Analysis and Control of Cyber-Physical Systems 2020-21

Master degree in:	Electronic Engineering
Semester/Credits/Hours:	Spring semester, 6 credits, 60 h
Instructor:	Alessandro Giua (giua@unica.it)
Webpage:	https://www.alessandro-giua.it/UNICA/ACCPS

Presentation. The course provides an introduction to *cyber-physical systems* (CPSs), i.e., dynamical systems composed by logical components (driven by event occurrences) interacting with physical components (described by time-driven models). From a control systems perspective CPSs are *hybrid systems*, combining discrete event and continuous dynamics. The course is structured into two parts. The first part presents *discrete event systems* and *supervisory control*. The second part is devoted to the modeling and analysis of *hybrid systems* and introduces some approaches for stability and stabilization of *switched systems*.

Syllabus

1 - Classification of dynamical systems (2h lecture)
Time-driven systems. Discrete-event systems. Hybrid systems.

Part I - Discrete event systems

2 - Automata models for discrete event systems (10h lecture + 4h homework)
Formal languages: alphabets and words, languages and operators. Deterministic finite automata: languages and properties. Nondeterministic finite automata and their languages. Equivalence between deterministic and nondeterministic automata. Fault diagnosis using automata: diagnoser, diagnosability. Modeling with automata and concurrent composition.

3 - Supervisory control of discrete event systems (6h lecture + 2h homework)
Plant, specification, supervisor and closed-loop system. Controllability and supremal controllable sublanguage. Supervisory design for language specifications. Supervisory design for state specifications.

Part II - Hybrid systems

4 - Hybrid systems and hybrid automata (8h lecture+ 2h homework + 2h lab)
State variable models of time-driven systems. Examples of hybrid systems. Autonomous hybrid automata and generalizations. Hybrid automata with inputs. Evolution of a hybrid automaton. Pathological cases of continuous and hybrid evolutions.

5 - Reachability analysis of hybrid systems (8h lecture + 2h homework + 2h lab)
State transition systems (STSs). STS associated with a hybrid automaton. Reachability of a STS. Equivalences between states of a STS. Bisimulation between states of an STS and quotient system. Classes of rectangular automata. Timed automata: regions, equivalence between states and region graph. Initialized rectangular automata and reduction to timed automata. Elements of model checking.

6 - Stability and stabilization of linear switched systems (8h lecture + 2h homeworks + 2h lab)
Elements of stability for linear and time invariants systems. Direct method of Lyapunov. Quadratic forms and singular values. Stability analysis of switched systems by common Lyapunov function. Quadratic Stabilization. Stabilization by slow switching.

Textbook

- A. Giua, Notes for the course *Analysis and Control of Cyber-Physical Systems*, 2020. Can be downloaded from rhe page https://www.alessandro-giua.it/UNICA/ACCPS/material