

AUTOMATED HYBRID STAIR CLIMBER FOR PHYSICALLY CHALLENGED PEOPLE WITH AI

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in
Mechatronics

By

KIRAN R (Reg. No. 40090017)

SANJAY R (Reg. No. 40090027)



DEPARTMENT OF MECHATRONICS

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade "A++" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600119

APRIL 2024



SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited "A++" Grade by NAAC | 12B Status by UGC | Approved by AICTE

www.sathyabama.ac.in

DEPARTMENT OF MECHATRONICS

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of KIRAN R (Reg. No. 40090017) and SANJAY R (Reg. No. 40090027) who carried out the project entitled "AUTOMATED HYBRID STAIR CLIMBER FOR PHYSICALLY CHALLENGED PEOPLE WITH AI" under our supervision from November 2023 to April 2024.

Internal Guide

Dr. B. KANIMOZHI, M.E., Ph.D.,

Head of the Department

Dr. B. KANIMOZHI, M.E., Ph.D.,

Submitted for Viva voce Examination held on

Internal Examiner

External Examiner

DECLARATION

We KIRAN R (Reg. No. 40090017) and SANJAY R (Reg. No. 40090027) hereby declare that the Project Report entitled "**AUTOMATED HYBRID STAIR CLIMBER FOR PHYSICALLY CHALLENGED PEOPLE WITH AI**" done by us under the guidance of **Dr. B. KANIMOZHI, M.E., Ph.D.**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechatronics.

DATE:

PLACE: CHENNAI

1.

R. Kiran

2.

Sanjay R.

SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my sincere thanks to **Dr. B. Kanimozhi, M.E., Ph.D.**, Head of the Department, Department of Mechatronics for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Dr. B. Kanimozhi, M.E., Ph.D.**, for her valuable guidance, suggestions, and constant encouragement paved way for the successful completion of my project work.

I also express my thanks to all Teaching and Non-teaching staff members of the Department of Mechatronics who were helpful in many ways for the completion of the project.

ABSTRACT

The "Automated Hybrid Stair Climber for Physically Challenged People with AI" represents a groundbreaking advancement in assistive technology, addressing the mobility challenges faced by individuals with physical disabilities. This innovative system combines automation and Artificial Intelligence (AI) to provide a safe and efficient means for people with limited mobility to navigate stairs, thereby significantly enhancing their independence and overall quality of life. The primary objective of this study is to develop an intelligent and adaptable stair-climbing solution, which seamlessly integrates mechanical and AI components. The AI component plays a pivotal role in real-time decision-making, allowing the device to assess and respond to dynamically changing conditions during stair traversal. This includes obstacle detection, speed adjustment, and continuous monitoring to ensure user safety throughout the climbing or descending process. The system's design places a strong emphasis on user-friendliness, ease of operation, and safety. It incorporates user-friendly controls, an ergonomic design, and robust safety mechanisms to prevent accidents, ensuring a secure user experience. The integration of AI augments the device's capabilities, enabling it to adapt to diverse staircase geometries and address a range of obstacle scenarios. Beyond assisting individuals with mobility challenges, this technology has the potential to make public spaces, buildings, and homes more accessible, thereby promoting a more inclusive and equitable society. Our research demonstrates the feasibility and benefits of merging automation and AI to create a reliable, efficient, and user-centric solution for individuals with physical disabilities. In summary, our automated hybrid stair climber is a significant advancement that empowers physically challenged individuals, fosters independence, and enhances overall accessibility. This project embodies a transformative step towards a more inclusive and accommodating world.

TABLE OF CONTENT

CHAPTER No.	TITLE	PAGE No.
	ABSTRACT	V
	LIST OF FIGURES	VIII
1	INTRODUCTION	
	1.1 CONTINUOS STAIR CLIMBING WHEEL CHAIR	1
	1.2 PLANETARY WHEEL MECHANISHM STAIR-CLIMBING	1
	1.3 TRACKED MECHANISHM STAIR CLIMBING CHAIR	2
	1.4 INTERMITTENT STAIR CLIMBING WHEEL CHAIR	3
	1.5 AUXILIARY STAIR CLIMBING WHEEL CHAIR	4
	1.6 WALKING MECHANISHM DESIGN	4
2	LITERATURE SURVEY	
3	AIM AND SCOPE	
	3.1 AIM AND SCOPE	14
	3.2 OBJECTIVE	14
	3.3 SCOPE OF THE PROJECT	14
4	MATERIALS AND EXPERIMENTAL METHOD	
	4.1 MATERIAL USED	17
	4.1.1 Dc Motor	17
	4.1.2 Frame	18
	4.1.3 Bearing	20
	4.1.4 Wheel	20
	4.1.5 Battery	21
	4.1.6 Motor Speed Controller	22
	4.1.7 Arduino Uno	23
	4.1.8 Relay Boards	25
	4.1.9 On-Off Switch	26

	4.1.10 Ultrasonic Sensor	27
	4.2 EXPERIMENTAL SETUP	28
	4.3 SOFTWARE	29
5	RESULTS AND DISCUSSION	
	5.1 DESIGN AND CALCULATION	30
	5.1.1 Structure Design	30
	5.1.2 Stress Analysis for climbing stairs	31
	5.2 PULLING FORCE ESTIMATION	32
	5.3 OPTIMIZATION	33
	5.4 FINAL PROTOTYPE	34
6	SUMMARY AND CONCLUSION	
	6.1 SUMMARY	36
	6.2 CONCLUSION	37
7	REFERENCES	38

LIST OF FIGURES

FIGURE No.	TITLE	PAGE No.
1.1	PLANETARY WHEEL CHAIR	7
1.2	TRACKED WHEEL CHAIR	8
1.3	INTERMITTENT STAIR CLIMBING WHEEL CHAIR	9
1.4	AUXILIARY WHEEL CHAIR	10
3.1	AUTOMATED WHEEL CHAIR	22
4.1	DC MOTOR	23
4.2	SEAT FRAME	25
4.3	FOOT REST	25
4.4	BEARING	26
4.5	WHEEL	26
4.6	BATTERY 12V	27
4.7	MOTOR SPEED CONTROLLER	28
4.8	ARDUINO UNO	29
4.9	RELAY BOARD	30
4.10	ON-OFF SWITCH	31
4.11	ULTRASONIC SENSOR	31
5.1	STRUCTURE DESIGN	34
5.2	ANALYSIS OF CLIMBING STAIRS	35
5.3	DESIGN OF WHEEL CHAIR	37

5.4	A) FINAL PROTOTYPE IMAGES	39
	B) FINAL PROTOTYPE IMAGES	40

CHAPTER-1

INTRODUCTION

A wheelchair is like a chair with wheels attached to it. It's a helpful device for people who have difficulty walking or moving around because of a disability. It lets them be more independent and do things on their own. Over time, wheelchairs have gotten better and better, with different types and features to make them more comfortable and useful.

