MIND

Erasmus+ strategic partnership for Higher Education

DEVELOPMENT OF MECHATRONICS SKILLS AND INNOVATIVE LEARNING METHODS FOR INDUSTRY 4.0

IO2 REPORT

Project Title	**Development of mechatronics skills and innovative learning methods for Industry 4.0** **2019-1-RO01-KA203-063153**
Output	**IO2 – MIND Curriculum**
Date of Delivery	**May 2020**
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Contents

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1 Introduction, objectives and tasks of IO2

The MIND project is focused on developing mechatronics skills and innovative learning methods for Industry 4.0. To meet the employment needs of the next 5-10 years, universities must train students and develop interdisciplinary skills that combine mechatronic qualification with IT knowledge and superior social skills to create 4.0 specialists.

The following partners were involved in development of IO2: STU, UNI, UPT, UTCN (all the MIND consortium universities are involved).

In month March 2020, at the second project meeting (M2) that took place in Timisoara, Romania (organizer UPT) at this meeting, all the partners discussed, during 2 days, about the status of the project and the review of skills and competences needed for Industry 4.0 presented by UNI. At the end of this meeting, the host UPT presented a short report containing the main conclusions and the evaluation scores of the meeting. An evaluation form was completed by all the participants. At this gathering, participated trainers, teachers, industry and human resources representatives (IHR).

The objectives of IO2 are:

- Development of MIND curriculum.
- The target group of this intellectual output will be the professors and the beneficiaries will be the students.
- The structure of the new curricula Mechatronics 4.0 will be based on the modular concept of mechatronics curriculum and the role of this is to provide better mechatronics qualification skills for Industry 4.0. The content will be presented as lecture notes which includes text, images, tables.
- The number of pages of Mechatronics 4.0 course support (which will be IO3 report) is minimum 160 and the number of training hours is minimum 18 hours.
- IO2 report to be disseminated to the target groups (professors, students, industry representatives, technical trainers).

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- Contribution of every participant to this intellectual output. All project partners were constantly available via mobile phones. Every participant to this intellectual output participated to regular based project meetings (Skype). Communication and cooperation were ensured by intensive use of the internet and e-mail contact.
- UTCN took the responsibility of collecting, organizing and uploading the materials on the project website. The other three Universities will be involved in the creation and delivery of this output.

The following issues were addressed in detail:

A. Does the current curriculum in Mechatronics introduce students to Industry 4.0?

B. How should Mechatronics departments in universities respond to Industry 4.0 through curriculum content enhancements?

C. How real and enduring is the Industry 4.0 phenomenon?

The MIND training curriculum in mechatronics for Industry 4.0 focuses on the strategic deployment of mechatronics in universities. This will allow lots of hands-on practical work with mechatronic systems designed by the project partners.

Task 1. Discussion of the 4 curricula existent in the consortium. Responsible partners: all universities from the consortium involved.

Task 2. Proposal of 7 courses/lectures/modules for 4 years. Responsible partner: UTCN - Romania. For each course proposed will be realized an associated curriculum.

Task 3. Validation of the new curricula with partners. Responsible partner: STU - Slovakia.

Task 4. Validation of the curricula with the private sector/trainers. Responsible partner: UPT - Romania.

Task 5. Proposal of the curricula to the decision makers, in order to be accredited. Responsible partners: all universities from the consortium involved.

The MIND strategy of acquiring knowledge and skills in mechatronics in this project promotes active learning through practical problem solving and not the classical memorizing of knowledge.

The concept of the MIND Curriculum in mechatronics with focus on Industry 4.0 needs is based on a new collaborative environment which includes the educational content of the educational platform and a toolkit containing the elements needed to apply the learning by doing concept. The modular concept of mechatronics curriculum is consistently aligned with the educational path of the mechatronics training.

2 *Occupation standards in Mechatronics*

Occupation standards in mechatronics are standardized according to the European standards. “Qualifications are the formal outcome of an assessment and validation process which is obtained when a competent body determines that an individual has achieved learning outcomes to given standards” https://ec.europa.eu/esco/portal/qualification and https://ec.europa.eu/esco/portal/occupation?resetLanguage=true&newLanguage=en.

mechatronics engineer

2.1 Code

2144.1.11

2.2 Description

Mechatronics engineers design and develop intelligent systems, such as robotic devices, smart home appliances, and aeroplanes, through combining technologies from mechanical, electronic, computer, and control engineering. They create blueprints or design documents for parts, assemblies or finished products using software programs, and also oversee and manage projects.

