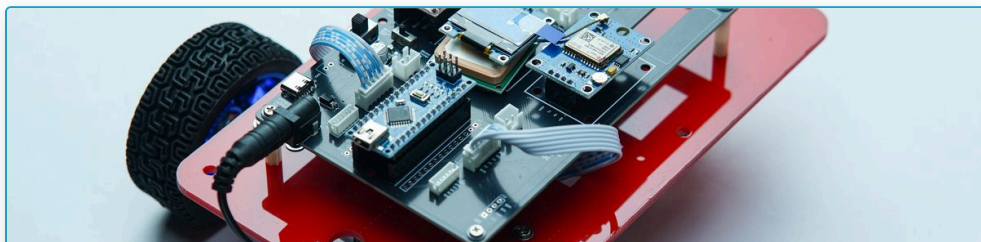


Kinematics. Odometry. Sensor Fusion.

A university-level robotics journey built entirely on the Car-3 you already have on your bench — no theory slides without a wheel turning.



YOUR CAR-3 · AS IT SITS ON YOUR BENCH

YOUR HARDWARE, MAPPED TO THE CURRICULUM

ESP32-S3-Nano

Dual-core 240MHz brain, WiFi/BLE for live telemetry

TB6612FNG Driver

Open vs closed-loop motor control

QMC5883L Compass

Absolute heading, hard/soft-iron calibration

2× JGA25 DC370 Encoder Motors

Ground truth for odometry & kinematics

MPU6050 IMU

Gyro/accel — heading & tilt estimation

0.96" OLED

Live pose, filter output & debug on the robot itself

THE PROMISE

Every concept ships with a demo you run in the same session it's taught — drift you can see, filters you tune live, a race between a dead-reckoning bot and a sensor-fused one. Theory is the debrief, not the lecture.

WHERE CAR-3 SITS IN THE ZAS JOURNEY

zas-robotics.com

UG Robotics · Hands-On Track

The Syllabus — 6 Modules

Each module = one bench session. Concept first in one line, then the demo that proves it — on your own Car-3. Plus one bonus module using the ultrasonic + IR sensors you've already got.

01 Differential-Drive Kinematics

Wheel speed $\leftrightarrow$ linear/angular velocity for a 2-wheel-drive + caster chassis.

DEMO Command 1 m straight + 90° pivot; measure actual vs. commanded, tune wheel-base constant.

02 Wheel Odometry

Encoder ticks $\rightarrow$ distance $\rightarrow$ pose (x, y, θ) by dead reckoning.

DEMO Drive a taped 1 m square open-loop; plot the odometry trail on OLED/serial and watch it fail to close.

03 Inertial Sensing (MPU6050)

Gyro integration for heading; accelerometer tilt; why gyro alone drifts.

DEMO Spin the robot on the spot for 60 s; show gyro-only heading walking away from true heading in real time.

04 Absolute Heading (QMC5883L)

Magnetometer heading, hard/soft-iron distortion, tilt compensation.

DEMO Live calibration "figure-8" dance; compare raw vs. calibrated heading on OLED.

05 Sensor Fusion I — Complementary Filter

Blend fast-but-drifty gyro with slow-but-noisy compass.

DEMO Tune the blend weight a live via serial slider; watch the fused trace beat both inputs on screen.

06 Sensor Fusion II — Kalman / EKF Pose & Capstone Race

Fuse encoder odometry + IMU + compass into one pose estimate; close the loop with PID waypoint following.

DEMO Race day: dead-reckoning-only bot vs. EKF-fused bot, same square course, same start line.

Format

6 $\times$ 2–3 hr sessions, teams of 2–3

Prerequisite

Basic C/Arduino; no control theory needed

Outputs

Tuned filter code + logged trajectory per team

BONUS • MODULE 07 Particle Filter (Monte Carlo Localization)

Your on-board ultrasonic (centre) + 2 $\times$ IR (left/right) act as a 3-beam rangefinder — exactly what a particle filter needs to correct itself against a known map, the same principle behind MIT's own autonomous-racing localization stack.

DEMO "Kidnap" the robot inside a taped rectangular pen from a random start; watch a scattered particle cloud collapse onto its true corner as it drives and takes range readings.

Bring this to your **Car-3** bench.

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