Erasmus+

DeCAIR

1.6 Concluding Report on Surveying and Identifying the Needs for AI and Robotics in Jordan and Lebanon

April 2021

Project full title & acronym:	Developing Curricula for Artificial Intelligence and Robotics - DeCAIR
WP No & Title	WP1. Surveys and Needs Identification
Task	WP1.6 Concluding Report
Responsible partner for deliverable:	UJ
Contributing partners:	JUST, TTU, LU, BAU, UNIPI, UNIGE, UGR, UST, CreThiDev
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Dissemination level:	Public
Total number of pages:	260

Revision History

Version	Date	Description	Action	Page(s)
1	10/04/2021	Original (base) document	C	260

(*) Action: C = Creation, I = Insert, U = Update, R = Replace, D = Delete

Disclaimer

This project has been co-funded by the Erasmus+ Programme of the European Union.

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Contents

Introduction

The first work package in the DeCAIR project "Surveys and Needs Identification" isconcerned with conducting a set surveying tasks to collect the information necessary to execute the other tasks in the project in order to achieve its objectives. Five different surveying tasks are specified in this work package. These are:

- **Task 1.1:** Surveying the needs for AI and robotics expertise and professionals in Jordan and Lebanon
- **Task 1.2:** Surveying and evaluating similar AI and robotics master programs
- **Task 1.3:** Surveying and evaluating AI and robotics courses in similar bachelorprograms
- **Task 1.4:** Identifying training needs for staff members in universities of PartnerCountries
- **Task 1.5:** Surveying the needs of facilities and equipment

For these tasks, partners in the consortium collaborated to execute one or more activity to collect the information that is crucial in executing other work packages in the project. Each of these tasks concluded with a detailed report.

These reports are available on the project website http://decair.ju.edu.jo/Lists/Results/Results.aspx and are also available in appendicesA through D in this report.

The purpose of this report is to combine and summarize the conclusions and recommendations for each of the five surveying tasks.

Task 1.1: Surveying the needs for AI and robotics expertise and professionals in Jordan and Lebanon

Two main activities were conducted in this task. The first one was an online workshop that was held on March 4th, 2021 that gathered the partners in the consortium, invited speakers from the industry, representatives from the private and public sectors in Jordan and Lebanon, faculty members and students. The workshop served as an opportunity to present the advancements, impact and needs of AIR and open space for discussion about the subject matter.

The second activity was the distribution of surveys to the stakeholders of the project including individuals from the industry, government, faculty members and students to evaluate different aspects of AIR in Jordan and Lebanon, including but not limited to:

- The need, importance and impact of artificial intelligence and robotics (AIR)
- The status of AIR adoption in Jordanian and Lebanese markets and the need for AIRgraduates
- The impact of AIR academic programs in strengthening the collaboration withindustry to solve local problems in Jordan and Lebanon.
- The adequacy of existing academic programs in Jordan and Lebanon to prepare graduates with experience in AIR.

- The need to establish specialized AIR academic programs and updating existingprograms in Jordan and Lebanon.

The survey was prepared using Google Forms and the link was distributed electronically to participants during the workshop. A total of 65 participants filled the survey; mostly from Jordan and Lebanon. The detailed numerical results for this survey are available in AppendixA.

Based on the discussion during the workshop and the analysis of the responses received through the surveys, the following conclusions and recommendations are made:

1) There is a tangible level of recognition among the participants in different categories regarding the need, importance and impact of AIR.
2) There is direct and indirect agreement regarding the insufficiency and inadequacy of existing programs in Jordan and Lebanon to qualify graduates of existing programs to engage in jobs related to AIR.
3) Establishing specialized AIR programs in Jordan and Lebanon are encouraged in order to satisfy the increasing demand for graduates specialized in AIR in the local, regional and global markets.
4) Industrial participants in Jordan and Lebanon showed great enthusiasm about the DeCAIR project and its objectives and showed interest in opening doors for fruitful collaboration.
5) There is a pressing need to train faculty members and instructors in different areasin AIR in order to support the new and updated academic programs.
6) There is a pressing need to establish new labs to support the new programs and those to be updated.

Task 1.2: Surveying and evaluating similar AI and robotics master programs

In this task, one major activity was conducted for the purpose of collecting information regarding the attributes and structure of international masters AI and robotics programs. A template was prepared to summarize the programs and was communicated by the activity coordinator to partners participating in the activity. Twenty-one AIR related master programs were surveyed. The programs are from diverse countries and universities, and are scattered among wide geographical areas. Specifically, we surveyed three programs from USA, two programs from Asia, and sixteen programs from Europe. Among the sixteen programs from Europe, there were 10 programs from universities of Program Countries in the consortium. Appendix B contains the detailed report that was obtained in this activity.

