AUTONOMOUS FIRE EXTINGUISHER ROBOT

Objective: Fire extinguisher Robots-***The robot should be used for large scale fire extinguishing uses, it should be able to detect the fire, and should take the cause of fire as input/ detect it if possible and should be able to climb the buildings, stair climbing, it should be fire resistant The fire-fighting robot we made was designed, built and operated with these project specifications in mind. · The robot is to be autonomous when in run mode. · The robot should voluntarily detects and extinguishes fire with water pump · The obstacles on the way must be detected by the 3 cameras on the design · The robotic arm is to be used to remove the obstacles through remote control · The robot is to implement obstacle avoidance at all times whilst tracking and extinguishing fire as much as it can · The size and the dimensions can be of your choice and you should give reasoning***.

Automatic Fire Extinguisher Robot is a Hardware based model used to automatically extinguish the fire during fire accidents. A Robot has been developed which features to move in the direction with respect to the fire intensity and avoids self-destruction using Aluminium that are capable of withstanding very high temperatures.

In the below section we gave a concise summary of each of the parts with their applications related to the proposed system.

CHASSIS:

MEASUREMENTS: The measurements of the chassis (excluding the wheel system and mechanical arm) are

The weight of the chassis is approximately

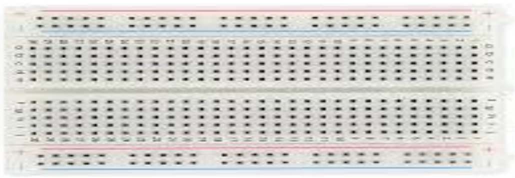
COMPONENTS INCLUDED IN CHASSIS

Arduino Uno R3 Board

We will be using Arduino Uno R3 microcontroller board to control all the electronic components used in the robot.

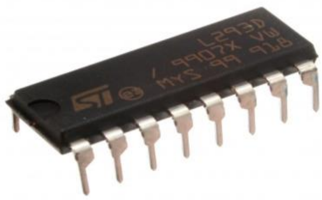
Breadboard(mini)

To help in effective wiring of all components to the Arduino Board.



L293D Motor Driver

We will be using L293D's as motor drivers to control the motors for the wheels and the



robotic arm.

Ultrasonic sensor

We will be using Ultrasonic sensor model HC -SR04 to determine the distance from the obstacles and help overcome them. It sends Ultrasonic waves in the movement direction and in case there is an obstacle, the wave bounces off the obstacle and returns to the sensor which then detects the distance between the robot and obstacle.

3 Flame sensors

We will be using IR fire sensors to detect flames which are in near proximity effectively. It

detects the IR waves radiated from flames.

MATERIAL USED

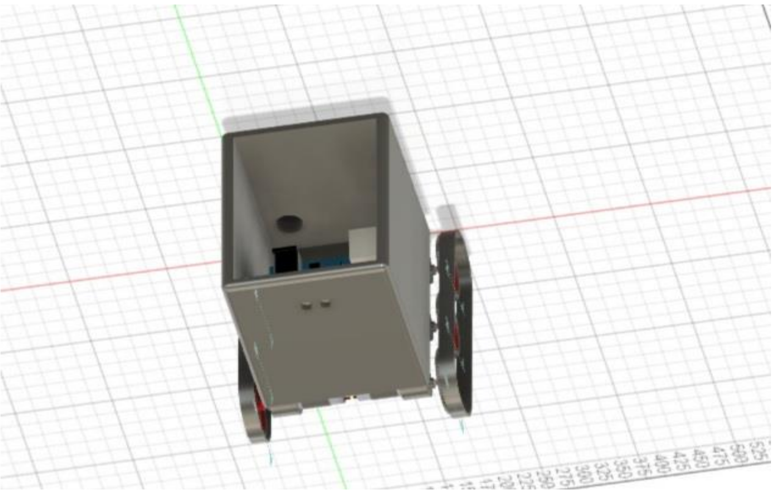
The chassis is made with Aluminium which is again plated with Polycarbonate sheets which can resist heat up to 200 degrees to shield the electronic components inside the body from the extreme heat of fire.

Aluminium body is preferred as it is lightweight and corrosion resistant but bit expensive than steel. It also adds a good look to the body of robot.

Acrylic sheet(Plexiglass) and Carbon Silicate but they are very fragile and also bit expensive. Hence, Polycarbonate is chosen as required material for heat resistant coating.

