RICAIP

Research and Innovation Centre
on Advanced Industrial Production

RICAIP
Educational and training tools

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CTU CZECH TECHNICAL UNIVERSITY IN PRAGUE
CZECH INSTITUTE OF INFORMATICS ROBOTICS AND CYBERNETICS CTU IN PRAGUE
BRNO UNIVERSITY OF TECHNOLOGY
CEITEC Central European Institute of Technology BRNO | CZECH REPUBLIC
DFKI German Research Center for Artificial Intelligence
ZeMA Zentrum für Mechatronik und Automatisierungstechnik

RICAIP

Research and Innovation Centre
on Advanced Industrial Production

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This deliverable is subject to final acceptance by the Executive Board.

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Further Information: www.ricaip.eu

Disclaimer

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1 Introduction

The following document describes the interconnection of RICAIP partners and teams in terms of education and training activities. RICAIP with its four core partners and the topics of industry 4.0, AI in production and robotics is composed of and involves various research fields and experts across and among its four core partners. The deliverable at hand “educational and training tools” summarizes available expertise in trainings and summarizes trainings to bolster internal RICAIP capacities and knowledge as well as for external services.

One main aspect of these “education and training tools” is to build the internal capacities and expertise in the various fields so RICAIP’s target groups can profit from them in the long run. At its core though – the document outlines the possibilities to bolster these internal capacities first. After building the internal capacities especially SMEs shall profit from the emerging training services. These will be provided in the different activities planned in RICAIP such as workshops, seminars and consulting hours and will be incorporated as long-term services. These trainings will be advertised with the other activities using the approach and tools described in the *D7.2 Communication Strategy and Standards*

In the following chapters, the document gives an overview of related work (chapter 2) e.g. regarding identified target groups, etc. Furthermore, based on today’s experience, equipment and capacities the document outlines various trainings which will contribute firstly to the RICAIP goal to exchange and build scientific knowledge between its four core partners (see chapter 3). Furthermore, the document describes the training needs of the partners, thus identifying potential shortcomings which should be addressed in the future either through internal expertise (yet to be build-up) or through external expertise (chapter 4). Chapter 5 gives an overview of the potential and possibilities for further trainings and knowledge exchange or activities build on the academic setup and experience of the partners. Chapter 6 provides a summary.

Despite its name this deliverable is not about developing educational or training tools. It’s about using existing knowledge and experience throughout the team member and their researchers to train either their internal fellows and (on a longer horizon) the target groups of RICAIP. So less about developing tools rather about providing trainings. Overall this document expresses the dual nature of RICAIP activities in terms of internal capacity and knowledge building as well as the distribution of it to the public and industry.

Deliverable *D3.2 Educational and training tools* has been developed within WP3 RICAIP Scientific Capacity. ZeMA was a leading partner and editor-in-chief, all other RICAIP partners provided their contributions.

2 Related work

This deliverable *D3.2 Educational and training tools* is linked to other deliverables or related work which was provided and described in other deliverables.

As mentioned in the introduction the trainings and scientific knowledge will benefit not only the internal team members but in the long run also the various target groups of RICAIP through various services/trainings. The target groups of RICAIP were identified beforehand and the deliverables *D7.1 Dissemination Strategy and Standards* and *D7.2 Communication Strategy and Standards* provide insight into the five target groups of RICAIP: industrial stakeholders, the academic and scientific community, general public, policymakers and associations as well as European networks. Especially the academic and scientific community is especially relevant for the trainings as there is a close connection between the four RICAIP partners and local universities. Relevant here is especially chapter 5 in D7.1 and D7.2.

As described in the various trainings these often rely on equipment used and training tools. The overall majority of the trainings have a strong focus on “hands-on” or practical experience which is provided mainly on-site at the machine or equipment itself. As this is and will not be possible in the majority of the time the trainings will be offered online as well. Despite the current situation of travel restriction or to save time and money in the long course these trainings will be held online. The “hands-on” or practical experience will be established and supported by the currently (due to COVID) suspended / limited RICAIP mobility programme as one major purpose of the programme is knowledge exchange and training of the internal staff members. The RICAIP mobility programme which shall provide a better personal exchange and visits of all the partners is going to be the foundation for enhanced visits including extensive on-site trainings using equipment and demonstrators. The mobility programme is described in the *D4.4 Mobility programme*.

Furthermore, the trainings and the experience and knowledge derived from these will benefit the different target groups of RICAIP through various services in the long run. The deliverable *D7.1 Dissemination Strategy and Standards* outline events and activities in chapter 6 such as workshop series and industry days or the showroom. In the deliverable *D4.5 Plan for interdisciplinary workshops, seminars and conferences* such activities were outlined in the shorter term. Whereas the workshops and seminars have the character of information and consulting events in the short term, the plan for workshops and seminars, which has to be extended past 2021/2022 will include trainings for RICAIP targets groups in the long run. Thus, the activities and the start of this internal knowledge exchange and trainings will boost dissemination activities and result/knowledge transfer. Furthermore, these will also contribute to the showroom, which is described in the upcoming deliverable *D7.11 RICAIP showroom.*

3 Catalogue of trainings

In this section, the training areas and topics proposed by the project partners are enumerated and explained in detail. Moreover, target groups are specified along with the type of training and the duration. Furthermore, the tools to be used during the trainings are also specified.

3.1 Training at CIIRC

Example of education events in the CIIRC Testbed

Here the topics of the trainings to be offered by CIIRC are presented along. A few notes regarding the availability of the Laboratory of robotics and manufacturing technology (LRMT). Regarding the laboratory:

- Some machines are already installed, some will be installed during 1-2Q2021. The ventilation system upgrade is planned for 3Q2021. Thus, first training and presentation activities are feasible in 4Q2021 (at the end of the year 2021).
- The laboratory has a small presentation room for 20-25 persons. Thus, small-scale events can be organized in the laboratory.

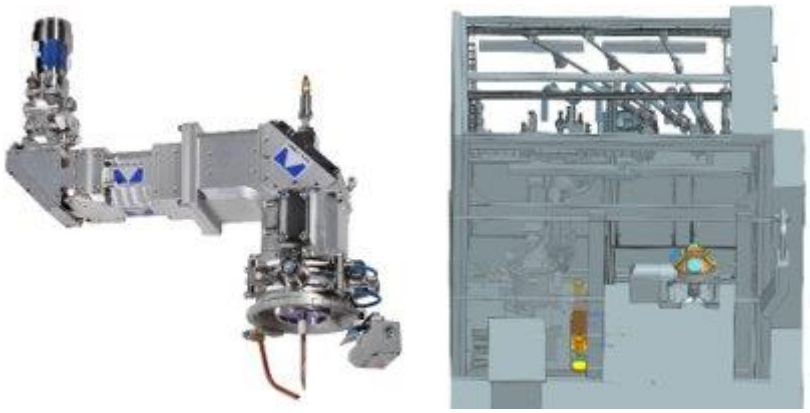
For the actual trainings the topics are like follows:

Training 1: Advanced high-power laser processes in manufacturing

This training is about the high-power (> 1 kW) laser process background. Fundamentals of the laser technology are presented. Demonstration of various laser processes includes: laser hardening, laser cutting, laser+powder additive manufacturing, laser+wire additive manufacturing. Practical comments on system setting is provided. The training content can be adjusted with respect to the target group interests.