Even though wheelchairs help people get around, they can't do everything that someone who can walk can do. This can make some people feel sad or like they're a burden to others. So, we want to make wheelchairs even better, so people can feel happier and more included in everything they want to do.

One idea we have is to make a wheelchair that can climb stairs and also has a bed. This could help a lot of people feel more comfortable and be able to do even more things. We hope that by working on ideas like this, we can make life easier and happier for people with disabilities.

1.1 CONTINUOUS STAIR-CLIMBING WHEEL CHAIR

The primary feature of the continuous stair-climbing wheelchair is its reliance on a single supporting device for continuous motion. This supporting device enables the wheelchair to navigate stairs seamlessly. Based on the mechanism driving its motion, the wheelchair can be categorized into two types: planetary wheel mechanism and tracked mechanism. The tracked mechanism, which is more established and widely utilized, is prevalent in stair-climbing anti-riot robots.

1.2 PLANETARY WHEEL MECHANISM STAIR-CLIMBING WHEEL CHAIR

The planetary wheel mechanism consists of multiple small wheels evenly arranged on a tie bar, forming shapes like "Y" or "+". Each small wheel can rotate on its own axis and also orbit around the central shaft. When the wheelchair moves on the ground, each small wheel rotates on its axis, while during stair ascent or descent, they rotate around the central axis. This type of stair-climbing wheelchair can handle heavy loads and move smoothly but lacks automation.

A notable example of this type of wheelchair is the IBOT, developed by an independent technology company affiliated with Johnson Company in the United States. The IBOT underwent over 8 years of development and cost over \$150 million, boasting top performance among existing stair-climbing wheelchairs. Its compact structure, flexible movement, and user-friendly operation are highlights, with the unique ability to stand up on two wheels. However, its high price tag of \$29,000 makes it inaccessible to many people.



Fig:1.1 Planetary wheel chair

1.3 TRACKED MECHANISM STAIR-CLIMBING WHEEL CHAIR

Right now, a popular type of stair-climbing wheelchair uses a tracked mechanism. This means it has tracks, like those on a tank, to move. Compared to the planetary wheel mechanism, the tracked mechanism allows for smoother and more continuous motion, and it's very efficient at transmitting power.

When this type of wheelchair goes up or down stairs, its center of gravity moves along a line that's parallel to the edge of each step. This makes the movement very smooth. However, when it's on flat ground, it can be a bit stiff to move around, and it faces more resistance. Also, because of the way it moves on stairs, it can sometimes put a lot of pressure on the edges, which might damage them.



Fig:1.2 Tracked wheel chair

1.4 INTERMITTENT STAIR-CLIMBING WHEEL CHAIR

The intermittent stair-climbing wheelchair has two sets of supports that take turns helping the wheelchair climb stairs. It works kind of like how people go up and down stairs. This method has been used since early stair-climbing wheelchairs, like the first one made in 1892.

Here's how it works: One set of supports lifts the wheelchair while the other set moves forward. Then, the roles switch, with the other set lifting and the first set moving forward. This cycle continues until the wheelchair has climbed all the stairs.

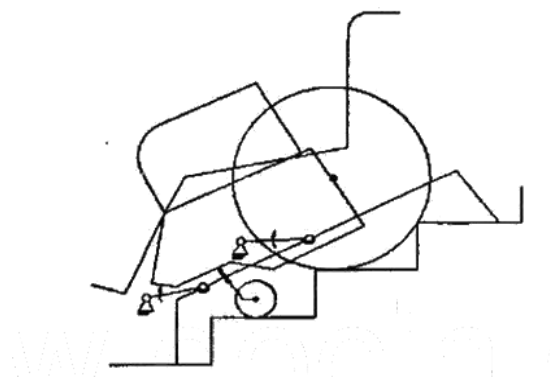


Fig:1.3 Intermittent stair-climbing wheel chair

The intermittent stair-climbing wheelchair isn't continuous in its climbing process. It has two sets of supports that take turns, which makes it less efficient and harder to balance.

1.5 AUXILIARY STAIR-CLIMBING WHEEL CHAIR

Another type of stair-climbing wheelchair uses extra devices to help it climb stairs. One kind attaches to the wheelchair itself, but it needs someone to assist in climbing stairs. Another type, called a stair lift, needs wide stairs to install and operate.



Fig:1.4 Auxiliary wheel chair

1.6 WALKING MECHANISM DESIGN

Choosing the right walking mechanism is crucial for the stability, safety, and comfort of a stair-climbing wheelchair. After comparing different types of climbing wheelchairs, we found that the planetary wheel mechanism has many advantages. It has a simple and compact structure, moves smoothly, stays stable, and has a small range of gravity center fluctuation. Plus, it combines well with both ground movement and stair climbing.

In our design, we've decided to use the planetary wheel mechanism as the walking mechanism. We've chosen to use three planetary wheels because it helps keep the wheelchair compact, lightweight, and stable. They are arranged symmetrically, and the structure is based on a system called 2K-H epicyclic wheels.

Even though wheelchairs help people get around, they can't do everything that someone who can walk can do. This can make some people feel sad or like they're a burden to others. So, we want to make wheelchairs even better, so people can feel happier and more included in everything they want to do.

One idea we have is to make a wheelchair that can climb stairs and also has a bed. This could help a lot of people feel more comfortable and be able to do even more things. We hope that by working on ideas like this, we can make life easier and happier for people with disabilities.

CHAPTER-2

LITERATURE SURVEY

INTRODUCTION

Modern Modern wheelchairs are very different from the ones used in ancient times. The earliest known wheelchair dates back to the sixth century AD, but it wasn't until the Renaissance that a movable chair, called a "rolling chair," was created. In the 16th century, King Philip II of Spain had a luxurious wheelchair made for him with adjustable leg and back rests. Louis XIV also used a wheelchair to get around after an operation.

The wheelchair we know today started to develop in the 18th century. These early wheelchairs had two large wooden wheels in the front and a smaller caster wheel in the back. They were heavy and decorative, making them difficult to use without assistance.

During the Civil War and World War I, lighter wheelchairs were made for amputees, but they still weighed about 50 pounds and didn't offer much mobility or independence.

The modern wheelchair was developed in the 20th century by Herbert Everest, who was paraplegic, and his engineer friend Harry Jennings. They created a foldable wheelchair made of aircraft steel, which was durable and practical. Their company, E&J, supplied chrome wheelchairs to WWII veterans. However, these wheelchairs were not customized and didn't provide great mobility.