MOVEMENT OF CHASSIS:

The body moves with help of continuous track system and is mounted on top of it. The continuous track system helps it climb stairs and provides high tractions even on wet floors and helps overcome small obstacles.



DESIGN

The front face of the body has 2 holes drilled for the ultrasonic sensor and flame sensors so that it can efficiently detect the obstacles and the fire.

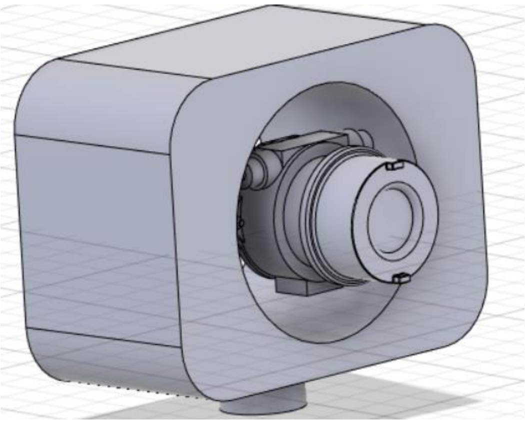
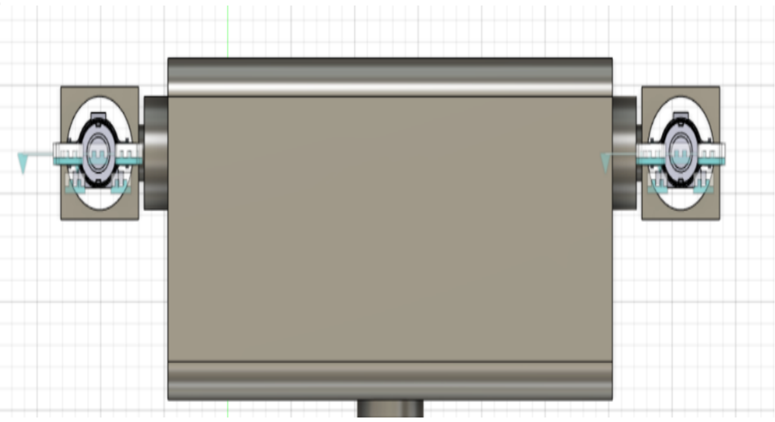
It also has a connection at the back for a water pipe to a large tanker outside the body of the robot.

VISUALISATION AND MOVEMENT:

Cameras and its Functions

The bot contains 3 cameras. One is primarily used for remote control of the robotic arm (camera-A), while the other two are used for visualising and mapping the neighbourhood of the robot while in motion and for detection of fire and its location when stationary (Cameras-B and C). Camera-A is mounted on the mechanical arm that can swivel around its base (attached to the chassis), for the ease of controlling the robotic arm without requiring the turning of the bot. While Cameras-B and C are attached to the chassis through a rig that can rotate and swivel (in order to look around for extreme heat signatures).

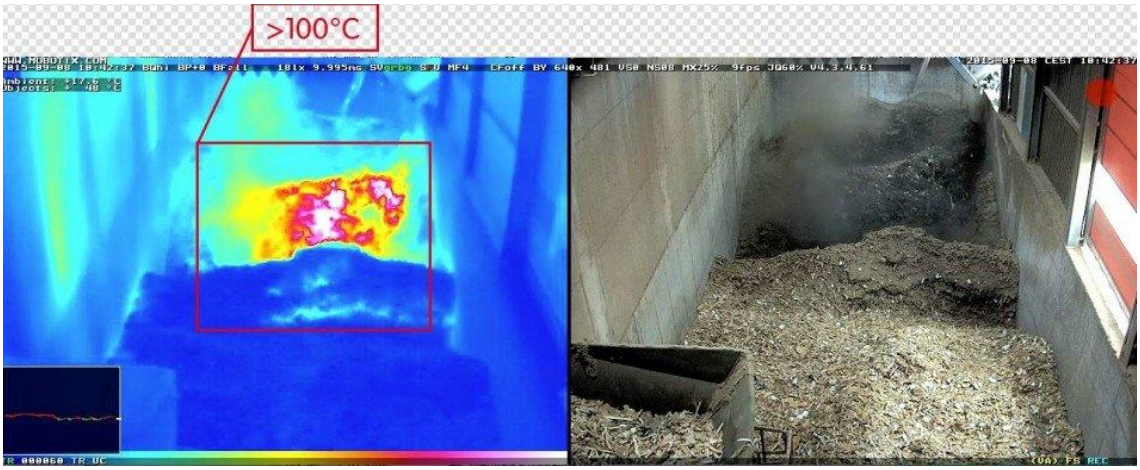
IMAGE OF CAMERAS AND MOUNTS:

