STUDENT INTERNSHIP REPORT

Summer Workshop 2025
School of Computing, National University of Singapore

Submitted to

KIIT Deemed to be University

Reporting Period:

11th May 2025 – 21st July 2025

BY

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In Collaboration With

LIU MINGYU (Huazhong University of Science and Technology, Wuhan)
PAN YUNZE (Sichuan University, Chengdu)
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School of Computer Engineering
KALINGA INSTITUTE OF INDUSTRIAL TECHNOLOGY
BHUBANESWAR, ODISHA -751024
2025-2026

PROJECT REPORT

on

"Smart Robob:

Pretty RAD (Rapid Action Delivery)"

Submitted to

KIIT Deemed to be University

In Partial Fulfillment of the Requirement for the Award of

BACHELOR'S DEGREE IN
Computer Science Engineering

BY
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In Collaboration With
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UNDER THE GUIDANCE OF
Dr. Boyd ANDERSON & Dr. TAN Keng Yan, Colin
Department of Computer Science, School of Computing,
National University of Singapore (NUS)

School of Computer Engineering
KALINGA INSTITUTE OF INDUSTRIAL TECHNOLOGY
BHUBANESWAR, ODISHA -751024
July 2025

KIIT Deemed to be University

School of Computer Engineering
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CERTIFICATE

This is to certify that the project entitled

"Smart Robob"

submitted by

SHREYA DUBEY ROLL NUMBER 23051218

is a record of bonafide work carried out by them, in the partial fulfillment of the requirement for the award of Degree of Bachelor of Engineering (Computer Science Engineering) at KIIT Deemed to be University, Bhubaneswar. This work was completed as a part of Summer Workshop 2025, School of Computing, National University of Singapore (NUS), for the period 11th May 2025 – 21st July 2025 in Hybrid mode, under our guidance.

Date: 01 / 08 / 2025

(Dr. Boyd Anderson) (Dr. Tan Keng Yan, Colin)

Project Mentor(s)

Acknowledgements

I am profoundly grateful to **Dr. Boyd Anderson** and **Dr. Tan Keng Yan, Colin** of the *Department of Computer Science, School of Computing, National University of Singapore (NUS),* for their expert guidance and continuous encouragement throughout to see that this project achieves its target from its commencement to completion.

I would also like to extend my gratitude toward my invaluable teammates from SWS3009–Group 04: **LIU MINGYU** (Deep Learning Track– Huazhong University of Science and Technology, Wuhan), **PAN YUNZE** (Deep Learning Track– Sichuan University, Chengdu), and **QIU ZISONG** (Robotics Track–Southwest Jiaotong University, Chengdu), without whose constant cooperation and adaptability, this project would remain a pipe dream.

Finally, I sincerely thank our TAs, **Sihan** and **Siyi,** for their ingenious troubleshooting skills and unwavering support. Their timely interventions and technical insights were instrumental in overcoming several key challenges, ensuring the project progressed in a smooth and timely manner.

Shreya Dubey 01/08/2025

SHREYA DUBEY (KIIT Roll no.: 23051218 | NUS ID: t0936535)

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Smart Robob – Pretty RAD

Summary:

A prototype system, "Smart Robob", was developed for **R**apid **A**ction **D**elivery (RAD) to allow real-time vision and sensor feedback to implement a state-based control architecture (search → approach → clamp → deliver) for robust task execution and recovery from failures. It was developed as a proof-of-concept autonomous delivery robot to assist in emergency and aid-administration scenarios (e.g., elderly care, rapid medicine administration, search and rescue).

Key features include object detection using a custom-trained YOLOv7 model assisted by ultrasonic feedback for object clamping and visual servoing, ultrasonic-based obstacle avoidance, and modular subprocesses for camera, motor, and communication control. The system integrated a Raspberry Pi 4 for high-level control and an Arduino Mega for low-level motor and actuator operations, communicating with the object detection model via a custom UDP and serial-based protocol for low-latency performance.

