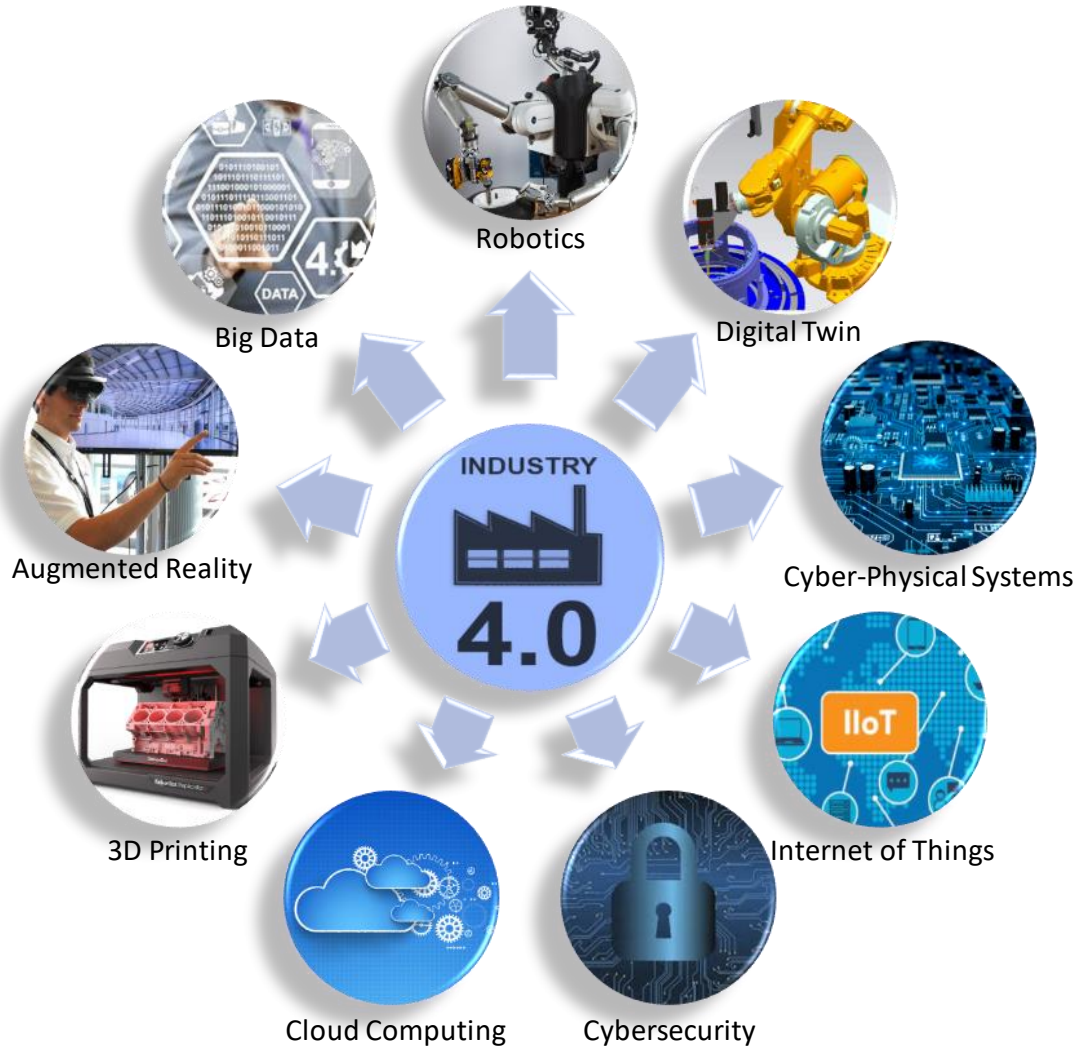
Isfahan University of Technology

Zurich University of Applied Sciences



Industry 4.0 Course Syllabus

A graduate course on Industry 4.0
Jointly taught by IUT and ZHAW

Version 1.0, June 6th, 2019

Isfahan University of Technology

Zurich University of Applied Sciences

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Revision history

Date	Ver.	Description	Author
30-May-2019	0.1	Initial version Suggestion for the course content and structure by vhns, comments and suggestions from IUT requested	vhns
03-June-2019	0.2	Some corrections and enhancements to the Modules Learning outcomes adapted	vhns
05-June-2019	0.3	Some corrections in module 12 and 13, suggested by asma, also changed product name in module 7	vhns
06-June-2019	1.0	Final Version 1.0 Comments & annotations removed	vhns