- **Target group:** Primarily for external auditorium: students, specialists of production companies or company directors and owners. Internal use is also possible. The event specific content can be adjusted with respect to the target group.

- **Type of training:** Workshop with hands-on demo. Preferably on-site. It can be changed into a webinar with pre-recorded demo videos in case of pandemic restrictions.
- **Equipment:** High-power robotic cell in LRMT (CIIRC).
- **Education tools:** PowerPoint presentation with the training content.
- **Duration:** 2x 90 minutes.

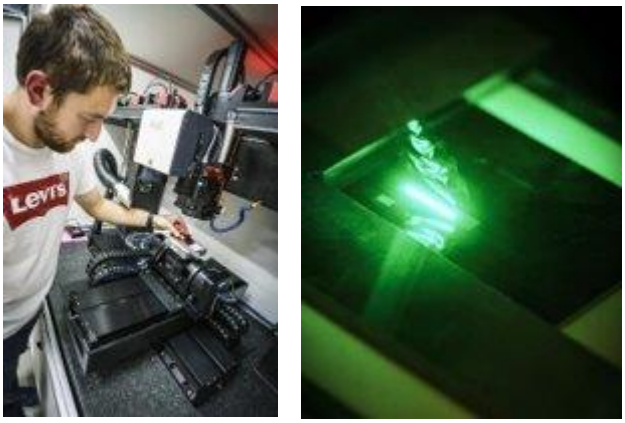


CAD model of the high-power laser robotic cell and AM application head

Training 2: Advanced high-frequency laser processes in manufacturing

This training is about nano-second and femto-second laser process background. Fundamentals of the laser technology are presented. Demonstration of various laser processes includes: surface structuring, micromilling, microdrilling on super-hard materials. Practical comments on system setting are provided. The training content can be adjusted with respect to the target group interests.

- **Target group:** Primarily for external auditorium: students, specialists of production companies or company directors and owners. Internal use is also possible. The event-specific content can be adjusted with respect to the target group.
- **Type of training:** Workshop with hands-on demo. Preferably on-site. It can be changed into a webinar with pre-recorded demo videos in case of pandemic restrictions.
- **Equipment:** Laser micro process cell in LRMT (CIIRC)
- **Education tools:** PowerPoint presentation with the training content.
- **Duration:** 2x 90 minutes.

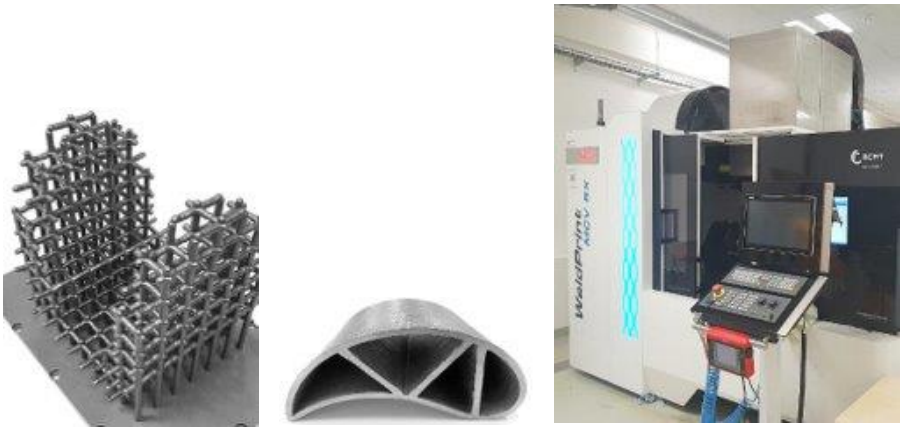


Working space of the high-frequency laser working cell

Training 3: Hybrid production based on wire-arc additive manufacturing (WAAM) and subtractive manufacturing in one working space

This training is an introduction to the process fundamentals of hybrid production combining wire-arc additive manufacturing and machining subtractive manufacturing. Key features of the machine tools for hybrid production are presented firstly. WAAM process control and optimization and machining of AM (additive manufactured) produced material follows. Tool path planning using specific CAM for hybrid processes is introduced. The process is demonstrated on the machine.

- **Target group:** Primarily for external auditorium: students, specialists of production companies or company directors and owners. Internal use is also possible. The event-specific content can be adjusted with respect to the target group.
- **Type of training:** Workshop with hands-on demo. Preferably on-site. It can be changed into a webinar with pre-recorded demo videos in case of pandemic restrictions.
- **Equipment:** Hybrid production machine Weldprint in LRMT (CIIRC).
- **Education tools:** PowerPoint presentation with the training content.
- **Duration:** 2x 90 minutes.



Hybrid production machine and examples of parts produced by this machine

Training 4: Speed dating with innovative production processes

The “speed dating” offers the unique opportunity to experience innovative production processes, learn about process fundamentals and see the process demonstration. These processes are currently available: laser-wire AM; laser-powder AM; hybrid production combining WAAM+machining; cryogenic machining; functional surfaces produced by nano- or femtosecond laser; laser drilling of superhard materials; machining stability; production machine integration with MES (manufacturing execution system).

- **Target group:** Students. Specialists of production companies.
- **Type of training:** Informative workshop (presentations + live demo). The format is really “speed dating“: attendees are split into groups of 5-8 people. Every process is presented within 20 minutes – description of process fundamentals, process demonstration, key feature explanation of demo parts. Total length of one block: 25 minutes, then 5 minutes for group changing. There can be 4-5 presentation posts in the Laboratory of robotics and manufacturing technology, IPA CIIRC. It can be combined with concurrent event in the “upper” testbed of CIIRC or remote broadcasting from Brno or Saarbrücken.
- **Equipment:** Machines in the Laboratory of robotics and manufacturing technology (CIIRC).
- **Education tools:** PowerPoint presentation with the training content. Live presentation of the production machines.
- **Duration:** 2x 90 minutes.

Training 5: OPC UA – communication and data models

OPC UA communication has become a standard for industrial communication especially with respect to Industry 4.0. An important part of OPC UA is the information model, which defines data to be exchanged. The importance of information models grows with an increasing number of various interest and standardization groups that contribute to creating so-called Companion Specifications.

- **Target group:** Students. Specialists of production companies.
- **Type of training:** Informative workshop in online and face-to-face modes. The principles of OPC UA and the information model will be explained in part 1 (90 minutes). The next part (90 minutes) will be dedicated to practical configurations with real hardware. A multi-vendor setup will be used to configure OPC UA communication and emphasize the most important aspects that are encountered in real applications. A follow-up hands-on training may be given.
- **Equipment:** Multi-vendor setup (PLCs, robots) in Testbed (CIIRC).
- **Education tools:** PowerPoint presentation with the training content. Live presentation of the production machines.
- **Duration:** 2x 90 minutes.

Training 6: Force-feedback robot control

Force feedback allows robots to adapt their movement to a given surface by applying defined force in a defined direction. It is also important for collaborative robots working in a collaborative mode to allow for stopping their movements and retracting if they encounter a human worker or another obstacle in their way. In this training, the force feedback will be examined in two ways: on a collaborative robot KUKA iiwa and on a delta robot equipped with a force-torque sensor at its flange. While the training with the collaborative robot will focus on user aspects of creating robotic programs, the training on the delta robot will focus on applying torque control in multi-axis positioning systems with parallel kinematics.

