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University of
Belgrade



**Implementation of Dual Education in Higher Education of
Serbia**

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**REVIEW OF MASTER ACADEMIC STUDIES - INDUSTRY 4.0
AT THE UNIVERSITY OF BELGRADE - FACULTY OF
MECHANICAL ENGINEERING**

(created by University of Lleida)

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Abstract	This document represents the concept of specific DHEM developed at UB and represents a basis for the presentation of this DHEM to interested companies.
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Benefits of introducing dual studies

One of the major conclusions of the employers' perceptions on the employability and skills of recent graduates, people that obtained a degree in the last two years before hiring, is that a significant percentage of the companies experienced difficulties in recruitment, especially because of the shortage of applicants with the necessary skills. This fact, produces that most of the organizations has to provide some kind of training within the enterprise or institution. The main reasons are for upgrading specific skills and/or training within the sector –which can make sense in many situations–, for adapting the new staff to the company or institution's characteristics, and finally, to improve the soft skills.

The third Bologna Objective states that “credits could also be acquired in non-higher education contexts, including lifelong learning, provided they are recognized by receiving Universities concerned”.

In this context, recognizing the company as a learning place can improve the competencies level of the graduates, their employability and improve the adjustment between the required skills and competencies required by the employers, while keeping the academic and quality level required for a degree program. The learning by doing and the role of the student as a worker at the company are the basis of the concept.

The benefits of a dual study model can be seen from different viewpoints. First, from the professionalization, it allow the students to validate their professional vocation from the beginning, improves the acquisition of skills, improves the entrepreneurial capacities and approaches them to the labor market. Second, it facilitates the university-company relationship, helps companies to find young talent and boosts the innovation inside the companies. Finally, it forces the different actors –tutors and students– to be updated in their knowledge.

Analysis of the contents and the relevance of the covered courses

The content of the MAS Industry 4.0 curriculum fits perfectly with the present trends in industry and the need of multidisciplinary engineers in relevant areas –the field of information technologies and the contemporary industrial production– that are applied in practice in leading high-tech companies.

The goals and learning outcomes of the MAS Industry 4.0 reflect a new approach to the production process, which involves networking smart digital devices with the products, machines, tools, robots and humans. All these goals are achieved throughout the program

combining the academic work with in-company training. The hours dedicated to each part are well stated and balanced.

MAS Industry 4.0 lasts for two years, i.e. four semesters and they are valued with 120 ECTS. The total workload of students during the two-year study program MAS Industry 4.0 is 1005-1125 hours of active classes and 920-992 hours of work-based learning, depending on the elected courses and other forms of classes performed by the employer. Every employer is provided with guidelines for proceeding with students, based on which students are assigned with industrial mentors who will, together with the academic mentor, form a development plan for students and quantified indicators of his/her improvement based on which the student will be graded.

Within the standard study program, according to the accreditation, both the practice and the master thesis of 435 hours will be carried out at the employer, whereby the activities of students will be monitored in close cooperation between the employer's mentor and the master thesis mentor, while other forms of classes will be performed in the academic institution.

The content of the courses studied at master academic studies Industry 4.0 is broad, covering a large number of areas that provide opportunities for students to acquire theoretical knowledge during these studies.

Several compulsory courses at the university are the basis of a good knowledge on the digital technologies required. These courses are:

- *Algorithms and Data Structures*. The goals are to acquire basic knowledge about data structures, fundamental algorithms, algorithm construction analysis and strategies. The learning outcomes are that students have the opportunity to acquire basic knowledge about data structures, construction strategies and algorithm analysis, and the acquired knowledge can be applied in solving new problems.
- *Robotics and Artificial Intelligence*. The aim of the course is to develop student's ability for implementation of intelligent robotic systems using the conceptual design and robot evolutiveness, in accordance with the basic paradigms of artificial intelligence. Students will acquire knowledge and skills necessary for further development of production technologies within the Industry 4.0 by learning the robotic system structure based on methodological approach which includes robot mechanics, sensor and actuator subsystems, control and robot movement optimization as well as hardware-software integration. It is done by using the laboratory equipment like re-configurable mobile robots with various sensors and embedded laboratory model of the manufacturing system in accordance with implementation of 3D computer simulation for Industry 4.0 development. Students will be able to implement developed software tools for modelling and analyses of intelligent robotic systems, choose the advanced methods based on