The process of analyzing the surveyed programs to get the final recommendations has some difficulties like: same courses may have different names in different universities, different course names may refer to the same course, and the numbers and periods of the courses are different among different universities, different rules in each university, and different assumptions and policies as well. However, the following recommendations are advised to be considered when designing the new master program in UJ and updating existing master programs in universities of Partner Countries:

1) Most master programs are better to focus on one or two areas at most (AI, Robotics, and/or Data science).
2) AI is needed in data science and robotics master programs. Therefore, master programs, whether in data science or in robotics, usually require one or more coursesin AI.
3) In the master programs which focus on two disciplines like in data science and AI, or master in AI and robotics, the students are required to register one to two core coursesin each discipline.
4) For programs that have two disciplines, the students are better to study set of courses from one group out of two or more groups of courses. For example, the student who is enrolled in a master of AI and robotics, if he/she likes to focus more on AI, at least x courses from a set of AI courses must be studied. The same thing is applied on the student who studies master in AI and robotics and who would like to focus on robotics.
5) The surveyed master programs divide the courses into mandatory and electives courses.
6) It is highly recommended that the master programs to be thesis-based or project-basedin order to maximize the benefits and expose students to hands-on experience.
7) It is better to have a big variety of elective courses and small set of mandatory courses. The elective courses fulfil the needs of different students who work in different areas.
8) The master programs which focus on AI may consider having the following structure:
    a. Mandatory courses: Machine Learning, Deep Learning, Applied Machine Learning or machine learning programming, and Intelligent agents.
    b. Elective courses: advanced machine learning, computational vision, natural language processing, speech processing and recognition, deep reinforcement learning, and machine learning for data science.
9) The master programs which focus on Robotics may consider having the following structure:
    a. Mandatory courses: Introduction to Robotics, Machine Learning, Computer Vision, and Robot Perception and Learning.
    b. Elective courses: Intelligent Systems, Mechanics of Robots, Basics of Mobile Robotics, Human-Robot Interaction, and System Theory and Control Theory.
10) The master programs which focus on data science may consider having the following structure:
    a. Mandatory courses: Database related course, Data mining, Machine learning, and Introduction to Data science.
    b. Elective courses: Advanced Data Mining, Large-scale computing, Optimization methods, Multimedia information retrieval and computer vision Social media mining, Data visualization, and Internet of things
11) AI and data science master programs do not need teaching labs other than a computer lab with high specifications computers and powerful graphical processing units.
12) Robotics master programs need robotics lab that allow the students to do their own testing and experiments.

Task 1.3: Surveying and evaluating AI and robotics courses in similarbachelor programs

In this task, one major activity was conducted for the purpose of collecting information regarding the attributes and structure of international bachelor AI and robotics programs. A template was prepared to summarize the programs and was communicated by the activity coordinator to partners participating in the activity. A total of 11 bachelor programs from USA, Europe, and Asia were selected for this survey. Appendix C contains the detailed report that was obtained in this activity.

According to the comprehensive and intensive search, it is clearly noticed that the majority of undergraduate programs are either in computer science or electrical and computer engineering programs with minors or concentrations that offer a set of courses in AIR. The following recommendations and guidelines are advised to be considered when designing the new bachelor program in TTU and updating existing master programs in universities of Partner Countries:

1) In general, the following courses are common between all programs:
    a) Introduction to Artificial Intelligence
        i) Principles of Machine Learning
        ii) Introduction to Natural Language processing
    b) Image processing and Computer Vision
    c) Introduction to Intelligent Robotic Systems/Autonomous Robotics
2) In addition, the following advanced topics were commonly listed as a compulsory oran elective for many programs:
    a) Artificial Intelligence II
    b) Machine Learning II
    c) Intelligent Systems/ Embedded Systems
    d) Introduction to Data Mining
    e) Neural Networks / Deep Learning
3) In general, these courses require prerequisites on mathematics and programming that provide students with the fundamentals and the necessary background. Most of these courses are usually covered in engineering programs such as computer and electrical engineering.
4) It is important to include a practical training component in the curricula. Preferably in areas relevant to AIR to expose students to the practical aspects of AIR and their application domains.