Components used: include-2xThermal imaging IR cameras,1xVisible Light camera, mount for camera-A (to be mounted on arm), mount for camera-B & C (to be mounted on chassis)

FIRE DETECTION AND EXTINGUISHING:

Fire detection and extinguishing is carried out using the combination Thermal imaging and 3-D mapping. Which can be accomplished using a pair special thermal imaging cameras (Cameras-B and C) - when in autonomous mode and with the help of all 3 cameras in remote controlled mode. (The visual from Camera-A along with the markers from Cameras-B and C are used for controlling the arm).



- REASONS FOR UTILIZATION OF THERMAL IMAGING:

  1) It has a long range for fire detection of up to 4miles/ 6Km.

  2) For operations which involve the traversal inside a building on fire, the thermal cameras can act as a source of vision even if there is heavy smoke. It is scientifically proven that thermal cameras can provide viable imaging of its environment even in the event of a room completely filled with smoke which can be virtually invisible when viewed from the perspective of a normal camera.

  ***(Reference: - https://www.flir.in/discover/cores-components/can-thermal-imaging-see-through-walls/ , Thermal cameras can see through smoke and has been used by firefighters or other first responder to navigate through smoke)

The person in the doorway is concealed by smoke in the visible light spectrum, but easily detected by thermal imaging.

  3) Thermal cameras can more effectively identify the hotter regions in the flame and not just its periphery thus being able to put out the fire more efficiently, thus reduce water consumption.

4) Finally, it can easily detect humans as heat signatures even if there is very little-to-no visibility, thus allowing the firefighters to make informed decisions and save more lives.

Thus, although the initial cost of setting up thermal imaging cameras can be costlier than normal cameras the cost is justified.

NAVIGATION AND TRAVERSAL:

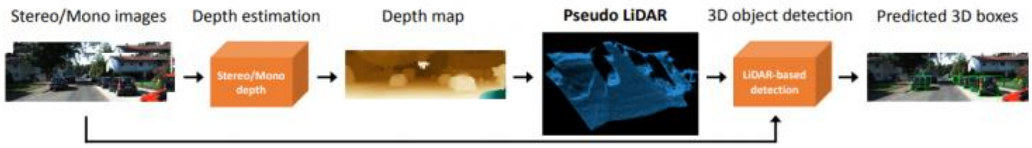
Navigation involves imaging and mapping the 3-D environment of the bot to detect obstacles and to use as eyes while operating it in remote control mode. The image capturing is done using the 2 thermal cameras (Cameras-B and C) which are spaced with a small gap between them to generate some depth perception (using the property of parallax) mimicking the human eyes. The two cameras are mounted on a housing that helps it hold the cameras in position. Further the housing is attached to the chassis in such a way that is can rotate and swivel. This functionality of the mount helps the bot to move in the desired direction without having to turn (as it required cameras pointing in a direction to move in that direction) when in run mode and will also allow the cameras to focus on fires that are higher up than the bot's plane (like in a high-rise building). Now the image is interpreted using ML models, which uses the feed of the two cameras to generate the 3-D environment of the bot, thus helping it to avoid obstacles while reaching its destination. This is similar technology like ADAS used in self-driving cars. (Eg: Tesla, McLaren etc)

- ### REASONS FOR UTILIZATION

  1.Thermal are not vulnerable to disturbances in surroundings like temperature changes and dust (which are experienced during a huge fire) unlike the usual sensors used for 3-D mapping. (like LiDAR)