- **Target group:** Students. Specialists of production companies.
- **Type of training:** Two independent trainings for each type of robots. The training with the collaborative robot can be taken as introductory, while the training with the delta robot as advanced one, because it goes into details of multi-axis synchronized positioning with stress on torque (force-feedback) control. For both trainings, theory presentations as well as live demo will be given. A follow-up hands-on training may be given.
- **Equipment:** Multi-vendor setup (PLCs, robots) in Testbed (CIIRC).
- **Education tools:** PowerPoint presentation with the training content. Live presentation of the robots.
- **Duration:** 2x 120 minutes.

3.2 Training at CEITEC

Here the topics of the trainings to be offered by CEITEC are presented:

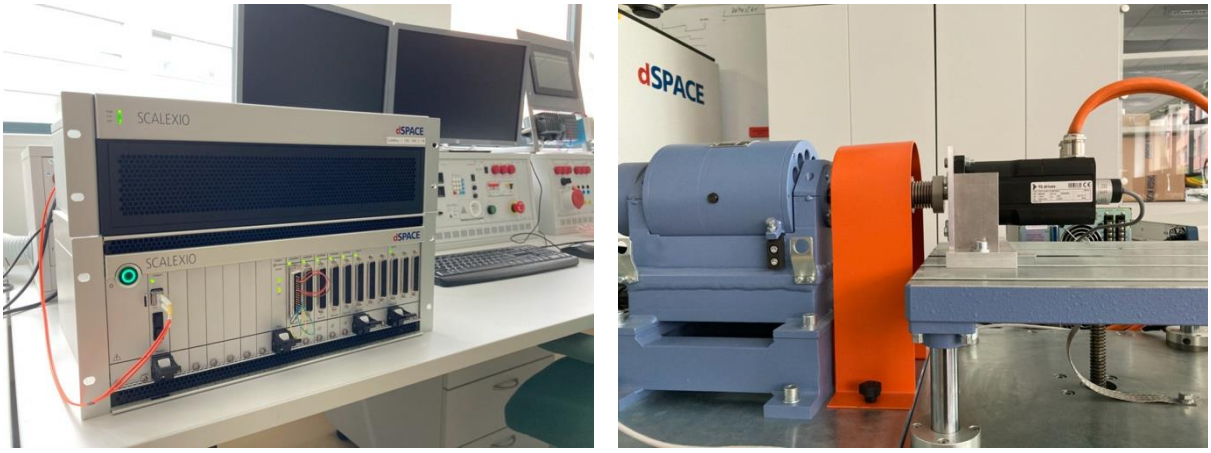
- Training 1: dSPACE Rapid Prototyping System for control of industrial electrical drives.
- Training 2: HIL systems for digital twinning in I4.0
- Training 3: Advances in vibration analysis using contact and non-contact measurements techniques
- Training 4: Modern methods for indoor and outdoor localization

Training 1: dSPACE Rapid Prototyping System for control of industrial electrical drives.

The idea of the training is not to teach how to realize and test the control algorithms of electrical drives using this platform but to use pre-prepared scripts, Simulink schemes and demonstrate what is possible with this platform. The idea of the model-based design of controllers will be explained and exemplified. The interaction between the real-time processing platform and the FPGA module will be outlined. The

real-time debugging will be demonstrated for conditioning and monitoring in runtime. The pros and cons of rapid prototyping will be shown.

- **Target group:** master and Ph.D. students, advanced researchers.
- **Type of training:** workshop with hands-on preferably on site.
- **Equipment:**
  - Hardware: dSPACE Scalexio Processing Unit with LabBox system, exemplary tested motor, dynamometer, DSI-GSI2.
  - Software: ConfigurationDesk, ControlDesk, MATLAB Simulink, Vivado for FPGA programming.
- **Education tools:** PowerPoint presentation with the training description, beamer.
- **Duration:** 90 minutes.



Workplace for the training - dSPACE Scalexio system with LabBox, dynamometer and tested motor

Training 2: HIL systems for digital twinning in I4.0

The training will present and compare two Hardware In the Loop (HIL) systems for building digital twins. One from dSPACE and one from National Instruments. Each system comes with the rich set of software tools. Their use will be demonstrated on real hardware. The fast deployment of SimScape models into FPGA hardware for fast hard-real-time simulations will be shown.

- **Target group:** Ph.D. students, advanced researchers.
- **Type of training:** lectures with demos in RICAIP premises in Brno.
- **Equipment:** dSPACE Scalexio HIL system, National Instruments PXI HIL system and their software tool. MATLAB Simulink, SimScape, LabView.
- **Education tools:** presentation, notebook/PC, beamer/screen according to number of participants.
- **Duration:** 2x 50 minutes.

Hardware equipment which is going to be used for training 2 – dSPACE HIL and dSPACE AutoBox

Training 3: Advances in vibration analysis using contact and non-contact measurements techniques

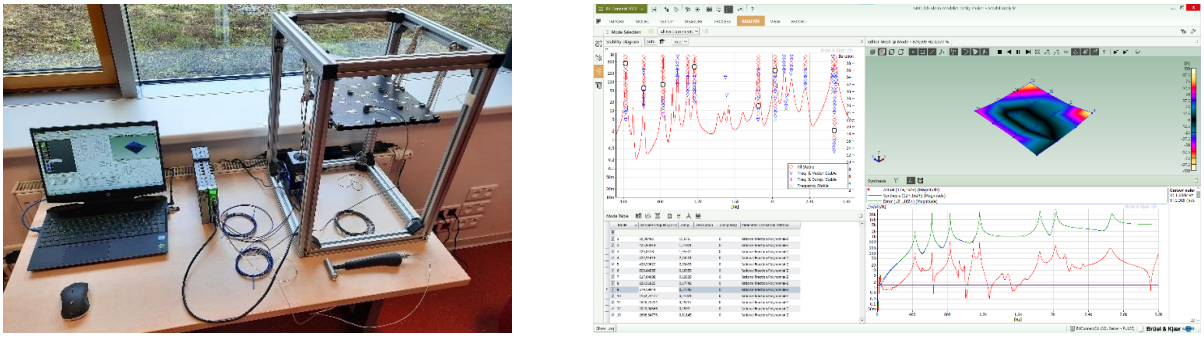
The idea of the training is to introduce participants with equipment and methods used in vibration analysis. The first part assumes an introduction to the basics of vibration measurement – quantities, types of sensors, measuring chain and methods typically used for identification and quantification of vibration. The second part will focus on the demonstration and live presentation of the selected vibration issue and its diagnostic method based on contact measurements. In this part, there will be used BK Connect software for data acquisition, processing and visualization. The third part will demonstrate advantages of non-contact methods in technical diagnostics, especially using laser techniques with practical utilization of Polytec laser vibrometer. Finally, there will be shortly shown other measurement systems for the development of specialized measurement tasks using modular hardware.

The training will lead with the following topics

- Basics of vibration measurement, sensors for vibration measurement.
- Advanced methods and tools for contact measurements – frequency analysis, signal analysis, system analysis, modal testing.
- Methods and tools for non-contact measurements – vibrations measured by LDV (Laser Doppler Vibrometer), LDV scanning technology, the vibration of rotating parts.

