COURSE OUTLINE

(1) GENERAL

SCHOOL	Social Sciences		
ACADEMIC UNIT	Department of Cultural Technology and Communication		
LEVEL OF STUDIES	Postgraduate Studies		
COURSE CODE	UA-TC1	**SEMESTER**	1
COURSE TITLE	Artificial Intelligence and Robotics in Circular Economy Ecosystems		

INDEPENDENT TEACHING ACTIVITIES *if credits are awarded for separate components of the course, e.g. lectures, laboratory exercises, etc. If the credits are awarded for the whole of the course, state the weekly teaching hours and the total credits*	**WEEKLY TEACHING HOURS**	**CREDITS**
Add rows if necessary. The organisation of teaching and the teaching methods used are described in detail in section (4).	3	6

COURSE TYPE *general background, special background, specialization, general education, skills development*	specialised general knowledge, skills development (technical)
PREREQUISITE COURSES	No
LANGUAGE OF INSTRUCTION AND OF ASSESSMENT	English
MODE OF TEACHING *in-person (%)* *synchronous distance learning (%)* *asynchronous distance learning (%)* *(In the case of synchronous distance learning, the total weekly duration of teaching is recorded)*	The course is delivered exclusively through synchronous distance learning. Each weekly lecture lasts 180 minutes.
AVAILABILITY TO ERASMUS STUDENTS	No
COURSE WEBSITE (URL)	TBA

(2) LEARNING OUTCOMES

Learning Outcomes

The course learning outcomes, specific knowledge, skills and competences of an appropriate level, which the students will acquire with the successful completion of the course are described.

Consult Appendix A

- *Description of the level of learning outcomes for each qualifications cycle, according to the Qualifications Framework of the European Higher Education Area*
- *Descriptors for Levels 6, 7 & 8 of the European Qualifications Framework for Lifelong Learning and Appendix B*
- *Brief Guide for drafting Learning Outcomes*

After the successful completion of the course, the student will be able to:

In terms of knowledge:

- Critically evaluate AI, ML, deep learning and robotics concepts and their relevance to circular economy optimisation across industrial systems.
- Demonstrate advanced understanding of data structures, interoperability requirements and ontologies enabling AI deployment in circular ecosystems.
- Analyse key methods for machine learning (KNN, decision trees, ensembles, regression, clustering) and explain their applicability to material-flow modelling and resource optimisation.

- Synthesise knowledge of automation, cognitive digital twins and sensor/robotic systems to explain how they enhance transparency, efficiency and scalability in circular value chains.
- Explain the ethical, operational and governance considerations required when deploying AI and automation in sustainable, circular production systems.
- Evaluate the performance, reliability and transferability of ML models reused or adapted for circular-economy applications.

In terms of skills:

- Design AI-enabled solutions for resource optimisation, waste reduction, or material recovery using ML models and relevant datasets.
- Apply robotics, sensors and agentic systems to map, detect and improve circular-economy processes such as waste sorting or automated recovery.
- Integrate interoperable datasets, ontologies and digital-twin inputs to support AI-driven decision-making across circular value networks.
- Assess automation and deep-learning case studies to identify efficiency gains, risks, and operational constraints within circular manufacturing systems.

In terms of responsibility and autonomy:

- Drive strategic decisions on adopting AI, robotics and automation technologies for circular-economy transformation, balancing innovation with environmental and societal responsibility.
- Manage complex AI/robotics deployment projects across interdisciplinary teams, ensuring technical feasibility, alignment with sustainability goals and responsible governance.
- Take responsibility for ensuring transparency, accountability and ethical oversight in AI use, including dataset governance and algorithmic impacts on workers and value-chain actors.
- Exercise advanced judgement in selecting appropriate AI/ML techniques and digital-twin architectures to address unpredictable circular-economy challenges.
- Orchestrate the integration of AI, sensor networks, robotics and cognitive digital twins into circular business models to enhance resilience and long-term value creation.

