



ENDSEM PRESENTATION

Human-Technology Interaction

*Chanakya Rao, Vaibhav
Chopra & Moksh Soni*



A WASTE DISPOSAL BOT

Altrus Healthcare, Dehradun



THE PROBLEM

Biomedical waste is usually contaminated and there should be as little human interaction to deal with it as possible.



THE SOLUTION

Phase One:

- A bot that can identify which bin to collect
- Collect said bin
- Using SLAM, reach destination without any problems using generated graymap over many iterations
- Deposit bin



THE SOLUTION

Phase Two:

- Bot with upgraded motors, Lithium Polymer battery, more generalized gripping mechanism
- A main dustbin attached to it
- Will shift the contents of individual garbage bins onto itself
- Will go to various preset locations to collect and dump the waste independently without any problems





Literature Review (Similar projects)

Chen, X., Huang, H., Liu, Y., Li, J., & Liu, M. (2022). Robot for automatic waste sorting on construction sites. *Automation in Construction*, 141, 104387.

<https://doi.org/10.1016/j.autcon.2022.104387>

- Designed a robot prototype for automatic on-site construction waste sorting and recycling.
- Used 3D LiDAR and RGB-D cameras for precise localization through a dual-sensor SLAM system.
- Applied Mask R-CNN deep learning for waste detection and classification in complex conditions.
- Devised a 3D grasping strategy enabling stable pickup with a 6-DOF robotic arm.
- Field tests confirmed accurate recognition, navigation, and sorting, proving feasibility for automated on-site waste recycling.

Wang, Z., Li, H., & Yang, X. (2020). Vision-based robotic system for on-site construction and demolition waste sorting and recycling. *Journal of Building Engineering*, 32, 101769. <https://doi.org/10.1016/j.jobe.2020.101769>

- Developed a vision-based robotic system for on-site construction and demolition waste (CDW) sorting and recycling.
- Integrated SLAM technology and instance segmentation to enable autonomous patrolling, detection, and handling in complex, uneven construction environments.
- Designed a robot prototype with a universal wheel base, a 6-DOF robotic arm, an RGB camera, and an RGB-D camera for adaptive movement and grasping.
- Built a CDW image database to train a computer vision model for recognizing and handling irregular waste objects such as pipes and cables.
- Laboratory and field tests verified the system's efficiency, high recognition accuracy, and reliable waste collection performance.

Wang, Z., Li, H., & Zhang, X. (2019). Construction waste recycling robot for nails and screws: Computer vision technology and neural network approach. *Automation in Construction*, 97, 220–228.

<https://doi.org/10.1016/j.autcon.2018.11.009>

- Created a robot prototype to detect, collect, and sort nails and screws on construction sites, enhancing safety and reducing material loss.
- Applied Faster R-CNN vision technology trained on a custom dataset for accurate, real-time detection in diverse backgrounds.
- Implemented a complete coverage path planning (CCPP) algorithm with omnidirectional laser scanning to navigate unknown, unstructured environments.
- Built a crawler chassis with a 4–5 DoF robotic arm, camera, multi-cell storage box, and control system for autonomous waste handling.
- Tests confirmed high detection accuracy, effective pickup, and efficient full-area coverage, supporting wider use in construction waste recycling.

Mohan, M., Kuppan Chetty, R., Mohammed Azeem, K., Vishal, P., Poornasai, B., & Sriram, V. (2021). Modelling and Simulation of Autonomous Indoor Robotic Wastebin in Webots for Waste Management in Smart Buildings. IOP Conference Series: Materials Science and Engineering, 1012(1), 012022.
<https://doi.org/10.1088/1757-899X/1012/1/012022>

- Proposes a Mobile Smart Waste Bin that autonomously manages indoor waste collection using robotic technologies and simple line-following navigation.
- When filled, the bin self-navigates to a common collection point, ensuring hygienic and efficient waste disposal in indoor environments.
- The system is modelled and simulated in Webots, integrating both physical behaviour and environmental conditions for performance analysis.
- Simulation results demonstrate that the proposed smart bin offers a superior autonomous waste management solution for smart buildings compared to existing systems.