2.3 Alternative label

- mechanical systems engineer
- mechatronic engineering specialist
- engineer in mechatronics
- robotics engineer
- electromechanical engineer
- cybernetics engineer
- engineer of mechatronics
- mechatronics systems designer
- specialist mechatronic engineer
- advanced mechatronics engineer

2.4 Regulatory aspect

To see if and how this occupation is regulated in EU Member States, EEA

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countries or Switzerland please consult the Regulated Professions Database of the Commission. Regulated Professions Database: http://ec.europa.eu/growth/single-market/services/free-movement-professionals/qualifications-recognition_en

2.5 Hierarchy

- 2 - Professionals
  - 21 - Science and engineering professionals
    - 214 - Engineering professionals (excluding electrotechnology)
    - 2144 - Mechanical engineers
    - 2144.1 - mechanical engineer
    - mechatronics engineer

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3 Design principles of a curriculum

In its most general definition, curriculum is a series of specifications regarding a sum of different topics and the level at which each of these must be understood in order to achieve a particular standard. A good model is presented by Harden et al. [HAR84], that identifies the following coordinates:

- **Student or teacher centered**: a student centered approach, the emphasis is on the students and what they learn, whereas in teacher centered approach the teacher is the central figure that decides what, when and with which methods is the information assimilated.
- **Problem based or information gathering**: problem based learning aims not only to gather information, but to put it to use, so that problem solving skills are developed.
- **Integrated or discipline based**: integrated learning blurs the border between different disciplines; there is horizontal integration, where several parallel disciplines are integrated, or vertical integration where disciplines usually taught in different phases of the curriculum are integrated.
- **Community or academia based**: one of the criticism to education is that students seldom know real-life problems, they are taught to solve problem that are more related to a didactic stand point, which foster a kind of “ivory tower” in which the University is more or less disconnected from the community problems.
- **Elective or standard program**: elective programs enables the choosing of subjects/projects that the student considers most relevant to her/his own personal growth and career.
- **Systematic or apprenticeship based**: a systematic approach in curriculum design strives to provide a similar experience to all student, whereas in an apprenticeship approach the gained experience might vary.

It is not necessary that a curriculum fits strictly into one extreme of these categories, it is more common to lie on a spectrum between the extremes; the main responsibility of the

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curriculum designer is to strike the adequate balance that allows maximum performance given the limited educational resources. According to Alsubaie [ALS16], the curriculum development must involve teachers, otherwise the successful implementation might be endangered. Hussain et al. [HUS11] identifies the following as characteristics that define a good curriculum developed as response to the fundamental questions “what”, “how”, “when” to teach and what is the impact of teaching:

- Development of social understanding;
- Promotion of maximum personal development;
- Promotion of continuity of experience;
- Provision of educational goals;
- Maintenance of balance among goals;
- Utilization of previous learning experiences and resources.

Nygaard et al. [NYG08] propose a curriculum development process that is focused on contextual learning, where the main components of learning, knowledge, skills and competences, are context-dependent through feedback and feedforward loops; skill is the ability of applying knowledge and experience to solve a task, and competences encompass the ability to combine multiple skills in order to meet a standard of performance implied or required by a particular context. Lunenburg [LUN11] presents three models for curriculum development: inductive, nonlinear and descriptive. Inductive models begin the development from curriculum materials and leads to generalizations. Nonlinear models permits entering in the model at various points, reverse the components order and attending multiple components of the model at the same time. A descriptive model implements platforms principles that leads to deliberation and design. It is worth noting that a real-life scenario for curriculum development implements all three models.

4 Proposed curriculum

4.1 Lecture 1 – "PLC based Project on Mechatronics System for Industry 4.0" Syllabus [UNI]

1. Information about the specialization

1.1 University	University of Nis
1.2 Faculty	Faculty of Mechanical Engineering, Faculty of Electronic Engineering
1.3 Department	Department of Mechatronics and Control; Department of Control Systems
1.4 Field of study	Mechatronics and Control
1.5 Degree level	B.Sc.
1.6 Specialization	Mechatronics

2. Information about the course

2.1 Course title	PLC based Project on Mechatronics System for Industry 4.0				
2.2 Year of study	4	2.3 Semester	2	2.4 Evaluation method	E
2.5 Course type	Formative category				Yes
	Optionality				No

3. Time budget

3.1 Number of hour / week	5	divided in:	3.2 Lecture	2	3.3 Seminary		3.3 Laboratory	2	3.3 Project	1
3.4 Number of hour / semester	70	divided in:	3.5 Lecture	28	3.6 Seminary		3.6 Laboratory	28	3.6 Project	14

3.7 Time budget distribution (hours / semester) for individual activity:	
(a) Individual study (course, obligatory bibliography, etc.)	26
(b) Additional documentation (recommended bibliography, etc.)	10
(c) Preparation for seminary/laboratory/project activities	28
(d) Peer learning	14
(e) Exam preparation	8
(f) Other activities	4

3.8 Total individual study (sum (3.7(a)...3.7(f)))	90
3.9 Grand total (3.4+3.8)	160
3.10 ECTS credits	5

4. Preconditions

4.1 curriculum	N/A
4.2 competences	N/A

5. Course requirement

5.1. for lecture	Computer, projector, projector screen

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5.2. for seminary/ laboratory/ project	PLCs, Festo training stations, industrial robot, associated software platforms (TIA portal, ...), computers

6. Gained competences

Professional competences	C6.1 - Description of the structure of PLC and main performances C6.2 - Use of specific tools to implement PLC control for different processes in industrial environment C6.3 - Application of basic principles and methods for specifying solutions to typical problems using PLCs and their communications' capabilities
Transversal competences	C6.4 - Choice criteria and methods for evaluating the quality, performance, and limits of PLC usage C6.5 - Development and implementation of professional projects for industrial automation