Task 1.4: Identifying training needs for staff members in universities ofPartner Countries

One major activity was conducted in this task in order to gather information about the training needs of faculty members in universities of Partner Countries and the training capabilities of partners in Program Countries. A needs template and capabilities template were prepared and were communicated by the activity coordinator to all partners in the consortium. The average number of targeted faculty members in Partner Countries is 20 for each university. The total number of courses to be delivered is 19. Each is a 5-day training course. The courses are to be delivered by EU partners with the following distribution: six courses by UNIGE, five courses by UNIPI, five courses by UGR and three courses by UST. The details of the training needs and capabilities report are available in Appendix D.

The surveyed training courses are laid under three main training areas; AI, Data Science and Robotics. The details of the requested and offered training courses in these categories areas follows:

1) Artificial Intelligence

Generally, the needed AI related training courses focus on six areas ranging from basic to advanced levels. In Basic level, mainly two training courses were requested: “Introduction to AIand Machine Learning” and “Neural Network fundamentals”. At the intermediate level, mostly two training courses were requested: “Deep Learning” and “Reinforcement Learning”. Finally, in advanced level; essentially two training courses were reported: “Natural Language Processing” and “Computer Vision”.

On the other hand, the partners from Program Countries offered several AI related training courses which focus on six areas range from basic to advanced levels. In Basic level; three training courses were reported: “Introduction to AI and Machine Learning”, “Neural Network Fundamentals” and “Fuzzy Logic Fundamentals”. At the intermediate level, one training course was reported: “Deep Learning”. Finally, in advanced level; essentially two training courses were reported: “Natural Language Processing” and “Computer Vision”. These courses are offered byUniversity of Granada (UGR) and University of Genoa (UNIGE).

2) Robotics

Generally, the requested Robotics related training courses focused on four areas ranging from basic to advanced levels. In basic level; mainly two training courses were reported: “Introduction to Robotics” and “Robot Control fundamentals”. Additionally, in intermediate level, one training course was reported: “Robot Programming”. Finally, in advanced level; one training course was reported: “Advanced Robotic Control”. On the other hand, universities from Program Countries offered Robotics related training courses that focus on six areas ranging from basic to advanced levels. In basic level; mainly four training courses were reported: “Introduction to Robotics” and“Robot Control fundamentals”, “Introduction to Mobile and Distributed Robots” and “Building non Expensive Robot”. Additionally, in intermediate level, two training courses were reported: “ROS Programming” and “Robot Modelling”. Finally, in advanced level; essentially two training courses were reported: “Controlling UAV” and “Distributed Control of Swarm Robots”. These courses offered by three universities; UNIPI, UST and UGR.

3) Data Science

Generally, the requested Data Science related training courses focused on three areas ranging from basic to advanced levels. In basic level; one training course was reported: “Introduction toData Science”. Additionally, in

intermediate level, one training courses was reported: “Data Analysis and Visualization”. Finally, in advanced level; one training courses was reported: “Big Data Analysis”. On the other hand, universities in Program Countries offered Data Science related training courses that focus on three areas ranging from basic to advance levels. In basic level; one training course was reported: “Introduction to Data Science”. Additionally, in intermediate level, one training courses was reported: “Data Visualization”. Finally, in advanced level; one training courses was reported: “Large scale Data Management”. These courses offered are offered by UGR and UNIGE.

Task 1.5: Surveying the needs of facilities and equipment

In this task, one major activity was conducted for the purpose of assessing existing labs in universities of Partner Countries and collecting information and specifications about modern equipment that are used in international programs in universities of Program Countries. Three different templates were prepared; one for assessing existing labs, another for listing an initial list of equipment to be ordered, and the last one for the equipment in programs in universities of Program Countries. These templates were communicated by the activity coordinator to all partners in the consortium. The collected information is available in the report in Appendix E.

Based on the collected information, the following recommendations are to be considered when establishing new labs and updating existing ones to support the adoption of AIR in academic programs:

1) The collected information shows large variation between the universities in Partner Countries in terms of existing equipment, but they all agree on that the available equipment in the labs is of low to medium specifications that is inadequate to support programs specialized in AIR.
2) Some of the existing labs can be upgraded with better equipment to serve AI and robotics needs. In other cases, there is a need to create new labs with modern high-end equipment that can be ordered through the DeCAIR project.
3) Finalizing the preliminary lists of the equipment to be ordered should be done as soon as possible in order ensure timely delivery, installation and training.

Appendix A: Stakeholders Survey Report

Developing Curricula for ArtificialIntelligence and Robotics

DeCAIR Stakeholders Survey

Results and Analysis

March 15th, 2021

1. Survey Description

This survey was conducted within the framework of the Erasmus+ project "DeCAIR: Developing Curricula for Artificial Intelligence and Robotics" to collect feedback and input on the DeCAIR project activities and objectives from different stakeholders, specifically; professionals from the private and public sectors, instructors and students. It was distributed during the DeCAIR Stakeholders Workshop that was held virtually over Zoom on March 4th, 2021.