Our Applications

- We have used a 4WD system with motors connected laterally instead of the standard shaft system. Wang used a crawler, but that was majorly for tight spaces in construction and isn't required for our use case.
- Inspiration for SLAM taken from these papers, but we haven't gone in-depth as they have. For instance, they have conducted SLAM to generate a 3-dimensional map. We have restricted ourselves to 2.
- Inspiration for sorting taken from simple web camera applications.
- Our Robotic arm currently features a single degree of freedom (up/down).

Experiment protocol

- The literature review has shown that SLAM is the most reliable method for navigation in such spaces, although it is rather difficult to conduct operationally.
- We deployed the robot in the Robotics lab to see if it could perform the 3 tasks allocated to it:
 - identify the dustbin
 - lift the dustbin
 - take it to its destination and drop the dustbin
- We set some random locations as pickup and drop and placed boundaries so that it wouldn't roam.
- Placed obstacles to see whether it would detect.

Experiment protocol

- We conducted trials of the bot at Plaksha and found several issues:
 - Our original design used the Lithium Polymer battery as a counterweight. Now that we're using wires and making the robot at half the cost, we need to place a brick or drill or something separately to act as a counterweight.
 - The tolerance of the lifting arms was lesser than expected. This is primarily attributed to the Makerspace's machine not being calibrated for our use case. We had to cut through using an angle grinder to make the robot work.
 - The LiDAR, ideally, should be mounted at an elevation higher than the robot to ensure that it has no obstructions. Now, our LiDAR was indeed above the robot, but lower than the dustbin.

Experiment protocol

- Because of this, there was a loss of torque due to friction.
- Even though the motor had torque for lifting 10 kg, we had to limit it to 7 accounting for these losses
- The motors to move the bot were very old and there was a significant torque differential between them
- The holes in the aluminium chassis weren't equally spaced on the edges. Therefore, we could not push the linear actuator system further down the middle which would have increased stability.
- Previous wiring on the bot was inconsistent

Experiment protocol

- Most of the papers have deployed the robots first in a familiar configuration, then in unfamiliar terrain to see how it would cope. However, we have manually moved the robot to generate an associated graymap as we cannot let a 25-kg robot roam free to (potentially) destroy hospital infrastructure.
- One paper did Complete Coverage Path Planning, which may be useful in our next iteration, but given that we have a restriction of ~15 meters of charging wire, futile in our current use case.
- We have had to pair with a simple web camera and Raspberry compatible LiDAR instead of really expensive RGB-D cameras (~18K).

Experiment protocol

- This experiment protocol aimed to mimic the environment at the target location so that we wouldn't have to spend any time there fixing the robot. We would merely deploy it.
- At the hospital, we conducted a survey encompassing 6 questions. We asked a range of personnel, including doctors, nurses, HR, administration & sanitation.
- The only privacy concern that can be raised has to do with the webcam. And since we're neither storing any data nor transmitting via any mechanism, this is technically taken care of.
- The only interventions in the experiment were to solve the problems that follow.

Experiment protocol

- Problems we faced at Altrus:
 - We had a pretty bad polyfix (fevikwik) leak in the suitcase. We spent quite a bit of time remedying that with acetone.
 - The tyres could not grip the floor as it was much smoother than ours. The tyres repeatedly came off the rims and this led to the robot drifting.
 - As the robot drifted, even with SLAM implemented, we had to account for this error as the robot wasn't moving as instructed.
 - Had to open both doors for the robot as it was unable to execute a perfect 90-degree turn along set lines.
 - The underlying torque differential only exacerbated our condition.

Design Components

Base & Chassis: An aluminum frame supports all components and resists minor collisions without tipping.