artificial neural networks and other computational intelligence techniques in order to carry out the intelligent behaviour of the mobile robot in interaction with manufacturing environment, understand the interaction between the software and hardware subsystems of intelligent mobile robot structure through robotic reconfiguration and programming and, finally, develop the ability for team work.

- *Machine Learning of Intelligent Robotic Systems.* The aim of the course is to gain student's ability for development and implementation of intelligent mobile robots which are capable to realize robotic tasks in advanced manufacturing environment, through hardware-software integration, without explicit human-operator control, and in accordance with the various paradigms of artificial intelligence. Considering the fact that production technologies of the 21st century involve this hardware-software integration of intelligent systems, especially mobile robots as well as automated agents, the course has its goal to educate students at master level through theoretical and practical aspects for complex development of modern robotized systems and processes, their modelling, implementation within the Industry 4.0 based on advanced algorithms and methods in domain of artificial intelligence. After completing the course the students will be able to implement information and communication technologies within the intelligent robotic systems; select methods based on the application of various artificial intelligence techniques (artificial neural networks, fuzzy logic and hybrid control, etc.) as well as biologically inspired algorithms in finding the optimal solution within the process of development and application of machine learning in intelligent robotic systems; Understand the interaction between the software and hardware subsystems of intelligent mobile robot in decision-making, during exploration of the manufacturing environment, through reconfiguration its physical structure and intelligent behavior programming in Matlab environment.
- *Cyber Physical Systems.* The objective of this course is that students acquire knowledge and skills in cyber physical systems design and implementation through experience in mechanical and control subsystems co-design. After successfully completing this course, the students should be capable to design cyber physical systems through augmenting mechanical devices with computation and communication capabilities; Implement smart and conventional sensors and actuators in various systems design; Design embedded control systems based on microcontrollers; Understand the principles of motion control and implement motion control in various tasks.

These compulsory courses are complemented by a group of elective courses that can be taken throughout the program. These elective courses are:

- *Digital Measuring Systems.* The goals are the acquisition of theoretical and practical knowledge in the field of the new generation of metrology systems - digital measuring systems required for the concept of digital quality and planning of inspection in the

context of Industry 4.0. Upon successful completion of this course, students should be trained to: recognize, improve existing and develop new protocols in communication between virtual and real measuring machines; automatically generate the measurement protocol and thus reduce the time of the measurement preparation; develop a new engineering ontology for the purpose of classifying reuse and sharing knowledge of a particular domain using an optimal set of information based on Big data and Analytics; develop an ontological knowledge base for the integration of geometry and machine machine tolerance; application of intelligent intelligence planning techniques based on artificial intelligence (GA and AC) techniques and simulate the measurement process in a virtual environment; optimally position the measuring part on the measuring machine, taking into account the geometric and metrological complexity of the work; Configure the optimal number of measuring sensors for each setting of the measuring part; generate an optimum measurement path and thus reduce the main measurement time.