Generally, the survey is designed to evaluate the following aspects:

- The need, importance and impact of artificial intelligence and robotics (AIR)
- The status of AIR adoption in Jordanian and Lebanese markets and the need for AIRgraduates
- The adequacy of existing academic programs in Jordan and Lebanon to prepare graduates with experience in AIR
- The need to establish specialized AIR academic programs and/or updating existing programs in Jordan and Lebanon

The survey was prepared electronically using Google Forms and is available in Appendix A.1.The survey contains 60 questions that are divided into three sections, one section for each categoryof the participants, such that:

- Questions 2 through 24 are for the Enterprise/Governmental Agency/Professional Organizations Survey
- Questions 25 through 38 are for the Student Survey
- Questions 39 through 60 are for the Instructor Survey

We present an executive summary of the survey results in Section 2. In sections 3 through 5, we discuss the results for each category. The detailed results are available in Appendix A.2.

2. Executive Summary

Sixty-five participants from different categories and countries participated in the survey with the distribution given in Figure 2.1.

Figure 2.1. Distribution of participants by category and country

In general, the analysis of the collected responses reveals that there is a tangible level of recognition among the participants in different categories regarding the need, importance and impact of AIR. In the enterprise and government category, responses indicated that around 82% of these organizations have already adopted AIR, mostly to improve the quality of their products and to drive the innovation of new ones. This recognition of the importance of AIR has stimulated70% of these organizations to define and execute training plans in AIR for their employees. Moreover, more than 90% of the participants agree that there will be an increasing demand on graduates skilled in AIR in the near future.

In the student category, the recognition of the impact and importance of AIR is reflected by the fact that 92% of the students have acquired some AIR knowledge through courses in curriculaor online training. Also, more than half of the student participants believe that there is a medium to high demand in the market on graduates with AIR background.

As for the instructor category, the responses show that around 90% of the instructors have general knowledge in AIR or have practiced teaching and/or doing research in AIR. Also, around90% of the instructors agree that the presence of AIR programs that advance and polish their skills and knowledge have direct impact on advancing their research and strengthening the collaborationwith the industry to solve real life problems. Moreover, 84% of the instructors agree with the factthat improving the AIR skills in graduate would increase their employability. Due to thisrecognition, 65% of the instructors reported that their curricula is undergoing minor or major update to improve the quality of the graduates in the AIR domain.

Nonetheless, there was a general direct and indirect agreement among participants from different categories regarding the insufficiency and inadequacy of existing programs in Jordan and Lebanon to qualify graduates of existing programs to engage in jobs related to AIR, and to satisfythe demand of the job market for qualified employees and skillful researchers who can help in solving problems and improving the products. The lack of funding and expertise were reported asthe main impediments to update existing programs, train instructors and establish/upgrade necessary labs and infrastructure.

Accordingly, 95% of the participants from all categories were in favor of establishing specialized AIR academic programs and/or updating existing ones in Jordan and Lebanon.

3. Enterprise/Governmental Agency/Professional Organization Survey Results

A total of 22 participants from this category filled the survey; 67% from Jordan, 24% from Lebanon and the rest are from Germany. The participants work in different enterprise domains such business analytics, control systems, image analysis, instrumentation and automation. As shown in Figure 3.1, 62% of the participants have more than three years of experience in AIR in the research and development domains.

