of potentially dangerous and harmful production factors created by its design [26] and measures to eliminate them will be considered.

3.1 Characteristics of the object and its components

3.1.1 Object characteristics

The main technical characteristics are given in table 3.1.

Table 3.1 – System characteristics

№	Name of the device and functional blocks	Main characteristics	Quantity
1	Kinect v1 camera	Dimensions - 27.94 cm x 6.35 cm x 3.81 cm; Color resolution and fps - 640 x380 at 30 fps or 1280 x720 at 12 fps; IR resolution and fps - 640 x 480 at 30 fps; Depth resolution and fps - 320 x240 at 30 fps; Specified min. Distance - 0.4 m or 0.8 m; Recommended min. Distance - 1.8 m; Tested min. Distance - 1 m; Specified max. Distance - 4 m; Tested max. Distance - 6 m; Temperature - Weak correlation.	1

Continuation of table 3.1

2	EMG Muscular Signal Sensor	Power supply voltage: +9V and -9V; 3.5mm Connector; 1000mm Cable Leads; Disposable Surface Electrodes.	1
3	Arduino microcontroller	Supply voltage 7… 12 V, Supply current 20mA, Load current 0.5 A, Temperature regime 0… 85º C, Product class according to the method of protection 1, Product class according to the degree of protection BF	1
4	RS-15-5 power supply	Input voltage 88 - 264 V, 60 Hz, Output voltage 5 V, Load current 3 A, Temperature mode -20… 70º C Protection against short circuit, overload, temperature drop, supply voltage drop	1
5	Adapter for camera	Input:100-240V ~ 0.3A, 47-50Hz, Output:12V , 2A.	1
6	Stepper motor	Operating supply voltage 4.8-7.2 V, Supply current, 0.5-2.5A, Torque, 15 kg / cm/.	

In the next subsection the functional scheme of the device will be considered.

3.1.2 Components of the system

In fig. 3.1 the functional scheme of the device for research of mechanical properties of biomaterials is shown. Since the camera and stepper motor require separate power supplies, it was decided to add power supplies to the circuit, which significantly increased the risk when working with the device. Everything else is powered by the microcontroller.

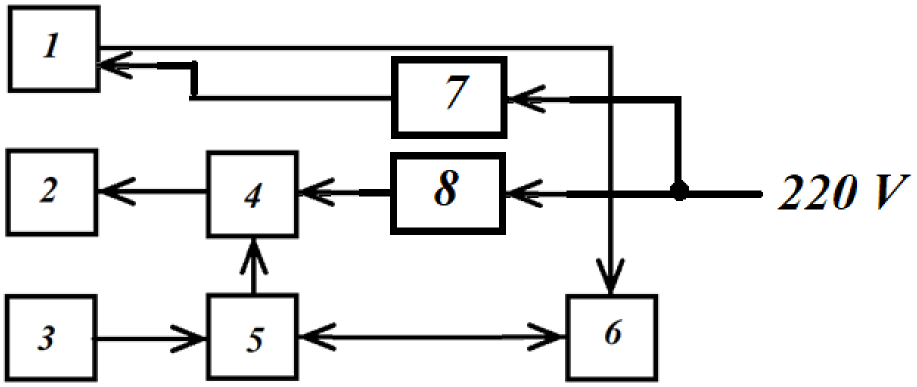

Figure 3.1 – Functional scheme of the complex device for gait research: 1 – Kinect v1 camera; 2 –stepper motor Nema17; 3 – EMG Muscular Signal Sensor; 4 – Stepper Driver; 5 – Arduino microcontroller (MK); 6 – Personal Computer; 7 - Adapter for camera; .8 - RS-15-5 power supply.

3.1.3 The nature of interaction in the system "man-object"

Means of obtaining information about the status of the device connection and system operation are presented in table 3.2.

Table 3.2 – Interaction of the object in the system "man-object"

№	Name of the functional block	Type of information display	Quantity
1	Kinect v1 camera	Connection indicator - LED	1
2	EMG Muscular Signal Sensor	Connection indicator - LED	1
3	Arduino Uno microcontroller	Connection indicator - LED	1
4	RS-15-5 power supply	Connection indicator - LED	1
5	Adapter for camera	Connection indicator - LED	1
6	Output data processing unit	The indicator of correct operation of the device - the monitor	1

When designing the device, it was decided to minimize the researcher's contact with the device, therefore, in addition to connecting a contact sensor, the complex device has a non-contact camera. Camera control is automated. This significantly reduces the risk of injury when working with a complex device. Also, the presence of indicators on the key elements of the complex device allows you to react in a timely manner in case of incorrect operation of this device.

3.2 Assessment of potential hazards created by the system design and measures to eliminate them

3.2.1 Mechanical hazard

Mechanical hazards can be created by the presence of moving parts in the structure, as well as rotating parts, and the possibility of destruction of individual parts and elements of equipment.