7. Course objective

7.1 General objective	Knowledge of PLCs as core of industrial automation; Principles of reinventing and reconfiguring PLCs as best option for industrial automation to fulfill requirements of Industry 4.0; Knowledge of communication between PLC and other devices in term of Industry 4.0; Knowledge of using PLCs of different PLCs' producers.
7.2 Specific objectives	Include the ability to analyze functional relationships in mechatronic systems; To provide fully integrated automation training, combining mechanics, pneumatics, electrical engineering, PLC control, and communication interfaces; To establish PLC communication using industrial network protocols and Internet; Knowledge of the steps required to provide communication of PLCs via TIA portal; Knowledge of establishing communication and connection of PLC with simulation software such as MATLAB

8. Contents

8.1 Lecture	Hours	Teaching methods	Observation
1 Industrial automation introduction	2		
2 PLC as core of Industrial automation	2		
3-4 The basic principles and structure of PLC	4		
5-6 PLC as Industry 4.0 component	4		
7-8 Communication capabilities of PLC	4		
9-10 Industrial Ethernet communication (Profinet, ...)	4		
11-12 Cyber PLC	4		
13 PLC Integration with MATLAB	2		
14 Other problems.	2		

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Bibliography			
8.2 Seminary / Laboratory / Project	Hours	Teaching methods	Observation
L1. PLC integration – basic examples	4		
L2. PLC control on Festo stations 1	4		
L3. PLC control on Festo stations 2	4		
L4. PLC integration with industrial robot	4		
L5. PLC control via internet	4		
L6. PLC control via TIA portal	4		
L7. PLC integration with MATLAB	4		
Bibliography As per references in Lecture 1 of IO3 Course support			

9. Evaluation

Activity	10.1 Evaluation criteria	10.2 Evaluation method	10.3 % of final grade
10.4 Lecture	Problem solving	Written exam	60%
10.5 Seminary/ Laboratory/ Project	**Projects portfolio**	presentation	40%
10.6 Minimum performance 50%			

4.2 Lecture 2 – "Vision technology" Syllabus [UTCN]

1. Information about the specialization

1.1 University	Technical University of Cluj-Napoca
1.2 Faculty	ARMM
1.3 Department	Mechatronics and Machine Dynamics
1.4 Field of study	Mechatronics and Robotics
1.5 Degree level	BSc.
1.6 Specialization	Mechatronics

2. Information about the course

2.1 Course title	Vision technology				
2.2 Year of study	4	2.3 Semester	1	2.4 Evaluation method	E
2.5 Course type	Formative category				
	Optionality				

3. Time budget

3.1 Number of hour / week	5	divided in:	3.2 Lecture	2	3.3 Seminary		3.3 Laboratory	2	3.3 Project	1
3.4 Number of hour /	70	divided	3.5	28	3.6		3.6	28	3.6	14

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semester		in:	Lecture		Seminary		Laboratory		Project	

3.7 Time budget distribution (hours / semester) for individual activity:	
(a) Individual study (course, obligatory bibliography, etc.)	26
(b) Additional documentation (recommended bibliography, etc.)	10
(c) Preparation for seminary/laboratory/project activities	28
(d) Peer learning	14
(e) Exam preparation	8
(f) Other activities	4

3.8 Total individual study (sum (3.7(a)…3.7(f)))	90
3.9 Grand total (3.4+3.8)	160
3.10 ECTS credits	5

4. Preconditions

4.1 curriculum	N/A
4.2 competences	N/A

5. Course requirement

5.1. for lecture	Computer, projector
5.2. for seminary/ laboratory/ project	Computers

6. Gained competences

Professional competences	C6.1 - Description of the components of image processing C6.2 - Use of field-specific tools to explain and understand the operation of image processing C6.3 - Application of basic principles and methods for specifying solutions to typical problems using image processing
Transversal competences	C6.4 - Choice criteria and methods for evaluating the quality, performance and limits of image processing C6.5 - Development and implementation of professional projects for image processing

7. Course objective

7.1 General objective	Understanding the concepts related to images, artificial vision and image processing. Learning and using image processing methods and designing specific applications.
7.2 Specific objectives	▪ Knowledge, evaluation and use of concepts, algorithms and methods specific to image processing: digital image representation formats, camera model, statistical analysis, filtering, quality improvement / restoration, segmentation, measurements. of time and resources

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	▪ Development of capacities for qualitative and quantitative evaluation of results, algorithms and systems based on image processing ▪ Knowledge and use of specific programming / processing tools (MATLAB, OpenCV)