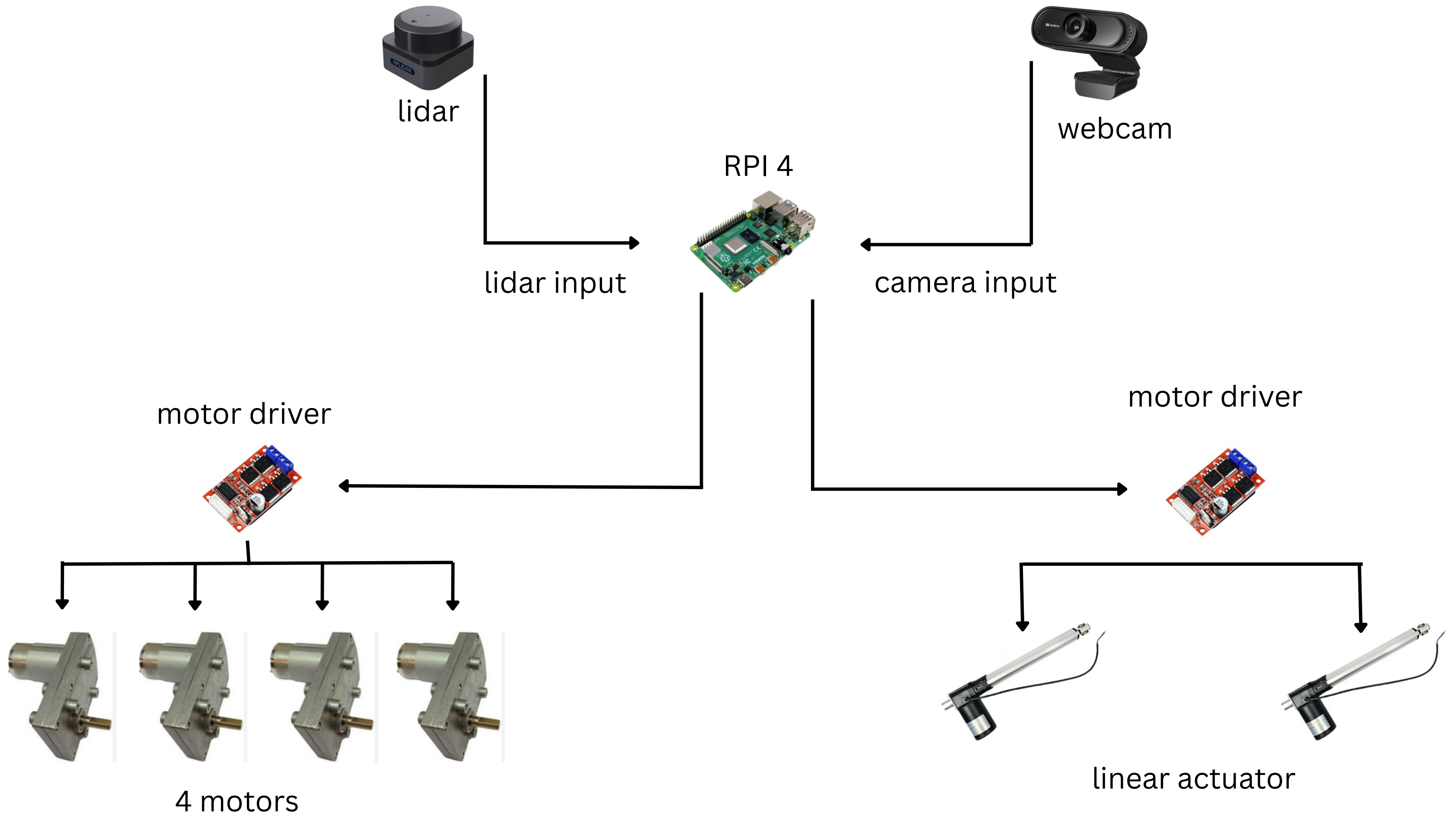
Drive System: Four DC motors connected via motor drivers enable smooth and controlled omnidirectional movement, ensuring precise navigation in narrow hospital corridors.