It wasn't until wheelchair users started participating in sports that manufacturers began making more comfortable, durable, and practical chairs. Inventions like the wheelchair bicycle and stair-climbing wheelchair have made mobility easier for users. Now, using a wheelchair doesn't mean being stuck in one place. These modern inventions have made life better for wheelchair users, allowing

Modeling and design of an stair-climbing wheel chair

Bihu Sharma(2022) in his research focusses on moving around in cities is difficult for people who have trouble walking due to leg problems or other issues. While wheelchairs are helpful, they can't always solve the problem of getting around in urban areas, even with special features. Stair Climbing Wheelchairs (SCWs) offer a

promising solution. These wheelchairs have different ways of moving so they can go up and down stairs.

Smart walking assistant for elderly care using an intelligent hybrid model

Suparna Biswas(2022) in his research created a smart system using cheap sensors that can detect if someone falls and their posture, whether they're inside or outside. It uses fancy computer tricks to figure out if the person fell and if they managed to get back up within a certain time. If they didn't get up, it sends a message to their family or caregiver with the date, time, and where it happened.

Automated hybrid stair climber for physically challenged people

Preeta Chatterjee(2021) in her research focusses on Climbing stairs is hard for people with disabilities, especially those with neurological problems. Some wheelchairs can climb stairs, like SCEWO, but they're often big and expensive. In India, where people have different levels of money, we need a cheaper option that still works well and is safe. So, we want to make a new device that combines the good parts of existing ones, like wheels and tracks, and add some new ideas. Our goal is to make a cheap, stable wheelchair that can climb stairs for people with neurological issues.

Stair-Climbing Robots: A Review on Mechanism, Sensing, and Performance Evaluation

Youngsoo Kim(2023) in his research focusses on people are using robots more and more indoors for cleaning, delivering things, teaching, guiding, and even providing healthcare. But these robots can't always move around easily, especially when they encounter stairs. Engineers have been trying to make robots that can climb stairs quickly and reliably, using different methods like legs, tracks, or special wheels. However, there's still no perfect stair-climbing robot that's widely used.

This review looks at all the efforts engineers have made to create these robots. It categorizes the different ways robots can climb stairs and summarizes how they sense their surroundings. The review also suggests some useful criteria for judging how good a robot is at climbing stairs. By comparing existing robots based on these criteria, we hope to help make better, faster stair-climbing robots in the future.

A Comprehensive Survey of Stair-Climbing Vehicles

Antonio Pappalettera(2023) in his research focusses on climbing stairs is really hard for vehicles, especially when they're carrying people or heavy things. While there are some solutions out there, we need to make them even better and safer. This paper looks at all the scientific and engineering research about climbing stairs, explaining how different systems work and pointing out their pros and cons. It also suggests different ways to measure how well these systems perform, like how much weight they can carry, how fast they can climb, how steep a slope they can handle, and how good they are at moving things. By using these measurements, we can compare different types of stair-climbing vehicles and figure out which ones are best for carrying people or heavy loads up stairs.

Mapping wheelchair functions and their associated functional elements for stair climbing accessibility: a systematic review

Abishek Sharma(2019) in his research discussed that people with disabilities have the best tools for their needs, it's important to design wheelchairs (WCs) that are safe, comfortable, and easy to use. This review looks at what WCs need to do for users, like providing safety and comfort, and the parts they need to do it, like seats and wheels.

WCs are a big deal for people who can't walk, so they should be made with a lot of care and understanding. Engineers need to think about everything the user might need, both physically and emotionally. There's been a lot of research into making wheelchairs that can climb stairs, thanks to improvements in technology like sensors and actuators. This review talks about some of these new ideas and how they can be combined with the basics of wheelchair design to make something even better.

By putting together what we know about stair-climbing technology and what we need in a wheelchair, we can make sure the design process is more thoughtful and considerate. This can make users feel more confident about using new assistive technology.

Robotic Technology and Artificial Intelligence in Rehabilitation Medicine

Kun Yan (2019) in his research work provided insights about traditional rehabilitation services and assistive technology. These are things that help people with disabilities do everyday tasks, like getting dressed or cooking. Doctors and engineers work together to make these tools and services better. With new technologies like robots and artificial intelligence (AI), these services are improving faster than ever. Things like the Internet of Things (IoT), super-fast 5G internet, and AI are changing how doctors help people recover. We used to divide daily tasks into basic things like dressing and eating, and more complex tasks like cooking and doing laundry. But now, we need a new category for tasks that involve technology, like using smartphones or computers. This section also talks about how robots and AI are being used in rehabilitation.

Recent development of mechanisms and control strategies for robot-assisted lower limb rehabilitation

Wei Meng(2015) in his research talks about how robots are being used more and more to help people who have trouble moving, like the elderly or those with disabilities. Specifically, it focuses on robots that help with exercising and training the legs. The article looks at the progress made in this field from 2001 to 2014, including the different ways these robots work and how they're controlled.

It talks about how some robots can adapt to the needs of the person using them and how they're evaluated to make sure they're helping properly. The article also looks at different ways these robots are used for training and how effective they are. Finally, it points out areas where more research is needed to make robot-assisted rehabilitation even better in the future.

Optimized obstacle avoidance trajectory generation for a reconfigurable staircase climbing wheelchair

R Morales(2009) in his research introduces about a new wheelchair design that can climb stairs. It explains how the wheelchair works mechanically and how it's controlled. The key design feature is that each wheel has two separate parts: one to handle going

up steps and the other to adjust the wheel's position to handle slopes. This makes controlling the wheelchair much simpler.

To make sure the wheelchair is comfortable for the person using it, the paper describes how they use mathematical models to figure out how the wheelchair moves and how to control it. They also talk about how they improved the control system to make the wheelchair move more efficiently and quickly, while still keeping the user comfortable. They tested the wheelchair on stairs and found that their improvements helped it climb stairs faster and more comfortably. However, the changes made the control system more complicated, used more power, and slightly reduced comfort.

Autonomous Stair Climbing for Tracked Vehicles

Larry Matthies (2007) in this paper evaluates this paper talks about a method for making a tracked vehicle climb stairs by itself. The method works well in real-world situations, even without knowing exactly how the stairs are shaped or how the vehicle moves on them, or even what the lighting is like.

To do this, the method uses a clever way to figure out which way the vehicle is facing and where it is in relation to the edges of the stairs. It does this by combining data from a gyroscope to measure how the vehicle rotates and a camera to see the edges of the stairs. Then, it uses a special controller made of two parts to guide the vehicle up the stairs quickly, safely, and accurately.

The paper explains all the details of how this method works and provides results from tests showing how well it performs.

Use of Artificial Intelligence Techniques to Assist Individuals with Physical Disabilities

Sidharth Pancholi (2023) in this paper review talks about how assistive technologies help people with disabilities live more independently and access services like healthcare and education. It explains how combining artificial intelligence with electronics, robotics, and software has led to groundbreaking technologies like mind-controlled exoskeletons, bionic limbs, smart wheelchairs, and home assistants. The article reviews different AI techniques, such as brain-computer interfaces and computer vision, that have helped people with physical disabilities. It also discusses the challenges and future directions for AI-powered technologies for people with disabilities.

