

Proposal for a New Course
Department of Intelligent Systems
Wadhvani School of AI and Intelligent Systems
Indian Institute of Technology, Kanpur

Course number: IS202

Course title: Embedded Computing for Cyber-Physical Systems

Course prerequisites: ESXXXX

Course credits: [12] (2-0-6-0)

Course duration: Full semester

Course type: DC

Proposing instructors: Indranil Saha

Other faculty members interested in teaching the course: Purushottam Kar

Other departments interested in the proposed course: None

Course description:

- a. *Objectives:* Interfacing with cyberphysical devices is a critical step in building autonomous systems. This course will introduce techniques to interface with cyberphysical devices using Python libraries as well as controlling virtual robotic agents using simulators. The course will also offer hands-on experience in conducting small-scale experiments involving cyberphysical data sources and agent simulators.
- b. *Logistics:* The course will serve as a DC for IS UG students (BT, double major), and as a DE for PG students (MT, MS, PhD) of the CSE and IS departments and CSE UG students (BT, double major, ML minor). The course may be offered one or more times every academic year depending on demand and availability of resources.
- c. *Content:* There will be an equivalent of 24 lectures of 50 minutes each and 24 labs of 3 hours each. A weekly breakup of lecture and lab content is given below.
- d. *Evaluation:* Evaluation will use a combination of graded lab exercises, lab exams, take-home assignments and projects, and traditional sit-down quizzes and exams.

Weekly breakup of content: Numbers in square brackets [] against each topic indicate the number of lectures/labs for that topic.

Lecture content (24 lectures):

1. Components of a cyber-physical system (CPS) [9]:
 - a. Introduction: physical process/plant, sensors, controllers, actuators, IoT “edge” devices.
 - b. Sensors and Actuators: Models for sensors and actuators (linear and affine models, range, dynamic range, quantization, signal-to-noise ratio, sampling, harmonic distortion, signal conditioning), common sensors (measuring acceleration, velocity, and position, measuring rotation, measuring sound, etc.), common actuators (Light-Emitting-Diode, motor control, etc.)
 - c. Controller: A brief introduction to feedback control

- d. Communication: types of media, interconnections between CPS devices, device-to-device messaging protocols such as MQTT
- e. Applications: Data collection from physical processes and processing via embedded devices, CPS applications and vulnerabilities

2. Introduction to Computer Architecture Design [15]:

- a. Fundamentals of Digital Logic [3]: Boolean algebra, combinational and sequential circuits, number representation and computer arithmetic (fixed and floating point)
- b. Basic building blocks for the ALU [3]: Adder, Subtractor, Shifter, Multiplication and division circuits.
- c. Processor [4]: Machine instructions and addressing modes. ALU, data-path and control unit. Instruction pipelining, pipeline hazards.
- d. Memory [3]: Memory technologies, Memory hierarchy: register file, cache, main memory and secondary storage
- e. I/O interfaces [2]

Lab content (24 labs):

1. Single-board computers (SBC) [8]

- a. Familiarization: popular SBCs e.g., Arduino, Raspberry Pi, system-on-chip (SoC)
- b. Physical interface: use of breadboards, jumper wires, ports, data lines and power lines, connecting external components such as sensors, actuators, best practices e.g., avoiding/detecting short-circuits or loose connections
- c. Digital interface: reading datasheets, Python-based IDEs to interface with SBCs by reading digital inputs, reading analog inputs, sending commands

2. App development [6]

- a. Simple “Hello World”-style apps such as creating an array of blinking LEDs
- b. Pipelining SBC data into pretrained AI/ML models to create apps
- c. Reading time series data from an air-quality sensor via SBC, building a web app detecting elevated particulate matter levels, say due to incense burning

3. Familiarization with simulators and agent programming [10]

- a. Introduction to robotics simulators such as ROS, Gazebo
- b. Controlling simulated autonomous virtual robotic agents

Lab equipment: PCs with internet connectivity and appropriate software (browsers, Python runtime with libraries, and robotics simulators, software to interface with cyberphysical systems etc) will be needed. Lego Mindstorms kits and device packages will need to be procured with Raspberry Pi/Arduino units (for instance [\[link\]](#)), AQ sensors say PM sensors, cameras, and peripherals such as breadboards, jumper cables, resistors, LEDs, antennae, etc. The number of device packages will be decided keeping in mind class strength. Extra packages will be acquired to account for spontaneous device malfunction, deterioration etc.

Short summary for inclusion in the Courses of Study booklet: Hands-on course on interfacing with cyber-physical devices and controlling virtual robots using Python and

simulators, covering sensors/actuators, embedded platforms, basic control and communication, and system-level I/O.

Textbook: There will be no textbook for this course.

Course proposer: Indranil Saha

Date: May 12, 2026

Convener DPGC:

Date:

The course is approved/not approved

Chairperson, SPGC

Date: