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Autonomous Stair Climbing Robot

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Team members details

Team Name	Mech Rockerz				
Institute Name	Birla Institute of Technology and Science, Pilani				
Team Members >	1 (Leader)	2	3	4	5
Name	Jash Shah	Aryan Pancholi	Nikhil Bhamwani	Devansh Vaghasiya	
Batch	2018-22	2018-22	2018-23	2018-23	
Area of expertise	Software dev and Computer Vision, Embedded Electronics, Control System and Mechatronics	CAD	Software Development	Finance, Mechanical design	

Functionalities of the Robot

- Staircase detection with a 360-degree vision.
- Automatic path planning with high virtual gradient towards the stairs.
- Flexible extendable container cart for handling different sized packages.
- Fully autonomous stair climbing and descending robot.
- Automatic detection on reaching the flat surface (Quarter Landing /top/bottom).
- The bot will detect humans coming in their way. They can hence shift accordingly to make way and/or check for theft.
- High speed and accuracy both while climbing and detecting.
- Simple design and low cost production.
- Can lift heavy weights upto 10 kgs

Robot Specifications

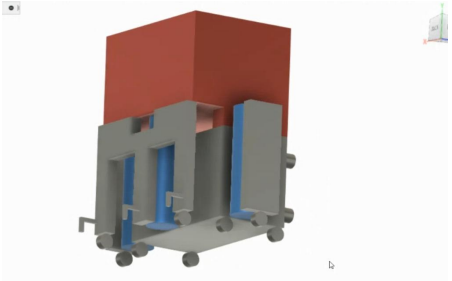
- The complete robot-cart will be of 450*250*450 mm dimension, so as to fit in the stairs.
- 3 Electrical Actuators will be responsible for vertical motion & uplifting the robot along the stairway. The structural specifications include a retracted length of 420mm for each actuator.
  Each actuator will have a stroke length of 300mm making them liable to attain an elevation of a maximum of 300mm. Each will have a base diameter of 85mm.
- The bot contains 8 wheels out of which 4 are support wheels and the other four are controlled using a stepper motor, which in turn in controlled by customized motor driver.
- 7 UV sensors, 4 in the front and 3 in the rear side are used for aiding the upward and downward motion, respectively.
- The Raspberry Pi Camera Module v2 which contains a a Sony IMX219 8-megapixel sensor, will be installed with the robot. This will have an ability to guide the robot even in low-light environments.

Robot/Solution Limitations

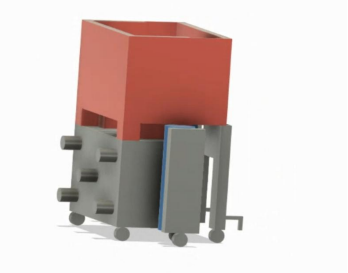
- The bot is still in the development phase and hence it is not programmed to climb(up/down) a spiral flight of stairs.

- In case the next set of stairs are not in direct vision to the bot, it won't be able to detect the flight of stairs.

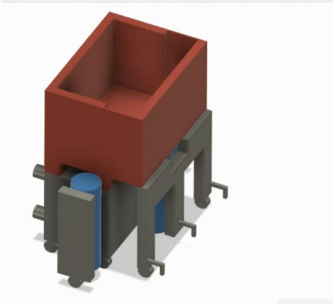
Robot Visualization -3D Diagram/Sketch



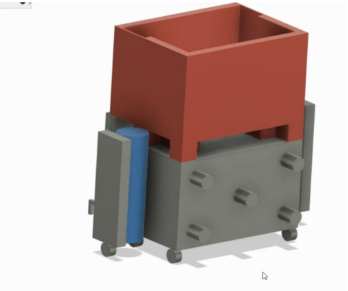
The red part is the carriage cart which carries the package. Also, the rear part of the bot, consisting of 3-pillared structure is clearly visible.



Side view of the bot. The side supports aid in balancing the centre of mass while moving/climbing

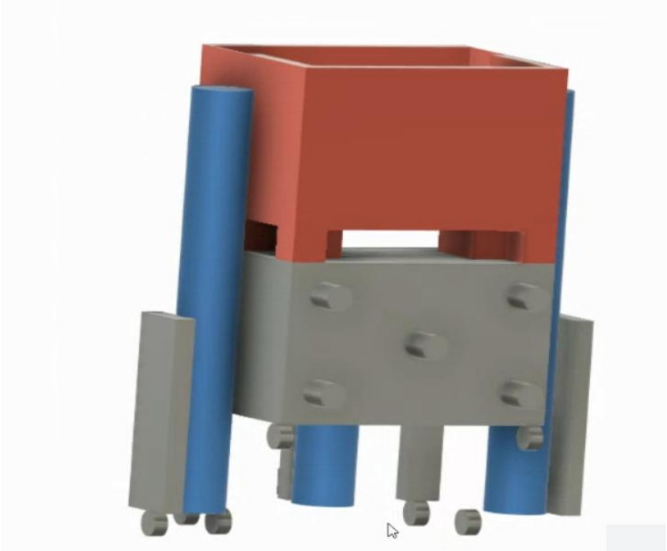


As show in the CAD, the bot has down-facing Ultrasonic sensors to aid while moving down.