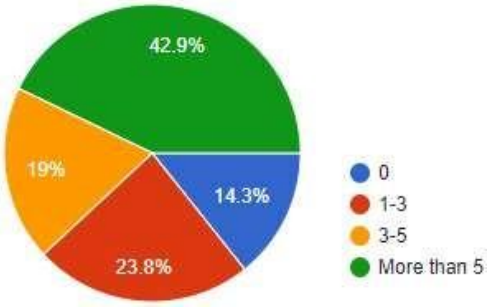


Figure 3.1. Participants AIR experience inyears

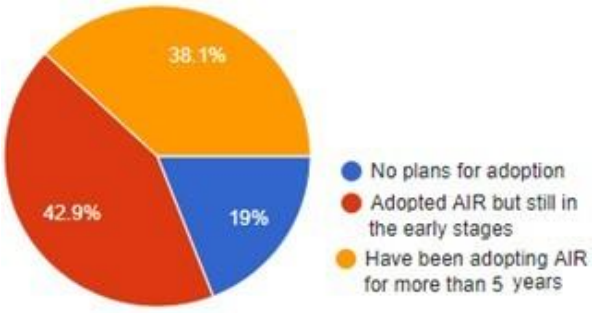


Figure 3.2. Distribution of AIR adoption inparticipants' organizations

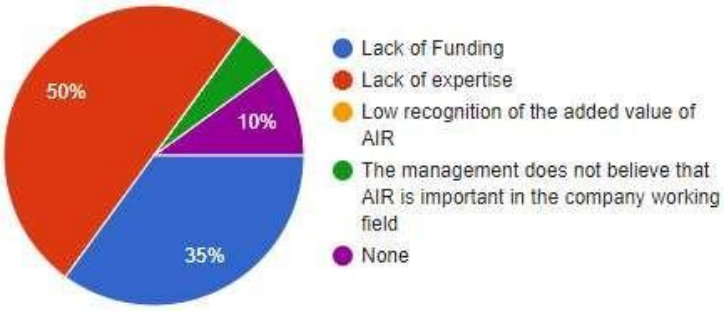


Figure 3.3. Challenges of AIR adoption

Figure 3.2 shows the level of involvement and adoption of participants' organizations in AIR.Around 43% of the organizations are in the early stages in the adoption of AIR while 39% have been adopting AIR for more than 5 years. Most of the participants (85%) believe that AIR will have direct impact on improving the quality of the products in their organizations, while 57% of them indicated that the adoption of AIR will motivate the creation of new products. However, mostparticipants believe that there exist challenges and impediments to adopting AIR in their organizations as shown in Figure 3.3. In general, the lack of funding and expertise are reported asthe main challenges in adopting AIR.

In terms of the capabilities of the workforce in the respondents' organizations, Figure 3.4 shows the distribution of the number of employees with AIR expertise in the participants' organizations with majority of organizations (57%) having between 1 to 5 employees with such experience. Also, and due to their recognition of the importance and impact of AIR, 70% of the organizations indicated that they have taken steps in the last five years to develop the AIR skills of their existing employees and 71% have established a training strategy for their employees in AIR as shown in Figure 3.5.

In order to expand their AIR workforce, Figure 3.6 shows that the frequent practice for of theorganizations is to train their current employees (57%), perhaps to cut the cost and speedup the learning curve due to the lack of AIR experience for graduates. Nonetheless, the organizations may resort to hire and invest in fresh graduates to fill their needs (29%).

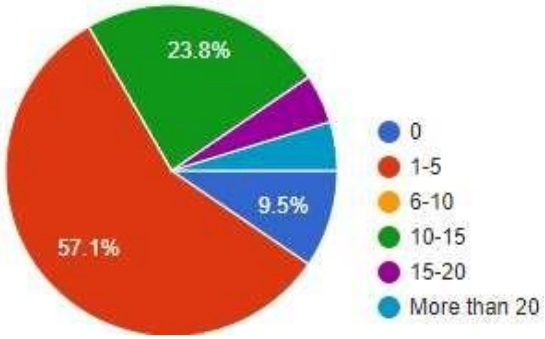
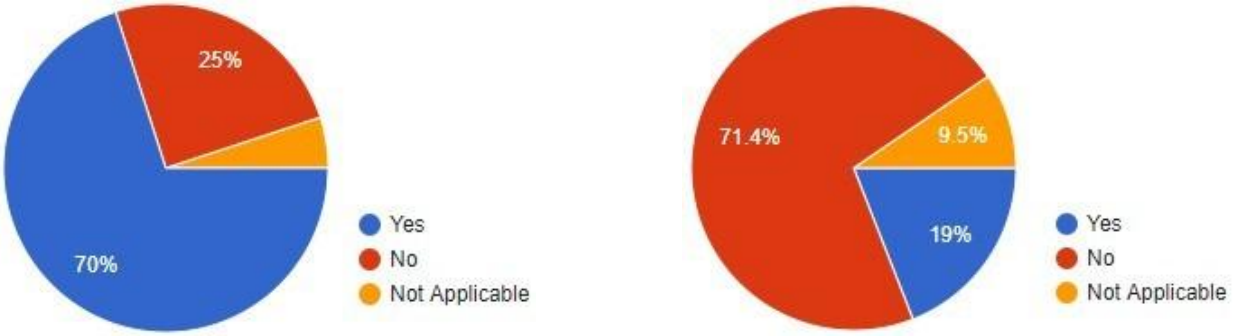


Figure 3.4. Number of employees with AIR experience in participants' organizations