Improving the climbing/descent performance of stair-climbing mobility systems confronting architectural barriers with geometric disturbances

J. Chocoteco (2015) in his research This paper is about making Stair-Climbing Mobility Systems (SCMSs) better at climbing obstacles like stairs, especially when the stairs are uneven or irregular. The SCMS in this study uses two different ways to climb stairs: one with wheels and the other with Sliding Supports. By combining these methods, the SCMS can handle different kinds of stairs, even ones with irregular steps. However, when stairs are really tall or have unusual shapes, it becomes harder for the SCMS to climb them safely.

To improve the SCMS, two main changes were made. First, the drive systems and wheel control mechanisms were redesigned to make the SCMS lighter, easier to control, and better at handling uneven stairs. Second, a new strategy was developed to estimate the size and shape of the stairs using laser distance sensors. This helps the SCMS plan its path more accurately, making it safer and more comfortable for the user. Experimental tests showed that these improvements worked well, even when dealing with challenging staircases.

Transformable Wheelchair–Exoskeleton Hybrid Robot for Assisting Human Locomotion

Ronnapee Chaichaowarat (2023) in this paper talks about a new type of robot that combines a wheelchair and an exoskeleton. This robot can switch between sitting and walking modes. The exoskeleton part helps support the hips and knees using special motors, while the ankles don't need extra support. The wheelchair part has wheels that can fold up against the legs when it's time to walk or step over obstacles. The legs of the chair are designed to keep the person stable while sitting and use less energy when moving on smooth surfaces. The robot is controlled by the user, who can command it to stand up or sit down, and the motors help with the movement. The researchers also studied how much support the exoskeleton provides to the legs and monitored the activity of leg muscles to make improvements.

Proprioceptive control of a hybrid legged-wheeled robot

Markus Eich (2008) in his paper work describes a new way to control our robot ASGUARD, which can move on both legs and wheels. The robot can handle stairs and rough terrain, and move quickly on flat ground. We've added a feature that helps

the robot handle slopes better by using feedback about its tilt. Unlike other methods that have a set walking pattern for stairs, our approach is adaptive, meaning it adjusts based on internal sensor information like body tilt and motor torque. This adaptability makes our controller versatile for different situations. We use a model that generates motion patterns, and instead of relying solely on pre-defined walking patterns, we use feedback from the robot's sensors to adjust how each leg moves in real-time. This helps improve the robot's efficiency and stability when climbing stairs.

Obstacle surpassing and posture control of a stair-climbing robotic mechanism

J. Chocoteco (2013) in his study introduces a new way to control a robotic mechanism for climbing stairs and overcoming obstacles like curbs, ramps, or stairs while ensuring passenger comfort and safety. The control method considers uncertainties in the environment and separately manages the moving parts and posture adjustments. It uses a combination of feedforward and proportional derivative (PD) control for movement and a unique multilevel feedback controller design for posture control. This approach maintains passenger comfort, handles uncertainties well, works efficiently, and requires minimal sensors. Simulations demonstrate the method's effectiveness in dealing with obstacles of different heights, and experiments validate its performance when climbing a 180mm curb.

A wheelchair with lever propulsion control for climbing up and down stairs

I. Kai Sasaki (2016) in his research discussed the study introduces a new type of wheelchair designed specifically for climbing stairs. Traditional wheelchairs struggle with stairs, limiting the mobility of users. Previous attempts at solving this problem involved heavy and bulky power-assisted wheelchairs. Instead, this study focuses on a wheelchair with a lever propulsion mechanism, which allows users to climb stairs using their upper body strength. The wheelchair has regular wheels for flat surfaces and a special mechanism for climbing stairs. Gas springs help shift the user's weight for stair climbing. In this paper, the study explores how users can also use the lever mechanism to descend stairs safely, with added safety features like torque dampers and fixed front wheels. Experiments were conducted to ensure that wheelchair users can effectively use this new propulsion system.

Designing of a Smart Wheelchair for People with Disabilities

Vaibhavi Kengale(2021) in this paper focussed on many people with disabilities face challenges in learning and completing everyday tasks. Some rely on assistance from others, while others use helpful gadgets to become more independent. One commonly used device is the wheelchair, which helps people who can't walk due to illness, disabilities, or injuries. But some elderly individuals with weak muscles or joints struggle to move traditional wheelchairs. Smart wheelchairs offer a solution by using electric power and advanced technology like computers and sensors to help users navigate safely and efficiently. These intelligent wheelchairs are designed to improve maneuverability tasks without needing human intervention for navigation and perception.

Simulation and control of multipurpose wheelchair for disabled/elderly mobility

Abdul Ghani (2016) in his research discussed about developing a wheelchair that can do more than just move around. It's designed for elderly and disabled people who may have weakness in their arms and legs. The wheelchair is made to be able to do different tasks without needing someone to control it all the time. They've come up with a new design that lets the wheelchair change shape and do various tasks. They used special software to model this design. They also created a fuzzy logic control system, which helps the wheelchair stay stable and perform different tasks like moving on flat surfaces, going up and down stairs, standing on two wheels, and switching back to four wheels. This new approach needs less initial power compared to older designs.

CHAPTER-3

AIM AND SCOPE

3.1 AIM

Over time, wheelchairs have improved from manual to powered versions, but they still don't fully meet the needs of disabled individuals. It's important to understand their challenges and create wheelchairs that address them. That's why we've designed a multipurpose wheelchair that can also function as a stretcher.

Our wheelchair is easy to construct, operate, and maintain. We've used simple mechanical linkages, along with rack and pinion and worm and wheel mechanisms, to achieve the necessary movements. This project aims to create a wheelchair that meets all the required functions and provides greater versatility for users.

3.2 OBJECTIVE OF STAIR CLIMBER

The objectives of the project are:

- Decrease the cost by using new mechanism.
- Work reliably under different operating conditions.
- Multipurpose such as stair climbing and stretcher to save space and
- precluding exertion of the disabled person.

3.3 SCOPE OF THE SYSTEM

The scope of the project and technology "Automated Hybrid Stair Climber for physically Challenged People with AI" encompasses a wide range of aspects and considerations, including but not limited to:

- Technology Development:

Design and engineering of an automated hybrid stair climber that integrates artificial intelligence (AI) and automation for the purpose of assisting physically challenged individuals in navigating stairs.

- AI Integration:

Development and implementation of AI algorithms and machine learning capabilities to enable the stair climber to recognize and adapt to various stair configurations, obstacles, and user-specific needs.

