



# IJRASET

International Journal For Research in  
Applied Science and Engineering Technology



---

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

---

**Volume:** 13    **Issue:** XII    **Month of publication:** December 2025

**DOI:** <https://doi.org/10.22214/ijraset.2025.76459>

[www.ijraset.com](http://www.ijraset.com)

Call:  08813907089

E-mail ID: [ijraset@gmail.com](mailto:ijraset@gmail.com)

# Autonomous and Solar-Powered Surface Water Waste Cleaning Robot

Srajan<sup>1</sup>, Dr.Kavitha A.S<sup>2</sup>, Rajath Ganesh BV<sup>3</sup>, Sathya Narayanachari D<sup>4</sup>, Srinivas ND<sup>5</sup>

<sup>1, 3, 4, 5</sup>Students, <sup>2</sup>Professor, Dept. of Artificial Intelligence and Machine Learning, East West Institute of Technology, Bangalore-560091, Karnataka, India

**Abstract:** *Water pollution caused by floating garbage has emerged as a pressing environmental challenge affecting lakes and ponds throughout the nation. Manual removal of this debris remains labor-intensive, unpleasant, and largely impractical for widespread implementation. This reality prompted our team to investigate whether automation could provide a more sustainable solution to this persistent problem.*

*Our research and development journey involved extensive experimentation with various electrical motors, photovoltaic panels, programmable microcontrollers, and waterproof housing materials. The outcome was an autonomous floating vessel capable of independent navigation while collecting surface waste through an integrated conveyor belt mechanism. The entire system operates exclusively on solar energy, eliminating dependency on conventional power sources.*

*Comprehensive field testing evaluated performance using diverse waste materials including plastic bottles, food wrappers, fallen leaves, and styrofoam cups. The device successfully captured and contained most debris types without significant difficulty. Energy performance exceeded initial expectations, with sufficient sunlight enabling nearly continuous operation throughout daylight hours without battery depletion concerns.*

*However, development was not without challenges. Heavier debris occasionally caused mechanical jams within the conveyor system, requiring design modifications. Additionally, strong wind conditions sometimes pushed the vessel away from intended navigation paths, highlighting the need for improved stabilization features.*

*Despite these obstacles, this academic project evolved into something with genuine real-world applicability. We believe that with continued refinement, this solar-powered waste collection robot could serve as an effective tool for restoring cleanliness to polluted water bodies across the country, offering an environmentally friendly approach to aquatic ecosystem preservation.*

**Keywords:** *Autonomous Robot, Water Cleaning, Solar Powered, Waste Collection, Embedded Systems*

## I. INTRODUCTION

Last monsoon, a few of us walked past Bellandur Lake here in Bangalore, and the smell hit us before we even saw the water. Foam covered large stretches of the surface, plastic bottles clustered near the shore, and food packets floated lazily with the breeze. It looked less like a lake and more like a landfill that someone had flooded. That sight stuck with us, and when our professor asked us to pick a capstone project, cleaning up water bodies felt like an obvious choice. Now, people have tried tackling this problem before. Municipal workers row out in boats, scoop up whatever they can reach, and row back. Rinse and repeat, day after day. Except they never really catch up—garbage accumulates faster than hands can grab it. Some cities brought in diesel-powered cleaning boats, which work faster but guzzle fuel, spew exhaust, and cost a fortune to maintain. Neither option scales well, and neither runs without constant human attention.

Robots seemed like a better bet. Machines don't get tired, don't complain about smelly water, and don't need lunch breaks. Slap some solar panels on top, and suddenly you've got something that feeds itself energy straight from the sky. The idea sounded almost too good, so we decided to actually build one and see what happens. Our goals were modest but clear. First, make something that floats without tipping over. Second, give it motors strong enough to push through water but efficient enough not to drain batteries in ten minutes. Third, attach some kind of scoop or conveyor that grabs floating junk. Fourth, wire up sensors so the robot can dodge obstacles on its own. Fifth, keep costs low enough that a small-town panchayat could realistically afford one someday. This work traces our attempt to meet those goals, the lessons we learned from both progress and missteps, and the possibilities that opened up as the project evolved.

## II. LITERATURE SURVEY

Rather than jumping straight into prototyping, we spent the first stretch simply reading through past work in this area. Seeing what others had already explored helped us figure out which ideas were worth building on and which ones we could safely skip.

Tatar's group published a paper describing a solar-powered debris collector concept [1]. Their calculations on panel sizing and motor power gave us a useful starting point. But here's the catch—they never actually built anything physical. All theory, no wet feet. We appreciated the math but wanted to go further and dunk a real prototype in real water.