- *Machine Learning*. The goals are acquiring knowledge about fundamental machine learning models, algorithms, key design elements, and evaluation techniques. After completing the course, the students understand basic machine learning techniques, they have applied them in practice, they are able to select techniques adequate for the problem at hand, they understand how the decisions made in the algorithm design phase affect the algorithm behavior, and can estimate the quality of the obtained models.
- *Computational Intelligence*. The goals are making student capable to develop and to use different Computational intelligence (sometimes called Soft computing) techniques to solve problems from various domains and to be well-prepared in practical programming. Upon finishing this course, student will be ready for work and further specialization in the field of Computational intelligence.
- *Introduction to Bioinformatics*. The goals are acquiring knowledge about types and sources of data available for computational biology, and about mathematical methods and algorithms used for solving substantial informatical problems in molecular biology. After the course, a student is capable of further studying and individual scientific work in bioinformatics.
- *Data Mining*. Goals are an introduction to general topics of data mining and its applications. After completion of the course, the student have adopted the elementary concepts and techniques of Data Mining and trained for their practical applications.
- *Virtual Reality*. Goals are introduction to the study of the basic principles of computer graphics, elementary and complex transformations integrated in the radar space. Delimited and improved models of use of ready-made software solutions in the control of control graphic products in 2D and 3D models conceived on the radar platform. Integrating knowledge in the realm of virtual things through 2D and 3D elements' systems eliminates' flat 'screens and modern hardware solutions designed on library synergy and capable of having hardware. After successful completion of the program provided by this subject student can apply the acquired knowledge in the scientific, technical and engineering applications of virtual reality technology; and design engineering software

based on computer graphics, • to integrate knowledge in the field of video game physicality.

As far as industrial technologies, the students are prepared in the following subjects:

- *Introduction to Production Systems.* Goals are adoption of basic concepts of production systems, their structure and mutual relations of systems in production machining as well as ways to automate processes within the production system; knowledge of the role and importance of computer information systems in the process of production planning and management; application of computer integrated technologies in the process of designing production systems. Upon successful completion of this course, students should be able to identify and solve problems in the work of production systems; apply knowledge from the domains of modeling, simulation and visualization in various industrial applications; use modern software tools in the design, development and use of production information systems; improve the performance of manufacturing systems by applying various tools.
- *Contemporary Management and Network Organizations.* The objective of the course is to familiarise students with the basics of network organisational structure and to master organisational and management skills in the business environment of Industry 4.0. Students are empowered to plan, organise and manage according to available resources with adequate management of quality, cost, time and risks in I4.0 business conditions. Upon completion of the course, students will be able to identify, consider, master and critically relate to contemporary, real-world problems of organization and management in I4.0, as well as identify and summarize the main practical implications of the issues and problems involved in organization and society.
- *Designing Business Models in Industry 4.0.* The course introduces the concepts, tools and principles of business model design aligned with the concept of Industry 4.0 and offers a hands-on approach to understanding, designing and testing business models. Upon completion of the course students will be able to explain the importance of business models for creating value and driving successful ventures in the modern economy; describe, compare and critically consider different approaches to business models. - Analyze and critically evaluate existing business models; design and present business models of innovative and sustainable ventures in I 4.0; understand the importance of disruptive innovations in I 4.0; design and improve all elements of business model templates on the basis of market success.
- *Interfaces for Interoperability in Industry 4.0.* The aim of the course is to provide students with an understanding of the importance and practical application of principles and concepts for the development, testing and enhancement of interfaces that allow for adequate interoperability / interaction / collaboration in the context of Industry 4.0. Upon completion of the course, the outcomes are as follows: 1. Adequate understanding and

reflection of issues, problems and challenges in designing user-friendly digital technology in an Industry 4.0 environment; 2. Understanding the design process focused on system interoperability, user-system interaction and collaboration; 3. Development of innovative ideas for interactive technologies; 4. Developing collaborative and conceptual design skills; and 5. Addressing complex real-world challenges in an innovative and self-organized way.

In this field, the education is also completed by choosing among a group of elective courses.

