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Development of a Wheelchair Equipped with Sensors and Worm Wheels and Designed to Climb Stairs

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Abstract— ***Using wheelchairs to access the upper floors of buildings with stairs or steps is a significant barrier for the elderly, those with disabilities, and injured individuals. These days, most buildings have lifts or escalators. That being said, numerous multistory buildings in underdeveloped nations are without elevators or escalators. Additionally, some locations are not accessible to wheelchair users. In each of these situations, the aged, the disabled, and the maimed will need to rely heavily on others to carry them or, in the worst situations, not move at all. This paper discusses the idea of a wheelchair with multiple motorised wheels, actuators, and sensors that detect the existence, height, and width of a step. The actuators are then used in conjunction with worm wheel linear gears to raise and lower the wheelchair wheel axles in a controlled manner. Electronic controls are used throughout the system. This design is capable of climbing stairs without toppling over. Because the user may walk around without exerting any physical effort thanks to the motorised wheels and climb stairs without assistance, this device can greatly increase the independence of elderly and differently-abled people by allowing them to move around freely.***

Index Terms—Motors, Sensors, Stair Climbing, Wheelchair, Worm wheel linear gear axle.

I. INTRODUCTION

Everybody in this world wants to be able to operate or work on their own. Currently, the majority of elderly individuals, individuals with disabilities, and those suffering from physical illnesses or injuries like fractures, need assistance from others in order to carry out their daily tasks. Recent technological developments have greatly facilitated the supporter's job. Further technological advancements that enable individuals to work autonomously without assistance are needed. When navigating public spaces or even their own homes in a wheelchair, one of the most frequent problems encountered by the elderly, individuals with disabilities, and those suffering from physical illnesses or injuries is having to ascend stairs. These individuals require assistance from a helper to carry them up the stairs or to assist them in ascending them. Both the helper and the person with a disability experience a great deal of stress and strain from this action. Furthermore, the chance of one or both of them sliding and falling and getting hurt again is constantly present. Numerous wheelchair designs attempt, in different ways, to address these problems. Our wheelchair's design makes use of sensors and motors so that it may ascend the stairs without the assistance of a person or any physical exertion. [1] Jansen's linkage is suggested as a substitute by M.S. Alphan and S.Monish Manoj, who investigate the shortcomings of walking machine wheels over uneven terrain, such as mine fields. It examines how adaptable this system is for a range of uses, such as mining and wheelchair movement. A prototype has been created for demonstration purposes that uses an electric motor to operate a scaled-down version of Jansen's linkage. Kinematic and dynamic analyses revealed its acceleration properties in the frequency and time domain carried out on a variety of terrains using appropriate software. Though it seems promising, more adjustments and enhancements are needed for the prototype to increase its functionality and suitability for real-world scenarios where navigating difficult terrain is crucial. A self-propelled wheelchair that can climb stairs is shown by J. Ram Kumar et al. from IIT Kanpur in [2], which addresses typical mobility issues. By allowing users to manoeuvre around obstacles manually, it provides a less expensive option than traditional wheelchairs. It emphasises ease of adaptation for those with mobility disabilities and is designed with safety and user-friendliness in mind. For stability, the wheelchair has two back triangular Y-shaped wheels, a rear caster wheel, and two front wheels. The frame and seat are joined by a central shaft, allowing for smooth movement. Awais Ahmad et al.'s goal is to develop a wheelchair that is both affordable and small, yet still has the ability to climb stairs. The wheelchair can be used independently in both structured and unstructured outdoor areas since it uses joystick control. The prototype model's architecture allows it to easily adjust to a variety of surfaces, such as stairs, uneven ground, and level areas. [4] Robert Quigg's invention focuses on a wheelchair that can climb stairs thanks to track assemblies that can make their way around obstacles like curbs and stairs. Smooth transitions over obstacles are made possible by the guide member in each assembly, which has rollers carrying an infinite cleated belt. The arched shape of the guide member