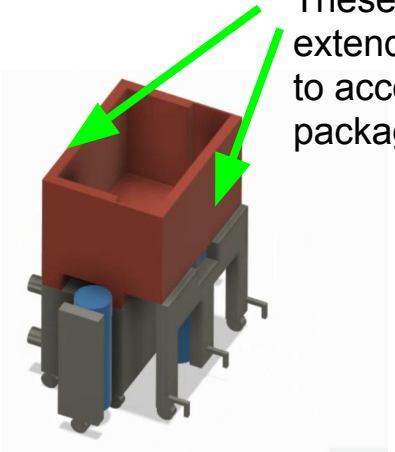


This is the front of the bot, and the 4 corners are occupied with proximity sensors, the central figure is the camera attached on a servo for flexible angle of vision.

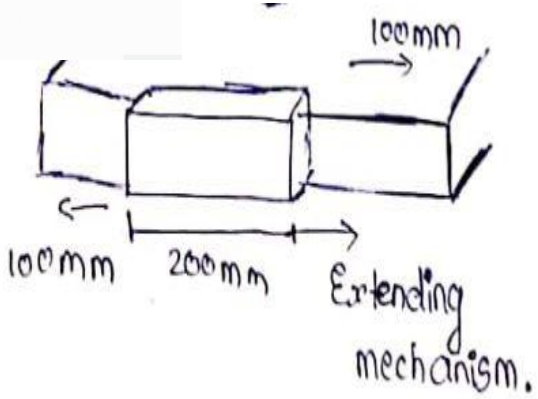
Robot Visualization -3D Diagram/Sketch



The bot's position while its climbing. All the 3 supports help the central carriage to rise. Once the bot has travelled half its length in forward direction, the side supports start rising. Lastly, the rear support rises up. The control is done using the sensors on the front and back side of the bot.



These two sides would extend like a drawer, so as to accomodate a larger package.



Architecture

Our simple but excellently planned design can work efficiently creating a low cost autonomous bot. Its main architectural features include the following:

- The bot, in itself is a simple cuboidal hollow structure, containing all the electronics.
- It has 3 supporting figures (one in the rear end and 2 on the sides) to help it climb up/down, while maintaining the balance.
- The bot has an upper carriage that carries the weight, and is extendable.
- The bot is designed in a way that all the structures support each other while climbing up/down. All this is done while creating as compact design as possible.
- To make the bot light weight, by using aluminium based sheets and hardpoint are given additional steel supports.
- The frontal UV sensors and camera modules pop out of the bot’s frontal side, so as to detect the frontal features.
- The rear UV sensors, pop out in a way that they face down and can detect if there is a step down available.

Brief on Programming Module - Stair detection

This part was programmed in python language using the OpenCV framework. For the Deep learning aspect, YOLO algorithm was used.

