FABRICATION AND WORKING OF A REMOTE-CONTROLLED STAIR-CLIMBING ROBOT

1. A. VISVESH SANATHAN
DEPT OF AI&DS
EASWARI ENGINEERING COLLEGE
I[st] YEAR CSE(AIML)

2. POOVARASAN. G
DEPT OF AI&DS
EASWARI ENGINEERING COLLEGE
I[st] YEAR CSE(AIML)

3. NAVEEN KARTHIK. R
DEPT OF AI&DS
EASWARI ENGINEERING COLLEGE
I[st] YEAR CSE(AIML)

4. VISVESWAR. R
DEPT OF AI&DS
EASWARI ENGINEERING COLLEGE
I[ST] YEAR CSE(AIML)

Abstract **- In the present scenario, there is an increasing demand for robots in every field to reduce human intervention as much as possible. Robots can operate on dangerous environments, help during rescue and military operations. The same applies to staircase-climbing robots. Staircase-climbing robots are considered to be one of the most effective types of robots as they can be used to traverse different, difficult and rugged terrains. They are also important for conducting scientific analysis of objectives, collecting samples and carefully transporting them to desired locations. The primary mechanical feature of a staircase climbing robot is its simplicity. In this article we will be representing one method of designing a staircase-climbing robot.**

1. INTRODUCTION

Robotics is the area of automation which integrates technology in many fields like mechanism, sensors and electronic control system, artificial intelligence and embedded systems. The synthesis of mechanism is the very first step in the design of a robot depending upon its applications. These mobile robots can be split on the basis of their mobility as follows: -

1. Wheeled robots.
2. Legged robots.
3. Track-type robots.

Adjustable staircase climbing robot has the best performance in legged and wheeled type of robots. The only limitation of such robots is the restriction of climbing ability based on the height of the stairs and its width. Many developments have been made in order to maximize climbing capabilities of such robots. Reducing body weight and energy consumption is also an important factor to be included in the designing of such robots. We will be restricting our model to a wheeled type robot that we find as the best model addressing the above conditions.

To better understand the working principles, the mechanisms and to know more in general about anything in nature, it is always a precursor to know about the existing types, in similar words, the classifications of the particular object so as to grasp the basis of division. On the same note, we will begin our paper by introducing, in brief, the types of the robots that can be designed to address our objectives.

1. LEGGED ROBOTS

The legged type of robots uses electro-pneumatic actuators and suction cups for stability and locomotion. An open loop-algorithm monitors the ability to climb stairs.

Source: - Agility Robotics

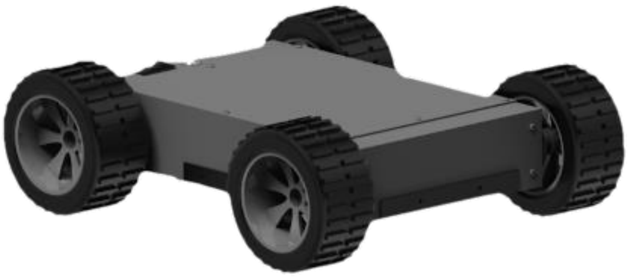
2. TRACKED ROBOTS

A tracked robot runs on continuous tracks instead of wheels. The advantage of tracked vehicles over wheeled vehicles is in their design as they come in contact with larger surface area than wheeled and legged type robots. The disadvantages of tracked robots is that the terrain that they can traverse is more restricted and requires constant manual intervention.

