Autonomous Stair Climbing Robot

Team Name : Tech Tequila

Institute Name: IIT Madras

Team members details

Team Name	Tech Tequila				
Institute Name	Indian Institute of Technology Madras				
Team Members >	1 (Leader)	2	3	4	5
Name	Sarin John	Siddharth Singh	Tarun Prasad	Anooj Gandham	Sai Venkat
Batch	2022	2022	2022	2021	2021
Area of expertise	Software, Control Systems	Design, Simulations	Design, Manufacturing	Product Development, Machine Learning	Design, Project Management

Functionalities of the Robot

The robot is capable of:

- ❑ Traversing staircases upto stair height of 250cm (ascent & descent) and various other similar dimensioned terrains and obstacles.
- ❑ Autonomously detecting the base of staircases and navigating to a perfectly aligned position before it.
- ❑ Automatically securely locking the payload once it has been placed into the docking area on the bot and also can release it upon reaching destination.

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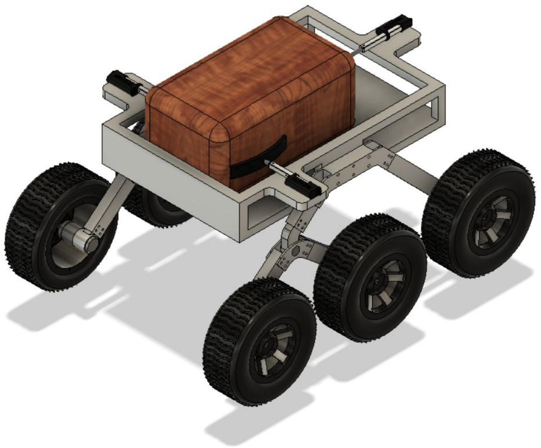


Fig 1. The proposed bot design for Autonomous Staircase Navigation.

Functionalities of the Robot (contd.)

The robot is further capable of:

- Detecting the borders of the staircase and aligning itself centrally between the borders of the staircase.
- Detecting any misalignment with the staircase it gains during its traversal and correcting it by continuously aligning to the ideal ascent/descent direction.
- Can take 90° turn at junctions and post ascending can directly reverse and descend without requiring a 180° turn thus saving time by switching to the rear camera for navigation.
- Can communicate with other robots during autonomous maneuver to prevent collisions and plan to optimise the automated task.

Robot Specifications

Technical & physical specifications:

- The robot is a 6-wheeled front bogie system with differential steering.
- It is equipped with a 2 - axis payload positioning mechanism driven by 3 linear actuators to lock the payload at a position minimising toppling possibility.
- The robot is equipped with two cameras at the front and rear for supporting staircase navigation in both directions by switching to the appropriate camera.
- Using the camera feed, staircase base detection and staircase edge detection is done through image processing with Deep Learning.
- The onboard 6 DOF Accelerometer-Gyroscope helps in accurate step counting for loading and unloading of the package besides providing yaw position.
- Equipped with IR distance sensors which along with edge detection through image processing decides the correction factor for the PID yaw-correction system.

Robot/Solution Limitations

- The IR sensors don’t come in handy with detecting proximity to a railing if present on the side of the staircase as it is not a continuous surface.
- Although designed to conveniently traverse the staircase dimension defined in the problem statement it is not dynamic to sense if an unknown staircase of certain dimensions is traversable.
- If the initial start point is such that the staircase is not in the field of view of the camera, then detecting the staircase could take time due to fixed predefined camera positions required for staircase navigation flexibility.
- Cameras require sufficient ambient lighting for proper detection of stairs.

Robot Visualization -3D Diagram/Sketch

Robot Visualization -3D Diagram/ Video

Fig 2. CAD representation of the front-bogie 6-wheeled robot system. A video with the robot's motion is here.
Video Link : https://bit.ly/3fmndrz

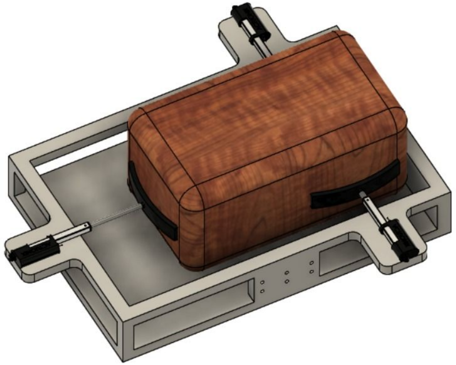


Fig 3. Payload positioning mechanism.