AIR training started

Existence of AIR training strategy

Figure 3.5. Status of AIR training in participants' organizations

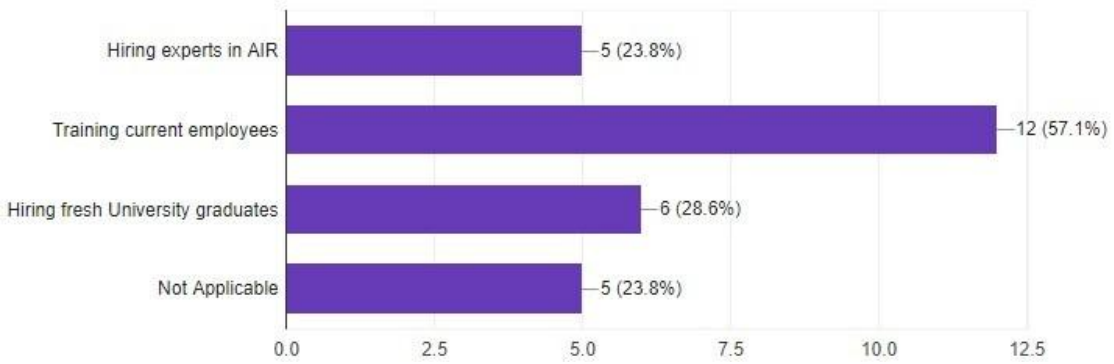


Figure 3.6. Approaches for increasing AIR workforce in participants' organizations

As for the role of universities in Jordan and Lebanon in adopting and supporting AIR, Figure 3.7 shows that half of the respondents see that there is low adoption of AIR in the academia whilethe rest think that the adoption is at medium level. However, and as shown in Figure 3.8, 90% of the respondents agree that the demand of for skillful graduates who are specialized in AIR will increase in the coming years and about 90% agree that the availability of AIR-skilled graduated may attract international companies to open offices in Jordan and Lebanon. Also, Figure 3.9 showsthat about 95% agree that the availability of AIR undergraduate and graduate academic programs

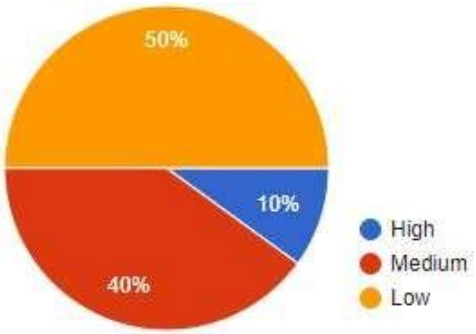


Figure 3.7. AIR adoption in Jordan and Lebanon

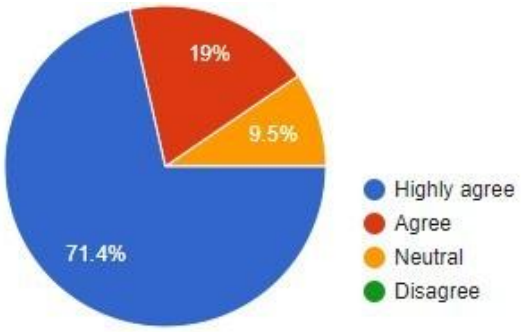
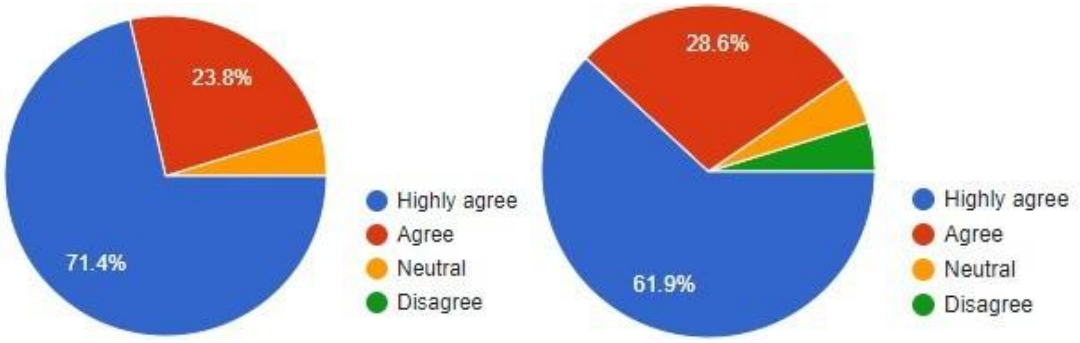


Figure 3.8 Agreement on the increasing demand for AIR graduates in Jordan and Lebanon



(a) (b)

Figure 3.9. Impact of AIR programs on (a) attracting international companies (b) increasing thecollaboration between academia and industry in Jordan and Lebanon