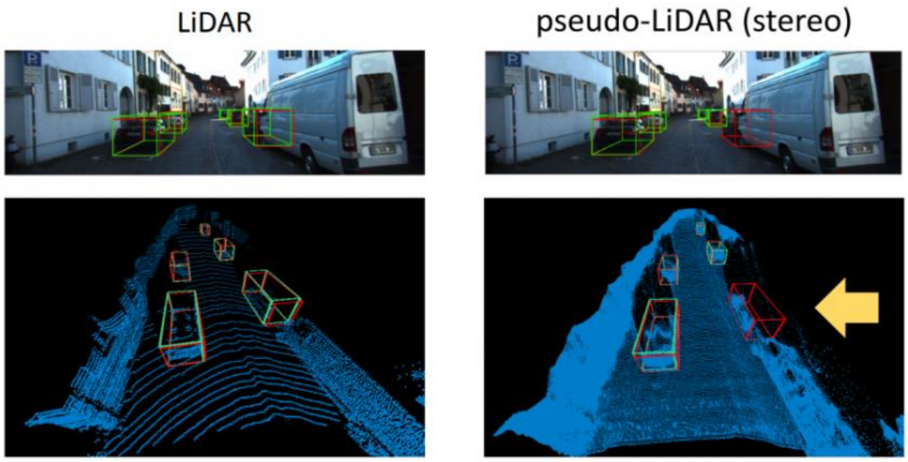
  (Reference:- https://medium.com/0xmachina/lidar-vs-camera-which-is-the-best-for-self-driving-cars-9335b684f8d- LiDAR is affected by ***wavelength stability and ***detector sensitivity***. The laser's wavelength can be affected by variations in temperature while poor SNR (Signal-to-Noise Ratio) affects the sensors in the LiDAR detector. LiDAR is also more expensive.)

The two cameras work in harmony to produce a pseudo-LiDAR like effect.



The proposed pipeline for 3D object detection.

***(Reference: https://neurohive.io/en/news/two-cameras-can-provide-lidar-like-object-detection-for-self-driving/)



2.Although it is more costly than normal cameras. Thermal cameras are more robust in terms of visual disturbances like glare, dust, smoke etc (most of which would be a present in the surroundings of a fire) and can severely impair vision and movement.

3.As it further mimics human vision it the data received by the cameras can be more easily used or comprehended thus leading to the make of more informed choices both during autonomous and remote-controlled mode.

4.Further during night times thermal cameras provide increased range of visibility (up to 4X), compared to a normal camera with illuminators. This helps in movement of the bot in both autonomous and remote-controlled modes. ***(Reference- https://www.flir.in/oem/adas/)

Thus although LiDAR sensors would have been an economically a sensible choice for 3-D mapping and navigation, since these cameras satisfy the purposes of both navigation (during run-mode) and detecting the exact distance/location of the fire by 3-D mapping and thermal imaging. This helps not only in reducing the total cost of the components but also justifies it.

OBJECT DETECTION:

The information from the camera array (Cameras B and C) and sensors is interpreted and is coordinated with the arm which is used for putting out fires and obstacle avoidance in autonomous mode. Now for detected obstacles the data from the cameras is analysed for shape and area. If there is no clear path to a vantage point, it chooses the least obstacle covered path. Now if the area of an obstacle is in a range (with upper and lower bounds) and has lots of edges (very uneven) it is moved out of the bot's path by the arm. While if it doesn't fall in either of the categories it is run over by the bot (as it is predicted to not hinder its motion).

ROBOTIC ARM:

The robotic arm of the Bot is a 6 DOF arm, used to lift objects in front of the bot that might cause toppling or make the bot loose balance. These objects are mostly uneven surfaced objects or sharp objects that are small and cannot be moved on. The bot tries to avoid all other obstacles and if the obstacle is heavy but not very tall it will try to climb over it or else it will avoid the object and move on. The robotic arm also has the nozzle of the hose attached to it, so during dousing flames the arm acts as a guide guiding the nozzle to the part where fire is present.

The robotic arm is remote controlled when it is moving to the area of fire, the cameras present at the front of the bot help in identifying potential objects that can knock over the bot putting it out of balance and these objects can be removed by the robotic arm.

Once the bot reaches the area of fire, it switches to autonomous mode identifying the places where there is a temperature spike through Thermal Imaging cameras mounted on top of the nozzle, and through 3d mapping by 2 visible light cameras the location of fire can be got and the arm position is adjusted to aim at the fire area and then the water from the source(firetruck) is pumped to the nozzle which fires water at the area of fire.