- **Target group:** students (Masters, PhD), advanced researchers, industry practitioners.
- **Type of training:** lecture, demonstrations, first part online, second part and the third part on site in RICAIP premises in Brno.
- **Equipment:**
  - Hardware tools - modular vibration analyser; laser vibrometers (both single point and 2D scanning), modular measurement hardware.
  - Software tools - BK Connect, NI LabVIEW, Polytec PSV.
- **Education tools:** pdf presentation with the theory description, beamer.

- **Duration:** 3x 50 minutes



Workspace for training 3 – modular vibration measurement hardware (on the left) and BK Connect environment for vibration analysis (on the right)

Training 4: Modern methods for indoor and outdoor localization

The training will deal with the following topics:

- basics of coordinate systems, and localization,
- differences between outdoor and indoor localization,
- methods for outdoor localization,
- methods for indoor localization.

In the opening part of the lecture, the basic theory of localization and coordinate systems will be presented. The main aim of the lecture is to provide relevant information about the main differences between localization indoors (production halls, warehouses, …) and outdoors, and to demonstrate the modern methods and equipment to deal with it. Since the RICAIP Testbed, Brno will be equipped with the optical localization system and various outdoor localization modules are accessible, the systems will be also demonstrated.

- **Target group:** students (Masters, PhD), advanced researchers, industry practitioners.
- **Type of training:** Lecture, demonstrations, first part online, second part on site in RICAIP premises in Brno.
- **Equipment:**
  - Hardware tools – optical localization system (RICAIP Testbed, Brno), RTK GNSS (Real Time Kinematic Global Navigation Satellite System) receivers.
  - Software tools – none.
- **Education tools:** presentation, laptop, beamer.
- **Duration:** 90 minutes.

Optical localization system (RICAIP Testbed, Brno)

3.3 Training at DFKI

Training 1: Dialog Systems and Multimodal Interaction

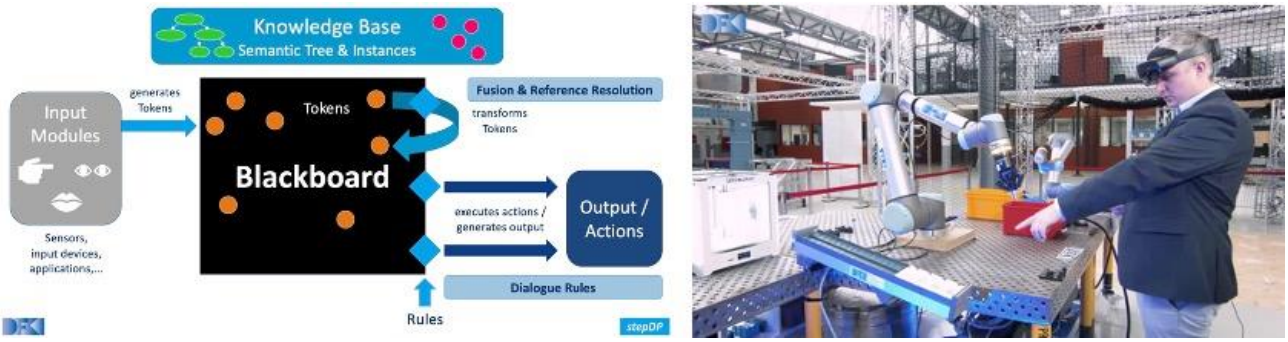
This training covers the concepts and uses of dialog systems in general as well as multimodal interaction. Trainees will learn about several linguistic or speech-related phenomena, in order to get a better understanding, why speech recognition (ASR) is just a small part of a dialogue-capable system. An introduction to intent-based speech understanding will give an insight into how popular speech-based assistants, like Alexa or Siri, work, but it will also show the limitations of that approach. On the example of DFKI's own StepDP dialogue system, it will be shown, how some of those limitations can be overcome, e.g. by introducing additional sensors to also capture gestures and thus moving towards multimodal interaction. Demonstrations of industrial use-cases will also be shown.

This training covers the following topics:

- From speech recognition to speech-understanding: Why it's not as easy as it seems
- Intent-based speech understanding: A step into the right direction
- Dialog Systems: Dialogs are more than just speech-understanding
- Multimodality: Understanding usually involves more than just hearing
- Video-Demonstrations of industrial use-cases

- **Target group:** People who want to get a better understanding on the basics of multimodal dialog/interaction, including students, researchers, industry.
- **Type of training:** Lecture style with videos of example applications online; if time permits more hands-on (coding) examples with StepDP will be presented.
- **Equipment:** PowerPoint, Teams /optional: StepDP.
- **Education tools:** lecture slides, demo videos, coding-examples.

- **Duration:** 90 – 150 min, can be extended by an additional date for StepDP workshop (if interest is high enough)



Basic block diagram of a multimodal dialogue system (left) and example of multimodal interaction with a robot including speech and gestures (right)

Training 2: Application-oriented Machine learning

The design of the training programme will be based on the results of the UPLINX project (2018-2019, https://www.dfki.de/en/web/qualifications-networks/qualification-opportunities/uplinx/), which developed the internal qualification programme in machine learning with direct practical and application relevance. In 2018-2019 the UPLINX training workshops and summer schools have been organized in 4 principal locations of DFKI. The set of training modules will be adjusted and upgraded to meet the demand of the RICAIP's trainees. The initial (tentative) list of modules includes the following:

- Basics of ML: Deep Learning, CNNs, LSTMs, Training, Evaluation.
- Robotics and ML
  - Mapping, localisation and mapping
  - Environment understanding
  - Manipulation
- ML for Industrial applications
- Wearable ML applications
- ML in Computer Vision application

- **Target group:** young researchers, postgraduate students, representatives of manufacturing industries.
- **Type of training:** Lecture style with videos of example applications online. Potentially, fully online training. Optionally hands-on examples with demonstrators (impossible in case of online training).
- **Equipment:** PowerPoint, Teams, optional: demonstrators (e.g. robotic manipulators).
- **Education tools:** Hand-on demonstrators.
- **Duration:** 1-2 days depending on the combination of modules.

DFKI's Robotic demonstrator to be used in training

3.4 Training at ZeMA

This section presents the trainings to be done by ZeMA. Those cover a large variety of topics from assembly systems simulation and planning to Human-robot interaction and sensitive robotics. Most trainings are in lecture forms that can be offered online if the covid19 restrictions persist. However, a practical aspect can be also offered on-site, if possible or in a life stream fashion.

Training 1: Human-Robot interaction and security concepts

This training will cover topics related to human-robot-interaction from the definition and basic concept to technology being used with practice examples and several demonstrations. More precisely, topics like types of Human-Robot-Cooperation and skill-based task sharing between humans and robots will be explained in depth. Moreover, safety concepts required in Human-robot interaction will be covered, also starting from the latest technologies used in the industry and the uses of each safety sensor type up to examples and practical use cases.

- **Target group:** The target group can vary from internal partners namely PhD students and researchers to external audience such as industrial parties interested. At first, the focus would be shed on internal student within the RICAIP program and the internal partners. For the long term, it can extend to external and industrial audiences.
- **Type of training:** If the training is to be held online it would be in the form of a lecture with videos and practical examples of applications, also an online live demonstrator presentation can be offered in case of interest. However, if the training is to be on-site, in addition to the lecture, a hands-on demonstrator test session can be included.
- **Equipment:** robot-cell & safety demonstrator.
- **Education tools:** Tools to be used in this training also depend on the type of training. Interactive presentations are used in both online and offline training. However, for the online

case, MS teams is used if the number of participants allows it. For the offline case, actual robots and on-site demonstrators are also explored.

- **Duration:** 90 to 150 minutes.

Synchronized HRC demonstrator

Safety demonstrator

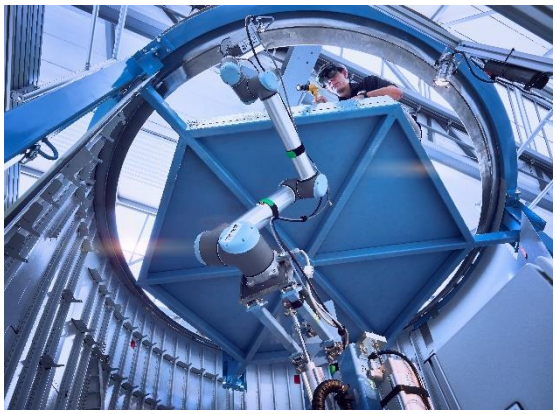
Training 2: Assembly system planning for collaborative systems

This training will cover procedures for the planning of assembly systems, concepts from arrangements of working cells to task scheduling, material supply considering the acceptance of the worker are discussed especially task-planning based on abilities of humans and robots. Furthermore, ready market HRC systems and real-world industrial applications will be discussed.

- **Target group:** The target group can vary from internal partners namely PhD students and researchers to external audience such as industrial parties interested. At first, the focus would be shed on internal student within the RICAIP program and the internal partners. For the long term, it can extend to external and industrial audiences.
- **Type of training:** If the training is to be held online it would be in the form of a lecture with videos and practical examples of applications, also an online live demonstrator presentation can be offered in case of interest. However, if the training is to be on-site, in addition to the lecture, a hands-on demonstrator test session can be included.
- **Equipment:** Robot cells and demonstrators showcasing assembly systems and collaborative systems.
- **Educational Tools:** The tools to be used in this training also depend on the type of training. Interactive presentations are used in both online and offline training. However, for the online

case, MS teams is used if the number of participants allows it. For the offline case, actual robots and on-site demonstrators are also explored.

- **Duration:** 90 to 150 minutes.



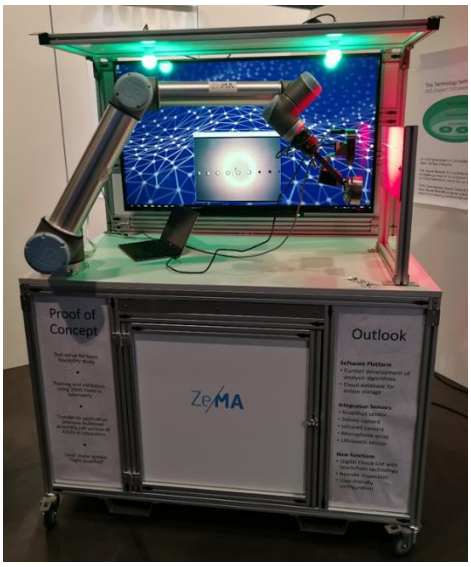
HRC riveting demonsrator

Woll demontrator for HRI and HMI

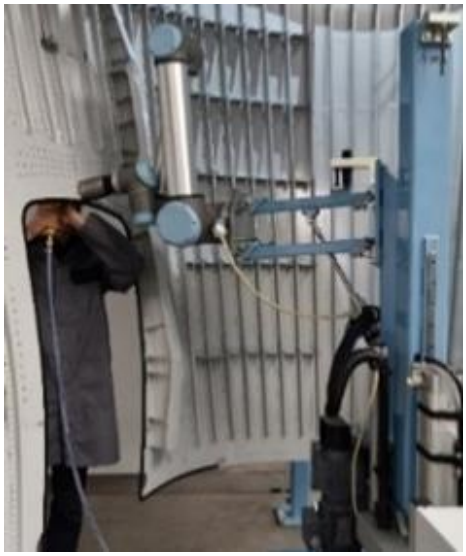
Training 3: Collaboration in a Hybrid Team for Improving Working Conditions and AI-based quality inspection in an Aircraft Riveting Process

Collaborative robots continue to take over the market and enable (partially) automated solutions that were difficult to realize with conventional robotics. The close cooperation between humans and robots creates new possibilities, but also new criteria to be considered. This training shows a practical example from the aircraft industry “semi-automated riveting process” for an HRC-application where a skill-based task sharing between robot and human is deployed. The example shows a strategy to automate a human unsuitable and difficult to automate workplace by combining the capabilities of humans and robots. Furthermore, the control concept in an HRC-application will be presented in-depth as well as an AI-based method for quality inspection in a semi-automated process.

- **Target group:** The target group can vary from internal partners namely PhD students and researchers to external audience such as industrial parties interested. At first, the focus would be shed on internal student within the RICAIP program and the internal partners. For the long term, it can extend to external and industrial audiences.
- **Type of training:** The training is to be held online. It would be in the form of a lecture with videos and practical examples of applications, also an online live demonstrator presentation can be offered in case of interest.
- **Equipment:** HRC-rivet system is used for the online live demonstrator. A worker is filmed via livestream and shows the functionalities and idea of the demonstrator. Livestream equipment is required for this.
- **Education tools: P**resentations are used in online training. MS teams is used if the number of participants allows it.
- **Duration:** 45 - 60 minutes.



AIQ inspect demontrator for quality inspection

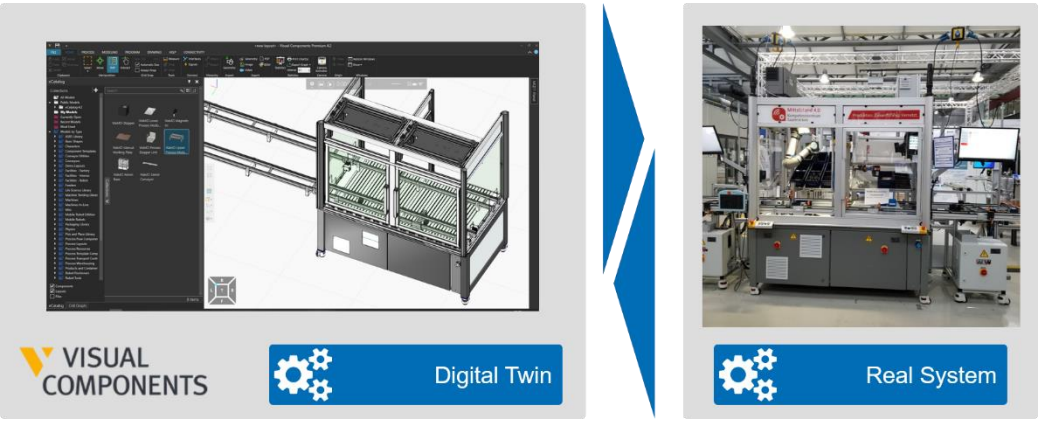


HRC riveting demontrator

Training 4: Simulation of Assembly Systems

This training will cover topics related to the simulation and a digital twin regarding event-discrete production systems. To define the behaviour of such production systems, Petri-Nets will be introduced and used during exercises. Additionally, the training will cover defining and simulating digital-twins of event-discrete production systems using the software Visual-Components. To enhance the simulation, point clouds of real production environments will be imported and an interface to externally control the environment will be used.

- **Target group:** The target group can vary from internal partners namely PhD students and researchers to external audience such as industrial parties interested.
- **Type of training:** If the training is to be held online it would be in the form of a lecture with videos and practical examples of applications, also an online live demonstrator presentation can be offered in case of interest. However, if the training is to be on-site, in addition to the lecture, a hands-on demonstrator test session can be included.
- **Equipment:** Software Visual Components and production line demonstrator.
- **Educational Tools:** The tools to be used in this training also depend on the type of training. Interactive presentations are used in both online and offline training. However, for the online case, MS teams is used if the number of participants allows it. For the offline case, actual robots and on-site demonstrators are also explored.
- **Duration:** 90 to 150 minutes.

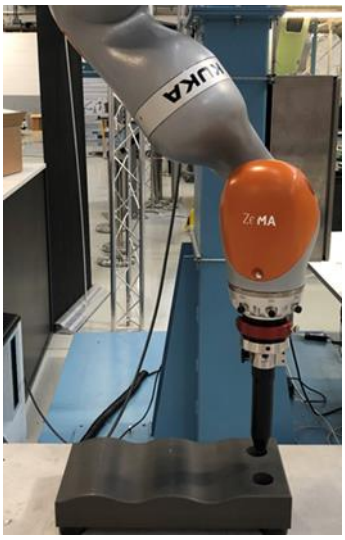


The WaMo station: real system vs. digital twin

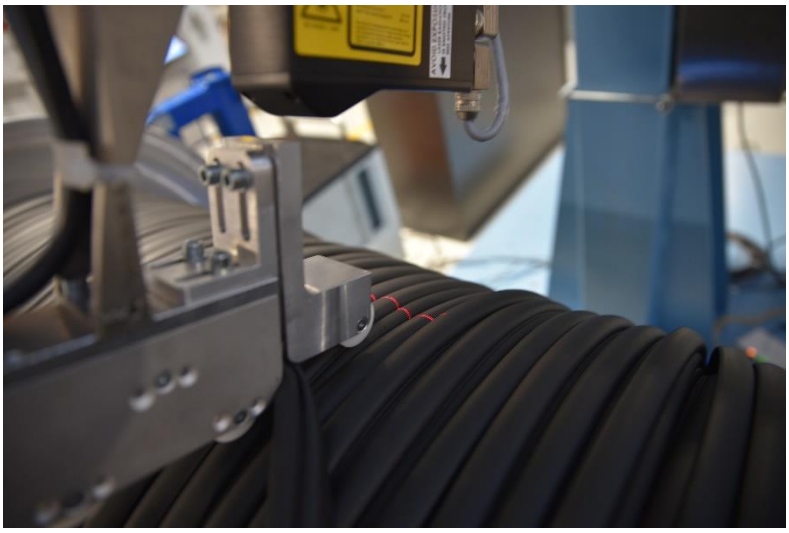
Training 5: Development and deployment of forced controlled (sensitive) robot applications

The training will introduce force-controlled applications in the domain of robotics. The motivation of those applications will be discussed as well. Participants will have the opportunity to learn how to plan a robotic sensitive application. Moreover, a method to design an appropriate measuring concept will be introduced. The training also deals with the conception of the robot controller to achieve the desired sensitive application based on the requirement of the process and monitoring of the exerted forces. Lastly, the introduced methods will be validated on a real demonstrator.

- **Target group:** The target group can vary from internal partners namely PhD students and researchers to external audience such as industrial parties interested. At first, the focus would be shed on internal student within the RICAIP program and the internal partners. For the long term, it can extend to external and industrial audiences.
- **Type of training:** If the training is to be held online it would be in the form of a lecture with videos and practical examples of applications, also an online live demonstrator presentation can be offered in case of interest. However, if the training is to be on-site, in addition to the lecture, a hands-on demonstrator test session can be included.
- **Equipment:** The tools to be used in this training also depend on the type of training. Interactive presentations are used in both online and offline training. However, for the online case, MS teams is used if the number of participants allows it. For the offline case, actual robots and on-site demonstrators are also explored.
- **Duration:** 90 to 150 minutes.



Sensitive robot performing a forced-controlled robot path



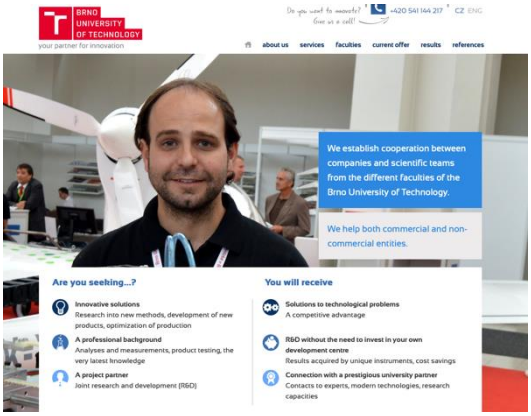
The Saargumi demonstrator

3.5 Individualized training – professional consultancies

Universities and research institutes in RICAIP provide professional consultancies in the domain of their specializations and expertise. Their doors are opened for this kind of activity since it simply belongs to their job which is teaching. The companies usually do not ask for lengthy trainings (because the time is money) but for helpful answers to their concrete questions. They either directly contact selected people based on their internet searches or they try to contact the people in leading positions on a level of departments, faculties or university and these people are forwarding the request in a top-down approach. In some cases, the university has a special department that operates as a mediator between academia and industry as it is the case of The Technology Transfer Office at the Brno University of Technology.

These consultancies are often led bilaterally since it brings some advantages for involved parts. No one is afraid to ask even “silly” questions in such a small audience, no need to think about keeping some topics secret before the competitors, the time required to acquire the knowledge is made short. On the university side, no preparation of slides is needed.

It is hard to characterize the spectra of the company sizes who ask for this kind of support but more frequently they are probably coming from SME’s rather than from LE/ME. As SME’s have fewer people for development and innovations, they are broader oriented, and they do not have the time and capacity to go deeply into the topic and thus they rather discuss it with professionals from academia.



Profile of Technology Transfer Office at BUT

RICAIP as a project gives us another important possibility which is the real demonstration of advanced topics/solutions right in the testbed. Therefore, we expect more frequent requests for professional consultancies with a demonstration from the companies in the future. And every successful consultancy is a seed for further cooperation between the industry and academia.

4 Offers and needs

In the following table, the offers, needs and interests of the RICAIP partners are summarized mainly with respect to the aforementioned trainings. As the table shows, the presented trainings highly intersect with partner's needs and interests even if they do not cover them completely. For the longer term and for topics that are of need or of interest and that have not been covered by the list of trainings, further support is to be looked for. This support can be either from further partners or from organizations that are specialised in those fields.