- **User-Centric Approach:**

User needs assessments to understand the specific requirements, preferences, and challenges faced by individuals with mobility impairments in the context of stair climbing. Tailoring the technology to individual user profiles, accounting for factors such as weight, height, type of mobility challenge, and personal preferences.

- **Safety Features:**

Implementation of robust safety features, such as emergency braking systems, obstacle detection, anti-tip mechanisms, and other fail-safe protocols to ensure user safety during operation.

- **Deployment Environments:**

Deployment of the automated hybrid stair climber in various environments, including private residences, public buildings, healthcare facilities, and commercial spaces.

- **Inclusivity and Accessibility:**

Promotion of inclusivity by enabling physically challenged individuals to access stairs, thereby reducing architectural barriers and fostering independence.

Encouragement of inclusive design principles in architectural and infrastructure planning, contributing to a more accessible world.

- **Quality of Life Enhancement:**

The primary goal of enhancing the overall quality of life for physically challenged individuals by providing them with increased mobility and independence.

- **Research and Development:**

Collaboration with experts in the fields of engineering, AI, and assistive technology to stay at the forefront of technological advancements and best practices.

- **Legal and Regulatory Compliance:**

Ensuring that the technology complies with relevant safety and accessibility standards and working closely with regulatory bodies to obtain necessary certifications.

- **Cost and Accessibility:**

Consideration of cost-effectiveness and affordability to make the technology accessible to a wide range of users, potentially through partnerships with healthcare providers or insurance companies



Fig:3.1 Automated wheel chair

CHAPTER - 4

EXPERIMENTAL WORK AND SETUP

4.1 MATERIALS USED

4.1.1 DC MOTOR

The Precision Micro Drives makes small DC gear motors that are essential for many electrical and electronic devices. These motors are compact and easy to install, fitting into a variety of products and equipment.

These gear motors have special gears that can provide strong twisting power even at low speeds. This helps in tasks like moving heavy equipment or controlling precise movements in industrial machines, medical tools, and robots.

Precision Micro Drives offers a variety of gear motors, including planetary and spur types, which are suitable for different uses. These motors are small but powerful, providing the strength and torque needed for various applications.



Fig:4.1 DC Motor

4.1.2 FRAME

The frame is like the skeleton of a wheelchair. It's the main part to which all other components are attached. Not only does it hold everything together, but it also provides support for the person sitting in the wheelchair. Think of it as the foundation that everything else relies on.

1.Front Legs

2.Back Legs

3.Supporting Legs

4.Seat Frame

5.Foot rest.

Front Legs

These are attached to the main frame and can move forward and backward. They have wheels at the ends for moving on the floor and stairs. They're made of hollow mild steel rods.

Back Legs

Similar to the front legs, these also move forward and backward using a rack and pinion arrangement. They have wheels for mobility and are made of hollow mild steel rods.

Supporting Legs

These are attached to the back of the main frame to balance the wheelchair while going up and down stairs. They have larger wheels and are made of hollow mild steel rods.

Seat Frame

This includes the backrest, seating portion, and footrest. These parts are joined together by hinges. The seat frame can be converted into a straight shape to turn the seat into a stretcher. A worm and worm wheel mechanism is used for this conversion.



Fig:4.2 Seat Frame

Foot Rest

Supports the feet of the person in the wheelchair. It can also move forward and backward to help with climbing stairs. Small wheels are attached mobility.



Fig:4.3 Footrest

4.1.3 BEARING

A bearing is a part of a machine that supports another moving part, called a journal. It allows these parts to move relative to each other while bearing the weight or load. When these surfaces rub against each other, it creates friction, which wastes energy and can cause wear and tear.

To reduce friction and wear, and to dissipate heat, a layer of fluid called lubricant is used between the journal and the bearing. This lubricant can be various types of oils like mineral oil from petroleum, vegetable oils, silicon oils, or greases. Its job is to keep the surfaces from directly contacting each other and to make the movement smoother.



Fig:4.4: Bearing

4.1.4 WHEEL

Wheels help things move by rolling smoothly along with the help of axles. To make wheels turn, you need to apply a force, either by gravity or by pushing or pulling them. In a wheelchair, wheels are attached to the ends of the legs to make it move. The wheels on the legs are smaller, while the supporting wheels are bigger to help with stability and smooth movement.



Fig:4.5: Wheel

4.1.5 BATTERY

In our project, we're using rechargeable batteries, specifically secondary type batteries. These batteries can be recharged multiple times because they store chemical energy and convert it into electrical energy.

There are two main types of batteries: primary (disposable) and secondary (rechargeable). Primary batteries can only be used once because they use up their chemicals in a one-way reaction. Secondary batteries, on the other hand, can be recharged because their chemical reactions are reversible. This means they can be charged by running a current through them in the opposite direction of discharging. Secondary batteries, also known as rechargeable batteries, can be charged and discharged many times before they wear out. Some worn-out batteries can even be recycled.



Fig:4.6: Battery 12V

4.1.6 MOTOR SPEED CONTROLLER

An A motor speed control is like a remote control for an electric motor. It regulates how fast the motor spins and can even make it go in reverse or stop smoothly.

In small electric toys and models, there are tiny electronic speed controls that adjust the motor's speed.

The speed control works by getting a signal from a throttle lever or joystick, which tells it how fast to make the motor spin. Then, it adjusts the motor's speed by changing how often it turns on and off. It does this by controlling a bunch of special switches called field effect transistors (FETs). By changing how often these switches turn on and off.



Fig:4.7: Motor Speed Controller

4.1.7 ARDUINO UNO

Arduino Uno plays a crucial role in the project as it serves as the central control unit responsible for coordinating various functions of the stair climber and interfacing with the AI system. Here's how the Arduino Uno is utilized in the project:

- **Motor Control:** Arduino Uno controls the motors responsible for the movement of the stair climber. It receives commands from the AI system or user inputs and translates them into signals to drive the motors for climbing stairs.
- **Sensor Interface:** Arduino Uno interfaces with various sensors integrated into the stair climber, such as proximity sensors, ultrasonic sensors, or pressure sensors. These sensors provide feedback about the environment and the position of the climber, allowing the system to adjust its movements accordingly.
- **Communication Interface:** Arduino Uno facilitates communication between the AI system and other components of the stair climber. It may utilize communication protocols such as UART, SPI, or I2C to exchange data and commands with the AI system.
- **User Interface:** Arduino Uno can also be involved in managing the user interface of the stair climber, including buttons, displays, or touchscreens. It processes user inputs and displays relevant information about the climbing process or system status.
- **Decision Making:** While the AI system might handle higher-level decision-making processes, Arduino Uno may perform basic decision-making tasks in real-time, such as obstacle avoidance or adjusting climbing speed based on sensor inputs.
- **Safety Features:** Arduino Uno oversees safety features of the stair climber, such as emergency stop mechanisms or tilt detection. It continuously monitors sensor data and takes appropriate actions to ensure user safety.