Short signs:

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1 General information

Industry 4.0 is a novel paradigm for industrial production in which digitization plays a fundamental role. Implemented examples are mainly characterized by closely linked machines and their virtual representations via data networks and IT applications. In future factories, cyber-physical systems are used to create a virtual representation of the real world and take decentralized decisions. Today's static central control (the automation pyramid) will change to a network of decentralized production units capable of adapting their behaviour to changing production conditions and batch sizes. The next step towards future production will be, that the factory itself will become an intelligent entity. Robots and machines know their abilities and can react flexible to varying process requirements. Products know their production process and interact with people and machines on the shop floor to optimize their way across production. Artificial Intelligence enables processes in the Smart Factory to be stable and fast. Customers, manufacturers and suppliers are digitally linked to each other and the individual product with lot size one in automated high-tech production becomes possible.

This course provides a comprehensive overview of the role of digitization, big data, cyber-physical manufacturing systems, robots, human robot collaboration, artificial intelligence and all relevant Industry 4.0 technologies. In particular, we focus on applications and case studies in order to make the audience understand the new technologies and demonstrate the benefits of Industry 4.0. We also include contributions from researchers and industry to the opportunities and challenges of Industry 4.0. One of the greatest challenges in upgrading to Industry 4.0 is education, without young academics the transition to Industry 4.0 won’t be sustainable.

2 Qualification

Students are required to have a BSc degree in Engineering or Computer Science with excellent knowledge of interdisciplinary subjects such as Automation, Mechatronics and Information and Communication technologies.

3 Expected efforts

The expected effort of this course will be 6-8 hours per week, including self-study, literature reading answering quiz questions and presence in discussion forums.

4 Learning objectives

This course provides students with an introduction to Industry 4.0, its building blocks, its applications and advantages compared to conventional production techniques. Learners get a deep insight into how intelligent processes, big data, and artificial intelligence can be used to build up the production of the future. It is also important that the theory is deepened by means of examples. The "Learning Factory Industry 4.0" set up in a joint project between IUT and ZHAW will, as far as possible, be actively involved in the lessons. For further practise modules it is intended to install a similar learning environment at IUT. With this setup, the aspect of "Connected Factories" can additionally be included as a practical session in this course and offers further possibilities for joint research and development projects.

5 Learning outcomes

Knowledge and understanding

1. Knowledge of basics, drivers and enablers of Industry 4.0
2. Knowledge of modern methods and techniques of planning, dimensioning, design and optimization of Industry 4.0 production systems
3. Knowledge and understanding of value chains in Industry

4. Knowledge and understanding of the Smart Factory paradigm

Applying knowledge and understanding

5. Development of practical skills in dealing with methods and techniques of production system planning and optimization through the application of theoretical learning content in the context of case studies and practical sessions
6. Practical lesson by remote video conferences to the "Learning Factory Industry 4.0" @ZHAW

Making judgements

7. Ability for timely and goal-oriented planning and implementation of technical projects
8. Ability for individual working, structuring and documentation of innovative problem solutions using modern technologies for information acquisition and processing.