Source: - robotpark.com

3. WHEELED ROBOTS

A wheeled robot requires no particular introduction. We are all familiar with wheeled vehicles like cars, bikes, trucks, etc. It is in the same manner that a wheeled robot too works. The advantages of using wheels is that it provides better stability than the its counterparts, provides high mobility of the robot and requires very less to none human intervention. It is this kind of robot that addresses our objectives and provides quick, efficient and the best solutions to the existing problems



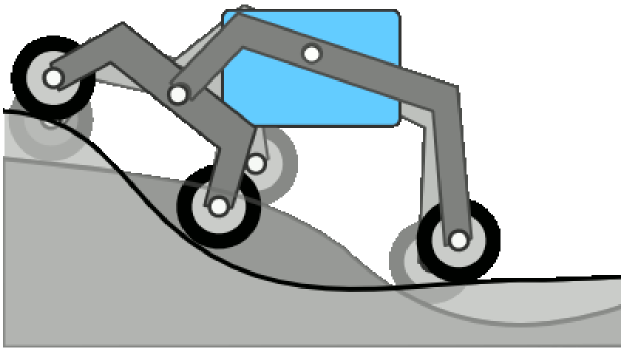
Source: - Michał Drwięga

2. LITERATURE SURVEY/ REVIEW

There are many existing works in this particular topic that particularly addresses our objectives and picking one as our reference does not provide justice to the rest. Hence, we will be using the basis of every such robot to provide a better picture of how we have implemented it in our model. The Rocker-bogie mechanism is common to all the robots including ours and we will be providing a brief explanation to make sure that we better understand the concept.

In itself, the Rocker-bogie mechanism is extremely easy to understand. It is a self-centering, self-adjusting mechanism that provides better stability and support to a robot. It usually includes a larger part called the 'Rocker', as in rocking the entire framework to adjust itself to the surface, and a smaller part called the 'bogie'. The bogie part is considered to be the front side of the robot, although it usually changes with respect to our desires and perspectives, and is connected to the rocker via flexible joints.

This suspension mechanism was invented for usage in the NASA Mars Rovers like 'The Sojourner' since the terrain of Mars was unknown and unbeknownst to humans. The advantage provided by this kind of a suspension mechanism is that if we consider a robot with certain number of wheels, then all the wheels of the suspension will always be passively in contact with any given surface at any given point in time. This massive discovery also led to the success of the Mars Rovers.



Source:- Wikipedia

Another advantage provided by the 'Rocker-bogie' mechanism is that chassis of robot is always perfectly aligned with the surface. This provides the necessary stability of the robot and also helps in carrying light-weighing objects as the weight is evenly distributed over the six wheels.

3. EXISTING WORKS

NASA developed the 'Rocker-bogie' suspension mechanism and has been used in projects like the NASA's Mars Pathfinder and the Mars Rover the Sojourner. This showcases the fact that this mechanism can be adopted to any model with a particular set of wheels and is more efficient than other suspension mechanism to traverse uneven terrains, surfaces, etc.
We will study some of the existing staircase-climbing robots that consists 2-legs (bipeds), 4-legs (quadrupeds), and the leg-wheel hybrids

3.1. BIPEDS: -

YANBO-1 is the one of the first developed bipedal robot that could climb stairs, designed by Yoneda since 1985. This model has extremely restricted Degrees of Freedom (DOF), DOF that are required to make the robot walk on level ground.

Source:- Yoneda, 1987.
Fig shows YANBO-1, stair-climbing motion

3.2. QUADRUPEDS: -

A quadruped walking robot (Hirose et al. 2009) has successfully managed to walk and climb stairs. The TITAN-VI Consists of two parts, the front and the back that can travel up and down to manage the large height differences of the frontal and the dorsal legs of the robot.

Source: -Hirose et al. 2009 (TITAN VI)

3.3. LEG-WHEEL HYBRIDS: -

The most adaptable type with its environment is the leg-wheel hybrid. The wheels provide the stability of flat surface and the legs provide the necessary lift to climb and thus higher mobility can be obtained.