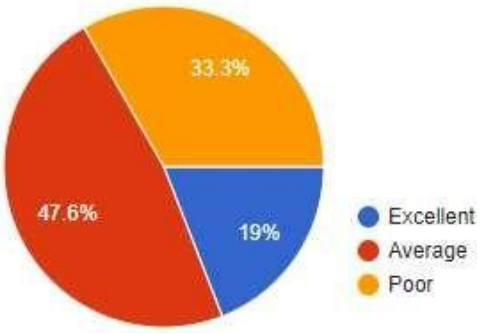


Figure 3.10. AIR Knowledge level of currentgraduates

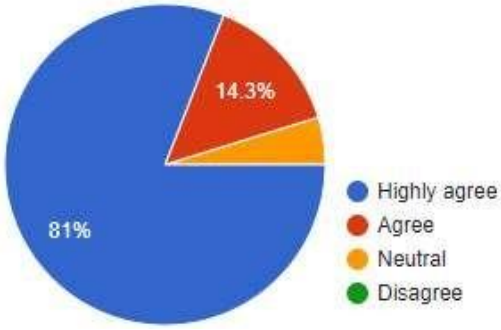


Figure 3.11. Agreement on the need to establishAIR programs/update existing programs

has direct impact on advancing the collaboration between the academia and local organizations in Jordan and Lebanon as this will help in solving their problems and advancing their products.

Nonetheless, around 81% of the respondents see that the AIR knowledge of current graduates in Jordan and Lebanon is at or below average level (Figure 3.10). This may reflect that there wouldbe a growing gap between the demand for AIR graduates and what universities may provide in terms of quality and quantity. Hence, most respondents (95%) agree that universities in Jordan and Lebanon should establish specialized AIR programs and/or upgrade their existing programs to incorporate significant AIR components in order to satisfy the projected growing demand on AIRgraduates as depicted in Figure 3.11.

The last part of the survey asked the respondent to list the AIR-related skills and knowledge that the market expects graduates to have. Responses emphasized on the need for knowledge in programming, machine learning tools, computer vision, natural language processing, deep learning, automation and control, and data mining and analysis. On top of them, respondents stressed on the need of the hands on experience that can be built through project-based learning.

4. Student Survey Results

A total of 21 students filled the survey; 52% from Jordan, 43% from Lebanon and 5% from other countries. Around 48% were graduate students while 52% were undergraduate students. Participating students are pursuing degrees that are relevant to AIR. Figure 4.1 shows thedistribution of the major of these students.

Most of the participating students (92%) indicated that they have prior knowledge in AIR. Mostly, they have obtained this knowledge from online courses and/or courses in the curriculum as shown in Figure 4.2. Among the responses, 14 participants stated that their current curriculumhas one course in machine learning only while two participants mentioned robotics.

Based on the received responses, different teaching methodologies were used in delivering thetaken AIR courses. It is clear in Figure 4.3 that using projects and assignments in teaching is lessthan 50%. The absence of specialized AIR labs or the insufficiency of existing labs to support AIRcourses could be the main factors contributing to the infrequent use of hands-on methodologies inteaching AIR as shown in Figure 4.4. Also, Figure 4.5 shows the level of sufficiency for the AIRcourses taken by the participants, where almost 43% either feel that the courses are not sufficientor they did not take courses in AIR previously.

Nonetheless, most of the participating students (67%) see that there is medium to high demand for graduates with skills in AIR in the local market as shown in Figure 4.6. Additionally, Figure

4.7 shows that most of the participants (95%) are in favor of establishing specialized AIR programs in their universities.

