Design and Build an Automatic Chair Wheel Control System with Microcontroller-Based Arduino Flex Sensors

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Abstract
This research aims to design and build an automatic chair wheel control system that can help improve the independence and mobility of people with disabilities. The system uses an Arduino Uno R3 microcontroller as the control center, as well as a joystick and flex sensor as motion command inputs. Other key components include a 24V DC motor, a driver motor, an I2C LCD, and a 24V 30Ah lithium-ion battery as a power source. The system is designed to respond to gesture commands such as forward, backward, left turn, right turn, and stop based on input from the user. The test results showed that the system successfully recognized the direction of movement through the signal from the joystick, controlled the DC motor in the direction, and displayed the motion status information in real-time on the LCD. The whole system works well, is responsive, and synchronous. Thus, this system can be an effective, economical, and applicative auxiliary technology solution for wheelchair users. Further development can be directed at the addition of security sensor features and body movement-based control (flex sensor).

Keywords: ***Automatic Wheelchair, Arduino, Joystick, Flex Sensor, Microcontroller.***

Introduction

Mobility is a basic human need that is very important in supporting independence, social participation, and access to education, employment, and public services. For people with physical disabilities, especially those with movement system disorders such as paraplegia or chronic muscle weakness, wheelchairs are a vital tool that allows them to continue their daily activities. However, manual wheelchairs have limitations because they require great physical force to move them and often require the help of other parties, which ultimately limits the autonomy and quality of life of the user (Setiawan et al., 2021).

Along with technological advancements, various innovations have emerged in the field of assistive technology that aim to improve the quality of life of people with disabilities. One of the solutions that is now being developed widely is an electric/powered wheelchair equipped with a sensor-based control system. This type of wheelchair not only provides flexibility of movement for the user, but can also be adapted to various physical conditions and levels of disability (Rashedi et al., 2018; WHO, 2022).

One of the technologies that has the potential to be integrated in wheelchair control systems is a flex sensor. This sensor is able to detect changes in bending angle and body position through changes in resistance when bent. By attaching these sensors to specific parts of the body such as fingers, wrists, or feet, the system can read the user's natural movement cues to translate them as control commands. This technology is more intuitive than joysticks or buttons because it utilizes minimal body movements (Kumar & Sharma, 2020; Ahmad et al., 2021).

This flex sensor can be combined with an Arduino microcontroller, which acts as the main signal processor and actuator controller. Arduino is known as an open-source platform that is flexible, easy to program, and supported by a large global community. Its ability to read analog sensors, perform logic processing, and control motors and other components makes them well-suited for applications in wheelchair control systems (Banzi & Shiloh, 2014; Kurniawan et al., 2022).

With this approach, automated wheelchair systems can be developed to be more responsive, adaptive and energy-efficient. In addition, the cost is also much lower than conventional automatic wheelchairs sold on the market, which are generally expensive and not easily accessible to middle-to-lower economies in developing countries such as Indonesia (Handayani et al., 2022). Therefore, the use of a combination of flexible sensors and Arduino not only brings technical efficiencies, but also has the potential to expand access to inclusive and sustainable assistive technologies.

This research aims to design and build an automatic chair wheel control system based on flex sensors and Arduino microcontrollers. Research focuses include hardware design, control logic programming, sensor calibration for body motion detection, and testing of system efficiency and reliability. With the development of this system, it is hoped that users will be able to operate the wheelchair independently, comfortably, and safely, without depending on external assistance. This research contributes to the development of the field of applied robotics and health technology, as well as answers social challenges in creating tools that are affordable and can be customized according to user needs. With wider adoption, this technology can support the achievement of the Sustainable Development Goals (SDGs), especially in point 3 (health and well-being) and point 10 (reducing disparities), as well as promoting life independence for people with disabilities (United Nations, 2021).

Literature Review

1) Automatic Wheelchair

   Automatic wheelchairs are a development of manual wheelchairs that use an electric power source and electronic control system to support the mobility of people with disabilities. This technology allows users to move more independently without physical assistance from others. Modern automatic wheelchairs are equipped with various control systems such as joysticks, remote controls, and body sensors (Rashedi et al., 2018). The development of automated wheelchairs aims to improve the comfort, safety, and efficiency of user mobility (Setiawan et al., 2021).

Figure 1. Electric Wheelchair

2) Flex Sensor (Flexible Sensor)

Flex sensors are resistive sensors that change their resistance value when bent. This sensor is highly sensitive to changes in position and bending angle, making it suitable for detecting human body movements such as fingers, wrists, or feet (Ahmad et al., 2021). The use of flex sensors in wheelchair controls provides the advantage of intuitive control based on the user's natural body movements. Various studies have shown the effectiveness of these sensors in wearable technology projects and rehabilitation systems (Kumar & Sharma, 2020).