Communication skills

9. Ability to structure, prepare and present scientific and technical documentation
10. Ability to describe project activities and to discuss them amongst each other and with lecturers (weekly face-to-face discussion forum and online forum)

Learning skills

11. Ability to autonomously extend the knowledge acquired during the study course by reading and understanding scientific and technical documentation
12. Ability to enlarge knowledge through self-study and consultation of scientific and technical texts

6 Learning content and teaching

The course consists of 15 modules. Each module has multiple sections. Typically, for each module, there is an introduction which can also be an introductory video and then for each section, there will be a series of slides supplemented by suggested readings and quiz questions. The suggested readings are listed under paragraph 9. "suggested readings" and will be made available on the course's website in English. Additionally, we will have a practical session where we present mainly the implementation and functionalities of Industry 4.0 principles in the Learning Factory of IUT/ZHAW. A weekly discussion forum will allow students to ask questions and discuss specific topics amongst each other and with the lecturers.

7 Grading Policy

There will be no written exam, but if the students want to evaluate their current knowledge level the quiz questions of the modules can be used for self-assessment throughout the course. All questions carry equal marks. For a good knowledge at least 70% (out of max 100%) must be answered correctly. There is no weekly deadline for the assessments. If Students want their actual knowledge level to be evaluated, they just have to answer the quiz questions every two weeks until Thursday, 1 pm and hand it in to the lecturers for evaluation. Every student will get an annotated feedback on her or his answers.

8 Discussion forum

We will offer a discussion forum in addition to the lectures. Interested students can attend it and have in-depth discussions on topics of Industry 4.0 with the professors. The schedule for this forum will be announced shortly before the beginning of the semester. Likewise, we will offer an online forum on changing topics, which can also be used. Please note the discussion forum etiquette guidelines for all discussions.

9 Recommended readings

Recommended Readings will be published on the course's website at IUT

10 Teaching language

This course is held in English.

11 Course schedule

The following table is the course schedule.
Any new information will be posted in the Course Updates & News on the course website at IUT

Course module	Contents
Week 1 **(Date and Time)** **Prof. [Name]**	**Module 1: Introduction to Industry 4.0** • Definition of Industry 4.0 What is it all about and why do we have to change industrial production Videos from Bosch, Siemens, ABB, Automotive Industry (VW, Audi, Mercedes) • Developments in USA, Europe, China and other countries • Comparison of Industry 4.0 Factory and today's Factory The 10 most important things that will change with Industry 4.0 • Difference between conventional automation and Industry 4.0 **Practical session:** Basics and overview of the IUT/ZHAW learning factory **Week 1 discussion forum:** Challenges and chances of a new industrial paradigm
Week 2 **(Date and Time)** **Prof. [Name]**	**Module 2: Basic principles and technologies of a Smart Factory** • Internet of Things (IoT) & Industrial Internet of Things (IIoT) & Internet of Services • Big Data • Cyber-Physical Systems • Value chains in manufacturing companies • Customization of products • Digital Twins • Cloud Computing / Cloud Manufacturing • Security issues within Industry 4.0 networks **Practical Session:** Insight into the IUT/ZHAW learning factory (a remote view into the learning factory @ ZHAW) **Week 2 discussion forum:** How to measure Industry 4.0 maturity in today's industrial companies?

Course module	Contents
Week 3 **(Date and Time)** **Prof. [Name]**	**Module 3: Cyber-Physical Systems (CPS) and Cyber-Physical Production Systems (CPPS)** • What are cyber-physical systems? (Definitions, demarcation to embedded systems, ubiquitous computing, etc.) • Core elements of Cyber-Physical Systems and Cyber-Physical Production Systems • Control theory and real-time requirements • Self-organization principles ("Self-X", autonomy, negotiations) • Communication in cyber-physical systems • Design Methods for Cyber-physical Systems (Modelling, Programming, Model-Integrated Development) • Applications for cyber-physical systems (examples of existing or future applications in the field of manufacturing, traffic, medical technology, etc.) **Practical Session:** Cyber-Physical Systems in the IUT/ZHAW learning factory (a remote view into the learning factory @ ZHAW) **Week 3 discussion forum:** How will Cyber-Physical Systems change the factories, what could be future consequences?
Week 4 **(Date and Time)** **Prof. [Name]**	**Module 4: The smart workpiece** • The intelligent work piece as basic functionality in implementing Industry 4.0 • What is an intelligent workpiece? • How to make a workpiece intelligent? • Work piece tagging • QR codes and RFID • Communication between work piece and environment • Multi-agent systems in production • Applications for smart work pieces (examples of existing or future applications in the field of manufacturing) **Practical Session:** The intelligent workpiece in the IUT/ZHAW learning factory (a remote view into the learning factory @ ZHAW) **Week 4 discussion forum:** The intelligent Work Piece for Production, Service, lifelong Product tracing and Recycling