Keywords:

YOLOv7, Visual servoing, Delivery robot, Autonomous navigation

Implementation:

Hardware–

Raspberry Pi 4, Arduino Mega, HW-130 L293D Motor Driver Shield, Raspberry Pi 5MP Camera module, HC-SR04 Ultrasonic Sensor, 4 DC Gear Motors, MG996R Servo Motor (for clamp).

Software–

Raspberry Pi OS (Raspbian–Linux), Python (high-level logic, socket programming–UDP, serial communication between Pi and Arduino), C++ (low level control), YOLOv7 (PyTorch-based object detection), OpenCV (camera feed and preprocessing).

GitHub Repository–

https://github.com/Pineapplee01/NUS-2025-SWS-Deep-Learning-Robotics

Week-wise Report

SWS3009– Group 04 (Robotics Track)

1st July 2025 – 7th July:

Per the lectures disseminated from 1st to 5th July and directives for the baseline project, the robotics and deep-learning team worked independently on their respective tasks until finally merging the functionalities on 5th July.

The robotics team focused on creating a remote-controlled 4-wheeled drive from the provided materials and chassis. The architecture adopted was as follows:

- Frontend: HTML/JavaScript interface served via Flask, enabling real-time control through Socket.IO. The camera feed and commands are rendered on different webpages.
- Raspberry Pi communicates with the onboard Arduino microcontroller over USB serial.
- User inputs, such as movement (W: forward, S: backward, A: left, D: right) or camera tilt commands (U: up, N: down), are emitted via WebSocket events and relayed to the Arduino through the Pi.
- Commands are interpreted and executed to drive the motors, adjust the mounted SG90 servo for camera tilting, or update the onboard LCD display with the latest control state.

The robot used a motor driver shield to control the DC motors for a tank-style differential drive, while an SG90 servo enabled vertical tilt control of the front-mounted camera. An I2C-connected 1602 LCD module displayed real-time commands for debugging or user feedback. The Pi was powered by a mobile power bank and designed to be responsive with low latency. Safety features such as a manual stop command and discrete directional control were built into both the Arduino firmware and the frontend interface.

Meanwhile, the deep learning team trained a YOLOv7 model on data scraped from the internet, in addition to Picam pictures of printed samples that would be used during our assessment, to detect and distinguish between 5 cat breeds: Singapura, Persian, Sphynx, Pallas, and Ragdoll. The camera feed from the Picam mounted on the vehicle was fed to the model through the webpage for inference.

The baseline model was evaluated on 8th July 2025 for its ability to be driven around remotely and recognise the cat breeds in pictures inside a maze-like setting. Our team achieved 100% accuracy in the cat breed detection. The primary challenge we faced was a latency in communication of commands to the hardware, which resulted in us overshooting turns immensely. This was accounted for in our final project, where we opted for a UDP connection over TCP and tuned the timeouts even more effectively, apart from keeping the architecture simple and robust.

