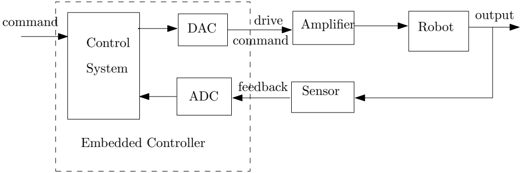
SC649: Embedded Control and Robotics

Course overview

Objective

Embedded System: Some combination of computer hardware, mechanical parts and software, either fixed in capability or programmable, that is specifically designed for a customized solution.



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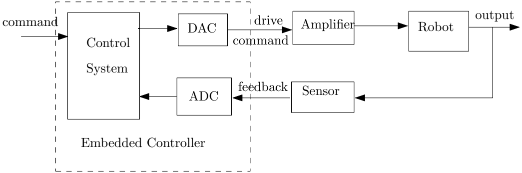

Advantages:

- Typically smaller semiconductor area
- Low power consumption
- Small size
- Typically cheaper option
- Good availability; easy in bulk production
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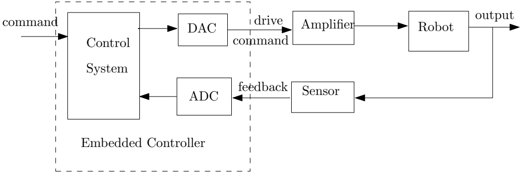

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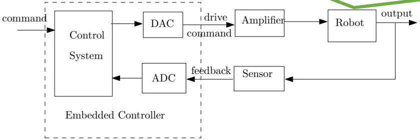
Challenges:

- Sensor processing and limited memory
- Digital computations, hence limited computation capability
- Requires special effort in designing controller

Illustrative cases

Wheel Robot



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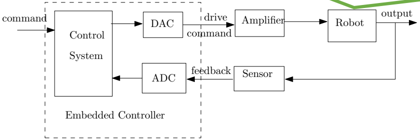

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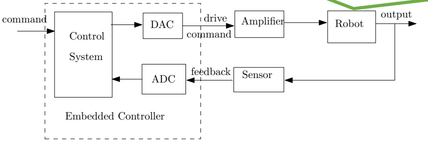

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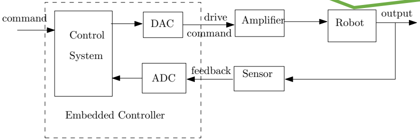


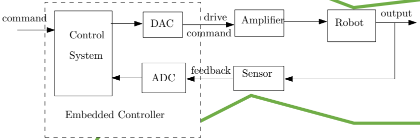
Illustrative cases

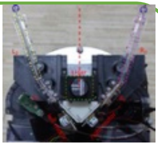
Spherical Robot

Underwater Vehicle

Aerial Vehicle

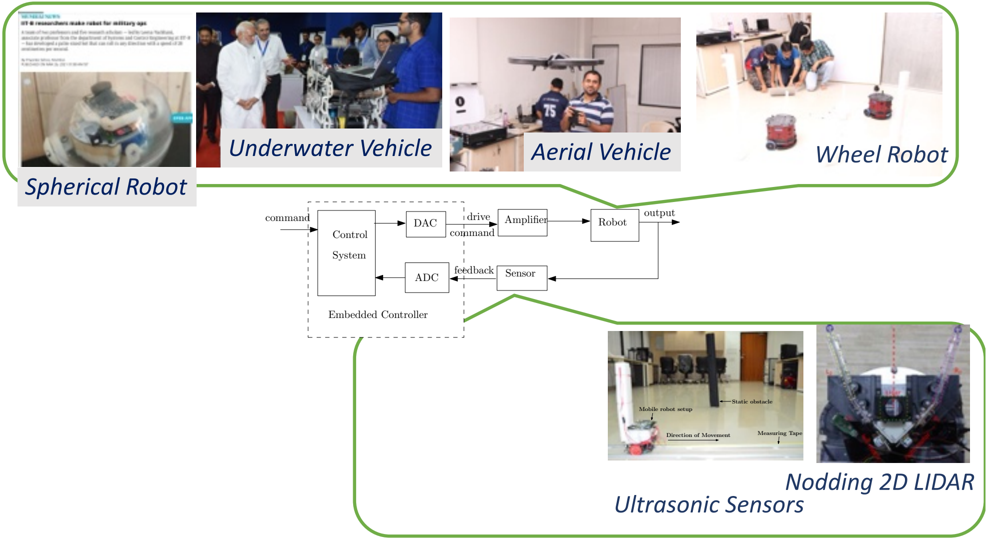
Wheel Robot





Nodding 2D LIDAR

Illustrative cases



Illustrative cases

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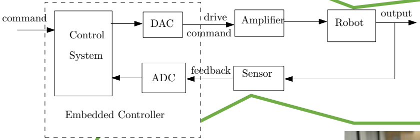
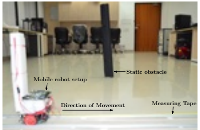
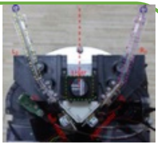