TOPIC O = Offered training N = Needed expertise / training I = Interested in training	**CIIRC**	**CEITEC**	**DFKI**	**ZeMA**
High-power and high-frequency laser processes in manufacturing	**O**	**I**		
Additive manufacturing processes (e.g. wire-arc)	**O**	**I**		**I**
Innovative production processes (e.g. laser-wire AM, WAAM, etc.)	**O**	**I**		**I**
Rapid prototyping for control of industrial electrical drives		**O**		
HIL systems for digital twinning in I4.0	**I**	**O**	**I**	
Vibration analysis using contact and non-contact measurement techniques	**I**	**O**		
Modern methods for indoor and outdoor localization		**O**	**N**	**N**
Dialog systems and multimodal interaction	**I**		**O**	**N**

Application-oriented machine learning	**I**	**I**	**O**	**N**
Human-robot-collaboration concepts and corresponding security measures	**I**		**N**	**O**
Planning methods for collaborative robotic systems	**I**		**I**	**O**
AI based quality inspection	**I**	**I**	**I**	**O**
Simulation of assembly systems (petri-nets, digital twins using visual components)		**I**	**I**	**O**
Force-controlled robot applications	**O**	**I**	**I**	**O**
Machine learning, reinforcement learning			**I**	**N**
Fundamentals and Introduction to machine learning	**N**			**N**
Introduction and technologies for augmented reality	**O**		**I**	**N**
AI for systems diagnostics / diagnostic functions of manufacturing machines	**N**	**N**		
Visual servoing			**N**	
Obstacle avoidance		**N**	**N**	
Gripper types and changing (autonomous)	**I**		**N**	**N**
Computer vision for robot applications (e.g. pick & place, bin picking, etc.)	**O**	**I**	**N**	**N**
OPC UA Communication and data models	**O**	**I**	**N**	**I**

5 Local academic activities

5.1 CIIRC activities

The Czech Technical University in Prague (CTU) is one of the largest and oldest technical universities in Europe. CTU currently has eight faculties (Civil Engineering, Mechanical Engineering, Electrical Engineering, Nuclear Science and Physical Engineering, Architecture, Transportation Sciences, Biomedical Engineering, Information Technology) more than 17,800 students. For the 2021/22 academic year, CTU in Prague is offering its students 227 accredited study programmes of which 94 are in foreign languages. CTU educates modern specialists, scientists and managers with knowledge of foreign languages, who are dynamic, flexible and can adapt quickly to the requirements of the market.

The technical fields related to the key RICAIP's research areas are covered primarily by lectures provided by the Faculty of Electrical Engineering (FEE), Faculty of Mechanical Engineering (FME) and Faculty of Information Technologies (FIT).

In the RICAIP project, there are participating multiple research teams that are concurrently involved in the teaching activities on the above-mentioned university faculties.

The team of Industrial Production and Automation (IPA) department is led by prof. Michael Valášek. Prof. Valášek is the guarantor of the study programmes Robotics and production machines and Industry 4.0. The teams of IPA department are involved in teaching of multiple subjects in the field of robotics, machine tool design, control, process-machine interaction, diagnostics and measurement, CNC and PLC programming of production machines.
The following RICAIP-related University departments are examples of academic units involving the professors directly involved in the RICAIP's activities:

- CTU, Faculty of Mechanical Engineering, Department of Mechanics, Biomechanics and Mechatronics – prof. Valášek is a professor responsible for the Group of mechanics and mechatronics.
- CTU, Faculty of Mechanical Engineering, Department of Production Machines and Equipment – Dr. Kolar is associated professor and deputy head of the department.

5.2 CEITEC activities

The Brno University of Technology (BUT) is the largest technical university in the Czech Republic. The institution consists of eight faculties and three university institutes and offers 295 accredited study programmes, of which 89 are in foreign languages (the academic year 2020/2021). With almost 20.000 students and 1000 academics staff, BUT is one of the major research institutions in the country. The scientific prestige of the University is guaranteed by 164 Professors (according to statistic data, December 2020). The technical fields related to the key RICAIP's research areas are covered primarily by lectures provided by the Faculty of Electrical Engineering and Communication (FEEC), Faculty of Mechanical Engineering (FME), and Faculty of Information Technologies (FIT).

Number of students at Brno University of Technology (Dec. 2020)				
	Bachelor's	Master's	Doctoral	Total
Faculty of Electrical Engineering and Communication (FEEC)	2119	847	335	3301
Faculty of Mechanical Engineering (FME)	2701	1307	357	4365
Faculty of Information Technologies (FIT)	1936	488	175	2599
University total	**12591**	**5537**	**1699**	**19827**

Students in BUT premises

In the RICAIP project, the BUT is represented by the university institute CEITEC, namely by the research group Cybernetics and Robotics led by prof. Ing. Pavel Václavek, Ph.D. The staff of the group counts 60 people. Primarily the senior researchers ensure the world-class science in the fields related to the comprehensive area of Industry 4.0 - robotics, automation, application of AI for industrial systems, industrial cybernetics, cyber-physical systems, smart sensors, signal processing, and others. Prof. Václavek is the guarantor of the study programme Cybernetics, Control and Measurements in the Department of Control and Instrumentation at FEEC. His courses for students within the academic year 2020/2021 are focused namely on topics of automatic control, modeling and simulation, optimization of controllers, discrete event systems.

The outlines of two selected doctoral courses follow just to present tight relation to RICAIP activities. The lectures in these courses are mostly being led by the people who are involved in the RICAIP project:

Selected Chapters from Automatic Control

The course focuses on studies of advanced control algorithms design methods including classical control structures as well as algorithms of robust, adaptive, and predictive control. Attention is also paid to information processing algorithms and state observers for the realization of so-called virtual sensors and algorithms of sensor-less control. Traditional methods for systems control and processing information are complemented by artificial intelligence-based approaches. They are oriented to AI-based control, identification, diagnostics. In addition to the theoretical aspects of the given topic, sample algorithms for advanced drives, mechatronic systems and mobile robots are also solved. Modern methods of autonomous outdoor and indoor self-localisation are explained and advanced 3D mapping - sensors, data fusion methods, data representation are shown in practical use.

Selected Chapters from Measuring Techniques

The course deals with modern and perspective methods of measurement of selected physical quantities, advanced processing of signals from sensors (time-frequency analysis, order analysis),

advanced image processing methods and modern trends in industrial automation. It covers diagnostic methods (Vibrodiagnostics, Acoustic emission, Thermo-diagnostics). Testing, environmental and life tests of electrical equipment are clarified. The focus is also on Risk, its perception and management in society, Security, safety culture and human factor from a safety perspective and resilience of the technical system.

The university is aware of the importance of bringing technical fields closer to children and high school students. In this context, BUT seeks to increase the attractiveness of its study programmes for girls.

Summer School (F) IT for Girls

The Summer School (F) IT for Girl takes place at the Faculty of Information Technology every August. The school includes courses, games, excursions, and competitions focused on IT and related topics. The participants can build e.g., their own digital watches or get acquainted with the basics of programming. The summer school is intended primarily for female students from 12 to 19 years of age who are interested in IT. As faculty tries to encourage young girls not to be afraid of computer science.

Photo from Summer School (F) IT for Girls

5.3 DFKI activities

DFKI is a research centre organically connected to 3 large German Universities, which are also the DFKI's shareholders (University of Saarland, Technical University of Kaiserslautern, University of Bremen). By Statute, all heads of research departments of DFKI are University professors, thus ensuring direct and mutually beneficial links between DFKI and its academic environment. The following RICAIP-related University departments are examples of academic units led by the professors directly involved in the RICAIP's activities:

- University of Saarland, Faculty of Informatics and Mathematics, Chair of Artificial Intelligence (Prof. Wolfgang Wahlster, Prof. Jana Koehler)
- University of Saarland, Chair of Artificial Intelligence in Retail (Prof. Antonio Krueger)
- Technical University of Kaiserslautern, Department of Mechanical and Process Engineering, Chair of Machine Tools and Control Systems (Prof. Martin Ruskowski)

Several other DFKI's professors are also heading academic programmes directly relevant to the RICAIP's objectives (e.g. the Chair of Robotics in University of Bremen, etc.)