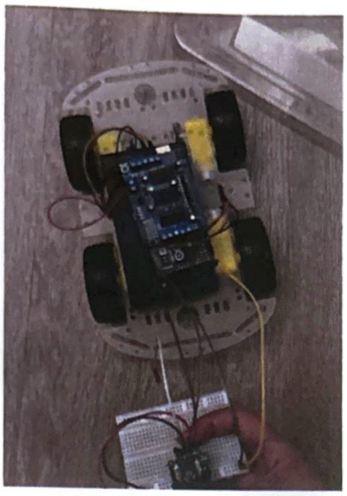

Figure 1: Joystick control– motion testing

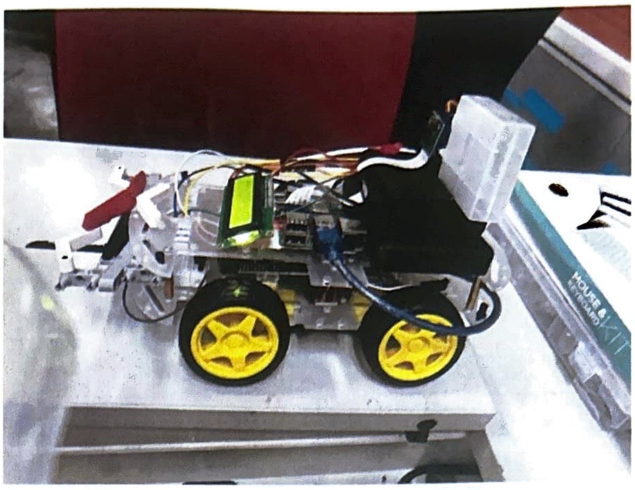

Figure 2: Cat Hunter– baseline model

9th July 2025 – 16th July 2025:

After submitting an initial proposal document detailing the intention for the final project, a series of consultations with the project mentors followed, wherein they checked our progress and helped us to set realistic and achievable targets, while maintaining the essence of the goal we wanted to achieve, in addition to providing hints to solve the obstacles we faced in development of the system.

The initial proposition was to create a hexapod robot (inspired by spiders) for rapid administration of medicine in emergency scenarios. For example, if a person goes into anaphylactic shock, then the robot should be able to identify and fetch EPIPEN and either administer the injection itself or deliver it to the person in distress.

The finalised design, keeping in mind the time and resource constraints, involved repurposing the previous chassis and installing a 3D printed pincer-claw to clamp on objects 5 cm in front of the vehicle for autonomous delivery to the object detected in the delivery phase of navigation— conserving the spirit of a rapid and autonomous delivery while being a realistic and achievable proof-of-concept.

The architecture of the final project was as follows—

System Architecture:

- Distributed three-layer architecture: host laptop (YOLOv7 object detection), Raspberry Pi (master control/state machine), Arduino Mega (motor driver/hardware control).
- Communication via UDP sockets for detection data and serial interface for motor commands, enabling concurrent processing across computational units.
- Modular design separates CPU-intensive tasks (laptop), real-time decisions (Pi), and immediate hardware responses (Arduino).

Control Logic and State Machine:

- Three-state finite state machine: searching (rotate/scan), approaching (center/navigate via visual servoing), delivering (find human target).
- Visual servoing uses camera center as reference, object bounding box center for feedback, with horizontal offset calculations driving course correction.
- State transitions triggered by object detection confidence, bounding box size (75% coverage). and ultrasonic proximity for servo-controlled clamping.

System Integration and Performance:

- Independent threads to enable concurrent object detection, motor control, and sensor monitoring while maintaining system responsiveness.
- Fault tolerance through timeout handling, graceful state transitions, and recovery protocols for vision loss or sensor errors.
- Closed-loop visual servoing implementation for autonomous object recognition, approach, grasping, and delivery capabilities.