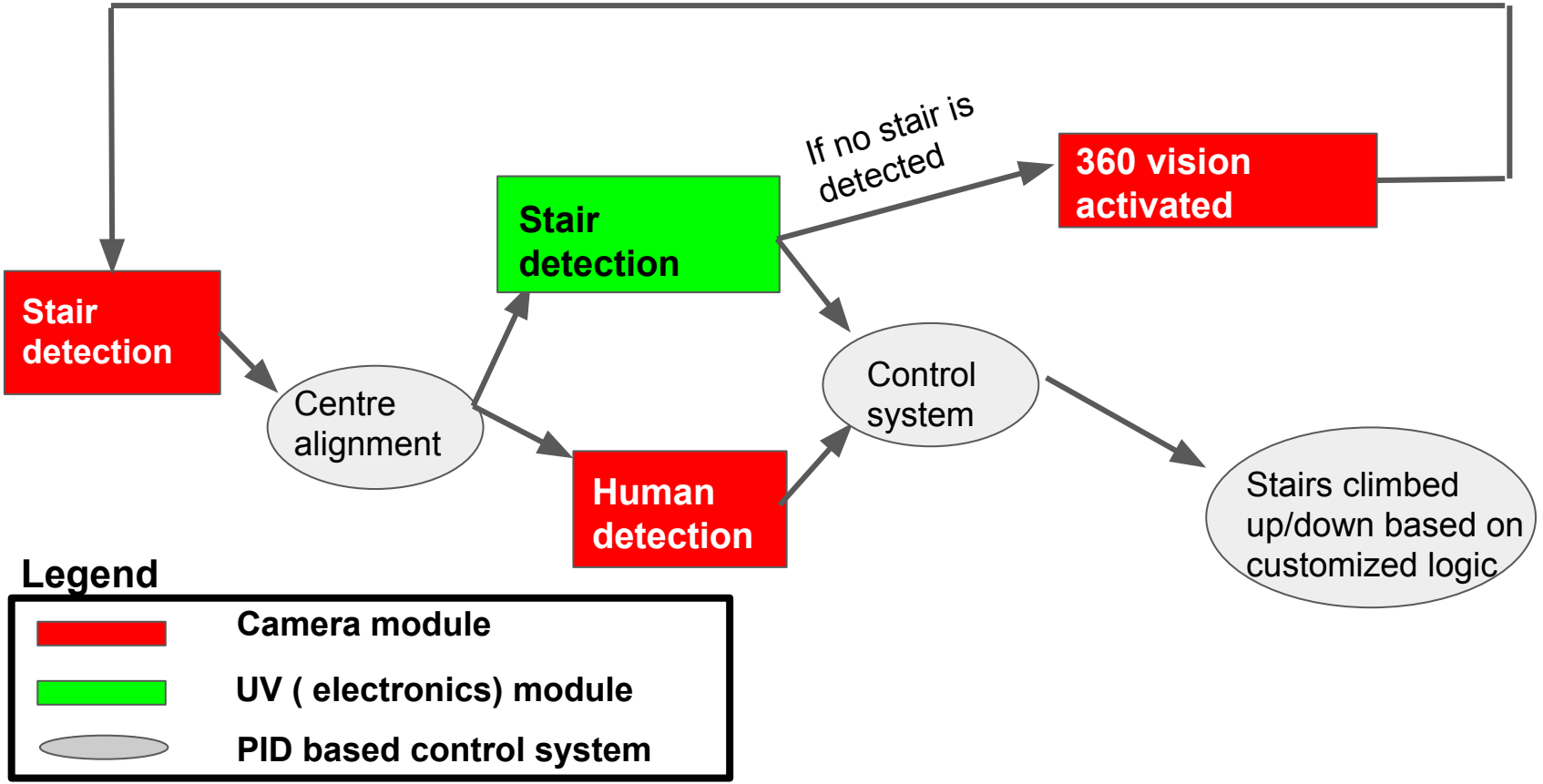
- Using YOLO the robot can easily detect the stairs in front, with bounding boxes around each stair. The accuracy of this process will be good enough to avoid any problems during the ascend/descend of the robot.
- Once each stair is detected, thresholding will be implemented to get a boundary for each contour and subsequently getting the coordinates for the center for every contour becomes easier.
- The camera module will then communicate with he motor driver and the PID algorithm will initiate the bot's approach towards the centre.
- Once the centre has been aligned, the control system will then shift the control to Ultrasonic sensors.
- The camera module will take back the control only when it has reached either the top or the bottom step.
- In the meantime, the camera module shifts to "human detection mode" where it detects any human being in front of it. This can be used to make way for other humans to access the stairs. Also, theft protection can be rendered using this additional feature.

Brief on Programming Module - Robot's Motion

The controller used would be Raspberry Pi 3 and Python language would be used.

- The robot would be having 4 control wheels controlled by a customized logic driver. This include Kalman filters and PID aided logics.
- The bot's frontal Ultrasonic sensor senses the step ahead and pulls up the bot, until it is above the step height.
- The bot would then be controlled using PID and smart control logic to bring up the side panes and the back structure later on. The 2 side parts would rise up/down together.
- Once the bot is on the highest step, the control will then be transferred back to the camera module. The bot turns 360 degrees to sense any further staircase. If not found, the bot starts its descent.
- The camera-motor-Ultrasonic sensor control system would be controlled using a customized software logic.
- While stepping down, the Ultrasonic sensor(Proximity), that is attached below the bot would be activated.

Complete executional flow chart



Execution Plan

The entire project will be developed using customized logics and prototypes. Thus, all the steps involved rigorous planning and prototyping. The plan below explains the further planned steps in brief:

- **Stage 1**: This stage initially involved establishing a detailed prototype in terms of physical design. The bot's mechanical aspects and bot balancing and maneuverability was experimented using different models. Finally, a CAD was generated.

- **Stage 2**: This step involved the technical aspects for bot control. The software and electronics involved were planned. Specific algorithms were researched.

- **Stage 3**: The next step involves simulation of the prototype to ensure the mechanisms and workings properly along with the proficiency of the blueprint structure. Simulations involving both mechanical and electronic simulations would take place to check and calibrate the control system.

- **Stage 4**: Finally, the hardware will be assembled and integrated with the control system to produce the final Stair-Climbing Robot.

All the team members are efficient in their fields, which involve software, electronics and, mechanical(structure) and mechanical (design and movements).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