Manikanda and Rajasekaran went the IoT route, adding smartphone connectivity so operators could track their robot remotely [2]. Cool feature, no doubt. Problem was, their sensors choked whenever water got murky. Since most polluted lakes pretty much define murky, this seemed like a dealbreaker for practical use. We filed away the remote monitoring idea for later but focused first on making sure our collection mechanism worked regardless of water clarity.

Subhashini's team built a working model that actually collected debris in test pools [3]. Finally, something tangible! Unfortunately, their bin filled up super-fast, forcing constant trips back to shore for emptying. Great for demos, less great for cleaning anything bigger than a backyard pond. We made a mental note to design a bigger storage compartment.

Megalingam and colleagues simulated a tank-cleaning robot inside Gazebo software [4]. Their path-planning algorithms looked slick—neat zigzag patterns covering every corner. But simulations assume still water, flat bottoms, and predictable boundaries. Real lakes laugh at such assumptions. Waves slosh, winds gust, and shorelines curve in weird ways. We borrowed some of their algorithmic thinking but braced ourselves for messier reality.

Kong's research pushed into AI territory, using cameras and neural networks to identify trash [5]. Impressive tech, honestly. The downside? Expensive hardware, heavy computation, and software complexity that would terrify most municipal maintenance crews. We shelved the computer vision dream for version two and stuck with simpler sensing for now.

Patterns emerged from this reading. Many designs stayed on paper. Those that got built often struggled with storage capacity, sensor reliability, or cost. Almost nobody combined solar power, autonomous navigation, and mechanical collection in one affordable package. That gap became our target.

## III. PROBLEM STATEMENT

Trash floating on the surface may look harmless at first, but its impact becomes painfully clear when the surrounding water can no longer support healthy aquatic life. Plastics block sunlight that underwater plants need for photosynthesis. Decomposing organic waste sucks oxygen out of the water, suffocating aquatic life. Microplastics work their way into the food chain, ending up on dinner plates eventually. Clogged drainage channels cause flooding during monsoons. Property values tank near polluted lakes, hurting local economies.

Current cleanup approaches suffer from hard limits. Manual labor puts workers in contact with contaminated water, risking infections and skin diseases. Hiring enough people to maintain continuous coverage blows municipal budgets. Human crews can only work during daylight and fair weather, letting garbage pile up overnight and during rains. Motorized boats burn diesel, adding pollution while supposedly removing it—ironic, right? Existing solutions rarely scale; what works for a temple pond fails miserably for a sprawling urban lake. We wanted to flip this script. Imagine a robot that cleans rain or shine, runs on free sunshine, steers itself without a driver, and costs peanuts to operate once you buy it. That vision guided every choice we made.

## IV. PROPOSED SYSTEM

Our machine floats on twin hulls, cruises using propeller thrust, scoops debris onto a conveyor belt, dumps the haul into an onboard bin, and powers everything through rooftop solar panels. Three subsystems—mechanical, electrical, and control—work together to make this happen.

### A. Mechanical Bits

Stability mattered above all else. A robot that tips over every time a wave hits becomes useless pretty quickly. Catamaran hulls solved this nicely. Two parallel floats spaced apart create a wide base that resists rolling. We cut hull pieces from thick polyethylene sheets—the same plastic used in water storage tanks—because it handles sun, water, and knocks without corroding or cracking.

A flat deck bridges the gap between hulls, holding everything else. At the fronted edge sits the conveyor assembly: a rubberized mesh belt stretched between two rollers, angled downward so the lower edge dips into the water while the upper edge rises above deck level. Debris floating ahead gets scooped onto the belt and carried upward, eventually tumbling into a collection bin behind the conveyor. Drain holes let water escape while solids stay put.

Propulsion comes from two brushless motors at the stern, each spinning a small plastic propeller. Running both at equal speed pushes the robot straight ahead. Speeding up on wheels slows the other cause turning. Reversing both back the robot up. Simple, effective, no rudders needed.

**B. Electrical Bits**

Two monocrystalline panels sit on top, angled slightly so rainwater slides off and low sun still reaches the cells. Together they crank out around forty watts under bright skies. An MPPT charge controller squeezes maximum power from whatever light hits the panels and feeds it in to a lithium iron phosphate battery pack. We picked this battery chemistry because it handles heat well, lasts thousands of charge cycles, and won't catch fire if something goes wrong—a comforting thought when electronics sit surrounded by water.