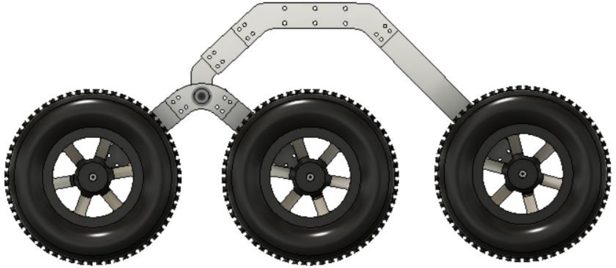
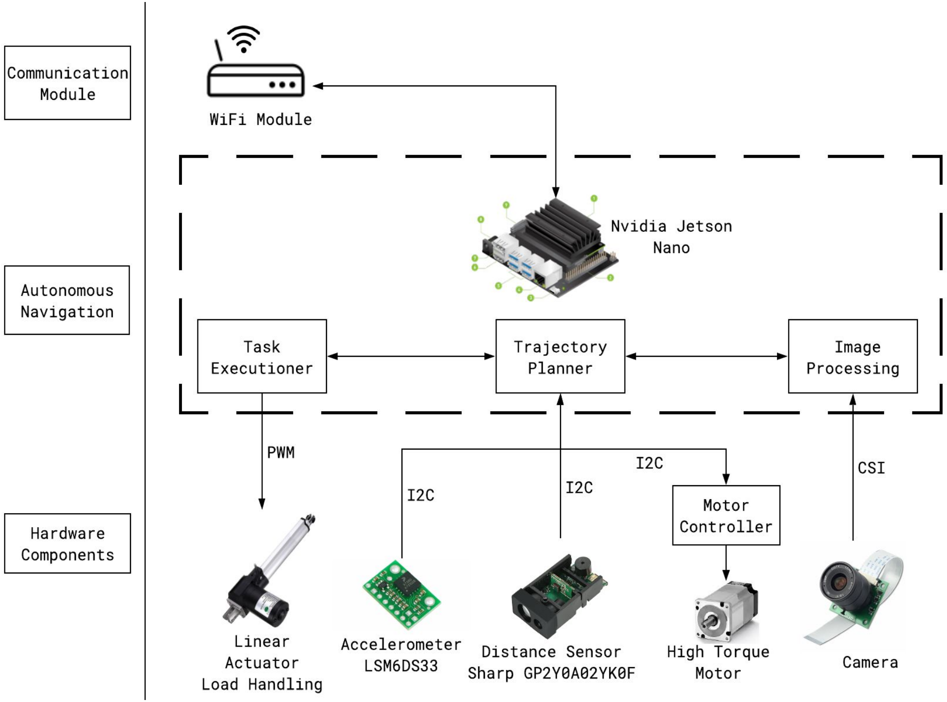


Fig 4. Front Bogie Mechanism Side View

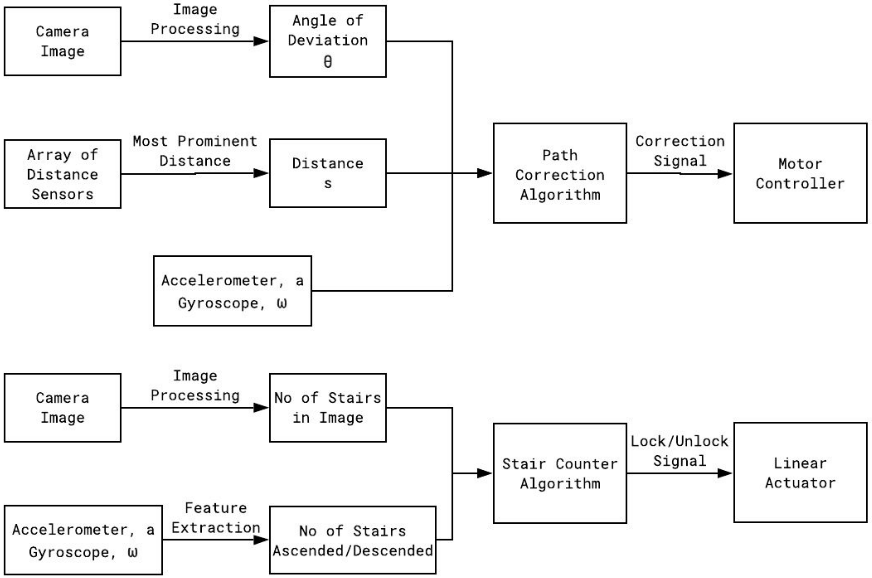
Architecture

The Bot runs using Nvidia Jetson Nano. There are IR distance sensors, Accelerometer-Gyroscope and a Camera. A WiFi module is used to communicate with the base station and other bots for efficient fleet management. Bot will be powered by rechargeable LiPo battery pack

Hardware Architecture Diagram



Sensor Decision Tree



Brief on Programming Module

Programming will be done using Python and C++.
Jetbot Image will be running in Nvidia Jetson Nano.

Software Modules:

- Stair Edge Detection Model, Path Correction Model and Stair Counter Model will be built using references from various research papers, trained locally or on cloud and implemented in bot.
- Software for data acquisition from various sensors and for the controlling of the movement of the bot will be built using Robot Operating System,(ROS version: Melodic).
- MQTT protocol will be implemented to communicate with base station and other robots.