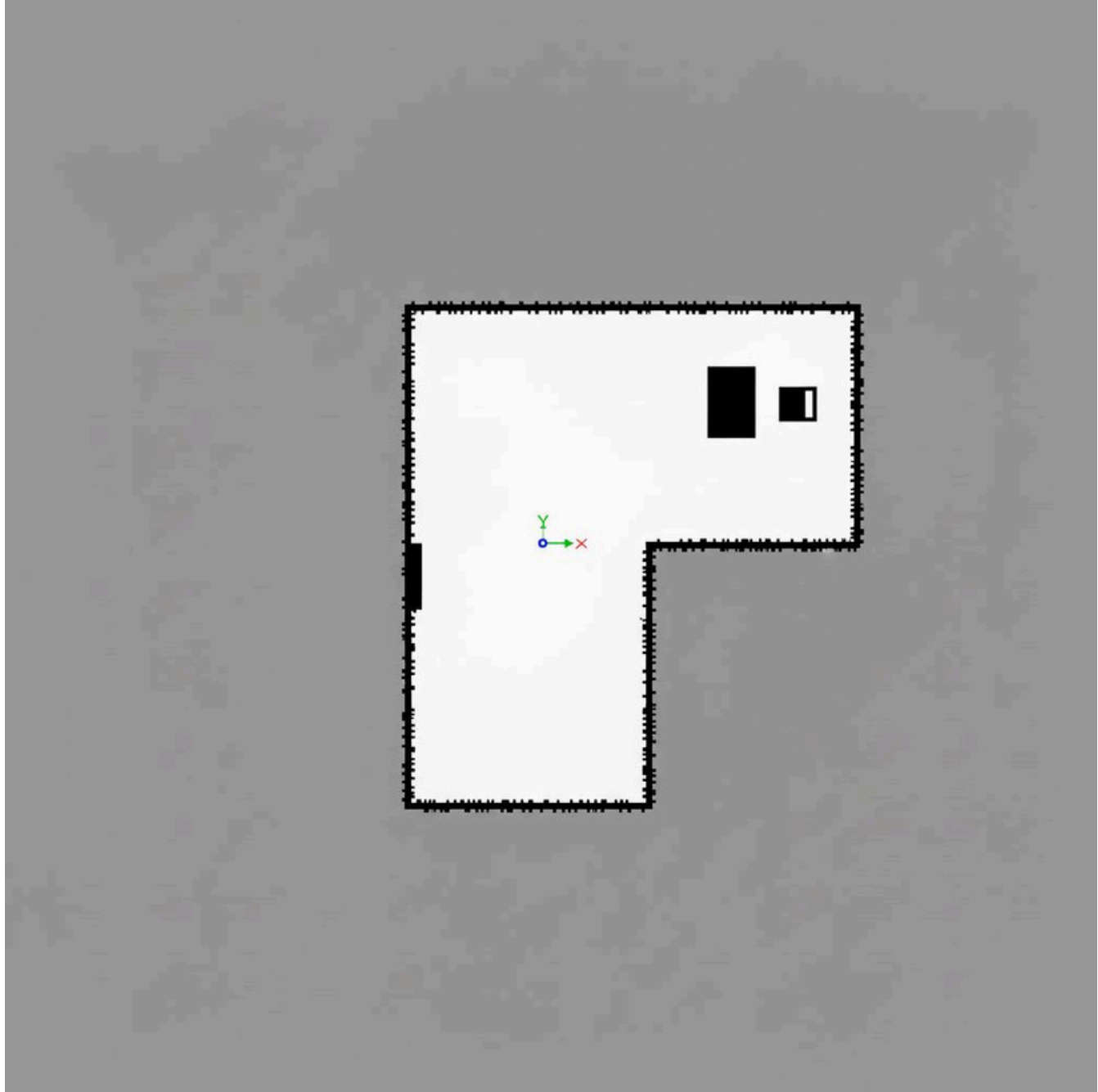
Waste Handling Unit: A system of 2 motor-powered linear actuator lifts and transfers collected waste into the main onboard bin, maintaining hygiene and minimizing manual intervention.