Source:- https://ej-eng.org/index.php/ejeng/article/view/2256

4. PROPOSED WORK

The intention of this project is to develop a Remote-Controlled (Bluetooth) Mars Rover that can climb stairs of a particular height and width. This provides the basic understanding of NASA's The Sojourner and how it operates with less to none human intervention in an unknown terrain. The proposed work is aimed to be economical and less technical knowledge is required in designing this rover. Hence there is clear need to lay out and understand the objectives to successfully develop the rover. We have pertained to the usage of 'rover' instead of 'robot' due to the similarities of our design with NASA's Mars Rovers.

4.1 OBJECTIVES: -

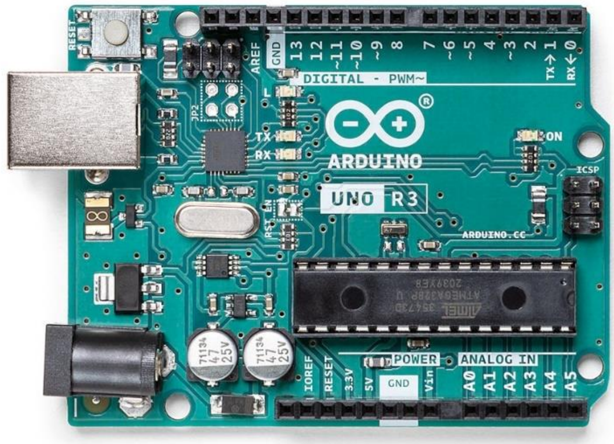
The objective of our project has been briefed in section 1 of the paper, i.e., in the introduction, but we will reiterate our objectives in detail as is customary.

1. OBJECTIVE 1: - To develop scaled down version of a remote-controlled rover.
2. OBJECTIVE 2: - Cost effective and economical
3. OBJECTIVE 3: - High maneuverability and mobility
4. OBJECTIVE 4: - Ability to carry light-weights to desired locations in double quick time.

4.2. COMPONENTS REQUIRED: -

It is always a pre-requisite to know the components involved in any build to maximize its efficiency and reduce recurring maintenance and repair cost. So is the case for our build. Let us work through the basic materials required and then develop the required CAD model.

4.2.1. ARDUINO UNO



Source: https://store-usa.arduino.cc/products/arduino-uno-rev3

• Microcontroller:	ATmega328P
• Operating Voltage:	5V
• Input Voltage (recommended):	7-12V
• Inout Voltage (limit):	6-20V
• Digital I/O Pins:	14
• PWM Digital I/O Pins:	6
• Analog Input Pins:	6
• DC Current per I/O Pin:	20 mA
• DC current for 3.3V Pin:	50 mA
• Flash Memory: (ATmega328P) of which 0.5 KB used by bootloader	32 KB
• SRAM: (ATmega328P)	2 KB
• EEPROM: (ATmega328P)	1 KB
• Clock Speed:	16 MHz
• LED_BUILTIN:	13
• Length:	65 mm

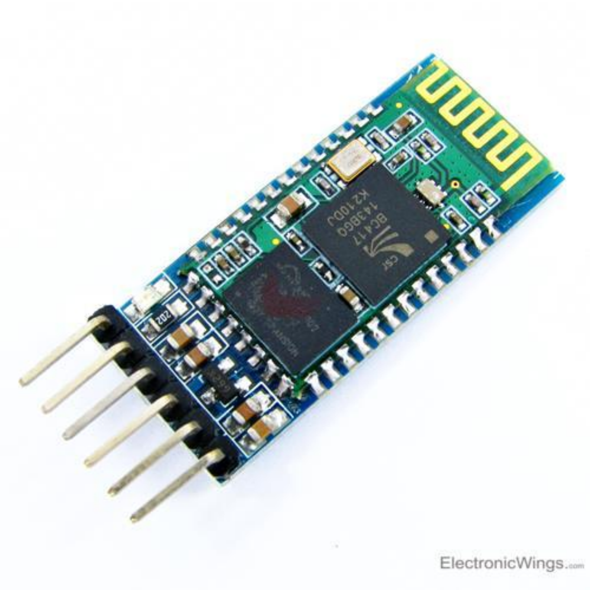
- Width: 52.5 mm
- Weight: 25 g

4.2.2. MOTOR DRIVER

Motor driver L298N has been used as the primary motor driver for the motors

- Motor output voltage:- 5V – 35V
- Motor output voltage:- 7V – 12V
- Logic input voltage:- 5V – 7V
- Continuous current per channel:- 2A
- Max Power Dissipation:- 25W