Table 3.3 presents the main hazards of a mechanical nature that arise as a result of operation of the device. Table 3.4 compares the actual and regulatory values of hazard factors [26, 27], and table 3.5 presents the relevant measures.

Table 3.3 – The main hazards of a mechanical nature

№	Name of the function block	Source of danger	Causes of danger	Consequences of danger
1	Stepper motor	Mechanical pressure	1 Increased pressure in the mechanism	Damage to the gearbox
			Jamming of the mechanism	Overheating of the engine, damage of a control system

Table 3.4 – Real and regulatory hazards.

№	Hazard factor	Actual value	Regulatory values
1	Pressure in the system	20-54 MPa	80 MPa

Table 3.5 – Measures to ensure labor protection

№	Group of nomenclature measures on OP	Type of the event	Selection criterion
1	Technical means	Limit the pressure that can occur in the system software	Preventing the occurrence of critical pressure values
2	Organizational tools	Instructions for servicing the appliance	Ensuring that the appliance is maintained in good condition
3	Mode	Not Provided	
4	Operational	Check the device for mechanical damage before use	Ensure safe operation of the device

The measures described in Table 3.5 significantly increase the mechanical safety of a complex gait analysis device.

3.2.2 Danger of electric shock

The main danger factor is the presence in the circuit of elements under the action of high voltage. Table 3.6 presents the main electrical hazards. Table 3.7 compares the actual and regulatory values of risk factors, and table 3.8 presents the appropriate measures to eliminate or minimize the risk [26, 27].

Table 3.6 – The main dangers of electrical nature

№	Name of the function block	Source of danger	Causes of danger	Consequences of danger
1	RS-15-5 power supply,	Alternating current	Insulation damage	Electric shock
			The appearance of high voltage as a result of failure	Damage to the microcontroller board, motor and
2	RS-15-5 power supply,	Alternating current	Incorrect wire connection	Damage to the microcontroller board, motor
3	Adapter for camera	Alternating current	Insulation damage	Electric shock

4	Adapter for camera	Alternating current	The appearance of high voltage as a result of failure	Damage to the microcontroller board, motor and
5	Adapter for camera	Alternating current	Incorrect wire connection	Damage to the microcontroller board, motor

Table 3.7 – Real and regulatory hazards

№	Hazard factor	Actual value	Regulatory values
1	Current in the system	3 A	5-7 mA

Table 3.8 – Measures to ensure labor protection

№	Group of nomenclature measures on OP	View of the event	Selection criterion
1	Technical means	Wire for power supply from the network of 220 V with the area of a cut of 1 mm^2 and isolation thickness of 0,7 mm	Preventing contact with the supply voltage and burnout of the conductor
		Selection of wires in different colors specified in the instructions	Reduce the risk of incorrect connection, facilitate diagnosis and repair
		The case from ABS plastic with a wall 3 mm thick	Isolation of power units
2	Organizational tools	Instruction on operation	Ensuring compliance with operating rules
3	Mode	Diagnosis and troubleshooting only when switched off	Preventing contact with live parts
4	Operational	Check for insulation integrity and compliance of power supply characteristics with nominal parameters	Ensuring the safe operation of the facility
		Check the connection of blocks to each other.	Ensuring the safe operation of the facility.

The measures described in table 3.8 significantly increase the electrical safety of the device.

3.2.3 Danger of fire

Ignition can occur due to voltage drop or heating of individual parts and their damage (table 3.9). Table 3.10 compares the classification of possible ignition in the process of using the device, and table 3.11 presents the appropriate measures to eliminate them or minimize the risk [26, 27].

Table 3.9 – The main dangers associated with fire

№	Name of the functional block	Source of danger	Causes of danger	Consequences of danger
1	RS-15-5 power supply	Voltage and electric current	Voltage surge	Occurrence of fire
			Short circuit	
2	Adapter for camera	Voltage and electric current	Voltage surge	Occurrence of fire
			Short circuit	
3	Stepper motor	Electric current	motor overheating	Occurrence of fire
			Short circuit on the control board	

Table 3.10 – Real and regulatory hazards

№	Hazard factor	Fire hazard class
1	Voltage jump	A, E
2	Heating wires	A, E

Table 3.11 – Measures to ensure labor protection

№	Group of nomenclature measures on OP	View of the event	Selection criterion
1	Technical means	RS-15-5 power supply	Protection against short circuit, overload, temperature drop, supply voltage drop
		LED that signals the malfunction of the device	Timely emergency shutdown
2	Organizational tools	Instruction on operation and safety	Reducing the risk of human exposure
3	Mode	In the event of a malfunction of any functional unit and in the event of a fire, disconnect from the power supply	Prevent significant damage to the appliance and transfer the ignition to other objects

The measures described in table 3.11 significantly increase the safety of the device.

3.3 Development of "Safety instructions for operation of the designed object"

1. Read these instructions carefully before use and subsequent use.

2. The complex device is intended only for gait analysis.

3. Before connecting to the network, make sure that the network voltage matches the supply voltage.

4. It is prohibited:

– contact with the mechanism of the complex device during operation;

- leave the complex device unattended during operation;

– use the complex device in case of existing damages or malfunctions;

- independently repair a complex device without the necessary qualifications;

- use the complex device for the wrong purpose;

- use a complex device outside the laboratory.