Advantages of mounting the nozzle on the robotic arm:

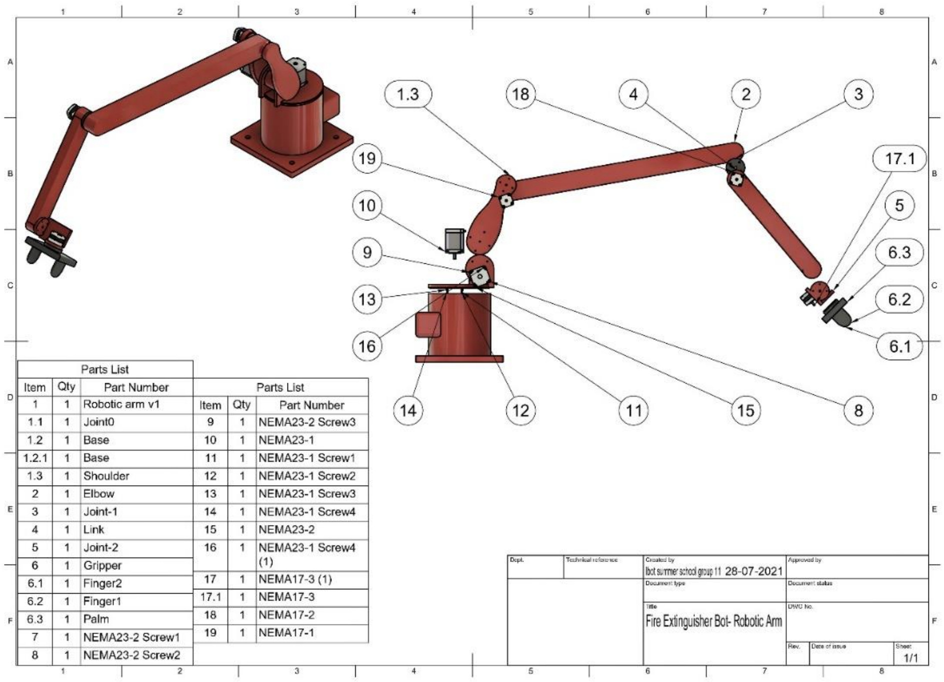
- Precise movement can be got thus it can effectively put off flames.
- No separate fixture needed for the nozzle to control its aiming.
- Allows the arm to double up as object lifter and water hose i.e arm of a firefighter.
- In cramped spaces the arm can easily navigate through and put off flames.

The pipe connecting the nozzle to the source is grounded to the chassis to minimize any recoil that the water coming out can provide.

Robotic Arm:

The robotic arm has 6 degrees of freedom, The arm is composed of a cylindrical base which can be rotated about z-axis using a Nema23 Stepper Motor. There is a shoulder component connected to the base which can rotate about y-axis using a Nema23 Stepper Motor. The shoulder is connected to an elbow component driven by Nema17 Stepper Motor about y-axis. The elbow component is connected to another link which is also driven by a Nema17 Stepper Motor about y-axis, this link is connected to a wrist component driven by a Nema17 Stepper Motor about x-axis. Then finally at the end there is a gripper which has slider movement of arms to adjust length to pick up objects. The base of the Robotic Arm is mountable on the chassis and the nozzle is attached to the robotic arm at the center of the elbow component.

There are 6 degrees of freedom in the bot, the shoulder part of the arm is a revolving joint, the elbow part , wrist and the other link are also revolving joints, The fingers of the bot are slider joints attached to the palm.



Parts List		
Item	Qty	Part Number
1	1	Robotic arm v1
1.1	1	Joint0
1.2	1	Base
1.2.1	1	Base
1.3	1	Shoulder
2	1	Elbow
3	1	Joint-1
4	1	Link
5	1	Joint-2
6	1	Gripper
6.1	1	Finger2
6.2	1	Finger1
6.3	1	Palm
7	1	NEMA23-2 Screw1
8	1	NEMA23-2 Screw2

Parts List		
Item	Qty	Part Number
9	1	NEMA23-2 Screw3
10	1	NEMA23-1
11	1	NEMA23-1 Screw1
12	1	NEMA23-1 Screw2
13	1	NEMA23-1 Screw3
14	1	NEMA23-1 Screw4
15	1	NEMA23-2
16	1	NEMA23-1 Screw4 (1)
17	1	NEMA17-3 (1)
17.1	1	NEMA17-3
18	1	NEMA17-2
19	1	NEMA17-1

The Robotic Arm is made up of Aluminum and coated with fire resistant material such as polycarbonate sheets.