From the battery, power flows through a distribution board with fuses protecting each branch. Motors get their own high-current line; delicate electronics get a separate regulated supply so voltage stays rock-steady even when motors draw sudden bursts. Wires run through sealed conduits, connectors use waterproof plugs, and every junction hides inside a silicone-sealed enclosure.

**C. Control Bits**

An ESP32 microcontroller acts as the brain. This little chip packs WiFi, Bluetooth, and enough processing muscle to handle sensor readings and motor commands without breaking a sweat. Ultrasonic sensors mounted around the hull ping nearby objects and measure how long echoes take to return, translating delay into distance. A digital compass chip tells the robot which way it faces, helping maintain headings despite drift.

When we want position tracking, a GPS module plugs in, reporting latitude and longitude every second or so. For communication beyond WiFi range, a LoRa radio swaps in, reaching shore stations several kilometers away. All components talk to the ESP32 over standard serial connections, keeping wiring straight forward.

Firmware stitches everything together: reading sensors, deciding where to steer, adjusting motor speeds, running the conveyor, monitoring battery voltage, and occasionally shouting status updates to whoever's listening.

**V. METHODOLOGY**

Building something that works in water took more sweat, more failed experiments, and more trips to the hardware store than we initially expected. Here's roughly how we attacked the problem.

**A. Pinning Down Requirements**

Before cutting any plastic or soldering any wires, we sat down and listed what the finished robot absolutely had to do:

- Float upright even when waves rock it or wind shoves it sideways.
- Move in any direction—forward, backward, left turn, right turn—under either remote control or its own decisions.
- Sense obstacles at least a meter away and dodge them without human help.
- Grab typical floating junk: bottles, wrappers, foam containers, plant debris.
- Run at least four hours on a sunny day without needing a wall socket.
- Survives splashes, drizzle, and the occasional accidental dunking of non-critical parts.

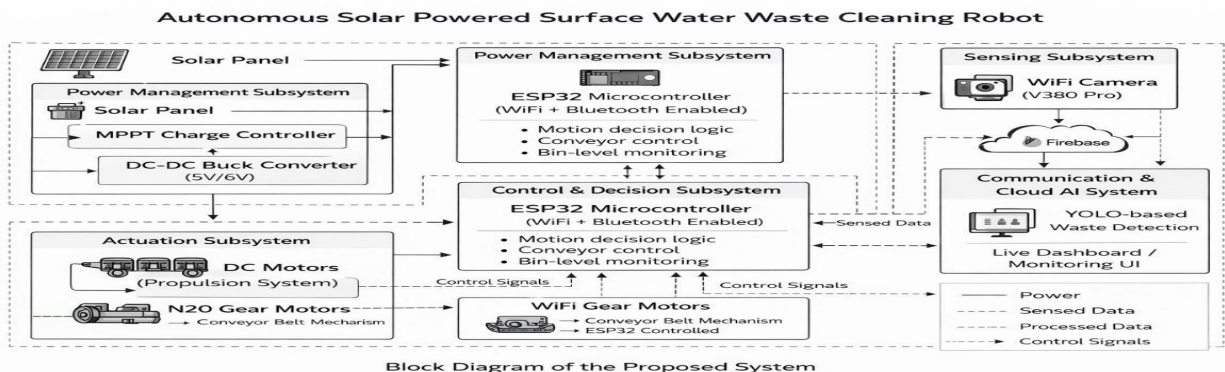


Figure 1: High-level system architecture of the autonomous water cleaning robot (placeholder)

### B. Splitting Up Work

Three parallel tracks kept progress moving. One subgroup handled mechanical construction: hull fabrication, deck framing, conveyor assembly, propeller mounts. A second subgroup tackled electrical wiring: solar panels, batteries, charge controllers, power distribution, motor drivers. The third subgroup wrote code: sensor libraries, motor control routines, navigation logic, communication handlers.

Weekly sync meetings brought everyone together to bolt parts onto the evolving prototype, test integrations, and troubleshoot mismatches. When the conveyor motor's power demands fried an undersized fuse, we caught it early and swapped in a beefier one before lake trials.

### C. Writing Firmware

Code lives on the ESP32, written mostly in C++ with Arduino libraries handling low-level details. We organized the code base into modules, each responsible for a distinct job:

- **UltrasonicDriver:** triggers pings, times echoes, filters out noise spikes caused by waves.
- **CompassDriver:** reads heading values, applies calibration offset to correct for nearby metal parts
- **MotorDriver:** converts desired speed and direction into PWM signals for motor controllers.
- **ConveyorDriver:** starts and stops the belt motor, monitors current draw to detect jams.
- **PowerMonitor:** samples battery voltage, estimates remaining capacity, triggers low-power mode when needed.
- **Communicator:** sends status packet over WiFi or LoRa, receives commands from shore
- **Navigator:** Implements patrol patterns, handles obstacle reactions, tracks progress across the water body.