Course module	Contents
Week 5 **(Date and Time)** **Prof. [Name]**	**Module 5: Digital Twins in Production** • Example: Real time use of Digital Twin (Video) • Basic concepts of Digital Twins • Benefits, impact and challenges • Features and Implementation of Digital Twins • Types of Digital Twins • Digital Twin use cases • Applications for digital twins in production (examples of existing or future applications in the field of manufacturing) **Practical Session:** The digital twin at the IUT/ZHAW learning factory (a remote view into the learning factory @ ZHAW) **Week 5 discussion forum:** Digital Twins in Production, Service and Repair, think about these and other applications
Week 6 **(Date and Time)** **Prof. [Name]**	**Module 6: Assistance systems for production** • The connected worker within the Industry 4.0 scenario • Diversity-driven workplaces (barrier free workplaces, accessibility in production) • Human-and task-centered assistance systems (e.g. motion capture system for training employees, etc.) • Technical tools (“Ambient Assisted Working” (AAW)) • Mobile information technologies • Shop floor information systems • Production line support systems (pick by light, assembly display systems, assembly control by vision, …) • Manipulator systems and intelligent chairs • Human work support by using exoskeletons • Applications assistance systems in production (examples of existing or future applications in the field of manufacturing) **Practical Session:** RoboMate Exoskeleton at the IUT/ZHAW learning factory (a remote view into the learning factory @ ZHAW) **Week 6 discussion forum:** Human power support by use of exoskeletons in production

Course module	Contents
Week 7 **(Date and Time)** **Prof. [Name]**	**Module 7: The six main use-cases for Augmented Reality in Manufacturing** • AR-devices an Overview (different versions, Videos) • Use case 1: Integrating Design and Manufacturing • Use case 2: Training Shop floor Workers • Use case 3: Supporting complex Assembly Operations • Use case 4: Service and Maintenance • Use case 5: Supporting complex Sales solutions • Use case 6: Executive Oversight and Data Visualisation • Applications with Augmented Reality (examples of existing or future applications in the field of manufacturing) **Practical Session:** An AR device at the IUT/ZHAW learning factory (a remote view into the learning factory @ ZHAW) **Week 7 discussion forum:** AR-devices: gaming device, research subject or already serious production support?
Week 8 **(Date and Time)** **Prof. [Name]**	**Module 8: Human-Robot Collaboration** • Human-Robot Collaboration in Industry, Example video Airplane Assembly and others • Collaborative Robots, tasks • Collaborative Robots, examples (Yumi, IIWA, UR, Panda, …) • Types of Human-Robot Collaboration • Safety of Human-Robot Collaboration (Standards and Norms in the EU) • Applications with Collaborative Robots (examples of existing or future applications in the field of manufacturing) **Practical Session:** Human-Robot Collaboration at the IUT/ZHAW learning factory (a remote view into the learning factory @ ZHAW) **Week 8 discussion forum:** Human-Robot Collaboration applications and safety issues, think about areas of application

