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Operating Wheelchair using Flex Sensor

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P A P E R I N F O

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A B S T R A C T

Disabled people find their movements extremely difficult with their current gadgets. Although there are numerous devices and instruments accessible to empower their mobility, they require fine and precise control, which may be impractical in instances of higher disability. The haptic innovations are very beneficial, but demands a user-friendly environment too. The number of strategies, designs and frameworks in this field are more in number, which depends on Joystick. But this can prove to be uneconomical. Therefore, the aim of this paper is to control a wheelchair through a utility that is budget-sensitive and practical to use. A flex sensor-based wheelchair is presented in this paper, which is user friendly within a low budget. The proposed system is also accompanied by a movement monitoring system that can help the user's kin to observe his/her movement. The aim is to provide such features which is affordable to the society and can be used with ease.

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NOMENCLATURE

R_{flex}	Flex Resistance	V_{In}	Input Voltage
V_{CC}	Voltage common collector	R_{const}	Constant resistance
V_0	Output Voltage		

1. INTRODUCTION

The wheelchair is one of the most utilized equipment to improve movement and enhance personal satisfaction for individuals, who experience issues in walking. This may be due to spinal line wounds bringing about paraplegia or quadriplegia, cerebrovascular accident, or a stroke, leading to impaired movement. Thus, people may suffer from various kinds of disabilities and this percentage cannot be neglected. A wheelchair provides comfort, improves mobility and provides a solution for an impaired person to partake in social activities, access organizations, human administrations and reliance on himself improving self-confidence. A properly assisted wheelchair benefits the physical well-being and personal satisfaction of the clients. Regardless of quick, innovative, and logical advancement in gadgets for people with disabilities, there has been practically little headway in the wheelchair plan in the course of the most recent years but still, efforts are being made [1]. In 1932, Harry Jennings, an engineer, fabricated the principal collapsing, cylindrical steel wheelchair. Then came the first motorized wheelchair, which was operated by turning the wheels of the seat physically. In the event where a patient could not do this, someone else would need to push the wheelchair and the patient from behind. A motorized or force/power wheelchair is one where a little engine drives the wheels to spin. Thereafter, the electric wheelchair was designed by the Canadian innovator, George Klein and his group of associates. These wheelchairs got progressively significant as assistive innovation and the number of clients soared. For instance, improving the suspension performances of an electric wheelchair [2]. Along these lines, a programmed wheelchair [3] was created to take care of the issue for route and safe development in the ideal course. Diverse information techniques can be utilized to perform this task. This human-machine interface includes eye-gaze following technique, voice recognition, joystick-controlled, and so on. But utilization of these techniques can prove to be a tough task for people with a physical disability as they may find it tough to operate it around.

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Some shortcomings for instance, in an eye following wheelchair [4], the user is not allowed to envision the adjoining environmental factors when the framework is dynamic, and a voice acknowledgment-based wheelchair cannot work appropriately in background noise conditions. Furthermore, a traditional joystick controller requires much strength which is more than the strength of seriously crippled individuals. Even if this situation is ignored, it is as yet a very troublesome assignment for physically incapacitated individuals to get authority over the proper utilization of a joystick. This implies that although these methods are available to the disabled, however, satisfaction and command control of the wheelchair is impaired in certain circumstances. Motion capture Systems using flex sensors in robotics has also helped in human locomotion [5]. This paper throws light on the usage of a Flex sensor [6] in a wheelchair to make the functional capacity as near normal as possible. Here flex sensors will be the spine of the wheelchair. A flex sensor or bending sensor can be put to use for navigating the wheelchair in numerous directions [7]. The proposed wheelchair objective is to provide the largest possible satisfaction to the individuals who are crippled/amputees. This motion-controlled wheelchair is partitioned into two segments, (i) Transmitter: Flex sensor and (ii) Receiver: Wheelchair. Furthermore, the data now gathered from this setup can be used to keep a tab on the position and the motion of the wheelchair. This is accomplished by uploading the generated information/data to ThingSpeak via NodeMCU. Section 1 explains the introduction and background. Section 2 emphasizes the technical stack of the proposed model. Section 3 exhibits the execution (equipment and programming) of the venture and section 4 explains the planning of our proposed model. Section 6 concludes the paper.

