Module Code	EEP55C21
Module Name	Cyber-Physical Systems and Control
ECTS Weighting[1]	10 ECTS
Semester taught	Semester 1
Module Coordinator/s	Harun Siljak
Module Learning Outcomes with reference to the Graduate Attributes and how they are developed in discipline	On successful completion of this module, students should be able to: LO1. Formally describe and design cyber-physical systems LO2. Make appropriate sensory, actuatory and computational choices for cyber-physical systems in a given context LO3. Write specifications of cyber-physical systems and required tests for them LO4. Verify a cyber-physical system's performance LO5. Design distributed and networked control schemes for cyber-physical systems and write software for their implementation LO6. Apply machine learning techniques to problems of sensing and control LO7. Coordinate heterogeneous teams of cyber-physical systems LO8. Critically assess cyber-physical systems in terms of security and ethics **Graduate Attributes: levels of attainment** To act responsibly - Attained To think independently - Enhanced To develop continuously - Enhanced To communicate effectively - Introduced
Module Content	Synergy of physical components (mechanisms) and software that controls them is a cyber-physical system (CPS). They adapt to changes in their mission and environment, aim to be autonomous, and are designed as networks of interacting elements. This course on cyber-physical systems and control hence brings together the knowledge of communications networks and self-organisation on one side, and control, robotics, and computing on the other. The requirements for a CPS stem from its application, laws, and the effects it has on the society. Our module will, in parallel, cover physical, cybernetic, and social challenges of CPS design. In this course, we learn to write software and select hardware for mobile autonomous CPS: as a platform of choice we use a light-weight, simple

[1] TEP Glossary

unmanned aerial vehicles (UAV) and/or unmanned ground vehicles (UGV). Design of such a system brings together multiple disciplines relevant to engineering: software architecture from computer science, dynamics, mechanics, and construction from mechanical engineering, as well as control engineering and communications engineering knowledge. The power of autonomy in cyber-physical systems is harnessed by cooperative, networked, distributed systems with many agents: in this course, we learn how to build these systems to be robust and reliable. Through formal models and theory of verification and validation, we make sure the individual agents perform their duty, and observe them in performing a joint mission. The practical project work goes from design, optimisation and construction of the mechanical system, over creation of testing architectures such as hardware-in-loop for assessment of control algorithms, to demonstration of collaboration and interoperability of different teams' vehicles.

Observing trends in the cyber-physical systems design, this course also presents a case for the use of machine learning techniques at different layers of the CPS structure.

From the standpoint of the interaction of such systems with humans, we study the questions of security, safety, and ethics in CPS. We discuss the role CPS play in the economy with Industry 4.0, and their repairability with challenges of open source vs proprietary architectures.

The module will comprise the following key components:

- Introduction to CPS
- Control: fundamentals of discrete and continuous systems
- Sensors, actuators, computers: hardware for CPS
- Observation and state estimation
- Models of CPS, simulation and prototype building
- Formal methods: temporal logic, model checking
- Learning for CPS
- Security and safety of CPS
- Economy and politics of CPS
- Ethics of CPS applications

Teaching and Learning Methods	Cyber-physical systems put together mechatronics, computer science, and control theory—bits of each united in a highly practical, and yet formal framework. In this symbiotic relationship, theoretical foundations are easily complemented by actual examples that come from modern technology, rather than simplified abstractions. Hence, the teaching strategy for this module is a mixture of lectures, laboratories and individual/groupwork. The theoretical concepts (design, choice of sensing, actuating, computing solutions, tests and verification) will be demonstrated in practice, as the students will build their own cyber-physical system. Individual work on the UAVs will lead to a group work on networking and coordination. The teaching strategy includes elements of Mastery Learning, mixed with Flipped Classroom. The social implications of CPS will be the main focus of the flipped classroom. These topics will be continuously running in parallel with the more technical topics, to emphasise the interconnectedness and stimulate society-conscious design in the lab.

Assessment Details[2]
Please include the following:

- **Assessment Component**
- **Assessment description**
- **Learning Outcome(s) addressed**
- **% of total**
- **Assessment due date**

Assessment Component	Assessment Description	LO Addressed	% of total	Week due
Examination	Written 2hr examination	2,4,7,3,5,6	40%	End-of-term
Assignments	Individual and group Assignments on the UAV/UGV platform are submitted on a bi-weekly basis	1,2,3,8,6	60%	Due Weeks 1 to 12

Reassessment Requirements

[2] TEP Guidelines on Workload and Assessment

Contact Hours and Indicative Student Workload[2]	**Contact hours: 66** **Independent Study (preparation for course and review of materials):** **Independent Study (preparation for assessment, incl. completion of assessment):**
Recommended Reading List	1. Alur, R., 2015. Principles of cyber-physical systems. MIT Press. 2. Taha, W.M., Taha, A.E.M. and Thunberg, J., 2020. Cyber-Physical Systems: A Model-Based Approach. Springer Nature 3. Nardelli, P.H., 2022. Cyber-physical systems: Theory, methodology, and applications. John Wiley & Sons.
Module Pre-requisite	None
Module Co-requisite	
Module Website	None
Are other Schools/Departments involved in the delivery of this module? If yes, please provide details.	No
Module Approval Date	2021
Approved by	
Academic Start Year	2021/2022
Academic Year of Date	