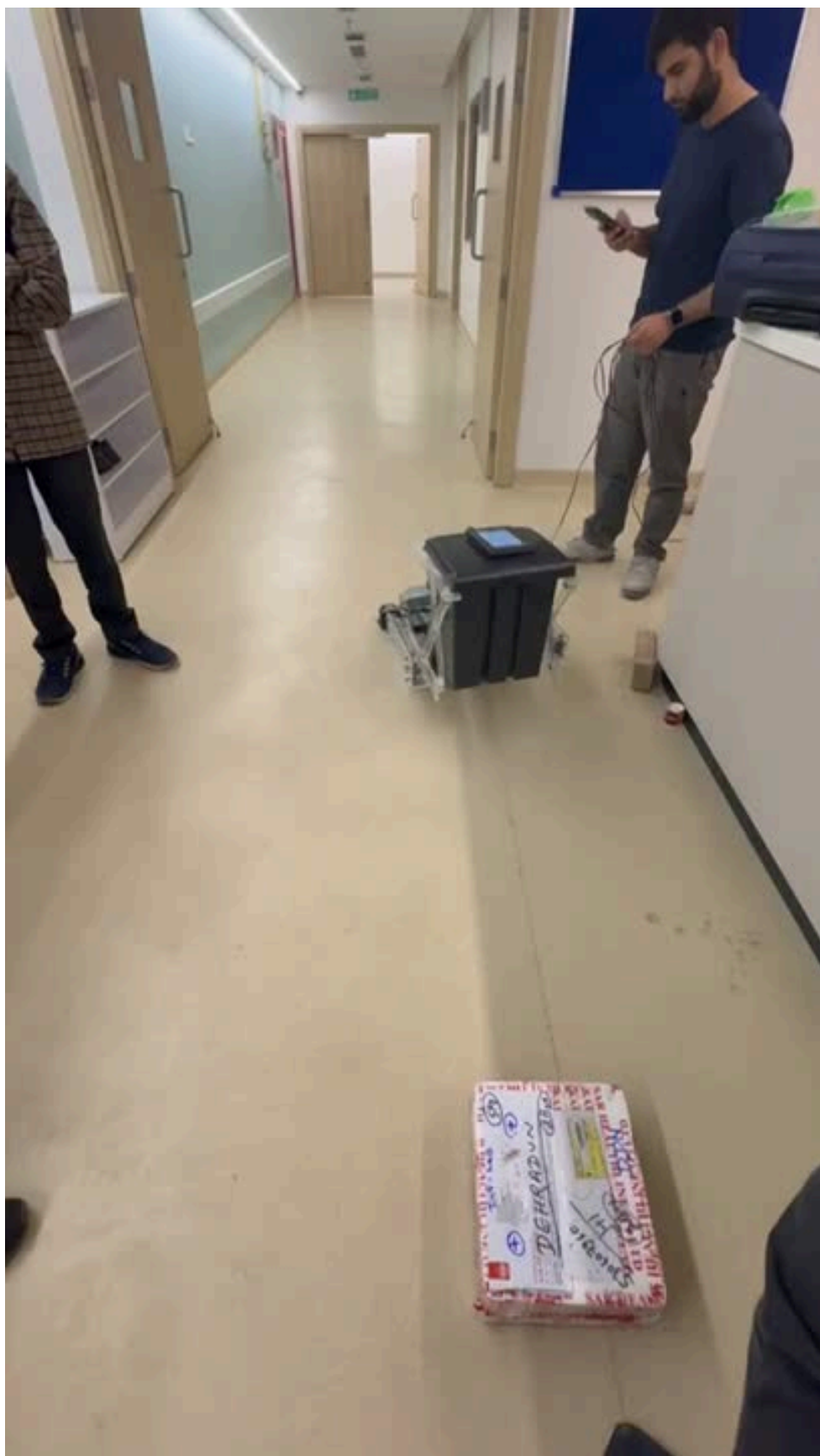
Charging system: via a ~15 metre wire.