8. Contents

8.1 Lecture	Hours	Teaching methods	Observation
1 Getting started Image processing introduction.	2		
2 Image processing with Matlab/Simulink.	2		
3 Binary image processing: Simple geometric properties of objects in binary images with Matlab/Simulink.	2		
4 Binary image processing: Object labeling. Contour detection with Matlab/Simulink.	2		
5 Binary image processing with Matlab/Simulink.	2		
6 Grayscale image processing: Statistical properties. Improving image quality with Matlab/Simulink.	2		
7 Convolution operation. Fourier transform.	2		
8 Noise in digital images with Matlab/Simulink.	2		
9-10 Filtering digital images with Matlab/Simulink.	4		
12-13 Edge-based segmentation with Matlab/Simulink.	4		
14 Other problems	2		
Bibliography 1. R. Gonzales, R. Woods, Digital Image Processing – 2-nd Edition, Prentice Hall, 2002. 2. S.Nedevschi, "Prelucrarea imaginilor si recunoasterea formelor", Ed. Microinformatica, 1997. 3. S. Nedevschi, R. Dănescu, F. Oniga, T. Mariţa, Tehnici de viziune artificială aplicate în conducerea automată a autovehiculelor, Editura U.T. Press, Cluj-Napoca, 2012.			
8.2 Seminary / Laboratory / Project	Hours	Teaching methods	Observation
L1. Image data import and export, conversion of image types and classes	2		
L2. Interactive tools for image display and exploration	2		
L3. Scale, rotate, perform other N-D transformations, and align images using intensity correlation, feature matching, or control point mapping	2		
L4. Image Filtering and Enhancement	2		
L5. Image Segmentation and Analysis	2		
L6. Deep Learning for Image Processing	2		
L7. 3-D Volumetric Image Processing	2		
Bibliography *MATLAB documentation			

9. Evaluation

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Activity	10.1 Evaluation criteria	10.2 Evaluation method	10.3 % of final grade
10.4 Lecture	Problem solving	Written exam	60%
10.5 Seminary/ Laboratory/ Project	**Projects portfolio**	presentation	40%
10.6 Minimum performance 50%			

4.3 *Lecture 3 – "Internet of Things, Digitalization, Industry 4.0, Cyber Physical Systems and Mechatronics" Syllabus [STU]*

1. Information about the specialization

1.1 University	Slovak University of Technology
1.2 Faculty	Faculty of Material Science and Technology
1.3 Department	Institute of Production Technologies
1.4 Field of study	Mechatronics and Robotics, Production devices
1.5 Degree level	Bc.
1.6 Specialization	Production devices and systems

2. Information about the course

2.1 Course title	Internet of Things, Industry 4.0, Cyber Physical Systems and Mechatronics					
2.2 Year of study	2	2.3 Semester	4	2.4 Evaluation method		
2.5 Course type	Formative category					
	Optionality					

3. Time budget

3.1 Number of hour / week	4	divided in:	3.2 Lecture	2	3.3 Seminary	0	3.3 Laboratory	2	3.3 Project	0
3.4 Number of hour / semester	52	divided in:	3.5 Lecture	26	3.6 Seminary	0	3.6 Laboratory	20	3.6 Project	6

3.7 Time budget distribution (hours / semester) for individual activity:	
(a) Individual study (course, obligatory bibliography, etc.)	26
(b) Additional documentation (recommended bibliography, etc.)	0
(c) Preparation for seminary/laboratory/project activities	20
(d) Peer learning	4
(e) Exam preparation	2
(f) Other activities	0
3.8 Total individual study (sum (3.7(a)…3.7(f)))	52
3.9 Grand total (3.4+3.8)	104
3.10 ECTS credits	6

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4. Preconditions

4.1 curriculum	N/A
4.2 competences	N/A

5. Course requirement

5.1. for lecture	Computer, projector
5.2. for seminary/ laboratory/ project	Computers

6. Gained competences

Professional competences	Knowledge and overview of IoT Understand and knowledge to use IoT
Transversal competences	Base overview of digital security

7. Course objective

7.1 General objective	IoT and its parts in context of Industry 4.0
7.2 Specific objectives	Cyberphysical systems Internet of things Industry 4.0 cybersecurity issues

8. Contents

8.1 Lecture	Hours	Teaching methods	Observation
Basic terminology	2	Lecture	
Cyberphysical systems	2		
Internet of things history and actual state of art	2		
IoT in Industry 4.0 context	2		
Possible negative/dangerous impacts of IoT	2		
Bibliography *internet			
8.2 Seminary / Laboratory / Project	Hours	Teaching methods	Observation

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Project preparation and presentation	2	Project preparation and presentation Group works	
Bibliography *internet			

9. Evaluation

Activity	10.1 Evaluation criteria	10.2 Evaluation method	10.3 % of final grade
10.4 Lecture	written exam		80%
10.5 Seminary/ Laboratory/ Project	**Project presentation**		20%
10.6 Minimum performance 56%			

4.4 Lecture 4 – "Virtual reality as a new trend in mechatronics engineering education" Syllabus [UTCN][www1]

1. Information about the specialization

1.1 University	Technical University of Cluj-Napoca
1.2 Faculty	ARMM
1.3 Department	Mechatronics and Machine Dynamics
1.4 Field of study	Mechatronics and Robotics
1.5 Degree level	BSc.
1.6 Specialization	Mechatronics