3). Arduino Microcontroller

Arduino is an open-source development board-based microcontroller platform that is easy to program, flexible, and widely used in automated control systems. Arduino Uno, one of the most common types, has the ability to read inputs from various sensors and output signals to control actuators such as motors (Banzi & Shiloh, 2014). Arduino supports the development of assistive technology prototypes that are cost-effective and quickly implemented in various application scenarios (Kurniawan et al., 2022).

Figure 2. Arduino One

4). Control System on Wheelchair

The wheelchair control system includes the logic of processing input signals from sensors, decision-making, as well as the activation of the drive motor based on a specific algorithm. Control algorithms can be simple if-else logic or fuzzy algorithms and machine learning. In this study, the input signal from the flex sensor will be calibrated and translated by Arduino to control the direction and speed of wheel movement. The quality of the control system is greatly influenced by the accuracy of sensor readings and signal processing efficiency (Handayani et al., 2022).

Research Method

Timer Design in Electrical Control System

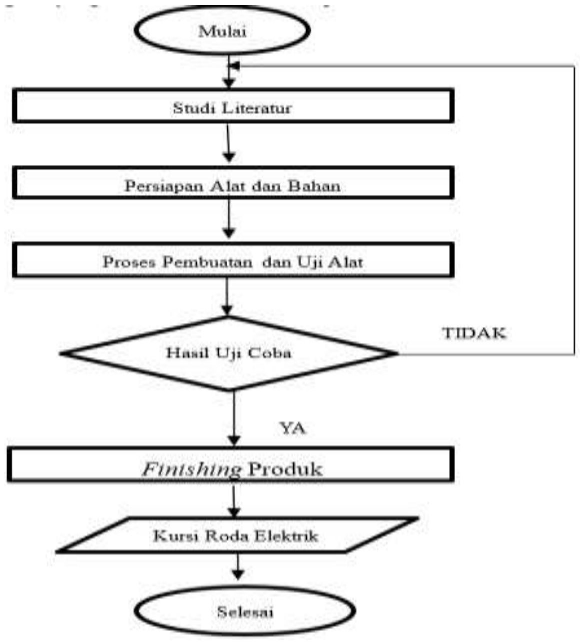

Figure 3. Research Methods

1) Start: The initial stage begins when the system is turned on. The Arduino microcontroller starts receiving the power supply from the battery source or adapter. This process is the main trigger to start the entire working series of automatic chair wheel control systems.
2) System Initialization: At this stage, Arduino performs the initialization process of all components. This process includes configuring the input and output pins, enabling serial communication if needed, as well as an initial reading of the flex sensor to ensure that the sensor is functioning properly before the system actively reads the data.
3) Flex Sensor Data Reading: Once the initialization is complete, the Arduino begins to read the resistance value of the flex sensor. This sensor will undergo a change in resistance value along with changes in the angle or bend of the user's body. The read value is analog data that reflects the body's movements.
4) Sensor Value Calibration and Filter: The sensor values received by the Arduino will be filtered first to eliminate interference (noise) that may arise due to small movements or vibrations. Furthermore, a calibration process is carried out so that the system can clearly distinguish every movement and direction of commands from the user, such as forward, backward, or turn.
5) Motion Condition Check: The system then evaluates whether the motion detected by the sensor is in accordance with a specific command. For example, if the sensor detects an upward bend, the system will interpret it as a command to move forward; if it goes down, it is considered a retreat order; to the left and right respectively to turn left and right.
6) Decision Making: Once the system understands the direction of the command based on the sensor value, the Arduino will make a logical decision based on the result of

that interpretation. This includes the decision to activate the motor in a certain direction, stop the movement, or adjust the speed.

7) Driver Motor Activation: The Arduino sends a digital or PWM signal to the driver motor such as the L298N. The driver motor will control the flow of current to the DC motor, which determines the direction and speed of movement of the seat wheels according to the commands from the Arduino.
8) Chair Wheel Movement: The wheel drive motor receives a signal from the driver's motor and starts rotating in the specified direction. At this stage, the wheelchair will move forward, backward, turn, or stop according to the movement commanded by the user through the flex sensor.
9) Monitoring and Looping: The system will continuously monitor sensor data in real-time. The entire process from sensor reading to motor activation will repeat in a single loop (loop) as long as the system remains active. This ensures that the system can respond quickly and accurately to changes in movement.