Examples of educational modules to be built on the basis of regular academic programmes led by the DFKI professors are below (the information is provided by the Chair of Artificial Intelligence, UdS):

Module 1: Fundamentals of Artificial Intelligence

This module is about: An online course on the fundamentals of artificial intelligence including intelligent agents, search algorithms, logic, and knowledge representation, which form the foundation for tackling industrial planning and optimisation problems. The course is self-contained and accessible to anyone with an interest in learning about artificial intelligence. Furthermore, the course is accompanied by the chatbot Alden. Alden supports students in working through exercise sheets by providing topic-specific natural language access in German and English to the course. In response to a question such as "Where can I find information on X?", Alden returns slides sorted by relevance and can hold the relevant passages from the course. This educational module can be delivered stand-alone or be integrated with other related courses. It targets anyone wanting to learn about the fundamentals of Artificial Intelligence, with no prerequisite knowledge required (the course is self-containing). This is an online course, delivered via the web in a form of lectures, self-learning materials, tests. The total volume is ca. 25 hours of video lectures, split into smaller lessons + 75 hours of reading and quizzes.

Module 2: Architectural Thinking for Intelligent Systems

This module is about: This course teaches established and successful methods that support participants in the systematic planning, conception, and evaluation of complex software/hardware architectures. Specific attention is devoted to methods for devising the architectures of AI systems deployed in an industrial context and in understanding the architectural concerns decisions, which must be taken to minimize risks in these systems. The blended learning course targets software engineers with a solid understanding of software and systems modeling and agile software engineering and development methods. Part of the course is a practical exercise (a software development project) to be designed and implemented via teamwork methods. The volume of the course is ca. 56 hours of teaching + practice project (100 hours).

5.4 ZeMA activities

The region of Saarland counts two main higher education institutions; the University of Saarland (UdS) with a total number of students of 16837 and the University of Technology and Economics (htw saar) with 5292 according to the statistics of 2019/2020. In the UdS there are several departments with topics related to ZeMA research topics as well as to RICAIP (10% of the overall number of students) namely the Systems Engineering department with 264 students enrolled in the summer semester of 2020 and 15 professors amongst which is Prof. Dr.-Ing. Rainer Müller. There is also the department of computer science with all its faculties with about 1446 students and 54 professors. For the htw saar a total number of students of 1754 are enrolled in majors related to ZeMA's activities, around 33% of the total number of students in htw saar. The number of professors in these majors is about 44.

ZeMA – especially the chair of Prof. Dr.-Ing. Rainer Müller (Montagetechnik) offers lectures throughout the year, in summer semesters as well as in winter semesters. The lecture covers multiple technical topics, for instance, assembly systems, robotics, Industry 4.0, etc. They present theoretical foundations as well as practical aspects and real-world applications as well as smaller workshops and projects. In addition to lectures, ZeMA offers activities in a seminar format, where students are supposed to accomplish a specific task in groups, their progress is then followed in milestones with a final meeting for assessment. The lectures are primarily at the two universities in Saarland and some chosen lectures are available through cooperations in the Greater Region (Lorraine, Luxembourg, Belgium, Rhineland-Palatinate, Saarland). The main target group is students in engineering studies.

Lecture: Human-Robot Cooperation in Industrial Production

The course "Human-Robot Cooperation in Industrial Production" (short Robotix) is organized in the framework of the Robotix Academy project. The aim is to bring together students from different countries of the greater region representing the project partner universities namely the University of Luxembourg, the University of Liege in Belgium, the University of Lorraine in France, Trier university of applied sciences and the University of Saarland in Germany. The first course version took place in 2015 and was established thereafter. This lecture is organized each winter semester in a different location across the aforementioned countries, the students have the opportunity to assist in courses offered by several professors, visit the organizing university labs and enjoy Team building activities. The Robotix course gives students insights into robotics, supplemented by exercises and practical project work. In this way, the master students gain a holistic understanding of automation with industrial robots. Issues from companies in the greater region are addressed. Current research topics are also included and keep the lecture always up to date. In addition, the Robotix 2 lecture is currently planned for the summer semesters.

Lecture: Kinematics, dynamics and application in robotics (KDARo)

The KDARo lecture is organized every year in the winter semester, alternating lectures and application-oriented exercises. The lecture "Kinematics, Dynamics and application in robotics" deals with the basics of robotics, the most important components of an industrial robot and the programming procedures. It gives an overview of different handling devices, the motion state of these handling devices and shows how to algorithms for the calculation of velocities and accelerations set up. More precisely, KDARo aims at giving the students a deep understanding of the fundamentals of robotics, expose them to the most important characteristics of the different handling devices and enable them to select the appropriate device structure for the handling task at hand.
Furthermore, the lecture covers the necessary methods and procedures for synthesis and analysis as well as the theoretical notions, to solve problems concerning the selection and design of industrial handling devices and the programming procedures of industrial robots.

Lecture: Industry 4.0 for engineers

The “Industry 4.0 for engineers” lecture, also called “I 4.0” is organized every year in the summer semester. Each week the students have one lecture slot and one exercise slot. The lecture presents

the components and basic technologies of Industry 4.0. The aim is for students to understand the basics of Industry 4.0 and be able to apply them to real-life problems. Along the course, students get familiarized with the application of methods that use I4.0 technologies. Moreover, students are required to prepare a written elaboration in a project team on a selected topic of the lecture and present it at the end of the lecture series. Through this project work, the students are able to independently develop suitable approaches and possible solutions for a given problem. They can develop suitable implementation strategies for their approaches and finally, they can concretely assess their respective learning status and, on this basis, define further work steps. The lecture is organized through the MHI – "Wissenschaftliche Gesellschaft für Montage, Handhabung und Industrierobotik" throughout Germany.

Robotix academy Summer School

The Summer School is also organized in the framework of the Robotix Academy project. Since 2017, a different partner university has invited participants to the Summer School each year, providing an opportunity for exchange at the working level. The workshop is usually complemented by a team-building event and a cultural social program, so that the participants can exchange ideas beyond the technical aspects. In the workshops of the Summer School, various issues in the context of human-robot collaboration are addressed and discussed in order to derive added value for further scientific work. Here, the content will be developed that will also be of interest to companies in the greater region in the future.

6 Summary

The deliverable at hand shows the capacities and possibilities to provide internal trainings and capacity building based on different topics and available expertise around production, manufacturing, control systems, mechatronics, Industry 4.0 as well as AI and robotics. With RICAIP's vision and mission in mind and its services for its target groups, the internal network and capacity building around these areas and fields will lead to a broad range of experts and services for these target groups. As described throughout the document the trainings will be installed for internal exchange between the various testbed in Germany and the Czech Republic and provide a boost to the internal work and capacities. As described in the previous chapters each group has already expertise in trainings through its affiliation and involvement in the different studies and lectures at the universities in Saarbrücken, Prague and Brno. Furthermore, the document captures an outlook on existing offers, needs and interests between the four research partners and teams thus showing potential area for a fast initiation of the trainings as well as areas in which further expertise and experts are needed – either internal or external.