- *Distributed Systems in Mechanical Engineering.* The goals are introduction to the paradigm of distributing data; knowledge of basic protocols for the transfer and sharing of distributed data; designing local area networks based on different technologies; introduction to multiprocessor distributed systems in the automotive and aircraft industry, introduction to algorithms that are typical of multi-processor distributed systems. Upon completion of the course students will be able to recognize the conditions for the formation of local area networks, to allocate names to resources on the net, to control and manage assigned resources; to understand the multi-processor and redistribution of data among them.
- *Supply Chain Management.* The objective of the course is to explore key issues related to the design and management of industrial supply chains. Upon completion of the course syllabus, students will be able to describe and explain the basics of the supply chain; describe the blocks of the supply chain network; explain the main functions of the supply chain; explain the major business processes in the supply chain; describe supply chain performance measures; describe strategic, tactical and operational decisions in supply chain networks; explain functionality, work and usage and modules of Supply Chain Monitoring Software (ERP, WMS, TMS) and Industry 4.0 environment; outline the role of internet technology and e-commerce in supply chain operations; describe the principles, algorithms and application of machine learning in the field of supply chain management; explain the role and method of applying Barcode and RFID technology in data acquisition and tracking of goods (supplies) in the supply chain; calculate performance measures, such as cost / profit; analyze the technical aspects of key components in supply chain management; use the Markov chain for the supply chain modeling; explain optimization of the supply chain model; demonstrate simulation in supply chain planning and decision making.
- *Quality and Risk Management in Industry 4.0.* The aim of the course is to provide students with an understanding and practical application of the principles, concepts, standards and tools for quality and risk management in I4.0 practice, with the aim of achieving the satisfaction of all stakeholders. Upon completion of the course, students will be able to explain the importance of quality and risk management under I 4.0; apply quality and risk management standards; apply and critically review the results of the applied quality and risk management methods and techniques under I 4.0; improve quality and mitigate risk within I 4.0.

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- *Scheduling of Manufacturing Systems and Processes.* The aim of the course is to provide master students with a sound understanding of advanced biologically inspired artificial intelligence techniques for effective and efficient optimal scheduling of systems and processes. This course gives an introduction to theoretical and practical knowledge and skills used to solve a broad range of scheduling problems that arise in intelligent manufacturing systems within the Industry 4.0 framework as well as to the software packages and programming skills needed to deal with these problems. The course will focus on production planning and scheduling, manufacturing resources planning and scheduling, job shop scheduling, transportation scheduling, and mobile robot scheduling. The course covers advanced evolutionary and swarm intelligence based approaches for dealing with optimal scheduling of systems and processes. After successfully completing this course, the students should be able to: - use information and communication technologies in scheduling of systems and processes; - formulate and mathematically model the scheduling problems; - implement advanced biologically inspired algorithms, approaches and strategies to optimize scheduling plans, with objective to minimize/maximize the fitness function according to optimization criteria; - develop their own software solutions in MATLAB environment; - experimentally evaluate the performance of the algorithms, as well as discuss and present achieved results; - work in team.
 - *Digital Factory and Intelligent Maintenance.* The aim of the course is to make students understand transformation of the way that products are being designed and manufactured through digital manufacturing and design (DM&D) – a shift from paper-based processes to digital processes in the manufacturing industry. After the course students will be able to understand what DM&D is and how it is impacting careers, practices and processes in companies both large and small and also the role that technology is playing in Industry 4.0. Students will receive foundational knowledge about digitally connected enterprise and become acquainted with the available tools, technologies and techniques that can be applied in production scheduling, maintenance, facility layout design, internal material transport and inventory. Students will become better prepared to participate, as a member of an advanced analysis team, in the implementation of intelligent machining into product lifecycle and digitally connected enterprise.
 - *Business Intelligence and Business Analytics.* This course introduces business intelligence as computerized support for managerial decision-making. It concentrates on the theoretical and conceptual foundations of business intelligence as well as on commercial tools and techniques available for effective decision-support. This is a course intended to familiarize students with business analytics concepts, fundamentals, tools and applications. The course place special emphasis on working through applications and examples of analytics in the real world. It also presents some of the fundamental and most important techniques in business intelligence, analytics and data mining. On successful completion of the course the students should be able to demonstrate

knowledge of key principles and techniques of business intelligence and business analytics; identify the right business intelligence and analytics tools/techniques for various business problems; categorize and carefully differentiate between situations for applying different data-mining techniques (association, correlation, classification, prediction, and cluster analysis); demonstrate knowledge and understanding the different of algorithms and quantitative techniques suitable for data analysis and mining in a broad range of application areas; design and implement systems for data mining and evaluate the performance of different data-mining algorithms; use a wide range of publicly available data mining tools; evaluate the effectiveness of these data mining tools based on different performance measures; make data driven decisions to optimize the business process according to the data analysis results and interpret the obtained results; use practical knowledge and skills in developing and using modern application software solutions for business decision support.