A simple scheduler cycles through tasks in a fixed order, ensuring sensors get read often enough and motors get updated smoothly. Nothing fancy, but reliable.

### D. State Machine Thinking

Rather than tangling ourselves in nested if-statements, we structured robot behavior as a finite state machine. Each state represents a mode:

- **Boot:** Power-on checks, sensor calibration, GPS fix acquisition.
- **Idle:** Sitting still, waiting for a start command or scheduled patrol time.
- **Patrol:** Following a cleaning pattern across the assigned area.
- **Avoid:** Maneuvering around a detected obstacle before resuming patrol.
- **Stuck:** Attempting to free itself if forward progress stalls unexpectedly.
- **Return:** Heading back to dock when bin fills or battery drops.
- **Dock:** Aligning with shore station for emptying and charging.

Transitions depend on sensor readings, timers, and operator commands. For example, spotting an obstacle closer than half a meter flips the state from Patrol to Avoid. Clearing the obstacle and waiting two seconds flips it back.

**Channel Pruning:** We analyzed filter activation magnitudes and removed channels contributing minimally to predictions. This reduced parameter count from approximately 80 million to 45 million.

**Post-Training Quantization:** We converted the pruned model to TensorFlow Lite format with 8-bit integer quantization. This reduced model size to 24.5 MB. Validation accuracy degradation from quantization was less than 0.3%.

### E. Choosing Navigation Patterns

Covering a water body efficiently requires more than just wandering randomly—though random wandering works as a fallback. We coded three patterns:

- **Back-and-forth:** The robot travels straight across, turns around at the far edge, shifts sideways a bit, and heads back. Like mowing a lawn. Great for rectangular ponds.
- **Expanding spiral:** Starting near the center, the robot traces ever-larger circles outward. Suits round or oval lakes.
- **Random bounce:** Pick a random heading, go until an obstacle appears, turn a random angle away, repeat. Handles irregular shapes where systematic patterns get confused.

Obstacle avoidance overrides pattern-following whenever proximity sensors yell "danger." Stop, back up, swing left or right, then resume.

## VI. SYSTEM IMPLEMENTATION

### A. Putting Hardware Together

Assembly happened in our college workshop over several weekends. Major steps included:

- Marking and cutting hull pieces from twelve-millimeter polyethylene sheet using a jigsaw.
- Heat-welding seams with a plastic welding gun, then testing for leaks by submerging in a bathtub.
- Bolted aluminium angle stock into a rectangular deck frame and screwing it onto the hulls.
- Mounting conveyor rollers on bearing blocks at the front, stretching rubberized mesh belt between them.
- Attaching propulsion motors to stern brackets, coupling shafts to propellers through waterproof seals.
- Wiring the battery pack, charge controller, distribution board, and motor drivers inside a sealed plastic box.
- Mounting the ESP32, GPS module, and LoRa radio on a separate board inside another sealed box.
- Installing ultrasonic sensors behind acrylic splash shields at front and sides.
- Running motor cables through waterproof glands, double checking every seal with a silicone goop.

The finished robot weighed about eighteen kilograms dry, displaced enough water to float with comfortable freeboard, and looked vaguely like a tiny catamaran ferry with a trash compactor strapped to its nose.

### B. Developing Software

Coding happened in parallel with hardware, using a desktop simulation to test logic before deployment. We faked sensor inputs, watched how the state machine responded, and squashed bugs without risking a swim to retrieve a malfunctioning robot.