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enables the belt to deflect upward in the event of an impediment, resulting in smooth operation. Stability and control are further improved by angled tail portions with independent cleated belts. [5] The stair-climbing wheelchair described in the patent by Baxter R. Watkins has a front-end sensor that can identify sloped ramps or stairs. The sensor emits signals, which are reflected off surfaces and picked up by a receptor that is linked to a CPU. In order to assess whether the slope is excessively steep, the microprocessor computes the height of the stair steps and the linear distance traversed. The wheelchair cannot descend the stairwell since its drive motors cut off if the slope goes above a preset value. [6] P. Waseem Rahees et al. works on creating a wheelchair that can automatically climb stairs and has a bed feature. The wheelchair is made to be able to move in both structured and unstructured areas. It provides versatility and ease with its use of DC motor-powered rack and pinion, worm, and gear systems that are remotely controlled. Because of its frame and seat design, the wheelchair can go over obstacles like stairs and transform into a bed when needed. In order to ensure stability and preserve the dimensions and appearance of a typical wheelchair, Shaival Shah et al. focused on creating a wheelchair that could be operated with hand gestures. This wheelchair included a track system for stair climbing. It provides an affordable way to improve mobility and freedom by making use of DC motors and batteries. It overcomes the challenge of manually moving a wheelchair and the shortcoming of ordinary wheelchairs when it comes to climbing stairs. The objective of M.R. Khushte et al. is to improve wheelchair stair-climbing functionality by means of ergonomic design and manufacture. A frame, a drive mechanism designed for frequent usage, and a conveyor belt are essential parts. Performance and safety are maximised during the design phase by assessing centre of gravity, stresses, and load distribution

II. CONCEPTUAL DESIGN

Six pairs of axles total are used in the wheelchair's design. Each pair would consist of an axle with two wheels on it, one on the left and one on the right, and an additional axle next to the first axle with the wheels slightly inset. With the use of separate linear gear units that run via worm wheel units, each axle is able to travel up and down on its own. In order for the wheels to travel forward or backward, they would also have drive motors.

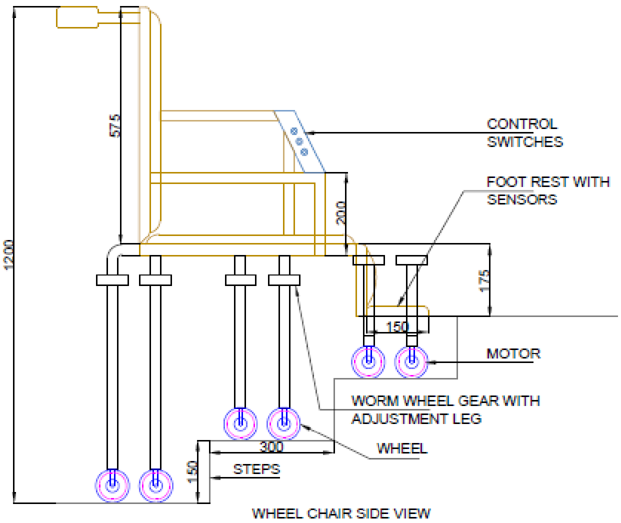

Fig 1. Side view of wheelchair

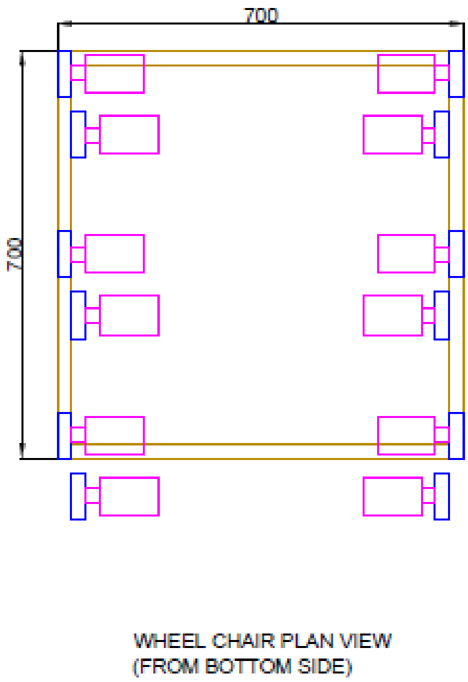

Fig 2. Plan view of wheelchair(from below)