Results And Discussion

1. Wiring Diagram

Before the production and implementation stage of the control system on an automatic wheelchair, a very important first step is to design and prepare **the electrical components** based on the wiring diagram. This wiring diagram illustrates the connections between the main components to be used in the system, as well as describes the current flow and working logic of the hardware thoroughly. The selection of the right components greatly determines the stability, efficiency, and overall reliability of the system.

In the automatic chair wheel control system based on flex sensors and Arduino microcontrollers, wiring diagrams play a crucial role because all control of the movement of the wheelchair, whether forward, backward, turning, or stop, is determined by the results of sensor readings processed by Arduino, then translated into the movement of the DC motor through the driver motor. A drawing of the wiring diagram is shown in this Picture:

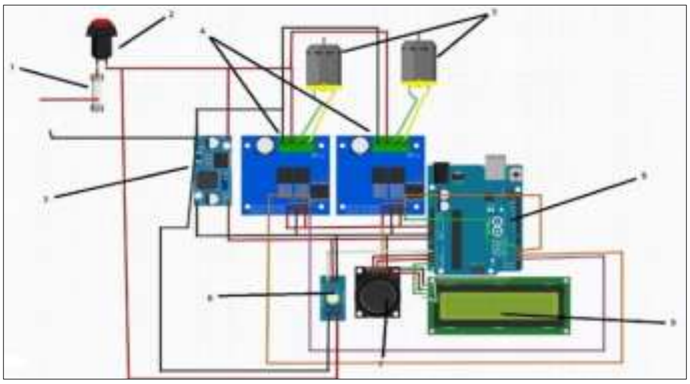

Figure 4. Wiring Diagram

Based on the wiring diagram used, the system gets its power source from the DC battery. When the switch is pressed, the system will activate and start running the control logic according to the program that has been embedded in the Arduino microcontroller. The entire range is designed to be able to operate a drive motor connected to the seat wheel automatically based on the user's body movements detected by the flex sensor.

4.1 Key Components in Wiring Diagram:

1. Fuse: Serves as a safety to automatically cut off the power in case of overcurrent. This component is essential to prevent damage to other components due to short circuits or overpower.
2. Switch: Used to manually turn the system on and off. This switch becomes the initial control point to activate all devices in the system.
3. Buck Converter: This tool works to lower the voltage of the battery (e.g. from 12V to 5V) to suit the needs of components such as Arduino and sensors that work at low voltages.
4. Driver Motor (L298N/L293D or similar): The driver motor is used to control the direction (forward/backward/turn) and speed of the DC motor. This driver works based on logic and PWM signals from Arduino, as well as regulating the large current required by the motor.
5. DC motor: Is the main actuator used to drive the seat wheels. This motor will respond to commands from the motor driver to make movements according to the instructions from the user.
6. Voltage Divider: Used to monitor the condition of the battery. By dividing the battery voltage to a level that is safe for the Arduino to read, the system can display the battery status in real-time.
7. Flex Sensor: In the context of this system, the flex sensor replaces the joystick function. This sensor detects the user's body movements such as the bending of a finger or arm, and converts it into an analog signal. This value is processed by Arduino to determine the movement of the wheelchair.
8. Arduino Uno: As the central control of the system, the Arduino functions to read the values from the flex sensor, process the data based on the program (sketch), and send commands to the driver motor. Arduino also handles communication with LCD modules and other monitoring systems.
9. LCD (Liquid Crystal Display): Used to display important information such as battery voltage, system status, and motor speed. LCD provides visual feedback to users to make the system more interactive and informative.

With this diagram wiring configuration, the automatic chair wheel control system is not only able to read commands based on the user's body movements through the flex sensor, but also is able to precisely adjust the speed and direction of motion. The entire process is carried out automatically and in real-time, thereby increasing the efficiency, comfort, and independence of wheelchair users.

4.2 Frame Installation Process

The frame installation process is the initial stage in the construction of the main structure of the automatic wheelchair which will be fitted with a flex sensor-based control system and an Arduino microcontroller. The frame serves as a mechanical foundation where all system components, such as DC motors, wheels, batteries, as well as control modules, will be structurally assembled and put together. In this study, the frame material used is stainless steel, because it has strong mechanical properties, is rust-resistant, and is light enough for mobility needs. The frame installation process begins with the cutting of stainless steel material according to the size and specifications of the pre-designed design. The design has been adjusted to accommodate the user's load, as well as providing optimal installation space for the electronic system and drive motor.