2. TECHNICAL STACK

The proposed mechanism will consist of a flex sensor, a Microcontroller and DC Motors. A flex sensor controls the motors, which will in turn control the wheels of the wheelchair. The aim is to blend hardware as well as a software interface to achieve this. ThingSpeak acts as a cloud to store the transmitted data via Hypertext Transfer Protocol, with the help of RESTful API. For constructing a monitoring system of the wheelchair, the data received from the flex sensor is used to analyze the movement of the wheelchair remotely. To access the data, ThingSpeak is chosen which eases the process of accessing the data remotely.

2. 1. Flex Sensor A Flex sensor is a thin, lightweight, and flexible strip where the resistance is proportional to the amount it is bent. It can operate from 0° to 180°. A flex sensor produces an analog signal. The carbon surface is engineered on a strip with the working voltage varying from 0 V to 5V and working temperature ranges from -45ºC to +80ºC. The scope of curve opposition is from 45 K to 125 K with a resilience obstruction of ±30%. The flex sensor works whenever the plastic strip is bent. Table 1 shows the value of the flex sensor at 0° and 90°. The resistance increases/escalates as the strip is bend from 0° to 90°.

This adjustment in obstruction relies on surface linearity, which implies that the resistance of this sensor would be diverse at different points. A Proper Filter can significantly improve the smoothness of fingers which will ease the movement of the wheelchair [8].

2. 2. Arduino Arduino is an open-source platform that can be utilized to develop certain objects by interacting with an assortment of physical entities. Arduino is chosen as a microcontroller for the proposed mechanism because it is highly compatible with a large no of sensors, has 13 GPIO pins and 5 analog pins making it expandable with many sensor modules.

2. 3. Nodemcu NodeMCU is chosen for the proposed mechanism as a result of its modest cost and the degree of network support. It can also be modified using Arduino IDE so it can run the libraries utilized by Arduino [9]. This tool is particularly helpful for IoT applications, because of its compact nature and inherent WiFi support. The connections of a flex sensor to a NodeMcu are akin to that of Arduino and flex sensor.

2. 4. L293D Motor Driver IC L293D is a (motor driver) IC that lets the DC motor drive on both routes. This 16-pin IC can manage a hard and fast of two DC motors concurrently in any course. 36V can be the maximum voltage supply. L293D consists of 4 inputs; 2,7 for the left motor and pin 15,10 for the right one. The benefit of utilizing the motor driver is that it can turn around the polarity of applied voltage without readjusting the circuit and can provide us current in both directions up to 600mA.

3. PROPOSED IMPLEMENTATION

3. 1. Control System To command the wheelchair to move in different directions just by bending the fingers, a control system is proposed. Detailed implementation of this process is discussed in further sections.

TABLE 1. Values of resistance at 0°and 90°

Angle Values	Resistance (ohm)
0°	40910.20
90°	93697.67

3. 1. 1. Interfacing the Flex Sensor with Arduino

To interface Arduino with flex sensor a voltage divider circuit is implemented to analyze the change in resistance of the flex sensor generated by bending of fingers, which produces different values of angles. The Flex sensor is interfaced with Arduino as shown in the pin configuration of the Flex sensor in Figure 1. One of the pins is connected to Arduino's power supply pin, VCC. The next pin is connected to Arduino's GPIO pin i.e the analog pin. Since there are five analog pins, it can be connected to any one of them because it generates an output in analog. As the aim is to create a voltage divider circuit, a resistor measuring 33k ohms is connected at A0 with a flex sensor.

Analog values received from the flex sensor via pin A0 are the output voltages obtained but these values need to be converted into discrete volts and then the flex resistance will be obtained by the formula as expressed in Equation (1):

$$V_0 = V_{in} * \left(\frac{R_{const}}{R_{const}+R_{flex}}\right) \quad (1)$$

The above equation can also be rewritten as shown in Equation (2):

$$R_{flex} = \left(\frac{V_{in}}{V_0} - 1\right) * R_{const} \quad (2)$$

The obtained resistance is then fed to an inbuilt function called map(). This function helps in converting the obtained resistance value to the exact angle which actuates the motors further. Table 2 shows the values of angles for different values of resistance.