2.1 Essential Elements

- Wheelchair Frame
- Motors with wormwheel gear and linear rack and pinion.
- Axles with wheels at the extreme ends
- Drive motors for the axle wheels
- Operation Console
- Combination of IR, Ultrasonic, Optical and Planarity Sensors
- Lithium Ion Batteries
- Microcomputer programmed to analyse the sensor inputs and provide output to the various motors.

2.2 Working

Imagine a situation in which a wheelchair is approaching an inclining stairway. The subsequent series of occurrences will transpire:

The wheelchair's sensors would detect a stair step as its first axle got closer and send information to the microprocessor about the step's location and height.

The wheelchair base would reach its highest point when all of the axles were fully extended.The first axle's linear actuator would rise on its own obeying the microcomputer's commands, precisely matching the step height.

The wheelchair would progressively advance forward until the first axle entered the first step after it had raised to the height of the first step.

The wheelchair would go ahead so that the second axle would rise and enter the first step after the first axle had.

When the third axle meets the first step, the wheelchair will then advance to that point. The sequence of events that were outlined for the first and second sets of axles would occur.

The axle would continue to travel forward in such a way that if it came into contact with a step, it would raise and move progressively forward until it was above the step.

Worm wheel arrangement is included so that, in the event of a motor failure, the wheelchair would remain stationary, unlike in the event of a hydraulic piston failure, where the actuator would collapse and the wheelchair would become un-horizontal.

Additionally, planarity sensors supply the microcontroller with input at all times to guarantee that the wheelchair stays horizontal.

The wheelchair could successfully navigate the staircase by doing the previously specified movements again.The microprocessor and the wheelchair's several motors would be powered by rechargeable lithium-ion batteries.

If the stairway ahead is pointing downhill, then:

Initially, every axle would be pulled all the way to the base, causing the base to descend to its maximum height.

After that, the load would only be taken on by the first axle to cross the step threshold and descend to the step's level.

The wheelchair would then proceed forward step-by-step until the second axle cleared the step threshold. After that, it would descend and take the front load and the front axle.

The wheelchair would be able to descend the stairs by repeating these steps in order.

The wheelchair can be turned left or right, moved forward or backward, sped up or slowed down, and stopped on level terrain using the Operation Console. .

III. DEVELOPMENT OF PROTOTYPE

To assess whether the idea could be implemented, a prototype was to be created. To save money and time, the prototype had to be a smaller model with fewer sensors and a microcomputer setup, built using readily accessible and reasonably priced materials.

3.1 Construction

The prototype is designed to be appropriate for climbing staircases and has four pairs of wheels. Four linear actuators would be housed in a shared structure at the top of the prototype. These actuators' plungers could move up and down in response to the motor's rotation since they are powered by a motor, worm gear, and rack and pinion system. Every plunger would have wheels attached to its axles. There would also be a driving motor on each wheel. To detect an oncoming step, infrared sensors would be positioned in every axle. With a 12V DC power source, every motor would function. The power needed to run the prototype will come from a 230V/12V, 5A converter. Both the input from the IR sensors and the control of the motor output will be handled by an Arduino Mega processing board. The motors will be powered by an L298N motor driver PCB, which will receive output signals from the Arduino. We can also regulate the direction in which the motors rotate using this configuration.