- *Flexible and Reconfigurable Manufacturing Systems.* The aim of the course is to acquire knowledge for the development of variable and reconfigurable production, in order to enable efficient manufacturing of products tailored to the customer with high variability of manufacturing, rapid introduction of new products, as well as variations in product quantity. After successfully completing the course, students will be able to demonstrate knowledge and understanding of variable, reconfigurable and flexible manufacturing concepts; demonstrate knowledge of parallel development of products and manufacturing systems; demonstrate knowledge of design support methods and tools for reconfigurability; demonstrate the ability to lead development for changing production solutions; demonstrate the ability to assess the current state of implementation and reconfigurable production systems; -demonstrate the ability to identify the need for variability and reconfigurability.

Most of the course are taken during the first year and the 3rd semester. There are two periods of internship at the company in the 3rd and 4th semester. This last semester is mainly dedicated to the internship and the preparation and defense of the master thesis. The Master thesis must contain at least two of the following fields: material on the topic studied and analysed, self-performed numerical calculation, self-done laboratory work, and/or self-performed mechanical design. Thesis defence cannot be conducted until all the exams have been passed.

According to the dual model every student studying will get an academic tutor when enrolling the studies. In addition to the academic tutor, every student will get a tutor from the company. The study plan for each student is defined and agreed separately with his/her academic mentor and the mentor from the employer, within the first month from enrolment.

Mentors have monthly meetings (or more than once per month if necessary) in order to make decisions about the work tasks for students, and reporting on the work and studying of students is performed every semester.

Adjusted dynamics of performance and the schedule of courses per years

At the beginning of the realization of the study program, students will get acquainted with the basic production systems, management and organization of the enterprise, as well as other courses enabling the student to get an insight into the functioning of one production organization. Getting acquainted with the current technological trends, such as robotics and artificial intelligence, machine learning, computer intelligence, students obtain the knowledge on current technological trends in the world, whereby they can connect their acquired theoretical knowledge with the later active work at the employer, but also with the experiences of other leading technological companies. The advantage of the study program is in the large number of elective courses, enabling students to focus in accordance with their interests.

The structure of the study program MAS Industry 4.0 contains 9 obligatory and 6 elective courses, 2 of which are professional practice during the third and fourth semesters, writing and defense of the master thesis at the end. The obligatory and elective courses have 6 ECTS, Practice part 1 – 6 ECTS, Practice part 2 – 9 ECTS, and activities connected to the Master thesis have 15 ECTS.

The aim of the master thesis is for the student to apply the obtained engineering knowledge and skills in order to be able to participate more efficiently in the identification and solution of a certain engineering task, then to efficiently participate in system, component or process design, within the real limitations, such as economic, ecological, health and safety, as well as to apply the computer and statistical methods and information technology for the analysis and synthesis of technological systems and to perform the overview of results.

The specificity of the program MAS Industry 4.0 is the professional practice, which will be performed during the second year of studies in two parts. The first part of the practice will be performed during the entire third semester (dynamics is as follows: one day per week with the total duration of 15 days), while the second part of practice will be performed in the fourth semester (the dynamics are as follows: the total duration of 40 working days). After the realization of practice, the defense of the master thesis is performed. 37 teachers and teaching associates work at the program MAS Industry 4.0, 6 of which are from abroad and 12 from the business sector.

Work-based learning in the first semester is represented by 24 hours, in the second semester by 72-96 hours, while in the third semester by 120-168 hours, and the fourth semester by 576-600 hours, it can be noted that the time spent on work-based learning is successively increased from semester to semester, whereby the possibility for the student to obtain theoretical knowledge acquired at the higher education institution is used and extended through work-based learning

at the employer, with the realization of the synergetic effect of active classes and work at the employer's.