Overall, Arduino Uno acts as the backbone of the automated hybrid stair climber system, providing the necessary computational power and control capabilities to integrate AI functionalities and enable seamless interaction between different components of the system.



Fig:4.8: Arduino Uno

4.1.8 RELAY BOARDS

Relay boards play a crucial role in facilitating the control of various electrical components of the stair climber. These boards act as switches, controlled by the Arduino Uno, to manage the power flow to motors for movement and safety mechanisms such as emergency stops and tilt detection. They ensure that power is efficiently supplied to different parts of the system and enable seamless interaction between the Arduino Uno and the AI system, allowing for precise control and coordination of the stair climber's actions based on real-time assessments of the environment and user inputs.



Fig:4.9: Relay Board

4.1.9 ON-OFF SWITCH

An on-off switch is employed as a simple but vital component for user control and safety. It serves as a manual control mechanism, allowing users to turn the stair climber system on or off easily. Through the system, activating components like the Arduino Uno, motors, and sensors. Conversely, when the switch is turned off, it breaks the circuit, cutting off power to the system, ensuring it stops functioning immediately. This on-off switch provides users with a straightforward means to operate the stair climber safely and conveniently, empowering them to initiate or halt the climbing process as needed.



Fig:4.10: On-Off Switch

4.1.10 ULTRASONIC SENSOR

Ultrasonic sensors are utilized to detect obstacles or stairs ahead of the climber. These sensors emit high-frequency sound waves, which bounce off objects in the environment and return to the sensor. By measuring the time it takes for the sound waves to return, the sensor calculates the distance to the object. This information is then sent to the system's brain, the Arduino Uno, which processes it to determine if there are any obstacles or stairs in the path of the climber. Based on this data, the system can adjust the climbing mechanism to navigate safely and efficiently, ensuring a smooth ascent or descent for physically challenged individuals.



Fig 4.11 Ultrasonic Sensor

4.2 EXPERIMENTAL SETUP

In our project to create an "Automated Hybrid Stair Climber for Physically Challenged People with AI," we're combining advanced technology to make moving around easier for those with physical disabilities. Our setup involves building a prototype stair climber and adding important electrical parts like an Arduino Uno (a small computer), motor drivers (to control movement), relay boards (for managing power), an on-off switch, and ultrasonic sensors (to detect obstacles). We carefully put these parts together to make sure everything works smoothly and can be controlled accurately. Additionally, we're creating smart software (AI) that uses data from sensors to make quick decisions and improve how users interact with the climber. We'll test everything thoroughly, making adjustments along the way, with the goal of creating a dependable, easy-to-use, and self-driving solution for people with physical challenges.

- **Stair Climber Prototype:** Construct a prototype of the stair climber using materials such as aluminum frame, motors, wheels, and a platform for the user to stand or sit on. Design the climber to be adjustable to accommodate various stair heights and widths.
- **Electrical Components:** Gather the necessary electrical components including an Arduino Uno microcontroller, motor drivers, relay boards, on-off switch, ultrasonic sensors, and any additional sensors for safety and navigation.
- **AI Integration:** Develop or integrate an AI system that can analyze sensor data,

make decisions, and control the stair climber autonomously. This may involve programming algorithms for obstacle detection, path planning, and user interaction.

- **Assembly:** Mount the electrical components onto the stair climber prototype. Connect the motors to motor drivers, sensors to the Arduino Uno, and relay boards to manage power distribution and safety features.
- **Software Development:** Write code for the Arduino Uno to interface with the sensors, motor drivers, and relay boards. Implement algorithms for obstacle avoidance, stair detection, and user control. Integrate AI algorithms for decision-making based on sensor inputs.
- **Testing:** Conduct extensive testing of the stair climber prototype in a controlled environment. Test its ability to detect obstacles, navigate stairs, and respond to user commands. Evaluate the performance of the AI system in real-time decision-making scenarios.
- **Iterative Improvements:** Based on test results, refine the design and algorithms as needed. Make adjustments to improve stability, speed, and user experience. Continue testing and iterating until the stair climber demonstrates reliable and efficient performance.
- **User Trials:** Once the prototype meets the desired performance criteria, conduct trials with physically challenged individuals to gather feedback on usability, comfort, and safety. Incorporate user feedback into further refinements of the design and functionality.

4.3 SOFTWARE

Programming the Arduino Uno involves using the Arduino IDE software, where C++ is the main language used for writing code to control the microcontroller. This code communicates with sensors like ultrasonic sensors for detecting obstacles, pressure sensors for user presence, or tilt sensors for safety. It reads data from these sensors, processes it, and decides what actions the stair climber should take based on that information. For motor control, C++ code directs the movement of the climber, managing tasks like going up and down stairs, adjusting speed, and stopping when needed. Additionally, C++ is used to integrate AI algorithms into the

Arduino Uno, which analyze sensor data to make decisions autonomously, such as avoiding obstacles or planning paths. Lastly, C++ code handles the user interface, interpreting inputs from buttons or switches and displaying information on screens, ensuring smooth interaction between the user and the stair climber. In summary, C++ and Arduino IDE software are vital for programming and controlling the Arduino Uno to achieve the desired functions of the automated stair climber for physically challenged individuals with AI integration.

Coding:

```
const int TRIG_PIN = 5;
const int ECHO_PIN = 4;
const int RELAY_PIN = 10;
const int DISTANCE_THRESHOLD = 50;
```

```
float duration_us, distance_cm;
```

```
void setup() {
  Serial.begin(9600);
  pinMode(TRIG_PIN, OUTPUT);
  pinMode(ECHO_PIN, INPUT);
  pinMode(RELAY_PIN, OUTPUT);
}
```

```
void loop() {  
  digitalWrite(TRIG_PIN, HIGH);  
  delayMicroseconds(10);  
  digitalWrite(TRIG_PIN, LOW);  
  
  duration_us = pulseIn(ECHO_PIN, HIGH);  
  distance_cm = 0.017 * duration_us;  
  
  if (distance_cm < DISTANCE_THRESHOLD)  
    digitalWrite(RELAY_PIN, HIGH);  
  else  
    digitalWrite(RELAY_PIN, LOW);  
  
  Serial.print("distance: ");  
  Serial.print(distance_cm);  
  Serial.println(" cm");  
  
  delay(500); }
```

CHAPTER-5

RESULT AND DISCUSSION

5.1 THEORETICAL DESIGN AND CALCULATION

First, we'll figure out the size and shape of the wheelchair's structure. Then, we'll use that information to create a computer model of the wheelchair.

Next, we'll analyze how the wheelchair's parts hold up under different movements, like going up and down stairs or across rough terrain. We want to make sure it can handle all these situations without breaking.