2. Information about the course

2.1 Course title	Virtual reality as a new trend in mechatronics engineering education				
2.2 Year of study	4	2.3 Semester	2	2.4 Evaluation method	E
2.5 Course type	Formative category				
	Optionality				

3. Time budget

3.1 Number of hour / week	4	divided in:	3.2 Lecture	1	3.3 Seminary		3.3 Laboratory	1	3.3 Project	2
3.4 Number of hour / semester	56	divided in:	3.5 Lecture	14	3.6 Seminary		3.6 Laboratory	14	3.6 Project	28

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3.7 Time budget distribution (hours / semester) for individual activity:	
(a) Individual study (course, obligatory bibliography, etc.)	18
(b) Additional documentation (recommended bibliography, etc.)	8
(c) Preparation for seminary/laboratory/project activities	22
(d) Peer learning	10
(e) Exam preparation	8
(f) Other activities	4

3.8 Total individual study (sum (3.7(a)…3.7(f)))	70
3.9 Grand total (3.4+3.8)	136
3.10 ECTS credits	5

4. Preconditions

4.1 curriculum	N/A
4.2 competences	N/A

5. Course requirement

5.1. for lecture	Computer, projector
5.2. for seminary/ laboratory/ project	Computer, virtual reality set

6. Gained competences

Professional competences	C1. Ability to use the MATLAB programming environment for development virtual reality graphics applications by mastering the techniques of analysis, modeling, design, implementation and evaluation of components that ensure interaction with the user in the virtual space of mechatronic systems. C2. Ability to use hardware and software concepts, techniques and technologies specific to the virtual reality domain using MATLAB or UNITY. 3. Ability to create complex applications in order to simulate mechatronic systems which integrates a wide range of tools available in MATLAB or UNITY. C4.5 Computer aided design and design for components and subassemblies mechatronic. Virtual and real prototype for mechatronic partial assemblies. Procedures manufacturing; choice of mechanical, electromechanical components, sensors and actuators in view of the optimal design of a complex mechatronic system
Transversal competences	CT1. Ability to develop MATLAB applications for the purpose of system design interactive virtual reality. CT2. Ability to use the MATLAB programming language for modeling and simulation of mechatronic systems in virtual reality. CT3 - Innovative design of intelligent and artificial vision systems and a components related software and hardware using specific tools CT3.1 - Demonstrate knowledge of technologies, programming environments and concepts specific to intelligent and artificial vision systems CT3.2 - Analysis and explanation of the role, interactions and functioning of software and hardware components developed on the basis of the latest methodologies proposed design in the scientific literature for intelligent and vision systems artificial.

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7. Course objective

7.1 General objective	Deepening and mastering advanced techniques and technologies modeling and programming of mechatronic systems in reality virtual using MATLAB or UNITY.
7.2 Specific objectives	O1. Ability to develop MATLAB applications for the purpose design of interactive virtual reality systems. O2. Ability to use the programming language MATLAB for modeling and simulation of systems mechatronics in virtual reality. O3. Make a project in the field of virtual reality according to the application development and evaluation methodology interactive; O4. Work individually or in a team.

8. Contents

8.1 Lecture	Hours	Teaching methods	Observation
C1. Introduction. Virtual reality technologies. What are virtual space and virtual reality? Technologies of virtual reality: a. Input devices b. Input devices playback c. User tracking devices.	2		
C2. Virtual reality systems architecture. components hardware and software resources. Components of virtual environments: a. Construction virtual worlds, b. Interaction with virtual worlds, c. Playing virtual worlds	2		
C3. Geometric patterns for virtual scenes and techniques associated. Virtual scenes, geometric patterns.	2		
C4. Modeling interaction and communication in systems for virtual reality. Modeling and communication techniques in systems for virtual reality.	2		
C5. Improved virtual reality.	2		
C6. Haptic playback - Haptic return. Haptic devices. Algorithms for rendering haptic.	2		
C7. Special classes of algorithms in virtual reality. Algorithms used in virtual reality.	2		
C8. Basics of programming in VRML / MATLAB-Simulink Basics of programming in Matlab/Simulink / VRML.	2		
C9. Advanced programming in VRML / MATLAB-Simulink Advanced programming in Matlab-Simulink / VRML.	2		
C10. Technologies, tools and application development	2		

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environments of virtual reality - UNITY software.			
C11. The evolution of virtual environments. The evolution of virtual environments. Classification of virtual environments.	2		
C12. Artificial vision. Introduction. Examples. Automatic visual guidance.	2		
C13. Image processing and analysis. Image processing and analysis. Design and implementation of Robot-View cooperation mechanisms Artificial. Artificial vision applications.	2		
C14. Virtual reality applications. Applications of virtual reality: modeling, simulation and visualization, experiments and simulations in the field of medicine, simulation systems.	2		
Bibliography www.mathworks.com www.unity.com			