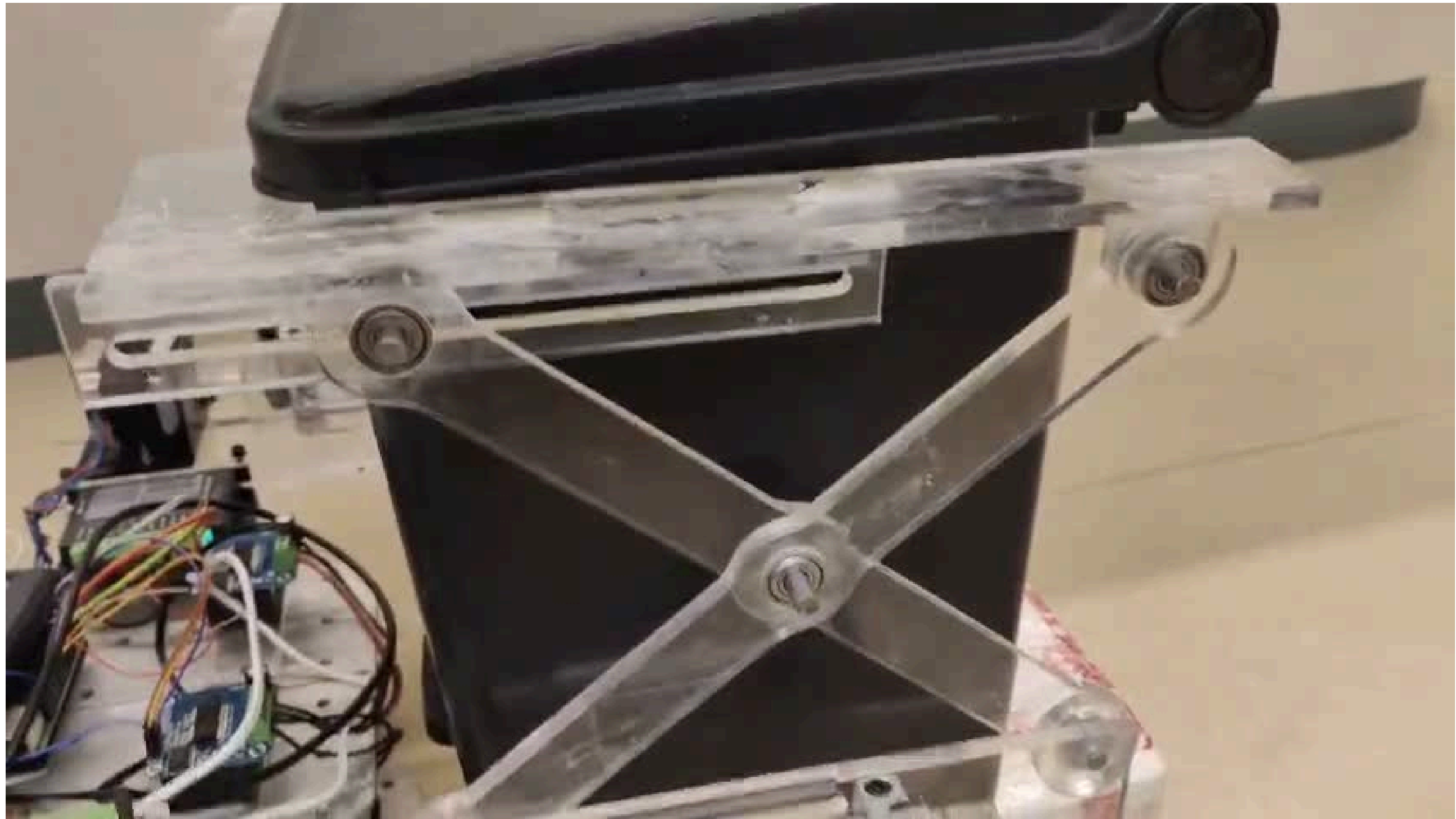
A summary of parts & algorithms

- TB6600 stepper motor driver
- BTS7690 motor driver
- Raspberry Pi 4
- A1M8 RPLIDAR 360-deg laser scanner
- YOLO v8
- Hector SLAM via ROS2
- NAV2









Performance metrics

- Our performance metrics were mostly qualitative or rated (via survey). The only quantifiable metric we could think of was no. of obstacles it crashed into.
- Fortunately, our algorithm was working precisely enough, that, even with drag, drift and torque differential, it still stayed true to its path for the most part.
- The only instance of it actually crashing was when the counterweight fell off the chassis and the dustbin sunk to the ground. We learnt to affix the counterweight better.
- Survey recorded on paper. Digital forms' responses can easily be faked, and the hospital did not have enough free staff anyhow to warrant making one.

Deployability

- The survey records that most people expected a humanoid, bipedal bot for this work.
- However, this is obviously not feasible given our deployability and budget constraints.
- Given a relatively stable environment, everyone agreed that the current speed of the bot was sufficient.
- Privacy concerns raised with webcam.
- People generally said that this current iteration fulfilled its task as a proof of concept, but expressed dismay as to its utility in its current stage.
- Appreciation for robotics in healthcare recorded.
- All in all, the robot performs the tasks required of it in this stage to a more than satisfactory degree.

Impact

- The survey records that many people think that robotics will emerge as a frontier in healthcare soon (except surgical robotics, which has already emerged), even as early as 2028.
- It records that they think experimentation like this is necessary to ensure that Indian hospitals do not play catch-up with the West.
- As said, in its current iteration, they do not think it's really useful. This is primarily due to the low tolerance of the holding mechanism, the wires and the lack of an onboard disposal system.
- However, they were very ecstatic about the next proposed iteration, and definitely agreed that this served as a valuable stepping stone.

The background features a dark blue gradient with abstract, glowing wireframe structures. On the left, a blue wireframe structure is visible, while on the right, a teal wireframe structure is prominent. The overall aesthetic is modern and technological.

THANK YOU

FOR YOUR TIME