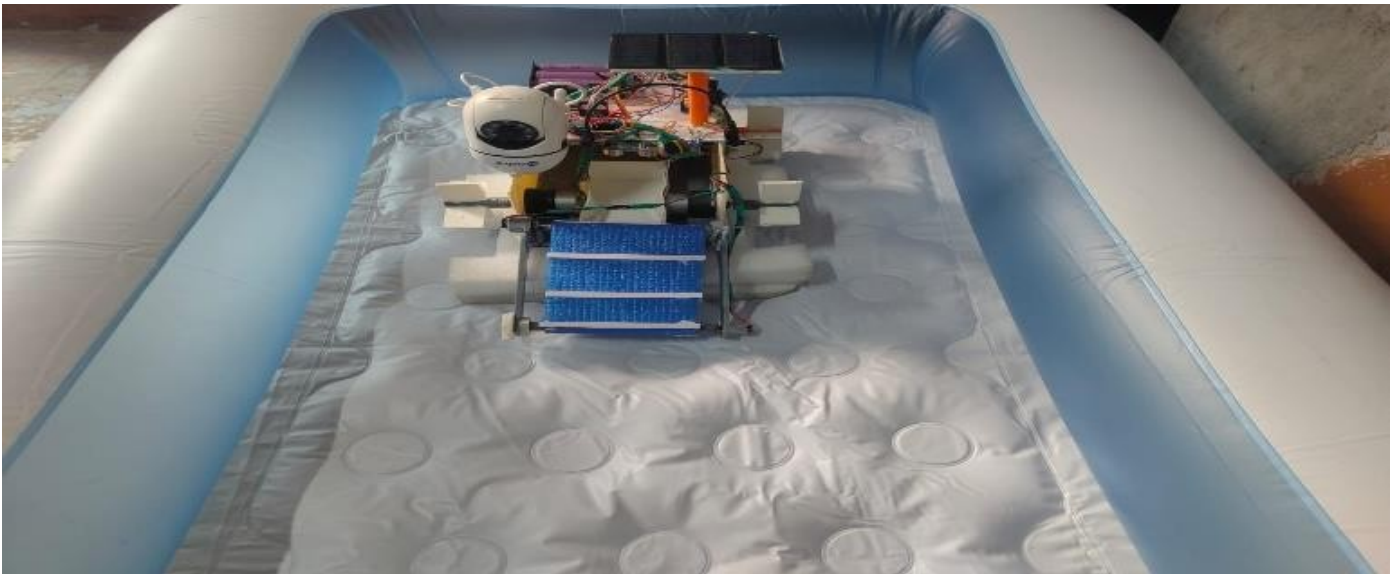


Figure 2: Finished prototype floating during early testing, conveyor belt and solar panels visible

Once confident, we flashed firmware onto the ESP32, powered up the prototype on dry land, and verified that motors spun, sensors returned sane values, and communication links connected. Only then did we dare carry the thing to water.

## VII. RESULTS AND DISCUSSION

### A. Stability in Water

The twin-hull layout turned out to be far steadier than we imagined. We even pressed down on one side just to see how it behaved, and it popped right back into place without fuss. Even when the breeze pushed against it, the platform stayed level enough that we never worried about it tipping.

### B. Handling and Movement

Figure shows the observed steering and movement behavior of the water robot during testing. Steering through differential thrust worked better than expected. Smooth turns were easy, while tight bends needed one motor to back off for briefly reverse.

The control software responded quickly, and although the robot wasn't fast—about a meter per second—it moved at a pace that let us actually observe what it was doing without sprinting after it.



Figure 3: Handling and movement behavior of the fabricated water robot

### C. Handling and Movement

During trials, we tossed in bottles, snack wrappers, foam cups, and even bunches of water hyacinth. Most of the debris rode up the conveyor without trouble. Thin plastic sheets caused the most irritation since they sometimes slid underneath instead of being scooped. A soaked branch jammed the rollers once, but widening the gap solved that issue for the rest of the runs.