8.2 Seminary / Laboratory / Project	Hours	Teaching methods	Observation
L1. The study of programming environments in virtual reality. Presentation of VR programming environments.	2		
L2. Elements of VR theory. Study of VR systems.	2		
L3. Virtual reality systems. General presentation. Immersive virtual reality systems. Systems of simulation. Projective systems. Telepresence systems. Augmented reality VR systems. Desktop virtual reality systems (desktop VR).	2		
L4. VRML. General presentation. VRML toolbox study.	2		
L5. Virtual reality applications in VRML. Making applications.	2		
L6. Virtual reality applications in UNITY. Making applications.	2		
L7. MATLAB-Simulink. General presentation. Study of the Virtual Reality / 3D animation toolbox.	2		
Bibliography www.mathworks.com www.unity.com			

9. Evaluation

Activity	10.1 Evaluation criteria	10.2 Evaluation method	10.3 % of final grade
10.4 Lecture	Problem solving	Written exam	60%
10.5 Seminary/ Laboratory/ Project	**Projects portfolio**	presentation	40%

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10.6 Minimum performance 50%

4.5 Lecture 5 – "Smart Manufacturing and Automation with Industry 4.0" Syllabus [UPT]

1. Information about the specialization

1.1 University	Politehnica University of Timisoara
1.2 Faculty	Mechanical Engineering
1.3 Department	Mechatronics
1.4 Field of study	Mechatronics and Robotics
1.5 Degree level	Bachelor
1.6 Specialization	Mechatronics and Robotics

2. Information about the course

2.1 Course title	Smart Manufacturing and Automation with Industry 4.0				
2.2 Year of study	4	2.3 Semester	1	2.4 Evaluation method	Exam
2.5 Course type	Formative category				Yes
	Optionality				No

3. Time budget

3.1 Number of hour / week	4	divided in:	3.2 Lecture	2	3.3 Seminary	0	3.3 Laboratory	0	3.3 Project	1
3.4 Number of hour / semester	42	divided in:	3.5 Lecture	28	3.6 Seminary	0	3.6 Laboratory	0	3.6 Project	14

3.7 Time budget distribution (hours / semester) for individual activity:	
(a) Individual study (course, obligatory bibliography, etc.)	5
(b) Additional documentation (recommended bibliography, etc.)	5
(c) Preparation for seminary/laboratory/project activities	7
(d) Peer learning	2
(e) Exam preparation	8
(f) Other activities	1

3.8 Total individual study (sum (3.7(a)…3.7(f)))	28
3.9 Grand total (3.4+3.8)	70
3.10 ECTS credits	4

4. Preconditions

4.1 curriculum	Project MIND, lectures 1…4
4.2 competences	PLC automation, Sensors and Actuators, IoT, manufacturing methods

5. Course requirement

5.1. for lecture	Notebook
5.2. for seminary/ laboratory/	PC, notebook, printer access, Internet access

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project	

6. Gained competences

Professional competences	- Envisioning and developing smart manufacturing solutions using state of the art components, concepts and tools. - Integration of smart manufacturing layers upon existing automation solutions, in an efficient way. - Knowledge base enlargement regarding manufacturing methods and information flow between automation entities. - Designing and supporting missing links in working applications in order to qualify the complete system as smart manufacturing. - Combining in a mechatronic approach all subsystems that could lead to smart manufacturing. - Responsible professional tasks approach, in an autonomous way, without qualified assistance.
Transversal competences	- Efficient management for conceiving, designing, planning and organizing specific activities. - Development of research projects, scientific studies or articles, BSc. Thesis. - Efficient use of IT, scientific and special resources, regarding the professional road - Applying efficient communication techniques within professional relation, with individual particularities.

7. Course objective

7.1 General objective	This course aims to develop the general and specific skills of the students within the MIND project consortium: - Formation of notions related to the concept of smart manufacturing and automation, - Formation of ideas on the advantages of Industry 4.0 implementation, - Understanding the relatively complex topics about smart manufacturing and automation with Industry 4.0.
7.2 Specific objectives	- To know the main Industry 4.0 paradigms with which they interact, - Knowledge of the steps required to develop smart manufacturing solutions, - To understand smart manufacturing concepts for manual processes, - To know how smart manufacturing helps energy efficiency, - To identify the opportunities for possible production optimization.

8. Contents

8.1 Lecture	Hours	Teaching methods	Observation
Introduction – general concepts of smart	2	Presentation, demo	

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manufacturing for Industry 4.0.		videos, dialogue, smartboard sketching/inking, real-life examples	
Smart manufacturing paradigms, Machine networking, Smart equipment.	4		
Advanced robotics, New manufacturing concepts.	2		
Connected devices and services, Big data & machine learning.	2		
Product traceability, Real-time production scheduling, Quality assurance & quality control.	2		
Communications and technology overview for complementing machine automation, M2M communication standards.	4		
The role of CV/ML in smart manufacturing.	2		
Smart maintenance – the key to keep a factory in top condition.	2		
Examples of smart manufacturing in other areas, Smart manufacturing for the energy-save challenge.	2		
Examples of Smart Manufacturing for manual processes.	2		
Adaptive pick by light.	2		
Conclusion and closing aspects.	2		
Bibliography As per references in Lecture 5			