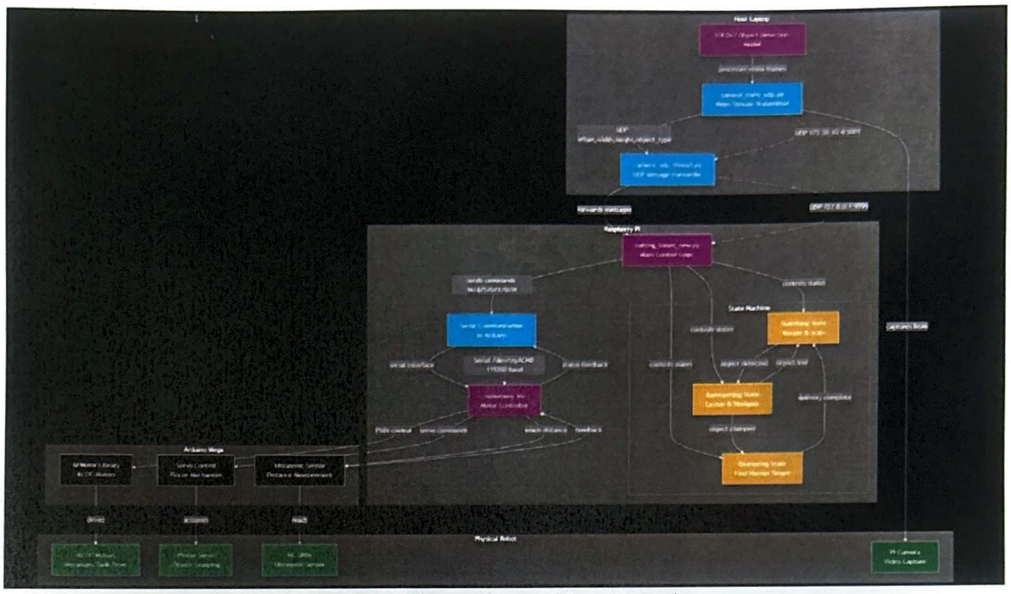

Figure 3: UML for workflow of Smart RoBob

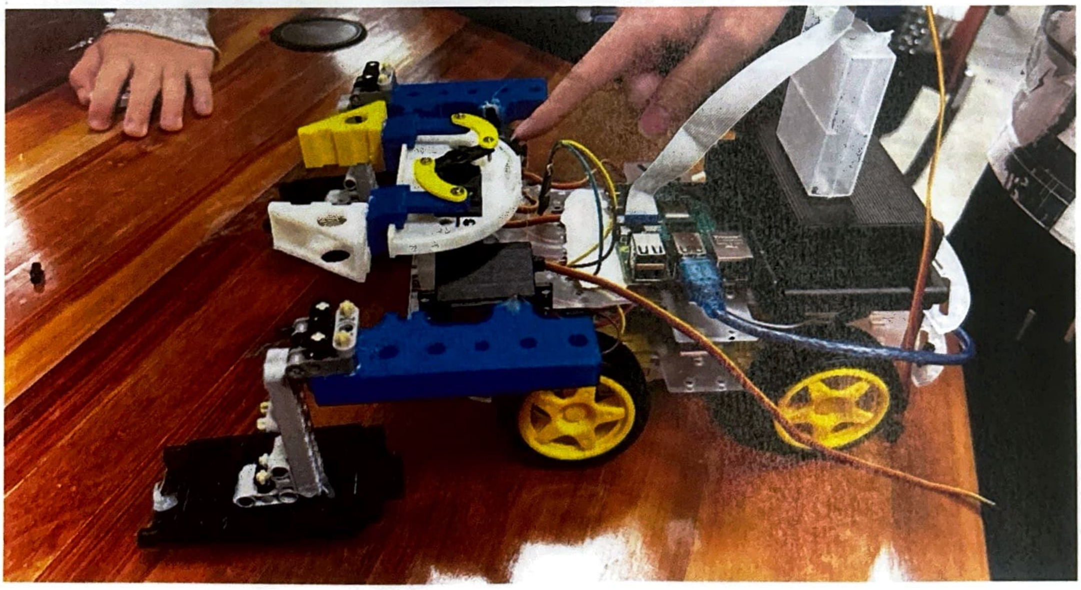

Figure 4: Finalised design for Smart RoBob with custom 3D printed servo driven pincer-clamp

By 16th July, the vehicle was able to autonomously detect and clamp onto the "Yanyan cup" and deliver it in a 6 cm radius of the "Milo" pack.

Challenges faced:

- The camera quality and positioning sometimes led to the model losing enough visual to stop detecting the object boundary, stopping just out of reach of the clamp. Thus, a failsafe was implemented where if the last instruction was to move forward with no new instructions from the Pi (meaning that visual has been lost) and the object remains at a distance between 5-7 cm for an extended amount of time from the ultrasonic sensor, the vehicle would then move forward and execute the clamping logic if the object is in grasping range.
- The Picamera module used deteriorated in performance in harsh sunlight. Using a better quality camera or shielding the module with some cardboard was recommended.
- While the drive was smooth and effective, implementing a PID would make heading correction smoother. However, the lower speeds calculated by the PID would result in stalling of the motors due to being unable to overcome floor friction. Thus, the robot still utilised the bang-bang controls with 3 default speed settings that would change according to proximity, apart from the custom timeouts that were finalised after several hours of trial and error.
- The team had designed a paddle mechanism to facilitate climbing over obstacles or stairs, but it could not be implemented due to power and time constraints.