General Competences

Taking into consideration the general competences that the degree-holder must acquire (as these appear in the Diploma Supplement and are stated below), at which of the following does the course aim?

Search, analysis and synthesis of data and information, with the use of the necessary technology	*Project planning and management*
Adaptability to new situations	*Respect for difference and multiculturalism*
Decision-making	*Respect for the natural environment*
Working independently	*Showing social, professional and ethical responsibility and sensitivity to gender issues*
Team work	*Criticism and self-criticism*
Working in an international environment	*Production of free, creative and inductive thinking*
Working in an interdisciplinary environment	*……*
Production of new research ideas	*Other…*
	…….

The current course will enable students to acquire the following competences:

- Search for, analysis and synthesis of data and information, with the use of the necessary technology, as UA-TC1 is centred on AI, ML, robotics, sensors, digital twins and data interoperability.
- Strategic and innovative thinking for managerial problem-solving, as the learning outcomes require students to design AI-enabled solutions, optimise circular processes, and make strategic decisions on automation adoption.
- Working in an interdisciplinary environment, as UA-TC1 integrates data science, engineering/ robotics, environmental sciences, circular-economy modelling, digital governance and ethics.
- Ethical, responsible, and sustainable decision-making in business contexts, as the course includes AI ethics, governance risks, worker safety, algorithmic impact, and responsible deployment of automation.
- Leadership and team coordination in complex or multicultural environments, as the Responsibility and Autonomy LOs require students to lead technology-adoption decisions, manage cross-functional deployment teams, and coordinate interdisciplinary stakeholders in circular value chains.

(3) COURSE SYLLABUS

UA-TC1 : Artificial Intelligence and Robotics in Circular Economy Ecosystems investigates how AI, IoT and robotics are used to optimize processes within circular ecosystems. Students will examine applications such as automated waste sorting, material recovery, and advanced manufacturing processes. The course highlights the role of AI and robotics in improving efficiency and scalability in circular economy.

The course consists of 13 lectures, as presented below:

1. **Introduction to Artificial Intelligence (Instructor: WU).** This lecture explores the foundations, history, and recent developments of Artificial Intelligence and Machine Learning. It introduces key learning paradigms including supervised, unsupervised, self-supervised, and reinforcement learning.
2. **Agents, Robotics and Sensors (Instructor: CEA).** This lecture introduces agentic systems and their relationship with robotics and sensors. Use cases illustrate how these technologies support circularity in practice.
3. **Learning without priors: KNNs and Decision Trees (Instructor: WU).** This lecture explores how KNNs and decision trees operate on non-linear datasets. Students examine their strengths, limitations, and applicability within circular-economy modelling.
4. **Learning without priors: ensembles and random forests (Instructor: WU).** This lecture introduces ensemble approaches such as random forests and boosting. It explains how combined models improve prediction accuracy and robustness.
5. **Model Reuse and Validation (Instructor: WU).** This lecture focuses on reusing and validating existing machine-learning models in circular-economy applications. Students learn practical methods for adapting models to new tasks and assessing performance.
6. **Application of AI in Circular Economy (Instructor: UMA).** This lecture shows how machine learning can model and implement circular-economy systems using Python-based tools. Students learn to analyse and optimise circular flows through applied modelling exercises.
7. **Data for AI in Circular Economy (Instructor: ATB).** This lecture covers approaches for collecting, structuring, and sharing data required for AI in circular systems. It introduces data interoperability principles and ontologies specific to circular-economy use cases.
8. **Automation in sustainable manufacturing (Instructor: CEA).** This lecture introduces challenges and advances in automation for sustainable manufacturing. It examines how robotics and AI-driven automation improve efficiency and environmental performance.
9. **Machine learning for resource optimisation (Instructor: UM).** This lecture demonstrates how ML models can support resource optimisation by analysing material flows and identifying inefficiencies. Students apply regression or clustering methods to predict consumption, detect hotspots, and improve recycling and reuse.
10. **Robotics for recycling (HYPE).** This lecture explores robotic systems designed for waste sorting, disassembly, and automated material recovery. It highlights how robotics improves precision, efficiency, and scalability in recycling operations.
11. **Research Direction of AI in CEE (Instructor: UiO).** This lecture presents emerging roles of artificial intelligence within circular economy ecosystems, highlighting how advanced analytics, automation, and intelligent decision-support tools can enable resource-efficient and regenerative systems.
12. **Case Studies: Deep Learning in Circular Economy (Instructor: UNL)**. This lecture presents real-world applications of deep learning in circular-economy processes. Case studies show how advanced models support prediction, optimisation, and automation across value chains.
13. **Cognitive digital twins in circular value chains (MAG).** This lecture examines how cognitive digital twins enhance decision-making in circular value networks. Students explore conditions under which AI models operating on digital twins enable trust, transparency, and optimised system behaviour.