Arm at initial position

Arm at Final position

AUTOMATIC PRESSURE NOZZLE:

Nozzles are one of the most important fire-fighting gears to put out fires. This nozzle is handled at the arm of the bot and it is connected to the fire hose that provides water flow that extinguishes fire. The quality of nozzle that we used ensures the effective fire extinguishing & better water flow.

Nozzle used: Automatic fire Nozzle

How it works:

The automatic nozzle concept is based totally on maintaining a near constant NP, thus producing the best possible stream. The nozzle pressure used here in this bot is 80 psi. Whatever the flow delivered by the pump operator will be controlled by the nozzle. We must have enough water to support the required gpm and have to calculate friction loss for the required flow in the hose and appliance.

Mathematical equations for calculation of pump discharge flow:

PDP=NP+TPL

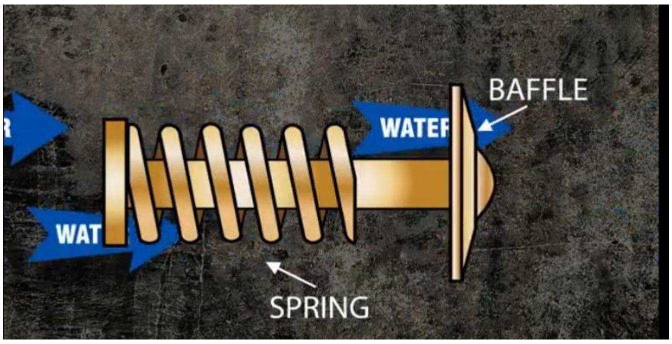
PDP=Pump discharge pressure

NP=Nozzle pressure

TPL=Total pressure loss(Hose line friction loss+ apparatus friction loss+ Elevation pressure)

Working principle:

This nozzle automatically changes the orifice to match our target fire flow at the correct nozzle pressure. The automatic nozzle has a baffle just like the a fixed or a selectable GPM fog nozzle. Automatic nozzle has a spring either inside the main waterway or within the baffle of the nozzle.



The spring of this automatic nozzle is set at a specific rate, which allows the baffle to constantly increase or decrease the orifice size to match changing fireground hydraulics. This increase or decrease in orifice size matches the target fire flow at the rated nozzle pressure.

Every automatic nozzle is rated at a constant nozzle pressure with a wide flow range reaching 75 gpm to 200 gpm based on the requirement.

Mathematical equations for the changes in orifice of the automatic nozzle:

GPM=(29.7)(d^2)(NP^0.5){for smooth bore nozzle}

GPM=Gallons per Minute

29.7= Constant

d=Nozzle orifice diameter in inches

NP= Nozzle pressure PSI

Here the bot don't need to rely on a fixed orifice size because the bot can choose its own target fire flow within the flow rating of the nozzle.

Since it is an automatic nozzle we should manually insert the pressure rating of the nozzle because it is constant throughout the entire flow.

Automatic nozzle can be used with foam and foam eductors. If the eductor manufacturer's recommendation for inlet pressure, maximum hose length and size are followed then the automatic nozzle will adjust itself automatically to the rating of the eductor. With any eductor system the nozzle valve must be fully open to prevent excessive back pressure on the eductor, which will prevent foam concentrate pickup.

The advantage of using an automatic nozzle is that any flow can be delivered by the pump operator and still be controlled by the nozzle operator. These results proves that how automatic nozzle automatically adjusts the orifice of the nozzle versus manually the bot adjusting a selector ring or changing tip, sizes of other nozzle types and coordinating with pump operator.

WHEELS:

Continuous tracks

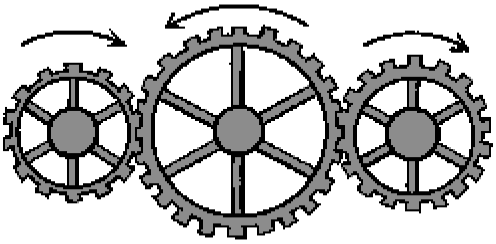
The movement of the bot can be done by continuous tracks or caterpillar tracks. Continuous track, also called tank tread or caterpillar track, is a system of vehicle propulsion in which a continuous band of treads is driven by two or more wheels. This band is typically made of modular steel plates in the case of military vehicles, or rubber reinforced with steel wires in the case of lighter agricultural or construction vehicles. The large surface area of the tracks distributes the weight of the vehicle better than steel or rubber tyres on an equivalent vehicle, enabling a continuous tracked vehicle to traverse soft ground with less likelihood of becoming stuck due to sinking. The prominent treads of the metal plates are both hard-wearing and damage resistant, especially in comparison to rubber tyres. The aggressive treads of the tracks provide good traction in soft surfaces but can damage paved surfaces. Special tracks that incorporate rubber pads can be installed for use on paved surfaces to prevent the damage that can be caused by all-metal tracks.