Course module	Contents
Week 9 **(Date and Time)** **Prof. [Name]**	**Module 9: Interoperability: Communication systems and standards for Industry 4.0 and cloud applications** • Industrial communication • Industrial Internet of Things (IIOT) • The Industry 4.0 Reference Architecture Model RAMI4.0 • Basics on Service oriented Architecture • OPC-UA as future standard in Industry 4.0 • Machine to machine interaction in practice (examples of existing or future applications in the field of manufacturing) **Practical Session:** OPC-UA at the IUT/ZHAW learning factory (a remote view into the learning factory @ ZHAW) **Week 9 discussion forum:** Standardized communication protocols: restriction or necessity
Week 10 **(Date and Time)** **Prof. [Name]**	**Module 10: OPC-UA in Detail** • Introduction into OPC • Classic OPC vs. OPC-UA • Information Modelling • Standard Information Model • OPC Services • System Architecture • Profiles • OPC-UA and the Cloud • OPC-UA in practice (examples of existing or future applications in the field of manufacturing) **Practical Session:** Using an open source OPC-UA implementation at the IUT/ZHAW learning factory (a remote view into the learning factory @ ZHAW) **Week 10 discussion forum:** Service oriented Architecture in Manufacturing vs. Fieldbus and SCADA Systems

Course module	Contents
Week 11 **(Date and Time)** **Prof. [Name]**	**Module 11: Cloud Manufacturing and the connected factory** • Virtualization • Cloud Platforms • Big data in production • Cloud-based ERP and MES solutions • Connected factory applications • IT security for cloud applications **Practical Session:** Cloud Manufacturing technologies at the IUT/ZHAW learning factory (a remote view into the learning factory @ ZHAW) **Week 11 discussion forum:** Using cloud technologies in Industry, advantages and drawbacks
Week 12 **(Date and Time)** **Prof. [Name]**	**Module 12: Introduction into Cloud Development Environments & a Predictive Maintenance Case** • Getting started • Creating an Account • Tools and Functions • Developer Tools • Application Management • Data Visualisation • Using a Cloud Development Environment to develop a Predictive Maintenance Tool for Manufacturing • Cloud Development in practice (examples of existing or future applications in the field of manufacturing) **Practical Session:** Big data Storage and Visualization at the IUT/ZHAW learning factory (a remote view into the learning factory @ ZHAW) **Week 12 discussion forum:** Predictive Maintenance as a Cloud Service a new Business Model for suppliers of producing companies?

Course module	Contents
Week 13 **(Date and Time)** **Prof. [Name]**	**Module 13: Artificial Intelligence in Production: Machine Learning Application** • Basics of Machine Learning • The Machine Learning Process • Into Machine Learning working cycle • Preparing Data • Running Experiments • Finding the Model • Training the Model • Deploying and using a Model • Machine Learning in practice (examples of existing or future applications in the field of manufacturing) **Practical Session:** Machine Learning at the IUT/ZHAW learning factory (a remote view into the learning factory @ ZHAW) **Week 13 discussion forum:** Machine learning in Industry useful or dangerous?
Week 14 **(Date and Time)** **Prof. [Name]**	**Module 14: Safety and Security in networked Production Environments** • What means Safety with Industry 4.0 • Safety for connected Machines and Systems • Safety in Human Robot cooperation • How Industry 4.0 can optimise Safety • Security & Security Risks with Industry 4.0 • Security and privacy risks in AI • Approach to Cyber-Physical Security in Industry 4.0 • Practical Security Aspects with Industry 4.0 (examples of existing or future applications in the field of manufacturing) **Practical Session:** Practical Security Aspects with Industry 4.0 **Week 14 discussion forum:** How do Safety and Security Aspects affect Industry 4.0 (Stuxnet case, cybercrime, examples, Shodan, the search engine for open industrial ports, https://www.shodan.io/)

Course module	Contents
Week 15 **(Date and Time)** **Prof. [Name]**	**Module 15: Cyber-Physical Systems and new Business Models** • How CPS can induce new Business Models • The Role of horizontal and vertical value streams • New Business Models for the Smart Factory • Characteristics of Business Models within the Smart Factory • Examples of new Business Models – Business Model: Service provider – Business Model: Data provider – Business Model: Technology provider – Business Model: Platform provider **Practical Session:** Working on a business Model for a Producer of collaborative Robots (a new Business case for Robotics) **Week 15 discussion forum:** Business cases for Start-ups in Iran