17th July 2025 – 19th July 2025:

The robot and its functionality was evaluated by the project mentors and Tas at 11:20 AM on 17th July 2025, and subsequently showcased on 19th July 2025 at the Summer Workshop Final Showcase.

Figure 5: Final Evaluation by Siyi

Figure 6: Explanation of the underlying working

Figure 7: Team photograph with Smart RoBob after testing (from left: Shreya, Zisong, Yunze, Mingyu)

INDIVIDUAL CONTRIBUTION REPORT

SMART ROBOB

Name: SHREYA DUBEY
Roll no.: 23051218

Abstract:
The objective of the project was to design and develop a proof-of-concept autonomous delivery robot capable of identifying, fetching, and delivering lightweight objects in emergency and aid-administration scenarios (e.g., elderly care, rapid medicine administration, search and rescue). Everyday objects like cups, cola bottles, cans, etc. were used as a placeholder for the objective. The robot utilized a Picamera module for real-time visual detection and servoing, ultrasonic sensors for proximity awareness, and coordinated Raspberry Pi–Arduino communication for responsive mobility. The project showcased a modular and scalable design for autonomous service robots in homes or institutional settings.

Individual contribution and findings:
As part of the project team, my primary responsibility was to integrate the software control logic for the robot's autonomous navigation and object-handling behaviour. This included establishing a reliable communication protocol between the Raspberry Pi (forwarding the deep learning inference and running state control logic) and the Arduino (handling low-level motor commands and sensor inputs). I implemented the UDP socket to receive real-time object detection data from the camera module and developed the serial interface protocol to transmit motor commands efficiently to the Arduino.

I was also responsible for implementing the modular motion pipeline, which managed state transitions such as search, approach, clamp, and deliver. These were designed to operate robustly even under partial vision loss by introducing fault-tolerant behaviours. My planning involved writing a finite-state logic system that could handle asynchronous sensor feedback and detect clamping success using serial feedback from the Arduino, while keeping the outputs predictable. This was also the reason we elected to keep a 4-wheeled differential drive, to maintain simplicity and predictability for similar results. To this, I tuned the command timeouts to fix and compensate easily for any overshoots. Additionally, I assisted in building the initial chassis that was repurposed for the final model.

I optimized the camera communication subsystem to decode the object detection message format (offset,width,height,type) and trigger specific behaviors when recognized object types such as "cup" or "milo" were detected. Furthermore, I implemented search behavior with directional adjustments and approach logic with positional corrections based on bounding box offset and size.

Technically, I gained hands-on experience with socket programming, asynchronous sensor polling, serial communication, and embedded robotics integration using Python and Arduino C++. I also deepened my understanding of visual-servoing (vision-based navigation using bounding box estimation for object proximity and heading correction). The project emphasised the importance of modular design and concurrency handling in robotics systems, as well as the significance of simplicity of design.

Individual contribution to project report preparation:

I contributed significantly to the Design and Implementation chapter of the project report, especially sections detailing the software architecture, communication protocols, and state logic flow of the robot. I also contributed to the Results and Discussion section by analyzing the behavioral performance and failure cases during testing.

Individual contribution for project presentation and demonstration:

I was responsible for preparing and presenting the live demonstration of the robot's vision-to-motion pipeline. During the group presentation, I explained the robot's control logic, how camera feedback maps to motor behavior, and how the system handles clamping feedback. I also demonstrated live object detection and autonomous approach with real-time serial logs and camera frames to the evaluators.

Declaration

I hereby declare that the information provided in this report is true and accurate to the best of my knowledge.

Signature: Shreya Dubey 01/08/2025

SHREYA DUBEY (KIIT Roll no.: 23051218 | NUS ID: t0936535)

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