3. 1. 2. Interfacing Arduino with Motor Driver

As mentioned under the technology stack, the L293D IC can control 2 motors simultaneously. Thus, its objective is to actuate the motors according to the command sent by Arduino to the motor driver.

For the hardware implementation of the motor driver (L293D) with Arduino, the output pins for each motor present in the motor driver are connected to Arduino GPIO pins. As shown in Figure 2, the ground and VCC of the motor driver are connected to Arduino's ground and VCC pin, respectively [10] To actuate the motors, an effective power source is required as their expected power input is much more than the maximum power supplied by Arduino. Hence the motor driver will be connected to an external power supply as well.

For the software implementation of the motor driver in Arduino IDE, the connected GPIO pins are set in output mode to actuate the motors. Now the decision-making part is analyzed. First, three functions in Arduino IDE are formed that are the stop ( ), forward ( ) and backward( ). The whole actuation process depends on the values of the angle generated by the map ( ) function. For the decision-making part, the flow of the program is controlled by using the if-else statement. For instance, if the angle is less than -10°, the backward () function is called and the motors start moving in the reverse direction hence making the wheelchair move backwards.

TABLE 2. Values of resistance and angle

Resistance (ohm)	Angle
74389	57°
88128	81°
107739.7	114°
108342.9	115°
150011.2	185°
134178.5	158°
44463.06	7°
40719.46	1°
40397.46	0°
36744.19	-5°
32286.95	-13°
29393.96	-17°

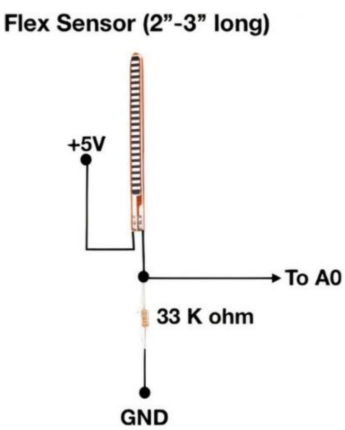

Figure 1. Pinout configuration of flex sensor

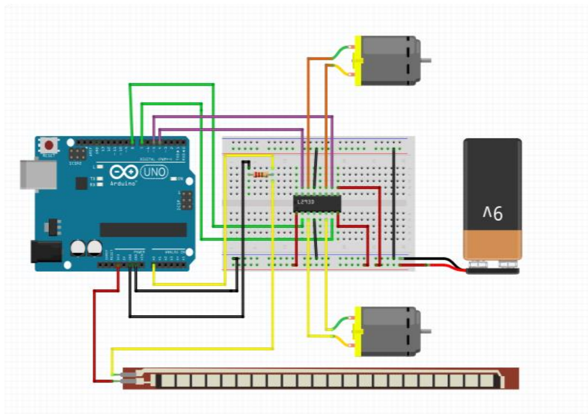
Figure 2. L293D Motor Driver IC with DC Motors and Arduino

3. 1. 3 Interfacing Motors with Motor Driver To drive the motors according to the bending of the finger, the motor driver will receive a request from Arduino to perform a particular function i.e. forward, backward, stop, etcetera. As L293D is an H-bridge, so motors can rotate clockwise and anti-clockwise according to the discrete signal sent by Arduino to the input pin of L293D. After the input is received, L293D will generate output according to the input signals. For instance, consider the case of a stop function. When both values are sent high or low, then the circuit remains open which stops the motors. Similarly, outputs of different functions can be generated.