(4) TEACHING AND LEARNING METHODS - ASSESSMENT

MODE OF TEACHING *Face-to-face, distance learning, etc.*	Distance Learning
MODE AND FREQUENCY OF COMMUNICATION WITH THE STUDENTS	Synchronous distance communication on a weekly basis, asynchronous on a daily basis through LMS platform
ENSURING THE MODE OF COMMUNICATION AMONG STUDENTS *Team assignments and discussions, collaborative learning platforms with the use of AI, video conference, QA sessions, κ.α.*	Weekly assignments, discussions through dedicated discussion forum, dedicated space per module on the learning platform, schedule video conference meetings through MS Teams, dedicated QA sessions per module
USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY *Use of ICT in teaching, in laboratory training, in the communication with students*	Use of ICT in Teaching, Communication with students Online Platforms will be used for teaching, tutorials, students' guidance, students' self-assessment and support on group projects
TECHNOLOGICAL EQUIPMENT REQUIREMENTS	PC /laptop for video conference meeting
PLAGIARISM POLICY/ PLAGIARISM DETECTION TOOLS	Gradescope, Turnitin
ARTIFICIAL INTELLIGENCE POLICY *(1) The use of Artificial Intelligence is prohibited in all circumstances* *(2) The use of Artificial Intelligence is allowed only with the permission of the instructor* *(3) The use of Artificial Intelligence is allowed only with an explicit reference to the literature* *(4) Students are free to use Artificial Intelligence*	The use of Artificial Intelligence is allowed only with an explicit reference to the literature. Additionally, students are free to use AI provided by the master programmes for contacting stimulations, practicing purposes, etc.
ORGANISATION OF TEACHING *The mode and methods of teaching are described in detail.* *Lectures, seminars, laboratory practice, fieldwork, study and analysis of bibliography, tutorials, work placements, clinical practice, art workshop, interactive teaching, educational visits, project, essay writing, artworks, etc.* *The student's study hours for each learning activity are stated, as well as the hours of independent study, according to the principles of the ECTS.*	see table below

Activity	***Semester workload***
Lectures	39
Participation in forum discussions	16,5
Study, analysis of bibliography and supplementary consolidation activities	73,5
Self-Assessment Evaluations	21
Course total	**150**

STUDENT ASSESSMENT *Description of the assessment method* *Language of assessment, methods of assessment, formative or summative assessment, multiple choice questions test, short answer questions, essay questions, problem solving, written work, essay/report, oral examination, public presentation, laboratory assignment, clinical examination of patient, art interpretation, other* *Specifically-defined evaluation criteria are given, and if and where they are accessible to students.*	Students will be evaluated following multiple-choice, short-answer, and open-ended questions. The assessment formula is the following: Self-Assessment Evaluations: 50% Final Assessment: 50%

(5) RECOMMENDED BIBLIOGRAPHY

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[11] IOF Consortium, "Industrial Ontologies Foundry." Accessed: Jan. 24, 2023. [Online]. Available: https://www.industrialontologies.org
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