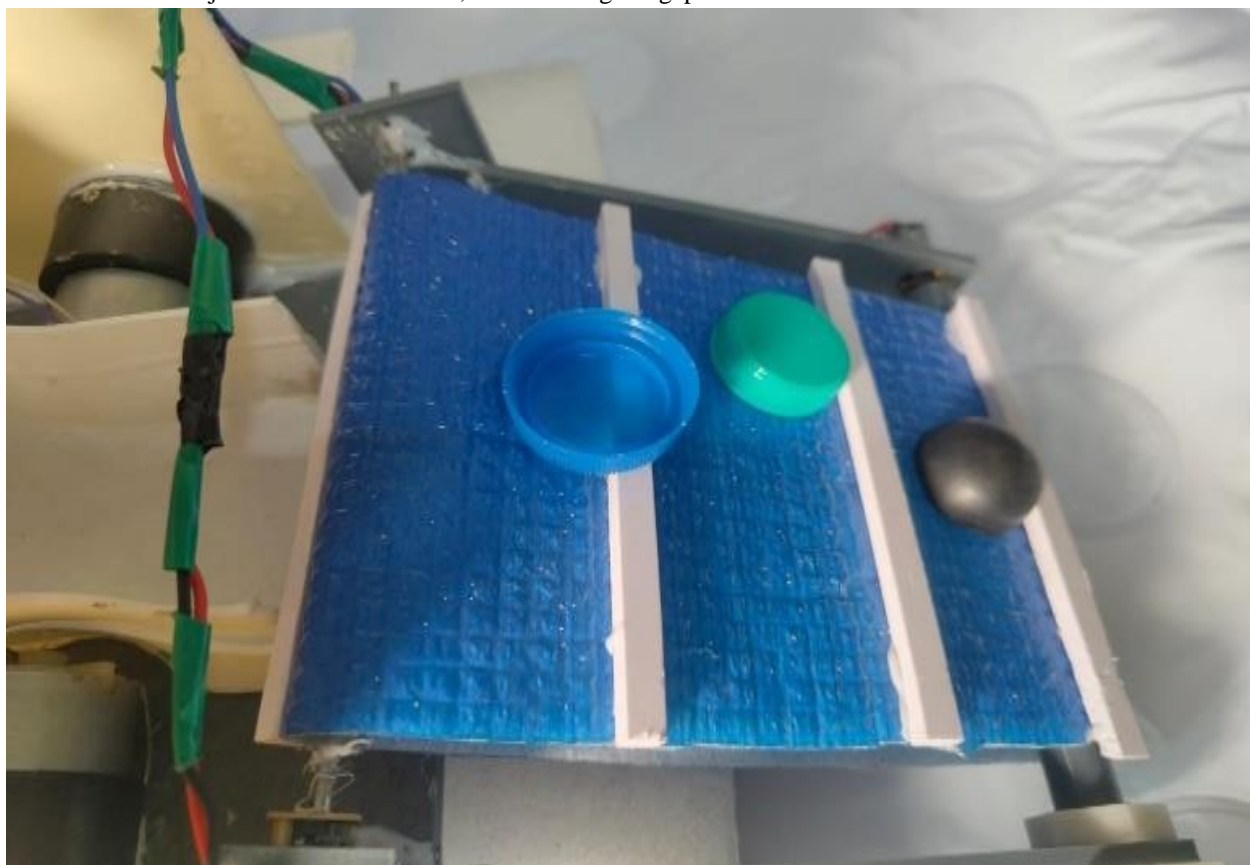


Figure 4: Debris collection operation of the fabricated water robot

**D. Sensing Obstacles**

In the tank and pond, the ultrasonic sensors behaved almost flawlessly—the walls gave clean echoes, making detection straightforward. The lake wasn't as cooperative. Partially submerged logs reflected sound in odd ways, giving inconsistent readings. Adding side-mounted sensors helped the robot spot objects that weren't directly ahead, reducing the number of sudden evasive maneuvers.