After the cutting process is completed, the material is put together through the welding process. Welding is done carefully to ensure each joint has good structural strength and is able to withstand vibrations when the wheelchair moves. The welding position is adjusted to the main meeting points on the frame design, such as the connection between the seat mounts, wheel supports, and the support of the control module. Once the frame has been thoroughly assembled, the next stage is physical testing of the structure, including stability, symmetry, and resistance to loads. The installed frame is then ready for the installation process of electronic devices such as Arduino, motor drivers, flex sensors, and batteries. The process of operating the wheelchair after all components are installed and the system is ready to run is shown in Figure 5.

Figure 5. Road Testing

Accurate and robust frame installation is a decisive factor in the overall success of the system, especially since the frame must be able to support electrical components while ensuring the safety and comfort of the user during the operation of an automatic wheelchair.

4.3 Electrical Component Installation Process

After the frame installation process is completed and the main structure of the automatic wheelchair has been formed, the next stage is the installation of the electrical components that are the core of the automatic control system. Installation is carried out with reference to the wiring diagram that has been designed beforehand, so that all components can be connected systematically and functionally. This process aims to integrate a flex sensor-based control system and Arduino with wheel drive actuators, as well as other supporting components. Installation illustration can be seen in the picture:

Figure 6. Automatic Wheelchair Structure

Here are the main electrical components installed on an automatic wheelchair system:

1) 24V 250W – 75 RPM DC motor: The DC motor is used as the main drive of the seat wheel. The motor has enough power to drive the user load and frame, with a 75 RPM rotation suitable for low and stable speeds. The motor is connected to the driver's motor and mounted on the left and right sides of the wheelchair.
2) 24V 30Ah Lithium-Ion Battery: This battery serves as the main power source of the system. With a capacity of 30Ah, the battery is able to provide enough power for the operation of the system for a long period of time. The battery is positioned on the bottom or back of the frame with a secure support to prevent shock.
3) 2104 Channel Driver Motor: The driver motor is used to control the direction and rotation speed of the DC motor based on the signal from the Arduino microcontroller. This module allows the motor to rotate forward, backward, or stop according to the system instructions based on input from the flex sensor.

4) I2C LCD: This LCD is installed to display important information such as battery voltage, motor speed, and system status. I2C communication makes installation easy because it only requires two main cables (SDA and SCL), making it more compact than regular parallel LCDs.
5) Arduino UNO R3 ATMEGA328P PU-16U2: Arduino is the control center of the system. All data from the sensor (such as the flex sensor or joystick) is processed here, then converted into logical commands to control the driver's motor. Arduino also handles the display of data to the LCD and the setting of the system security logic.
6) Joystick – 4 Axis Potentiometer (Optional/Additional): Although the main system is controlled by a flex sensor, the joystick can be added as a manual control option. This joystick uses a potentiometer to detect the direction of the thrust (right, left, forward, backward), and the signal can be connected to the Arduino as an alternate or backup control.

All of these components are installed using appropriate connecting cables, equipped with safeguards such as fuses and connectors to ensure that there is no short circuit. The installation process also pays attention to the ergonomic position and safety of the cable so as not to interfere with wheel movement or user comfort.

4.4 Arduino IDE Program Analysis

The Arduino IDE program serves as the control logic center of the entire automatic wheelchair system. In this study, the program was developed using the C/C++ programming language in the Arduino Integrated Development Environment (IDE), which was then uploaded to an Arduino Uno R3 microcontroller to execute all system instructions. The initial stage of the program is initialization, where all the variables, I/O pins, as well as the required libraries are defined. This initialization is important to define the role of each pin—for example, as an input from a joystick/flex sensor or output to the driver motor and LCD. The initialization program for the automatic wheelchair controller can be seen in this Image:

Figure 7. Arduino Idea

Initialization also includes setting the baud rate for serial communication and configuring PWM pins to regulate the speed of the DC motor. The main program consists of two main parts, namely the setup() function and the loop() function. In the setup() function, Arduino sets all the initial parameters such as starting communication with the LCD via the I2C protocol, as well as determining the initial value of the driver motor so that it does not start immediately when the system is on. The loop() function is a part that is continuously executed repeatedly and reads inputs, processes logic, and provides control outputs to the actuator.

