UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Embedded Systems Architectures and Design

2627-1-F9103Q012

Aims

This course aims at to the following specific learning outcomes:

- **Knowledge and understanding** (DD1): providing the students an advanced understanding of the main aspects of Embedded and Cyber-Physical Systems (ECPS) with AI capabilities.
- **Applying knowledge and understanding** (DD2): at the end of this course the students will know the main concepts of ECPS, their most relevant applicative fields, the essential requirements for ECPS in the different applicative fields, the current technologies available to build ECPS with AI capabilities. The course will teach students how to design embedded applications with AI capabilities satisfying the most relevant categories of requirements. The acquired knowledge will be applied by realizing some simple example ECPS during the laboratory sessions.

Contents

Embedded and cyber-physical systems (ECPS) in their context. The structure of ECPS: processing units, memories, communication systems, sensors, actuators. Introduction to real-time scheduling. The design of ECPS.

Detailed program

Embedded and cyber-physical systems (ECPS) in their context:

- Definition of ECPS; categories of ECPS; application domains, market value and diffusion.
- Basic requirements: timing, reliability, efficiency.
- ECPS and AI: cloud, edge and endpoint AI.

The structure of ECPS:

- Processing units: CPU and microcontrollers, DSP and GPU, ASIC, programmable logics; AI accelerators.
- Memories; Communication systems: GPIO, synchronous and asynchronous serial buses.
- Models of sensors and actuators: Affine models, saturation, harmonic distortion, dynamic range. Analog-to-digital and digital-to-analog converters.
- Sensors: accelerometers, gyroscopes, pressure sensors, magnetometers; IMU; temperature sensors and other sensors. Actuators: solenoids, DC motors.

Introduction to real-time scheduling:

- Definition of real-time system and basic concepts in real-time scheduling: tasks and jobs, periodic, aperiodic e sporadic tasks, metrics, optimality.
- Scheduling for periodic tasks; schedulability conditions; nonidealities and blocking.
- Scheduling for heterogeneous sets of tasks with sporadic tasks: servers.
- Shared resources: critical sections and locking; priority inversion; resource access protocols; blocking time due to resource conflict.

Designing ECPS:

- Typical requirements in the different ECPS application domains.
- Models of real-time and cyber-physical systems; state machines.
- System engineering.

Prerequisites

Basic knowledge of programming in the C and Python programming languages; basic knowledge of operating system principles (processes, threads, scheduling) and of computer architecture; basic knowledge of principles of software requirements analysis and software design with UML; basic knowledge of the principles of machine learning as taught in the course Advanced Foundations of Artificial Intelligence.

Teaching form

In-presence classes and laboratory practice consisting in the development of project works in small groups. Attendance to classes and laboratories is highly recommended.

Textbook and teaching resource

The topics that are taught in the course are not comprehensively discussed by any single book: Correspondingly, the course has no textbook. The learning material will be provided during the course as handouts, slides, research articles and a selection of chapters from books including:

E. A. Lee, S.A. Seshia. Introduction to Embedded Systems: A Cyber-Physical Approach. Second Edition, MIT Press, 2017.
G. C. Buttazzo. Hard Real-Time Computing Systems, Predictable Scheduling Algorithms and Applications. Third Edition. Springer, 2011.

P. Warden, D. Situnayake. TinyML: Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power Microcontrollers. O'Reilly, 2019.

Semester

Second.

Assessment method

Written examination with open questions, problems and exercises; written report on the laboratory activity.

Office hours

By appointment (send an email to the course instructor to agree a date and time for a meeting).

Sustainable Development Goals