5. When cleaning the complex device after the examination, it is allowed to use only those means specified in the operating instructions.

6. After work, the complex device must be disconnected from the power source, packed and stored in a safe place.

7. Calibration, calibration and adjustment of the gait analysis device should be carried out by a representative of the developing company or a certified engineer.

8. During operation, it is necessary to observe all safety rules specified in this section.

Conclusions to section 3

This section analyzes the key hazards and harmful production factors that can be created by the design of the developed complex device.

The means of eliminating possible dangers and harmful production factors are considered.

The main hazards in the system are pressure and electric current.

Instructions for the safe operation of the designed complex device for the analysis of human gait have been developed.

CONCLUSIONS

During the implementation of this thesis, the assigned tasks were completed and significant results were achieved. The analysis of the technical literature showed the advantages and disadvantages of the sensors used in the analysis of human gait.

The search for inexpensive contact and non-contact sensors for a complex gait analysis device made it possible to identify the key blocks of such a device and, accordingly, develop a structural diagram.

Developed software for contact and non-contact sensors for automated operation of the installation in Arduino IDE and Kinect SDK software.

Details for 3D printing and subsequent assembly of the working model of the installation were developed.

The "Occupational safety" section lists the factors of the main hazards and ways to eliminate them or minimize the risk of possible hazards and harmful production factors. Instructions for the safe operation of the designed complex device for the analysis of human gait have also been developed.

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APPENDIX A
PROGRAM LISTING

//EMG Arduino sketch

```
int EMGPin = A1;

int EMGVal = 0;

void setup() {

Serial.begin(115200);
}
void loop() {

EMGVal = analogRead(EMGPin);

Serial.println(EMGVal);

}
```

//Stepper motor control code using a joystick

```
// http://www.progdron.com/proekty-s-arduino/spisok-materialov/377-upravlenie-shagovym-dvigatelem-s-pomoshchyu-dzhojstika.html
#define step_pin 9 // Pin 9 connected to Steps pin on EasyDriver
#define dir_pin 8 // Pin 8 connected to Direction pin
#define MS1 10 // Pin 10 connected to MS1 pin
#define MS2 11 // Pin 11 connected to MS2 pin
#define SLEEP 12 // Pin 12 connected to SLEEP pin
#define X_pin A0 // Pin A0 connected to joystick x axis
#define Joy_switch 4 // Pin 4 connected to joystick switch
#define Limit01 2 // Pin 2 connected to Limit switch out
#define Limit02 3 // Pin 3 connected to Limit switch out
int step_speed = 10; // Speed of Stepper motor (higher = slower)
void setup() {
pinMode(MS1, OUTPUT);
pinMode(MS2, OUTPUT);
pinMode(dir_pin, OUTPUT);
pinMode(step_pin, OUTPUT);
pinMode(SLEEP, OUTPUT);
pinMode(Limit01, INPUT);
pinMode(Limit01, INPUT);
pinMode(Joy_switch, INPUT_PULLUP);
digitalWrite(SLEEP, HIGH); // Wake up EasyDriver
delay(5); // Wait for EasyDriver wake up
/* Configure type of Steps on EasyDriver:
// MS1 MS2
//
// LOW LOW = Full Step //
// HIGH LOW = Half Step //
// LOW HIGH = A quarter of Step //
```

```
// HIGH HIGH = An eighth of Step //
*/
digitalWrite(MS1, LOW); // Configures to Full Steps
digitalWrite(MS2, LOW); // Configures to Full Steps
}
void loop() {
if (!digitalRead(Joy_switch)) { // If Joystick switch is clicked
delay(500); // delay for deboucing
switch (step_speed) { // check current value of step_speed and change it
case 1:
step_speed=10; // slow speed
break;
case 3:
step_speed=1; // fast speed
break;
case 10:
step_speed=3; // medium speed
break;

}
}

if (analogRead(X_pin) > 712) { // If joystick is moved Left
if (!digitalRead(Limit01)) {} // check if limit switch is activated

else { // if limit switch is not activated, move motor clockwise

digitalWrite(dir_pin, LOW); // (HIGH = anti-clockwise / LOW = clockwise)
digitalWrite(step_pin, HIGH);
```

```
delay(step_speed);
digitalWrite(step_pin, LOW);
delay(step_speed);

}

}

if (analogRead(X_pin) < 312) { // If joystick is moved right
if (!digitalRead(Limit02)) {} // check if limit switch is activated

else { // if limit switch is not activated, move motor counter clockwise
digitalWrite(dir_pin, HIGH); // (HIGH = anti-clockwise / LOW = clockwise)
digitalWrite(step_pin, HIGH);

delay(step_speed);

digitalWrite(step_pin, LOW);
delay(step_speed);

}

}

}
```