3. 1. 4. Compilation of Control System of Wheelchair All the implementations covered above are compiled together in this section. Figure 3 is a flowchart depicting the flow of the process. The flex sensor is connected to the Arduino, along with the voltage divider circuit. Then the motor driver, L293D, is connected to the Arduino with a nine-volt battery. After these connections are established, a pair of motors are connected to the motor driver. This completes the hardware compilation and it is ready for the software simulation. The code written in Arduino IDE is uploaded and is executed by the sequence of commands written in embedded C. The compilation starts with the setup in Arduino IDE. All the GPIO pins are set to INPUT/OUTPUT mode. The value of the constant resistor (33k ohms) and the resistance of the flex sensor at 0° and 90° are set which is measured by the multimeter. Finally, the board rate is set at 9600 to print the data on Serial Monitor for the Arduino board. After execution of the loop, the first value generated from the flex sensor is retrieved which is then converted to a discrete value as flex voltage. The resistance of the flex sensor when the finger is bent is calculated by Equation (2). This value is then sent to the map function which will generate the angle created by bending the flex sensor. After the angle is generated, it is sent to perform a logical operation, which compares the generated value of the angle with predefined ranges, to execute the particular function. If a proper match is found, then that function is executed, which will send the request to the motor driver to drive the motors. Now the compiler will again return to the start of the loop and repeat the procedure i.e a value is received and then it will execute another function. By this procedure, the aim to control the wheelchair by bending the fingers is achieved successfully.

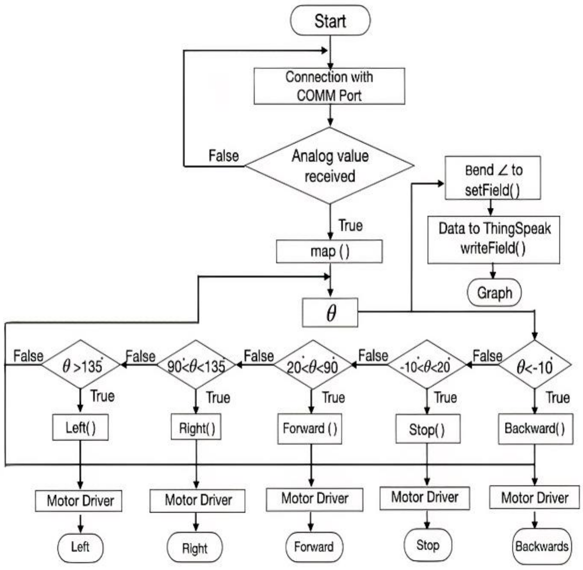

Figure 3. Flowchart

3. 2. Movement Monitoring System To monitor the movement of the person sitting in the wheelchair, a monitoring system is framed. The concept of the Internet of Things is implemented to achieve this. The monitoring system aims to send real-time data to the guardian of the person sitting in the wheelchair. This data will signify whether the person is moving or not. It will reveal if it is moving forward, backward, left or right. So, with the help of this data, the guardian will be able to keep track of the person.

3. 2. 1. Implementation of Monitoring System To implement the movement monitoring system, the NodeMCU board is interfaced with the flex sensor. The NodeMCU receives data from the flex sensor and sends the data to the ThingSpeak server. Once the data is posted, a graph is plotted. With the help of the graph, the guardian can track the movement of the patient in real time. Detailed implementation of this process is discussed in further sections.

3. 2. 2. Hardware Implementation of NodeMCU with Flex Sensor The power pin of the flex sensor will be connected to NodeMCU's power supply pin, VCC (3.3 volts). The other pin will be connected to NodeMCU's GPIO pin i.e the analog pin. It is connected to A0 since it has only one analog pin. This connection is made because the flex sensor generates output in analog. Both the Arduino and the NodeMCU will be connected with the same voltage divider circuit as mentioned before.

3. 2. 3. Software Implementation of NodeMCU with Flex Sensor The data generated from the flex sensor is required to be sent to the cloud with the help of the map () function to reveal the movement of the wheelchair. For instance, a wheelchair moves backward when the angle is less than -10°.This data from the flex sensor is received by NodeMCU. The aim is to post the data to the ThingSpeak website. This is achieved by using the RESTfull API and HTTP. To write data to ThingSpeak, the write API Key is included in the code. As NodeMCU acts as a client and ThingSpeak acts as a server, the client will send a request to write the data by using the API Key. Flex sensor data needs to be sent to the selected field. The channel id needs to be specified in the code as well so that the data is sent to the right channel id created. To accomplish all this, the wifi module is connected to the internet network to send a request to access the ThingSpeak website and post data into it. This is performed by the function "WiFiClient". Then the compiler will check the status of the wifi whether it is connected or not and will repeat till the ESP8266 wifi module gets connected to the network. Furthermore, the ThingSpeak.begin( ) function will help in initializing ThingSpeak libraries. The main function of posting the data starts when setField( ) is called, where field specified is set as a parameter of this function along with data to be posted. Finally, the writeField( ) function along with the channel number and the write API Key calls the setField function to post the data to ThingSpeak.