Drive sprocket

A sprocket, sprocket-wheel or chainwheel is a profiled wheel with teeth, or cogs,[3][4] that mesh with a chain, track or other perforated or indented material.[5][6] The name 'sprocket' applies generally to any wheel upon which radial projections engage a chain passing over it. It is distinguished from a gear in that sprockets are never meshed together directly, and differs from a pulley in that sprockets have teeth and pulleys are smooth except for timing pulleys used with toothed belts. In the case of vehicles with caterpillar tracks the engine-driven toothed-wheel transmitting motion to the tracks is known as the drive sprocket and may be positioned at the front or back of the vehicle, or in some cases both. There may also be a third sprocket, elevated, driving the track.

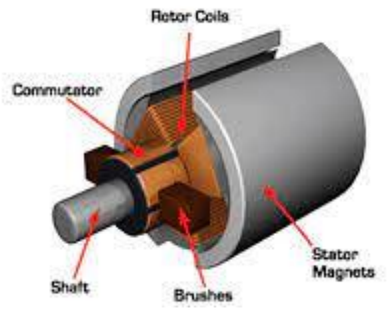
Idler wheel

An idler-wheel is a wheel which serves only to transmit rotation from one shaft to another, in applications where it is undesirable to connect them directly.



Brushed DC motors

A brushed DC electric motor is an internally commutated electric motor designed to be run from a direct current power source.. Depending on the connections of the field to the power supply, the speed and torque characteristics of a brushed motor can be altered to provide steady speed or speed inversely proportional to the mechanical load.



Advantages of tracks/Disadvantages of wheels

Drive over obstacles– depending on the terrain, a robot needs to pass small or large obstacles. For a wheel to get over a vertical obstacle, it has to be at least twice as tall as the vertical obstacle;

Advantages of wheels:

- **power efficiency** – compared with wheels, continuous tracks have high performance and optimized traction system, which is a plus in power delivery efficiency;
- **traction** – the traction is high even on slippery surfaces like snow or wet concrete;

- **moving on rough terrain** – using continuous tracks, a robot can operate on rough terrain while the wheels can get stuck. Also, the continuous band of treads can ascend and descend stairs, surmount obstacles, or cross ditches;
- **aesthetics** – the tracks look more aggressive than wheels;
- **ground impact** – a robot that moves on rubber tracks has a lower PSI on the ground. That means a less impact on the ground, especially when the robot is heavy;
- **weight growth potential** – a robot with continuous tracks has a weight spread over the entire surface of the track. This is one of the reasons that a robot with rubber tracks support a heavy load.

Disadvantages using continuous tracks:

In general, continuous tracks are not used in cases of:

lower speed – due to more friction and a complex mechanical system, the robots with continuous tracks has lower speed compared with robots on wheels;

less maneuverability – robots on tracks are less precise in maneuverability and require more power when turning;

easily break – the continuous tracks can be easily broken or dislodged than wheels;

short life – rubber tracks have a running time much smaller than the wheels;

difficult to repair – the continuous tracks are difficult to repair or replace than wheels;

Proposed model

The model will have 3 road wheel , 2 drive sprocket and one idler wheel on each side of the bot. The two drive sprocket will be situated in the front with one above the other. They wont be connected to each other, and can work together to move the connected tracks. As both of them are situated in front the bot will able to climb over obstacles more easily.

The road wheels will rotate freely with the movement of the connected tracks and act as support. There will also be suspension built into them to allow the bot to move in uneven terrains. The sprockets will be moved by brushed DC motors.

The idler wheel will be placed above, almost parallel to the top drive sprocket, and helps in maintaining the shape and orientation of the connected tracks.

The height of the wheel system should come up t0 50-60 cm so that it will be able to climb stairs as high as 30 cm.