Finally, we'll estimate how much force it takes to pull the wheelchair. This helps us understand how much effort is needed to move it around, which is important for both the person using the wheelchair and anyone helping them.

5.1.1 Structure Design



Fig:5.1 Structure design

5.1.2 Stress Analysis for Climbing Stairs

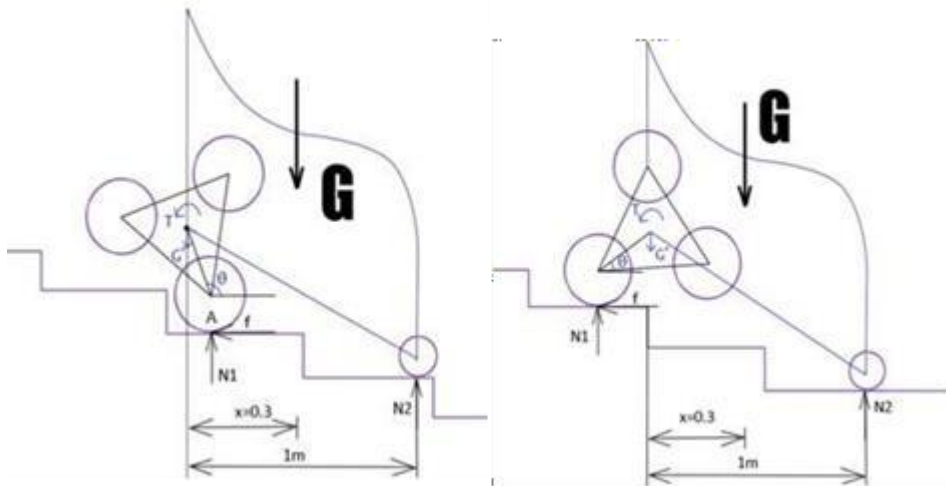


Fig:5.2 Analysis of climbing stairs

The gravity can be transferred to the planetary wheel system and marked as G' , which plays two important roles when the wheelchair climbs stairs, one helps the planetary wheel turning (left picture of the figure 4.9), the other hinders the planetary wheel turning (right picture of the figure 5.2).

And the calculation obtained is as follows,

$$G' = (1 - x)G = 0.7 \times 750 = 525N \quad (5.1.1)$$

The balance equation for point A :

$$T = G' m \cos \theta = 54.6 \cos \theta \text{ Nm} \quad (5.1.2)$$

Where T is the torque, G' is the total gravity of the wheelchair act on the planetary system. The design weight of the wheelchair is supposed to be 50kg, and the weight of user is 100kg, so the total weight is $M=150\text{kg}$. And the single side gravity $G=75 \times 10=750\text{N}$, m is the length of the turning arm.

which is: $m=104\text{mm}=0.104\text{m}$.

It is easy to see that when the rotating arm of the planetary wheel in the horizontal state, i.e. $\theta = 0$, the distance between the barycentre of the wheelchair and the supporting point of the planetary wheels train is farthest, where it also needs the

largest Motor torque,

$$T_{\max} = 54.6 \text{ N} \cdot \text{m} \quad (5.1.3)$$

The results which are calculated in above three situations are listed in table below.

Situation	Torque
Moving on ground	$T_1=6.73\text{N.m}$
Moving on slope	$T_2=7.02\text{N.m}$
Climbing Stairs	$T_3=53.4\text{N.m}$

5.2 PULLING FORCE ESTIMATION

We measured the distance from the fulcrum to the handle, which is 1.173 meters (D).

We also calculated the maximum torque, which is 54.6 Newton-meters ($T_{\max}$).

Now, according to the moment equilibrium theorem, we can calculate the force that people use to pull the wheelchair up a stair:

$$F_1 = 54.6 \div 1.173 = 46.55 \text{ N} \quad (5.2.1)$$

$$F_2 = 46.55 \times 2 = 93.1 \text{ N} \quad (5.2.2)$$

This force is the maximum critical point force during the process of climbing up and down stairs, because the driving force will be provided by the motors which will be introduced in the motor selection section. And the main role which the assistant play is supports the wheelchair and protects it from turning backward during climbing stairs.

5.3 OPTIMIZATION DESIGN

In order to improve our wheelchair, the following optimizations are designed: planetary wheels mechanism optimization, seat backrest adjusting mechanism, locking system and improvement the comfort and convenience based on the ergonomics theory.

Planetary wheels system optimization

The ordinary planetary wheel setup uses a central shaft to drive a central gear, which then drives smaller planetary gears and the wheels forward. When the wheelchair climbs stairs, the resistance locks the planetary wheels, and the whole system moves forward by rolling the central shaft. However, this setup puts a lot of stress on the planetary gears, making them prone to breaking.

To address this, we're considering a solution inspired by car clutches. Just like pressing the clutch in a car disconnects the engine from the wheels, we can implement a similar mechanism in the wheelchair. When the "clutch" is engaged, the power from the central shaft won't pass to the wheels, preventing strain on the planetary gears.

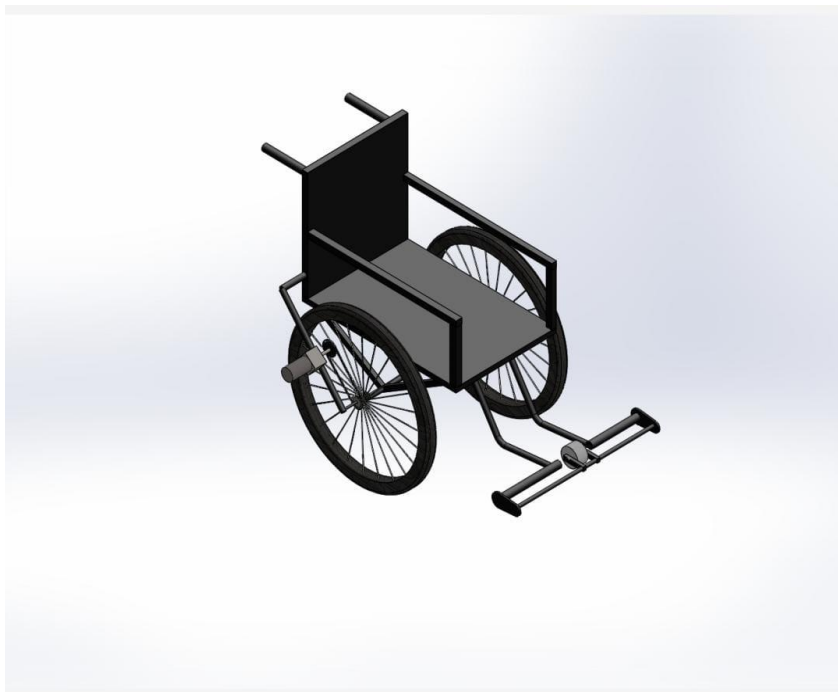


Fig:5.3 Design of Wheel Chair

5.4 FINAL PROTOTYPE



Fig;5.4 a) Final prototype Images



Fig:5.4 b) Final Prototype Images

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

The "Automated Hybrid Stair Climber for Physically Challenged People with AI" is a groundbreaking technological innovation designed to empower individuals with mobility impairments. It integrates automation and artificial intelligence (AI) to redefine accessibility and inclusivity. This device is constructed using carefully selected materials that provide structural integrity, safety, and user comfort.