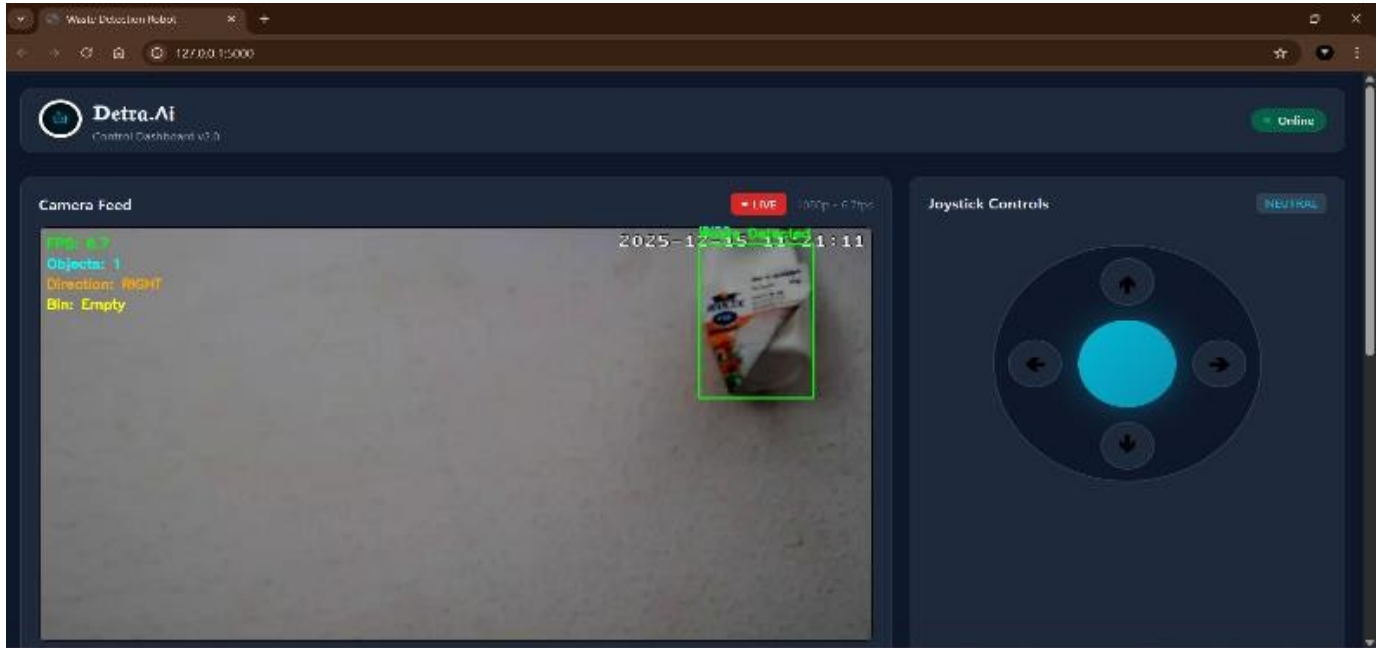


Figure 5: Real-time obstacle detection and sensor response observed during water environment testing

**E. Model learning trends for water waste categories**

The figures show how the water waste classification model learned over time. Accuracy improves gradually while validation results remain close to training values, suggesting stable learning. At the same time, the reduction in loss indicates that the model becomes more reliable as training continues. The recall and precision results remain fairly consistent across all data splits, showing balanced performance for different water waste categories.

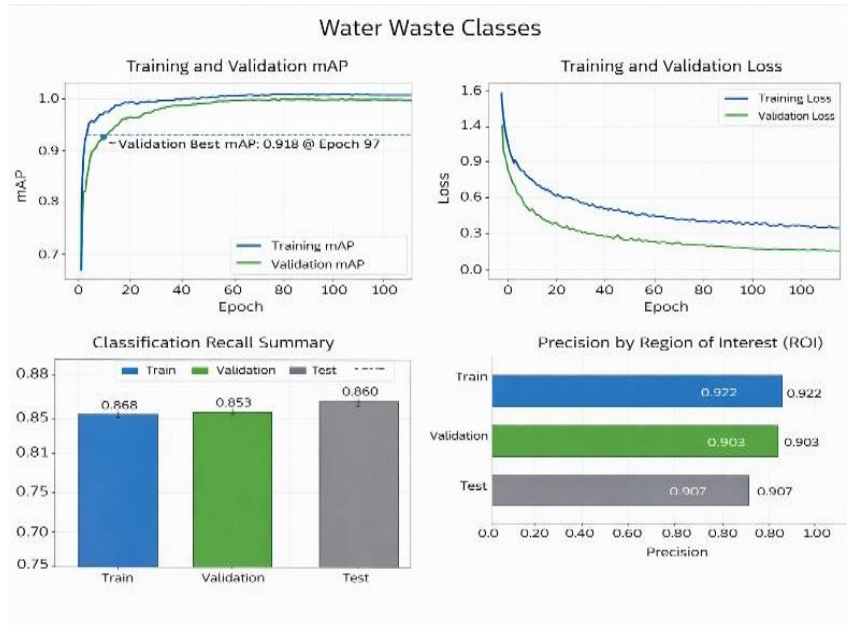


Figure 6: Model training overview for water waste classes

#### F. Power Use and Runtime

When the sun was strong, the solar panels supplied nearly as much energy as the system consumed, and the battery level stayed steady or climbed slightly. Overcast days were a different story; sunlight dropped drastically, and the robot ran for about three hours before hitting the cutoff voltage. Leaving it in the sun afterwards for an hour or so was usually enough to recharge it for a short follow-up run.



Figure 7: Solar charging and battery response of the water robot during testing

#### Issues That Showed Up

A few problems still reminded us that this is an early prototype. Heavy wood end debris was simply too much for the conveyor system, causing the belt to slip. Strong winds on the lake occasionally shoved the robot sideways faster than the motors could compensate, which messed with the planned cleaning route. The GPS had moments where it randomly shifted position by several meters, which made the path log look a bit chaotic. None of these setbacks broke the robot, but they gave us a clearer idea of what to refine next. Despite all the quirks and surprises, the overall results were encouraging. The robot stayed afloat reliably, moved under its own control, gathered debris, and managed to keep itself powered on sunlight for most of the testing. It wasn't perfect—early versions never are—but it showed that the concept works in real water and not just in design sketches.