4.5 Working Mechanism of Automatic Wheelchair Program:

1) Signal Input from the Joystick or Flex Sensor: When the joystick is moved (or in alternate versions using the flex sensor), the Arduino will pick up the analog signal from the respective directions (X and Y axis). These values are converted into digital data for analysis. The joystick's center value (usually around 512) indicates a neutral (stationary) position, while a higher or lower value indicates direction and speed.
2) Logic Processing on Arduino: Arduino reads the joystick axis movement (or flex sensor bending value) and translates it into logic instructions, for example:
    a) If the X axis is greater than the middle value → turn right.
    b) If the Y axis is smaller than the middle value → advanced.
    c) If there is no change → stop.
3) Output to the Motor Driver: The result of the interpretation of the movement command is then transmitted in the form of a digital signal or PWM to the motor driver (e.g. L298N). Arduino controls two directional pins and one PWM pin for each motor so that direction and speed can be precisely adjusted.
4) DC Motor Movement and Feedback to LCD: When the DC motor starts moving, the program also activates a function that sends data to the LCD. Information such as motor speed or the status of the direction of motion (forward, backward, left, right) will be displayed in real-time, providing feedback to the user.
5) System Powers: The entire system—including Arduino, joystick/flex sensor, driver motor, DC motor, and LCD—gets its power supply from a 24V 30Ah lithium-ion battery. The voltage is regulated using a buck converter to suit the needs of each component.

With a modular and efficient program structure, Arduino can control the wheelchair automatically based on input from the user. The system's response to input changes is also relatively fast, given the use of analog sensors and direct processing without intermediaries.

Wheelchair System Testing Scenarios

Expected Results	Information
	1. Starting Position (Motion: Stop): When the system is turned on and the joystick is in the neutral position, the Arduino detects that there is no movement command. The DC motor is off, and the LCD displays "Motion: Stop". This indicates that the system successfully recognizes the idle condition and provides the user with appropriate information as a sign that the system is ready for use.
	2. Forward Position (Motion: Forward): When the joystick is moved upwards, the Arduino successfully reads the signal as a command to move forward. The DC motor moves forward, and the LCD displays "Motion: Forward". This indicates that the system is already running well, where the movement of the wheelchair and the LCD display are in accordance with the given commands.

	3. Reverse Position (Motion: Backward): When the joystick is moved downward, the Arduino detects the command to reverse and activates the DC motor in the opposite direction. The wheelchair moves backwards, and the LCD displays "Motion: Backward". This indicates that the system is successfully executing commands and displaying the appropriate motion information to the user.
	4. Left Turn Position (Motion: Left): When the joystick is shifted to the left, the Arduino receives an input value on the X axis that decreases from the midpoint. This value is interpreted as a command to turn left. The system will adjust the speed of the motor so that the right wheel moves faster than the left wheel, causing the wheelchair to turn to the left. This information is then displayed on the LCD with the inscription "Motion: Left". The left turn mechanism works well, both in terms of movement and visualization of system status on the LCD screen.
	5. Right Turn Position (Motion: Right): When the joystick is moved in the right direction, the value of the X axis increases and is read by Arduino as a command to turn right. The Arduino adjusts the left motor to move faster than the right motor, resulting in a right-hand maneuver. The display on the LCD will change to "Motion: Right", which means the system not only executes the gesture commands, but also provides the user with clear and timely visual feedback.

Discussion

Based on the test results of the automatic wheelchair control system using the Arduino joystick and microcontroller, it can be concluded that the system has worked well and successfully responded to every movement command given by the user. Each direction of movement—forward, backward, left turn, right turn, or stop—can be precisely recognized by Arduino based on the input signal from the joystick. Next, the command is passed on to the driver motor and the DC motor that moves the wheel in the desired direction.

In addition, the LCD successfully displays motion status information in real-time, such as "Motion: Stop", "Motion: Forward", "Motion: Backward", "Motion: Left", and "Motion: Right". The display provides visual feedback to the user and is an indicator that the system is running on command. The alignment between joystick commands, motor movement, and LCD display proves that programs embedded in Arduino work synchronously, responsively, and accurately. With these results, it can be concluded that the Arduino-based and joystick-based automatic wheelchair control system has been successfully implemented as intended. The system is not only able to carry out the motion control function, but also presents motion information clearly, thus providing comfort and confidence for users in operating the wheelchair independently.

Conclusion

Based on the results of design, implementation, and testing that have been carried out, it can be concluded that the Arduino microcontroller-based automatic chair wheel control system has been successfully built and functions according to its purpose. The system is capable of receiving input from the joystick and translating it into movement commands such as forward, backward, left turn, right turn, and stop. All movement commands can be properly executed by the DC motor through the driver motor, as well as displayed in real-time on the LCD in the form of motion direction information. The display on the LCD shows good synchronization between user commands and system responses, which means that the processes of data processing, motor control, and visual feedback run responsively and accurately. With this success, the designed automatic wheelchair control system can be an effective assistive technology solution to improve independence and mobility for users, and can be further developed with the addition of safety features and other supporting sensors.

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