8.2 Seminary / Laboratory / Project	Hours	Teaching methods	Observation
Project thematic selection	2	Dialogue, argumentation, documentation, analysis, presentation.	
State of the art exposal	2		
Proposed solution selection	2		
Proposed solution description	2		
Project compiling and writing	4		
Project presentation and grading	2		
Bibliography As per references in Lecture 5			

9. Evaluation

Activity	10.1 Evaluation criteria	10.2 Evaluation method	10.3 % of final grade
10.4 Lecture	Ability to express notions and make correct decisions, related to S.M./I4.0	Written Exam, 2h, 5 items, max. 9 points.	70% (max. grade=10)
10.5 Seminary/ Laboratory/ Project	Ability to develop a written project related to S.M./I4.0	Content check, max. 6 points; Presentation 10 min., max. 3 points;	30% (max. grade=10)

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10.6 Minimum performance:	5.0/10

4.6 *Lecture 6 – "Implementation of new manufacturing technologies and systems for Industry 4.0" Syllabus [UNI] [UPT]*

1. Information about the specialization

1.1 University	Politehnica University of Timisoara
1.2 Faculty	Mechanical Engineering
1.3 Department	Mechatronics
1.4 Field of study	Mechatronics and Robotics
1.5 Degree level	Bachelor
1.6 Specialization	Mechatronics and Robotics

2. Information about the course

2.1 Course title	New manufacturing technologies and systems for Industry 4.0				
2.2 Year of study	4	2.3 Semester	1	2.4 Evaluation method	Exam
2.5 Course type	Formative category				Yes
	Optionality				No

3. Time budget

3.1 Number of hour / week	2	divided in:	3.2 Lecture	2	3.3 Seminary	0	3.3 Laboratory	1	3.3 Project	1
3.4 Number of hour / semester	42	divided in:	3.5 Lecture	28	3.6 Seminary	0	3.6 Laboratory	14	3.6 Project	14
3.7 Time budget distribution (hours / semester) for individual activity:										
(a) Individual study (course, obligatory bibliography, etc.)										3
(b) Additional documentation (recommended bibliography, etc.)										2
(c) Preparation for seminary/laboratory/project activities										14
(d) Peer learning										2
(e) Exam preparation										6
(f) Other activities										1

3.8 Total individual study (sum (3.7(a)…3.7(f)))	28
3.9 Grand total (3.4+3.8)	70
3.10 ECTS credits	4

4. Preconditions

4.1 curriculum	Project MIND, lectures 1…5
4.2 competences	-

5. Course requirement

5.1. for lecture	Notebook
5.2. for seminary/ laboratory/ project	3D printer, PC, notebook, printer access, Internet access

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6. Gained competences

Professional competences	- Understanding of rapid prototyping – state of the art - Integration of rapid prototyping in smart manufacturing in an efficient way - Designing of parts according to selected 3D printing technology - Knowledge base enlargement regarding additive technology - Responsible professional tasks approach, in an autonomous way, without qualified assistance
Transversal competences	- Efficient management for conceiving, designing, planning and organizing specific activities. - Development of research projects, scientific studies or articles, BSc. Thesis. - Efficient use of IT, scientific and special resources, regarding the professional road - Applying efficient communication techniques within professional relation, with individual particularities.

7. Course objective

7.1 General objective	- Formation of notions related to the concept of rapid prototyping, - Formation of ideas on the advantages of new manufacturing technologies and systems, - Understanding the relatively complex topics about learning and prototyping with the help of rapid prototyping.
7.2 Specific objectives	-To know and understand main 3D printing technologies, -Knowledge of the steps required for rapid prototyping, -To prepare CAD model for specific 3D printing technology, -To know how it works, -To identify the causes of a possible problem.

8. Contents

8.1 Lecture	Hours	Teaching methods	Observation
Introduction in rapid prototyping	2	Presentation, demo videos, dialogue, examples	
Types of 3D printing	4		
Specifics of 3D printing – support structure, slicer	4		
FDM	4		
SLA	2		
SLS	2		
Other 3D printing technologies	2		
Examples of 3D printing in industry	4		

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Bibliography As per references in Lecture 6			
8.2 Seminary / Laboratory / Project	Hours	Teaching methods	Observation
Project thematic selection	2	Dialogue, argumentation, documentation, 3D printing, pre and post processing of 3D printed parts, presentation	
State of the art exposal	2		
Proposed solution selection	2		
3D printing of selected projects	12		
Bibliography As per references in Lecture 6			

9. Evaluation

Activity	10.1 Evaluation criteria	10.2 Evaluation method	10.3 % of final grade
10.4 Lecture	Ability to express notions and make correct decisions, related to Rapid prototyping	Written Exam, 2h, 5 items, max. 9 points.	60% (max. grade=10)
10.5 Seminary/ Laboratory/ Project	Ability to carry out 3D printing	Content check, max. 6 points; Presentation 10 min., max. 3 points;	40% (max. grade=10)
10.6 Minimum performance:			5.0/10