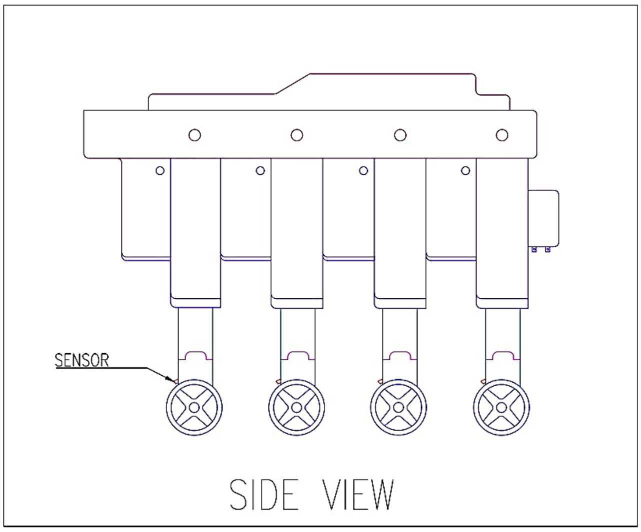

Fig 3. Prototype Side View

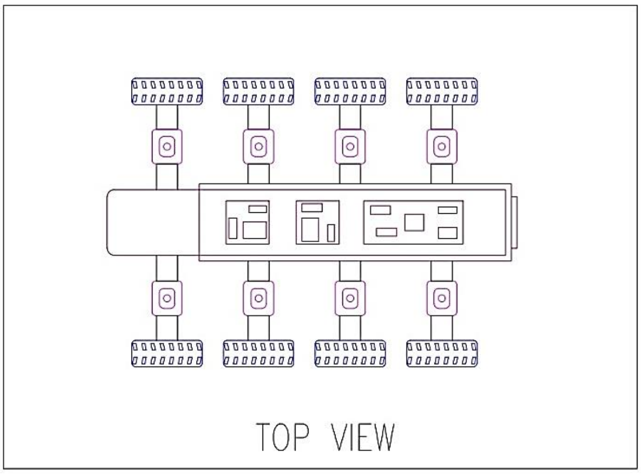

Fig 4. Prototype Top View

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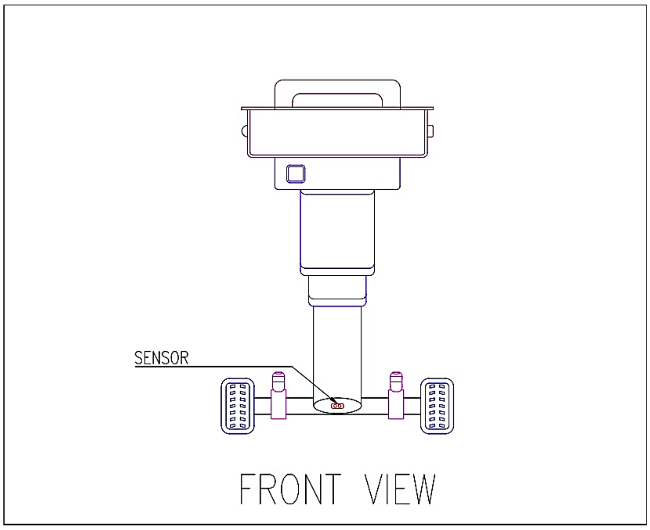

Fig 5. Prototype Front View

IV. WORKING(PROTOTYPE)

According to plan, a prototype was created with success. Using lightweight foam boards, a mock-up of the staircase was also made. After the Arduino was configured per the specifications, the prototype was tested. The sensitivity of the sensors was adjusted in light of the trial's observations to guarantee that the actuator lifts up precisely as it approaches a step.