4.2.3. BLUETOOTH MODULE



- HC-05 has red LED which indicates connection status, whether the Bluetooth is connected or not. Before connecting to HC-05 module this red LED blinks continuously in a periodic manner. When it gets connected to any other Bluetooth device, its blinking slows down to two seconds.

- This module works on 3.3V. We can connect 5V supply voltage as well since the module has on board 5 to 3.3 V regulator.

- As HC-05 Bluetooth module has 3.3V level for RX/TX and microcontroller can detect 3.3 V level, so, no need to shift transmit level of HC-05 module. But we need to shift the transmit voltage level from microcontroller to RX of HC-05 module.

- The data transfer rate of HC-05 module can vary up to 1Mbps is in the range of 10 meters.

4.2.4. MOTORS

BO motors of the below mentioned specifications are used for the project.

- Operating Voltage (VDC)
  3 ~ 12

- Shaft Length (mm)
  8.5

- Shaft Diameter (mm) (Double D-type)
  5.5

- No Load Current (mA)
  40-180mA.

- Rated Speed After Reduction (RPM)
  100

- Rated Torque (Kg-Cm)
  1

- Weight (gm)
  30

- Dimensions in mm (LxWxH)
  64 x 22 x 18

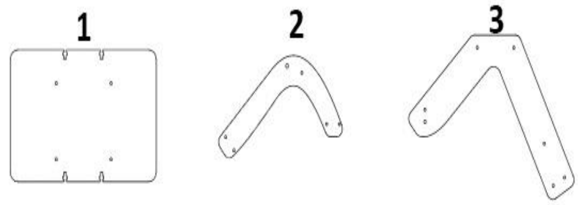
4.2.5. POWER SOURCE

A 7.9 V DC power source supplies for the connections

4.3. CAD MODEL AND DESIGN: -

The CAD model is one of the most important steps in the building of any functional device. It is in this step that we can identify the limits, implement conceptual ideas, etc.to obtain the perfect model for the required task. For our project, we have decided to use the model produced by 'THESTEMPEDIA', visit https://thestempedia.com/project/diy-stair-climbing-robot/ for more information on the build and the CAD model.

We deem this model as the most efficient one for our build as it is light weight and offers more stability as well as follows the 'Rocker-Bogie' mechanism.



SOURCE CREDIT: - THESTEMPEDIA

1. Is the base plate of the model. It acts as a joint connection between the two sides of the robot. The Arduino and other connections that is a part of the brain of the robot is placed on the base plate.

2. Is the frontal leg of the rover. It is the 'bogie' part of the suspension mechanism that provides maneuverability to the robot.

3. It is the dorsal leg of the rover. It provides the necessary connection and stability to the 'bogie' part. This 'Rocker' part is considerably larger in size than the 'bogie' part

4.3.1. CONSTRUCTED MODEL

We have derived our body framework from the CAD model provided by THESTEMPEDIA.