References

- https://github.com/NVIDIA-AI-IOT/jetbot/wiki
- https://doi.org/10.1109/ICUS.2017.8278337
- https://www.mrt.kit.edu/z/publ/download/schwarze_icip15.pdf
- https://doi.org/10.3390/s16040530
- http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.78.4633&rep=rep1&type=pdf

Execution Plan

Stage	Task	Start Date	End Date	Timeline			Status
				July	August	September	
Brief Submission	Initial Research	6/30/2020	7/2/2020				Completed
	Ideation	7/3/2020	7/7/2020				Completed
	Concept Formulation	7/8/2020	7/12/2020				Completed
Prototype (Mechanical)	Traversal System Design	7/5/2020	7/25/2020				Active
	Chassis Design	7/4/2020	7/25/2020				Active
	Simulation Feasibility Tests	7/24/2020	7/30/2020				Upcoming
	Material Procurement	7/31/2020	8/5/2020				Upcoming
	Manufacturing	8/6/2020	8/25/2020				Upcoming
	Assembly	8/15/2020	8/25/2020				Upcoming
	Rework	8/26/2020	9/14/2020				Upcoming
Prototype (Electronics & Software)	Architecture Design	7/4/2020	7/25/2020				Active
	PCB design	7/26/2020	7/30/2020				Upcoming
	Component procurement	7/31/2020	8/5/2020				Upcoming
	Sensor implementation	8/6/2020	8/31/2020				Upcoming
	Stair-Detection Training	7/13/2020	8/31/2020				Upcoming
	Autonomous implementation	8/6/2020	8/31/2020				Upcoming
Systems Integration and Testing	Chassis Validation	8/25/2020	8/31/2020				Upcoming
	Traversal Validation	8/25/2020	8/31/2020				Upcoming
	Autonomous Testing	9/1/2020	9/5/2020				Upcoming
	Final Payload Test	9/6/2020	9/14/2020				Upcoming

- Experience in design and synthesis of rocker bogie for all terrain rovers (Team Anveshak) enables us in the best application of this technology to the stair climbing bot.
- Having manufactured real-life prototypes,the technical knowledge we acquired allows us to minimise error and failures in the designs.
- Having experience in Image recognition and CNNs using Embedded Hardware for previous competitions enables us to build optimized Computer Vision Applications.

Link : www.anveshak.team/

Choice of Traversal Type:

Types of Mechanisms	
Track-Type Robot	1. Offers good traction but lacks in mobility
	2.Requires a dynamic load positioning
Legged Robot	1.Lacks in traction and mobility
	2.Requires higher actuator power
Wheeled Robot	1. Good surface adaptability and decent traction
	2. Better choice in terms of traction, stability and mobility

Fig 5. Image of a previous Mars Rover Project that we have worked which was capable of traversing stairs.

Video Link:

https://www.youtube.com/watch?v=LI7Wsg5GcxQ

Wheeled Mechanism Choice:

<table>
<tr><th>6-wheeled Rocker-Bogie System with a differential mechanism about the rocker joint</th><th colspan="2">Other Wheeled Options</th><th>Selected Option: 6-wheeled Front Bogie System</th></tr>
<tr><td>1. Offers an extra degree of freedom about the rocker joint, customised for a need where only side of wheels is required to traverse an obstacle</td><td rowspan="3">8-wheeled Double-Bogie System</td><td>1. Has a very good staircase traversal capability and is very stable due to its 8 points of contact</td><td rowspan="2">1. Identical to a rocker-bogie system with a fixed rocker joint for reducing the chances of unstable roll tilts of the bot due to misaligned approach of ascent</td></tr>
<tr><td>2. Could run into issues during staircase navigation if there is a misalignment in approach when one wheel ascends a step before another</td><td>2. Has a very huge turning radius for linkage and wheel dimensions required to navigate the given steps and would not fit into the 900 mm * 900 mm quarter landing</td></tr>
<tr><td rowspan="2">3. The differential enables this wheel to ascend the obstacle easily leading to an unstable bot position</td><td>3. Would increase the cost significantly due to increased actuator requirement</td><td>2. Has good stability with 6 points of contact and the bogie joint, wheel and linkage dimensions have been optimised for 250 mm high stairs</td></tr>
<tr><td rowspan="2">4-wheeled Bogie System</td><td>1. Does not possess enough surface adaptability</td><td>3. Should posses good traction if emphasis is given on tyre traction selection</td></tr>
<tr><td>4. Thus a rocker joint coupled with a differential mechanism is not suitable for staircase navigation</td><td>2. Offers lesser points of contact</td><td>4. Capable of descent without 180° turn with the gravity assist and this is good for maintaining ideal centre of mass which will be lost with a 180° turn</td></tr>
</table>

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