4.7 Lecture 7 – "Digitalization and Industry 4.0" Syllabus [UNI]

1. Information about the specialization

1.1 University	University of Nis
1.2 Faculty	Faculty of Mechanical Engineering
1.3 Department	Department of Mechatronics and Control
1.4 Field of study	Mechatronics and Control
1.5 Degree level	Bachelor
1.6 Specialization	Mechatronics

2. Information about the course

2.1 Course title	Digitalization and Industry 4.0				
2.2 Year of study	4	2.3 Semester	1	2.4 Evaluation method	E
2.5 Course type	Formative category				Yes
	Optionality				No

3. Time budget

3.1 Number of hour /	4	divided	3.2	2	3.3	0	3.3	1	3.3	1

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week		in:	Lecture		Seminary		Laboratory		Project		
3.4 Number of hour / semester	56	divided in:	3.5 Lecture	28	3.6 Seminary	0	3.6 Laboratory	14	3.6 Project	14	

3.7 Time budget distribution (hours / semester) for individual activity:	
(a) Individual study (course, obligatory bibliography, etc.)	20
(b) Additional documentation (recommended bibliography, etc.)	10
(c) Preparation for seminary/laboratory/project activities	14
(d) Peer learning	8
(e) Exam preparation	8
(f) Other activities	4

3.8 Total individual study (sum (3.7(a)…3.7(f)))	64
3.9 Grand total (3.4+3.8)	120
3.10 ECTS credits	5

4. Preconditions

4.1 curriculum	N/A
4.2 competences	N/A

5. Course requirement

5.1. for lecture	Computer, whiteboard, projector, projector screen
5.2. for seminary/ laboratory/ project	Computers, embedded platforms

6. Gained competences

Professional competences	C6.1 - Description of the structure of the Digitalisation and Industry 4.0 C6.2 - Use of specific tools to implement data technologies in Industry 4.0 C6.3 - Application of basic principles and methods for specifying solutions in Industry 4.0 related to digitalization
Transversal competences	C6.4 - Choice criteria and methods for evaluating the quality, performance, and limits of using digitalization techniques and data technologies C6.5 - Development and implementation of professional projects for implementing data technology in industry environment

7. Course objective

7.1 General objective	Introduction to the Big data concepts and characteristics; Understanding different technologies for acquiring, analyzing, and processing data; Introduction to the Blockchain technology; Understanding fundamental Blockchain features: security, decentralization, mining,

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	hash functions, privacy and authentication; Gaining the knowledge of machine learning types commonly applied for analytics
7.2 Specific objectives	Understanding the requirements for providing optimal analytical environment; Introduction to descriptive, predictive, and prescriptive analytics; Presentation of real-world applications in the domains of Big data, Blockchains and Machine learning powered analytics

8. Contents

8.1 Lecture	Hours	Teaching methods	Observation
1 Digitalization and Industry 4.0-Introduction	2		
2 Introduction to Big Data Concept	2		
3 Big Data characteristics	2		
4 Technologies for collecting, pre-processing, and analyzing Big Data	2		
5-6 ML training techniques for advanced analytics	4		
7 Requirements for providing optimal digital analytical environment	2		
8 Descriptive, predictive and prescriptive analytics	2		
9 Introduction to Blockchain technology	2		
10 Security and decentralization	2		
11 Mining	2		
12 Cryptographic hash function	2		
13 Rewarding the miners	2		
14 Privacy and authentication	2		
Bibliography As per references in Lecture 7 of IO3 Course support			
8.2 Seminary / Laboratory / Project	Hours	Teaching methods	Observation
L1-L3 Application of Big Data Analytics	6		
L4-L5 Real-world ML applications and analytical approaches in Industry 4.0	4		
L6-L7 Blockchain applications	4		
Bibliography As per references in Lecture 7 of IO3 Course support			

9. Evaluation

Activity	10.1 Evaluation criteria	10.2 Evaluation method	10.3 % of final grade
10.4 Lecture	Theoretical understanding Problem solving skills	Written exam	60%
10.5 Seminary/ Laboratory/ Project	**Project portfolio**	Portfolio	40%
10.6 Minimum performance 50%			

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5 Conclusion

Developing a curriculum for mechatronics has to take into account the current industry standards and the future trends, namely industry 4.0; it has to be student centered, with the emphasis of what they learn in a problem based learning; it is important to take into account an integrated approach, to blur the lines between different disciplines, as real-life scenarios are not solved by using only one field. Also, it is important that students are taught to solve problems that are related more to the community needs and less didactic centered. The curriculum must allow the students to choose their own subject that are most relevant to their personal growth and career choosing. Ideally, an apprenticeship-based curriculum might enable the previously stated points.

The proposed syllabuses covers the main aspects of industry 4.0: PLC based projects that enable understanding of automatization technologies, computer vision technology which paves the future for fully autonomous artificial intelligence agents, the internet of things which allows ad hoc networking between smart equipment, virtual reality that empowers the individual to innovate and learn in a new way, smart manufacturing and implementation of new manufacturing technologies which provide the tools for developing of smart eco-aware products, and digitalization, all these thematic constitutes a solid ground for teaching the main aspects of industry 4.0.

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