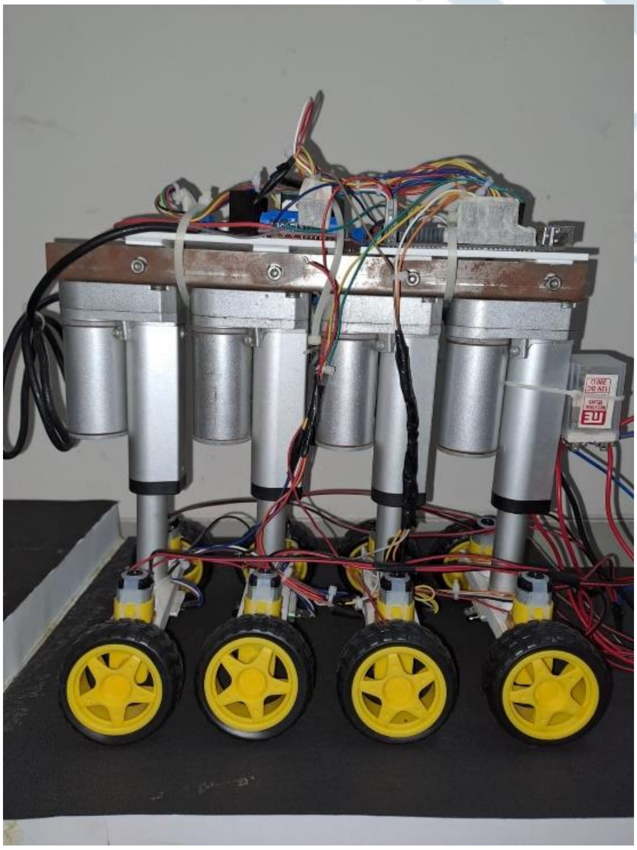

Image 1- Photo of Prototype from side

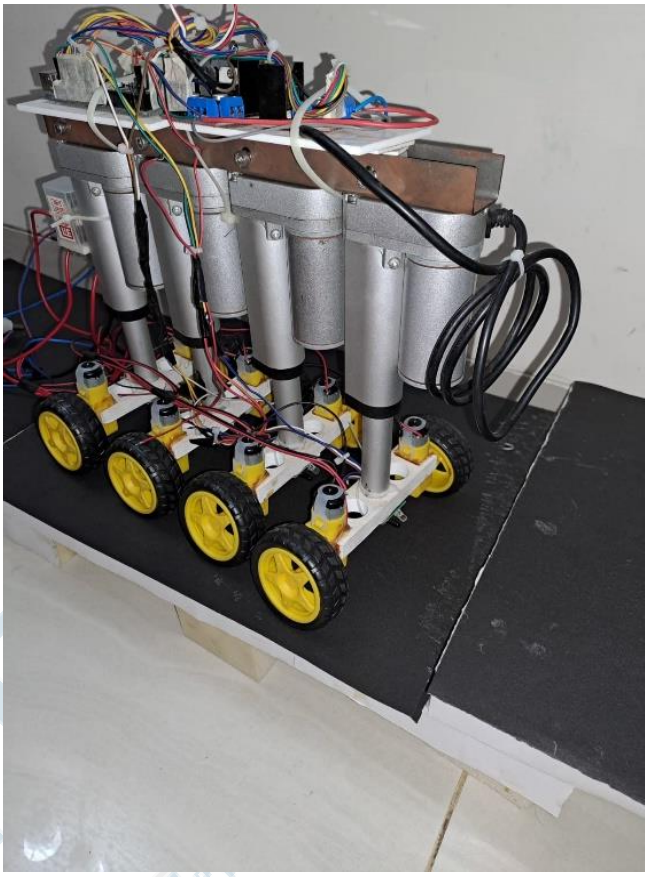

Image 2- Photo of Prototype(isometric)

The prototype could ascend the stairs by itself step by step when all of the sensors' sensitivity settings were properly set.

The suggested wheelchair design has a "Proof of Concept" thanks to these tests.

V. CONCLUSION

The prototype wheelchair was able to sense the staircase based on the IR sensor, and the wheelchair was able to climb on the model staircase built using foam board. This was completely in line with the design expectation. Based on this, it is clear from the experience acquired in the creation and use of the prototype that the Stair Climbing Wheelchair, as envisioned, is workable and that a full-scale model that will grant independence to individuals with disabilities can be developed

5.1 Further Improvements

A significant amount of time was needed for the axles to raise during the prototype's testing. In order to get around this, the wheelchair must be constructed with appropriate high-speed motors to enable fast rise of the event that each of the two wheels of an axle is equipped with its own actuator, the wheelchair will also be capable of navigating on uneven ground in which the left and right wheels differ in elevation. When navigating on unpaved surfaces, this would be really helpful.

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