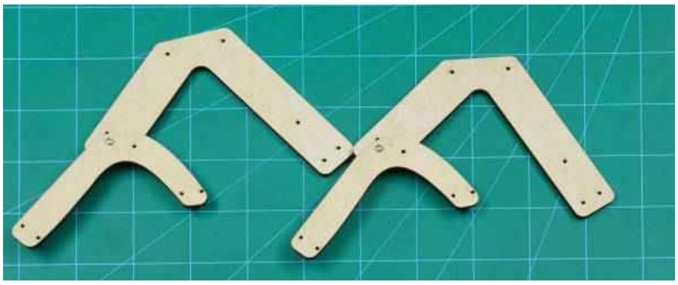
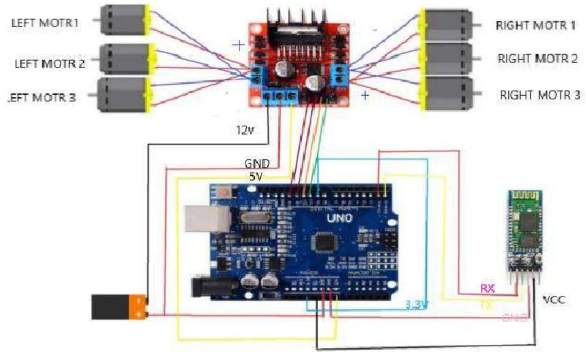


IMAGE CREDIT: - THESTEMPEDIA

4.3.2. CIRCUIT DIAGRAM

Here is a very crude representation of the connections made in the rover. These connections, complex in actuality, were drawn extremely simple to make sure that everyone can understand the connections why those particular connections were made. The colour of the wires used have no particular meaning. They were made so to add visual appeasement and aesthetic sense to the circuit diagram.



4.3.3. MATERIAL SELECTION

Keeping the constraints present in our minds, we have used MDF sheets for the following reasons:-

4.3.3.1. LIGHTNESS

MDF sheets are considerably lighter in weight compared to its counterparts like wood, stone, ACP, etc.

4.3.3.2. RIGIDITY AND STRENGTH

MDF sheets, though appear brittle, are rigid and somewhat strong. For this reason, if we choose MDF sheets of appropriate thickness, the rover can be made to carry little weights.

4.3.3.3. AVAILABILITY

MDF sheets are easily available and can be easily cut into desired shapes.

4.3.3.4. FEASABILITY

MDF sheets are economical and most of them have cheaper variants too and can be easily afforded by everyone. This provides opportunities for builds that cannot be made using the latter options

Even though there are certain disadvantages in the usage of MDF sheets, the collective advantages are greater and hence nullify its disadvantages. For larger and more efficient builds, it is recommended to not use MDFs and choose one of the other available options wisely.

5. CONCEPTUAL DETAILS/ MECHANISMS

DESIGNING THE ROCKER-BOGIE SUSPENSION SYSTEM

The basis of any Rover type robots is the ability to actively suspend itself even if it has to continually and simultaneously pass through many uneven surfaces and still not lose its mobility or stability. This can be achieved by appropriately designing the suspension mechanism. The most important factor here is achieving the rocker and bogie linkages and angles as per the requirement of the objectives. This angle of linkage can be calculated by measuring the height and width of the stairs and then by calculating the angle using Pythagoras theorem.

$$c^2 = a^2 + b^2$$

Using the above formula, we can find the slant length, the hypotenuse, of the triangle formed. The design can then be modified to suit the needs.

To have higher climbing stability it is required that only one pair of wheels traverse the height of the stairs. In certain cases, the subsequent pair of wheels can also be allowed to climb the stairs simultaneously.

To achieve the best climbing stability, the rover is required to have a certain distance between the first and the second pair of wheels. For the ideal condition to be satisfied, it is required for the wheel to traverse the entire height of the stair within 2 revolutions so as to make the subsequent pairs climb up efficiently.

