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| **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:<br><br>1. Formally describe and design cyber-physical systems<br>2. Make appropriate sensory, actuatory and computational choices for cyber-physical systems in a given context<br>3. Model and simulate cyberphysical systems<br>4. Write specifications of cyber-physical systems and required tests for them<br>5. Verify a cyber-physical system's performance<br>6. Design distributed and networked control schemes for cyber-physical systems and write software for their implementation<br>7. Apply machine learning techniques to problems of sensing and control<br>8. Critically assess cyber-physical systems in terms of security, environmental impact, socioeconomic impact, and ethics<br><br>**Graduate Attributes: levels of attainment**<br>To act responsibly - Attained<br>To think independently - Enhanced<br>To develop continuously - Enhanced<br>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.<br><br>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 unmanned aerial vehicles (UAV). Design of such a system brings together |

[1] TEP Glossary

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| | 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 on real systems.<br><br>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.<br><br>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.<br><br>The module will comprise the following key components:<br><br>• Introduction to CPS<br>• Control: fundamentals of discrete and continuous systems<br>• Sensors, actuators, computers: hardware for CPS<br>• Observation and state estimation<br>• Models of CPS, simulation and prototype building<br>• Formal methods: temporal logic, model checking<br>• Security and safety of CPS<br>• Economy and politics of CPS<br>• 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.<br><br>Hence, the teaching strategy for this module is a mixture of lectures, laboratories and individual/groupwork. The theoretical concepts (design, |

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| | 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.<br><br>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]**<br>**Please include the following:**<br>• **Assessment Component**<br>• **Assessment description**<br>• **Learning Outcome(s) addressed**<br>• **% of total**<br>• **Assessment due date** | (see table below) |
| **Reassessment Requirements** | |
| **Contact Hours and Indicative Student Workload[2]** | **Contact hours:** 66<br>**Independent Study (preparation for course and review of materials):** 60<br>**Independent Study (preparation for assessment, incl. completion of assessment):** 124 |
| **Recommended Reading List** | 1. Alur, R., 2015. Principles of cyber-physical systems. MIT Press.<br>2. 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** | No |

| Assessment Component | Assessment Description | LO Addressed | % of total | Week due |
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| Examination | Written 2hr examination | 2,4,7,3,5,6 | 40% | End-of-term |
| Assignments | Individual and group assignments in labs | 1,2,3,8,6 | 60% | Due Weeks 1 to 12 |

[2] TEP Guidelines on Workload and Assessment

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| **module? If yes, please provide details.** | |
| **Module Approval Date** | |
| **Approved by** | Prof. Naomi Harte |
| **Academic Start Year** | September 2025 |
| **Academic Year of Date** | 2025/2026 |