Vision



Ultrasonic Sensors



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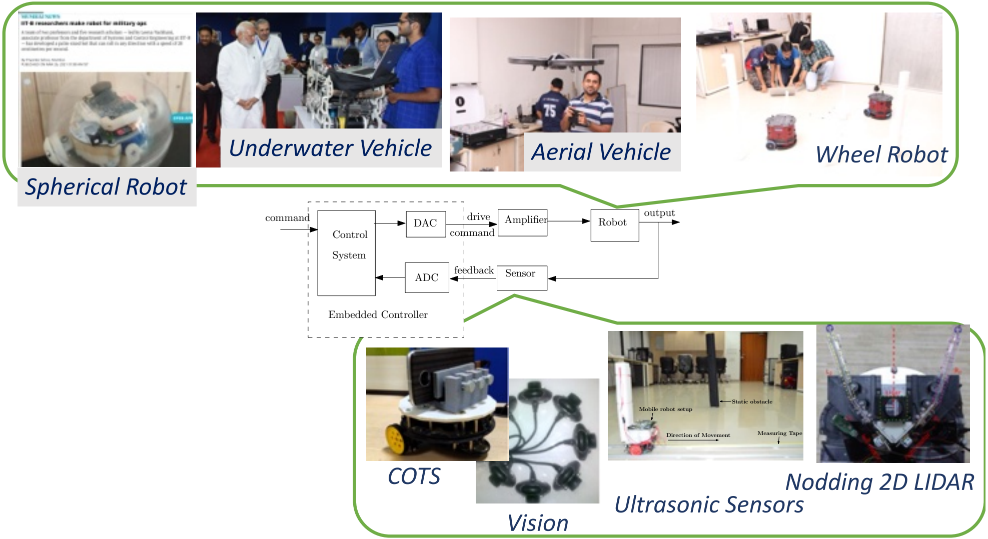

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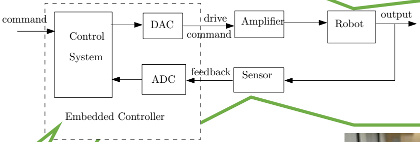

- FPGA (Field Programmable Gate Array
- Microcontroller
- Embedded Linux

COTS

Vision

Ultrasonic Sensors

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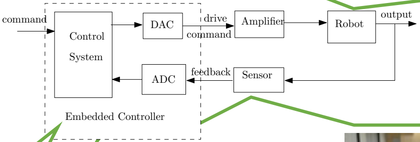


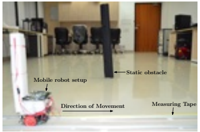
Open-source Simulators

- ROS (Robot Operating System) + Gazebo
- SUMO (Simulation of Urban MObility)

- FPGA (Field Programmable Gate Array)
- Microcontroller
- Embedded Linux


COTS


Vision



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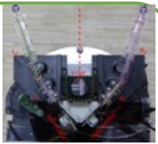
Nodding 2D LIDAR

Take Away

- Study of design concepts and popular *embedded technologies implies* the available benefits and limitations through embedded implementations.
- Understanding existing *mobile robot models* $\implies$ system for controller designs.
- Learn methods to obtain *approximated discrete-time representation* for control system $\implies$ ensuring stability
- Relate the control objectives to the embedded requirements
- Exploiting the benefits of *parallel hardware* architecture in FPGA in mobile robotic applications, learn a systematic way to implement embedded controller using specific examples.

Course Delivery Plan: Before MidSem

- Embedded Technologies: Design challenges, Processors (General purpose – software and single purpose- hardware, application specific), Peripherals (Timer, counter, PWM, ADC) (3 weeks)
  - Quantization and sampling time
  - Interfacing with DC motor
  - DC Motor characterization (open-loop control)
- Mobile robot kinematics– direct and inverse kinematics, nonholonomic constraints, unicycle, differential drive, omnidirectional (3 weeks)
  Lab modules:
  - PID control of one DC motor
  - Differential-drive robot control

Course Delivery Plan: Post MidSem

- Sensors and actuators – range sensors, motors and their interfacing (1 week)
- Control – Discrete-time model, Stability in embedded implementation, position control, nonlinear control methods (3 weeks)
  Lab modules:
  - MatLab Simulink/ROS-Gazibo environment and interfacing range sensing
  - 2D position control (Robot model)
- Localization – Kalman filter, triangulation, trilateration, topological (3 weeks)
  Lab modules:
  - Trilateration for location measurement
  - Kalman filter design for localization

Text Book Reference

- Embedded Control for Mobile Robotic Applications, L. Vachhani, P. Vyas and Arunkumar G.K., Wiley-IEEE Control Series, Under production.
- Probabilistic Robotics, S. Thrun, W. Burgard and D. Fox, MIT Press, 2005.

Pre-requisites

Some course on..

- Embedded Systems + Digital Systems
- Control Theory

Evaluation

- Four assignments (theory + practise) - each having weight of 15%
  - Before mid sem - 2 assignments
  - Midsem - 1 in-person assignment
  - Post midsem - 1 assignment
- Main project - 20%
- Demo + Viva - 20%