### VIII. CONCLUSIONS

What started as a frustration with a smelly lake became months of late nights arguing over hull shapes, melting our fingers on soldering irons, and cheering when the robot finally scooped its first bottle without sinking. Along the way, we learned that building something real beats reading about it any day. Our robot demonstrates that autonomous, solar-powered water cleanup is achievable without exotic materials or astronomical budgets. Twin hulls keep it stable, solar panels keep it fed, conveyors keep debris moving, and simple sensors keep it out of trouble. Municipal bodies looking for affordable cleaning options might find platforms like this worth a look. Plenty of rough edges remain. Heavy debris still defeats the conveyor. Currents and wind push harder than our motors prefer. GPS wanders more than we'd like. Fixing these flaws will take another round of design, fabrication, and testing work. We're eager to continue.

### IX. FUTURE IMPROVEMENTS

What started as a frustration with a smelly lake became months of late nights arguing over hull shapes, melting our fingers on soldering irons, and cheering when the robot finally scooped its first bottle without sinking. Along the way, we learned that building something real beats reading about it any day. Our robot demonstrates that autonomous, solar-powered water cleanup is achievable without exotic materials or astronomical budgets. Twin hulls keep it stable, solar panels keep it fed, conveyors keep debris moving, and simple sensors keep it out of trouble. Municipal bodies looking for affordable cleaning options might find platforms like this worth a look. Plenty of rough edges remain. Heavy debris still defeats the conveyor. Currents and wind push harder than our motors prefer. GPS wanders more than we'd like. Fixing these flaws will take another round of design, fabrication, and testing work. We're eager to continue.

- Onboard visual cues: We've talked about adding a tiny camera so the robot can get a basic sense of what it is collecting. Nothing complicated—just enough to tell plastic apart from plants or random junk drifting around.
- Reducing sideways drift: Whenever the water started moving, the robot liked to wander off-course. A simple IMU or flow sensor could help it hold its line instead of sliding gently in the wrong direction.

- Letting the robot dock itself: Right now, someone has to bring it back, empty the bin, and plug it in. A small guiding frame on the shore, plus wireless charging, would let the robot finish a run and settle itself without assistance.
- Team-based cleaning: We keep imagining what would happen if several robots worked together instead of one doing all the laps. With basic communication between units, they could divide the water body and clean much faster.
- Testing beyond controlled sites: We eventually want to see how the robot behaves in real problem areas. Working with lake groups or local authorities would give us feedback from people who deal with polluted water everyday.

#### X. ACKNOWLEDGEMENT

This project only came together because a lot of people quietly helped us along the way. Our professors at East West Institute of Technology encouraged the idea even when it was still just a rough sketch on paper. The lab staff guided us through tool mishaps, wiring mistakes, and the occasional accidental splash zone we created during testing. Our classmates pushed us with questions that forced us to rethink parts of the design we thought were done. And we owe a grateful nod to the park's security guard, who watched us carry a strange floating machine toward the pond and, wisely, chose not to ask too many questions. We appreciate every bit of support we received.

#### REFERENCES

- [1] A.B. Tatar, A.K. Tanyildizi, and B. Tasar, "A Conceptual Design of Solar-Powered Water Surface Garbage Cleaning Robot," in Proc. 2<sup>nd</sup> Int. Conf. Artificial Intelligence and Robotics (ICAIR), 2023.
- [2] M. Manikanda and C. Rajasekaran, "Design of Sensor Assisted Lake Water Cleaning Robot Using IoT," in Proc. 3<sup>rd</sup> Int. Conf. Intelligent Communication Technologies (ICICV), 2023.
- [3] K. Subhashini et al., "Autonomous Floating Debris Collection System for Water Surface Cleaning," in Proc. Int. Conf. Sustainable Environmental Solutions (ICSES), 2024.
- [4] R.K. Megalingam et al., "Simulation of Autonomous Water Tank Cleaning Robot in Gazebo," in Proc. Int. Conf. Power, Energy, Control and Transmission Systems, 2022.
- [5] S. Kong et al., "Intelligent Water Surface Cleaner Robot for Floating Garbage Collection," IEEE Trans. Systems, Man, and Cybernetics: Systems, 2021.



10.22214/IJRASET



45.98



IMPACT FACTOR:  
7.129



IMPACT FACTOR:  
7.429



# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089  (24\*7 Support on Whatsapp)