3. 2. 4. Final Compilation of Monitoring System

After Node MCU is connected with the Flex sensor and the power supply, the data of the Flex sensor is ready to be posted to the ThingSpeak cloud. The graph obtained will help in monitoring the movement of the wheelchair. When the data is around the x-axis, it will signify that the wheelchair is not moving. When the data is approximately 10 units below the x-axis, this will imply that the wheelchair is moving in a backward direction. If the data is around 20 units above the x-axis, this will mean that the wheelchair is moving in a forward direction and whenever the data is about 90 units above the x-axis, this will signify that the wheelchair is moving in the right direction. Finally, if the data is around 135 units above the x-axis, this will denote that the wheelchair is moving in the left direction. The data is posted in the intervals of approximately 17 seconds which is revealed in Table 3 and simultaneously the graph is plotted as shown in Figure 4.

TABLE 3. Angles uploaded to thingspeak

Time (s)	Angle Values
0	-17°
17	62°
34	-19°
51	62°
68	92°
85	78°
102	74°

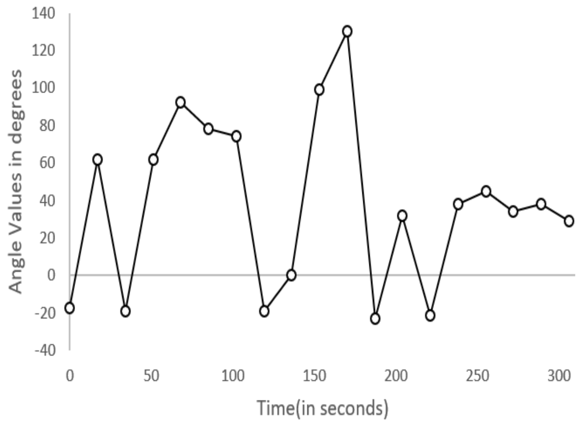

Figure 4. Graph for Thingspeak

4. DESIGNING OF THE WHEELCHAIR

To demonstrate the working of the wheelchair a prototype is assembled as shown in Figure 5. The prototype comprises of a flat chassis with the DC motors attached to it. Furthermore, wheels are appended to the motors. For the assembly of the prototype, a breadboard, Arduino, and NodeMCU are placed at the top of the chassis but for the actual wheelchair, all the components will be present inside a box named processing module and that will be placed below it for a steady flow. Only flex sensor is present at the grip of the user who is sitting on the wheelchair. The systems that are controlling and monitoring the framework will simultaneously update the data. Figure 6 shows the actual block diagram for the same.