The core components of this technology include AI algorithms and electronic systems that enable real-time decision-making, sensors for environmental awareness, powerful microcontrollers and processors, energy-efficient batteries, and safety mechanisms. These components work together to ensure the device adapts to diverse stair configurations while prioritizing user safety.

The device's materials, including rubber tracks, wheels, and anti-slip surfaces, facilitate smooth mobility and interaction with stairs. The frame is constructed from durable materials, striking a balance between strength and weight, while components are designed for proper weight distribution and user comfort.

The automated hybrid stair climber enhances independence and inclusivity, allowing users to conquer staircases in various environments. It contributes to a more accessible world, fosters mental and emotional well-being, and encourages inclusive design. This technology, with its AI and electronic components.

6.2 CONCLUSION

The "Automated Hybrid Stair Climber for Physically Challenged People with AI" is not just a technological marvel; it is a beacon of hope, empowerment, and inclusivity for individuals facing mobility challenges. This innovative solution, which seamlessly merges automation and artificial intelligence, has the potential to transform lives and redefine what's possible. By carefully selecting the right materials, this technology is not only structurally sound but also safe and comfortable for users. It embodies the perfect synergy of advanced AI and electronic components, incorporating sensors, microcontrollers, power systems, and user interfaces that make it a responsive and intelligent system. This device is more than just mechanical components and materials; it is a lifeline to independence. It enables individuals to navigate stairs confidently and access spaces they may have once deemed inaccessible. It offers newfound freedom, improves mental and emotional well-being, and contributes to the creation of a more inclusive world.

In conclusion, the "Automated Hybrid Stair Climber for Physically Challenged People with AI" is a testament to human ingenuity and compassion. It stands as a symbol of progress and inclusivity, and its impact extends far beyond technology. It extends to the hearts and lives of individuals who can now face stairs with courage, independence, and a sense of belonging in a more accessible world.

REFERENCES:

1. Behera, P.K., Gupta, A.: Novel design of stair climbing wheelchair. *J. Mech. Sci. Technol.* 32(10), 4903–4908 (2018).
2. Belcher, M.J.H., Frank, A.O.: Survey of the use of transport by recipients of a regional Electric Indoor/Outdoor Powered (EPIOC) wheelchair service. *Disabil. Rehabil.* 26(10), 563–575 (2004).
3. Castillo, B.D., Kuo, Y.F., Chou, J.J.: Novel design of a wheelchair with stair climbing capabilities. *ICIIBMS 2015 - International Conference on Intelligent Informatics and Biomedical Sciences* 2(1), 208–215 (2016).
4. Edwards, K., McCluskey, A.: A survey of adult power wheelchair and scooter users. *Disabil. Rehabil.: Assist. Technol.* 5(6), 411–419 (2010)
5. Frerreira, A.F., Leite, A.D., Pereira, L.d.F., Neves, J.M.d.J., de Oliveira Pinheiro, M.G., Chang, S.K.J.: Wheelchair accessibility of urban rail systems: Some preliminary findings of a global overview. *IATSS Research* (xxxx) (2021).
6. Grand View Research: Personal mobility devices market size, share, and trends analysis report by product (Walking Aids, Wheelchairs, Scooters), By Region (Europe, APAC, North America, MEA), And Segment Forecasts, 2021–2028. Technical report, San Fransisco (2021).
7. Jamin, N.F., Ghani, N.M.A., Ibrahim, Z.: Movable payload on various conditions of two-wheeled double links wheelchair stability control using enhanced interval type-2 fuzzy logic. *IEEE Access* 8, 87676–87694 (2020).
8. Lawn, M.J., Ishimatsu, T.: Modeling of a stair-climbing wheelchair mechanism with high single-step capability. *IEEE Trans. Neural Syst. Rehabil. Eng.* 11(3), 323–332 (2003).
9. Liu, J., Wu, Y., Guo, J., Chen, Q.: High-order sliding mode-based synchronous control of a novel stair-climbing wheelchair robot. *J. Control Sci. Eng.* 2015 (2015).
10. Mostyn, V., Krys, V., Kot, T., Bobovsky, Z., Novak, P.: The synthesis of a segmented stair-climbing wheel. *Int. J. Adv. Robot. Syst.* 15(1), 1–11 (2018)..
11. Ning, M., Yu, K., Zhang, C., Wu, Z., Wang, Y.: Wheelchair design with variable posture adjustment and obstacle-overcoming ability. *J. Braz. Soc. Mech. Sci. Eng.* 43(4) (2021).
12. Onozuka, Y., Tomokuni, N., Murata, G., Shino, M.: Dynamic stability control of inverted-pendulum-type robotic wheelchair for going up and down stairs. *IEEE International Conference on Intelligent Robots and Systems*, 4114–4119 (2020).

13. Prajapat, M., Sikchi, V., Shaikh-Mohammed, J., Sujatha, S.: Proof-of-concept of a stair-climbing add-on device for wheelchairs. *Med. Eng. Phys.* 85, 75–86 (2020).
14. Quaglia, G., Franco, W., Oderio, R.: Wheelchair.q, a motorized wheelchair with stair climbing ability. *Mech. Mach. Theory* 46, 1601–1609 (2011). Yuhua Cheng, Libing Bai, Fan Yang, Yifan Chen, Shenhua Jiang, and Chun Yin. “Stainless Steel Weld Defect Detection Using Pulsed Inductive Thermography.”
15. Shin, G.W., Lee, K.J., Park, D., Lee, J.H., Yuri, M.H.: Personal mobility device and user experience: A state-of-the-art literature review. *Proceedings of the Human Factors and Ergonomics Society* 2(21), 1336–1337 (2018).
16. Tao, W., Xu, J., Liu, T.: Electric-powered wheelchair with stair-climbing ability. *Int. J. Adv. Robot. Syst.* 14(4), 1–13 (2017).
17. Wang, H., He, L., Li, Q., Zhang, W., Zhang, D., Xu, P.: Research on a kind of leg-wheel stair-climbing wheelchair. 2014 IEEE International Conference on Mechatronics and Automation, IEEE ICMA 2014, 2101–2105 (2014).
18. Yuan, J., Hirose, S.: Research on leg-wheel hybrid stair-climbing robot, zero carrier. In: 2004 IEEE International Conference on Robotics and Biomimetics, pp. 654–659 (2004).