Therefore, the ideal wheel diameter is given by the formula

$$v = \frac{DN}{60}$$

Where 'v' is the velocity, 'D' is the diameter of the wheel, 'N' is the RPM of the motor. This equation can be transposed to obtain the desired diameter of the wheel

$$D = \frac{60v}{N}$$

From this eqn., we can calculate the diameter of the wheel. Since the rocker part is desired to have at least twice the diameter of the wheel, we can measure the distance from the dorsal pairs of the bogie to rocker as follows

$$L \geq 2D$$

This formula provides us with the minimum length the shaft of the rocker must be to produce the ideal climbing stability. Another important factor is that the width of the stairs must also be greater than at least twice the diameter of the frontal wheels.

$$W \geq 2D$$

But this condition does not necessarily imply that the length of the shaft of the rocker must be same length as that of the width of the stair.

$$W \geq L$$

It is better to have stairs that have width greater than the entire length of the rover. But such ideal conditions cannot be applied in real-time. Hence the above findings holds good for locally suited environments.

6. WORKING PRINCIPLE

The working principles of rovers is very simple. The first of the frontal pairs of wheels is pushed against the rear wheels. The rotation of the wheels then causes the front of the rover to lift up. Simultaneously, the middle wheels are pushed against the obstacle by the frontal and rear wheels. This rotation causes the middle wheels to rise up and over the obstacle. Now the entire bogie part of the suspension is over the obstacle.

Following the same pattern, the rear wheels are now pushed against the obstacle which are pulled over by the frontal wheels. This process of climbing over obstacles is extremely stressful to the rovers. Hence while traversing obstacles, the forward progress is slowed-down or completely halted. These rovers are slow and climb obstacles by having each pair of wheels lifting up a part of the suspension model.

7. FUTURE WORKS AND EXTENSIONS

There are many possible upgrades/ modifications / extensions that can be made to our rover and we would like to discuss some of the possible immediate upgrades that can be done to enhance the overall performance of the rovers.

- Using of sturdy, rigid and highly resistive materials can increase the life span of the robot.
- Large wheels can be used to scale obstacles taller than the rover.
- High torque motors can be used to produce more RPM which helps to easily lift the rover over the obstacles.
- Number of legs and wheels can be increased to improve stability and mobility.
- The rover can be automated to reduce manual intervention.
- The robot can be made to evade unnecessary obstacles by adding sensors to avoid the risk of tipping-over.
- Lastly, greater stability can be provided by adjusting the rocker-bogie mechanism

8. CONCLUSION

In this paper, the fabrication of Remote-Controlled Stair-Climbing Robot is proposed and its workings are specified. It involved some basic knowledge in designing and developing a model with CAD. This also involved a particular kind of suspension system called the 'Rocker-bogie' suspension system that enables the rover to passively keep all its wheels in contact with the surface, however uneven it may be, and distributes the payload to all the wheels present in the rover. This mechanism can be modified to increase its applications like carrying and transporting weights to the desired locations thereby reducing human efforts and intervention. Other common examples that require the application of this particular kind of robots is during natural disasters, military and rescue operations and in hospitals to transport medicines to the patients during pandemic times to avoid physical contact.

We then proceeded to discuss the components needed in designing the robot and discussed its working principle. It also involved the calculations needed to figure out the basic measurements of the wheels, length of the shaft and distance required between the 'bogie' wheels. Lastly, we ended our paper by discussing some of the future modifications that can be made in order to enhance the quality, stability, mobility and the rover in general.

9. BIBLIOGRAPHY

1. https://arxiv.org/pdf/1809.02891

2. https://www.ijert.org/research/design-and-development-of-adjustable-stair-climbing-robot-and-remote-controlled-vehicle-IJERTCONV2IS11022.pdf

3. https://www.ijert.org/design-and-fabrication-of-unmanned-terrain-vehicle

4. https://www.robotpark.com/academy/all-types-of-robots/wheeled-robots/tracked-robots/

5. https://en.wikipedia.org/wiki/Rocker-bogie

6. https://cdn.intechopen.com/pdfs/10096/InTech-Stair_climbing_robots_and_high_grip_crawler.pdf

7. https://ej-eng.org/index.php/ejeng/article/view/2256

8. https://store-usa.arduino.cc/products/arduino-uno-rev3

9. https://www.tomsonelectronics.com/blogs/news/arduino-uno-specification