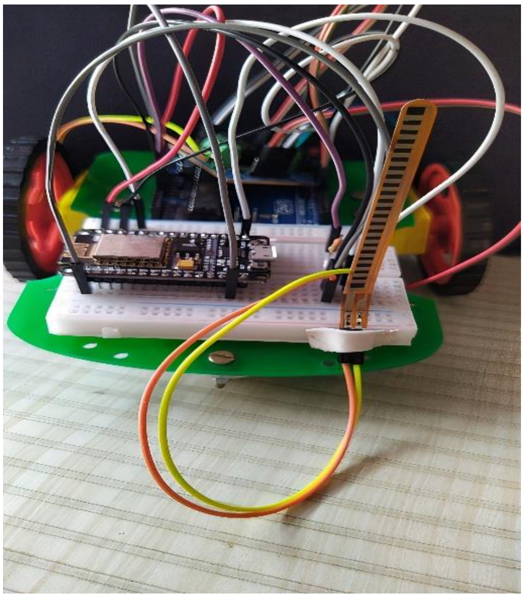
Figure 5. Prototype

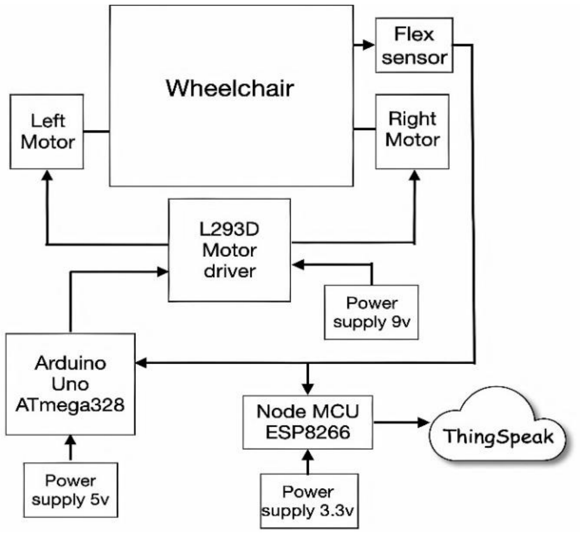

Figure 6. Block Diagram for Wheelchair Using Flex Sensor

5. COMPARISON WITH EXISTING MODELS

The point of our exploration is to structure and improvise the existing scenario for individuals with higher in-adaptability by the means of the flex sensor. The existing wheelchairs are mostly based on a joystick that controls the direction as per the user's wishes. But this framework is susceptible to internal faults and hence requires fault diagnosis and fault-tolerant control [11]. Other works include a camera-based and voice-based controlled wheelchair. The restriction with camera-based structure is that they require the client to keep up the head in a fixed position and a voice-based framework does not fare well in noisy conditions [12].

This proposed framework intends to improve the lives of physically disabled people at an affordable range. The most critical piece of this wheelchair is that it can be easily controlled by the movement of the user/patient fingers. This won't just assist the patient, but will also benefit the specialist and their family members who are in contact with the patient through the monitoring system. Hence, this system will provide better execution than the previously mentioned ongoing applications. Moreover, the direction can be very easily controlled with lesser strength as compared to existing wheelchair systems.

6. CONCLUSION AND FUTURE SCOPES

In this paper, a method has been proposed to interface the flex sensor and the processing module with the existing wheelchair. The control of the wheelchair has been achieved by bending the flex sensor and actuating the motors. Furthermore, a monitoring system has been successfully implemented by sending the data generated from the flex sensor to the cloud which would help the guardian to track the movement of the person sitting in the wheelchair. The future scopes may include implementation of a health monitoring system that can provide numerous provisions such as blood pressure, temperature, heart rate monitoring and many more. To extend the movement monitoring system, GPS can be installed to give real time location of the user.

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Persian Abstract

چکیده

افراد معلول با وسایل فعلی خود حرکات خود را بسیار دشوار می دانند. اگرچه دستگاه ها و ابزارهای بی شماری برای توانمندسازی تحرک آنها در دسترس است ، اما آنها به کنترل دقیق نیاز دارند ، که ممکن است در موارد معلولیت بالاتر غیر عملی باشد. نوآوری های لپ تاپ بسیار سودمند است ، اما یک محیط کاربر پسند را نیز می طلبد. تعداد استراتژی ها ، طرح ها و چارچوب ها در این زمینه تعداد بیشتری دارد که به جوی استیک بستگی دارد. اما این می تواند غیر اقتصادی باشد. بنابراین ، هدف این مقاله کنترل ویلچر از طریق ابزاری است که از نظر بودجه حساس و کاربردی باشد. صندلی چرخدار مبتنی بر سنسور فلکس در این مقاله ارائه شده است که با بودجه کم کاربر پسند است. سیستم پیشنهادی همچنین با یک سیستم نظارت بر حرکت همراه است که می تواند به خویشاوندان کاربر در مشاهده حرکت او کمک کند. هدف تهیه چنین ویژگی هایی است که برای جامعه مقرون به صرفه باشد و بتوان از آن به راحتی استفاده کرد.