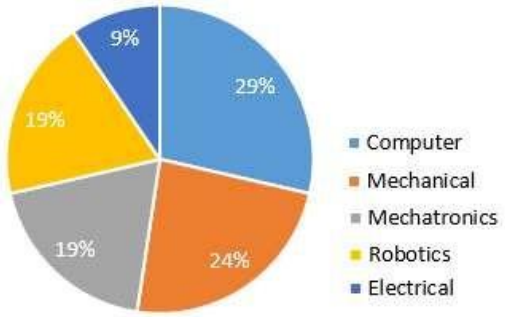


Figure 4.1. Major of participating students

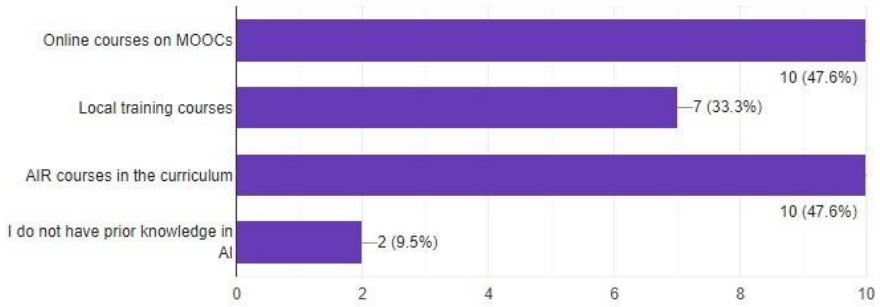


Figure 4.2. Source of AIR Knowledge

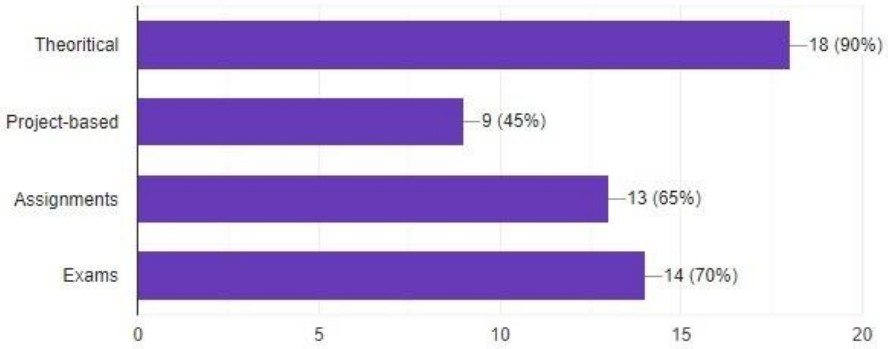


Figure 4.3. Teaching methodologies in taken AIR courses

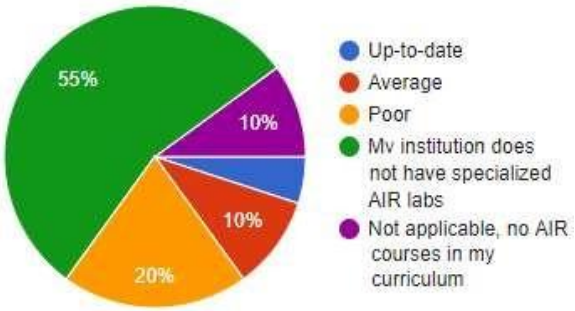


Figure 4.4. Quality of AIR labs

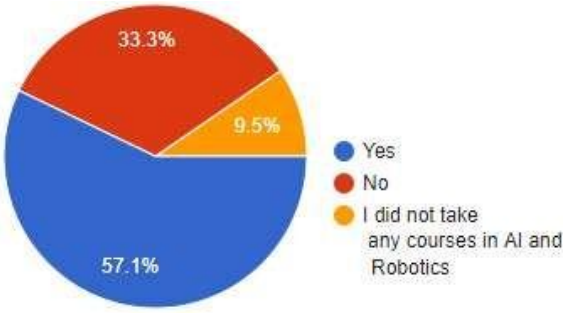


Figure 4.5. Sufficiency level taken AIR courses

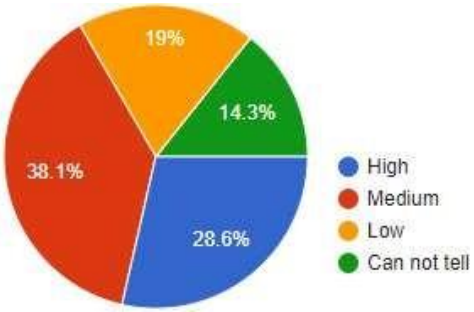


Figure 4.6. Demand on AIR graduates fromstudents' perspective

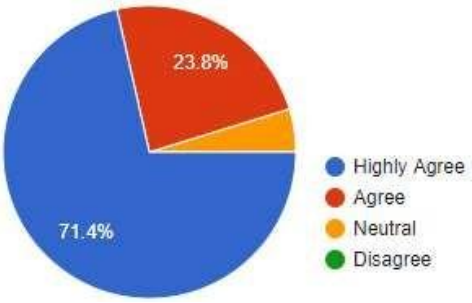


Figure 4.7. Agreement level on establishingspecialized AIR programs

5. Instructor Survey Results

A total of 21 instructors filled the survey; 57% from Jordan, 38% from Lebanon and 5% from other countries. Participants were from different specializations including computer, electrical, mechanical and mechatronics engineering and computer science. All participants have prior experience in AIR; mostly, in doing research, while many of them have general AIR knowledge and/or teaching experience in AIR as shown in Figure 5.1. Their experience is in different domainsrelated to AIR such machine learning, fuzzy logic, control systems and robotics.

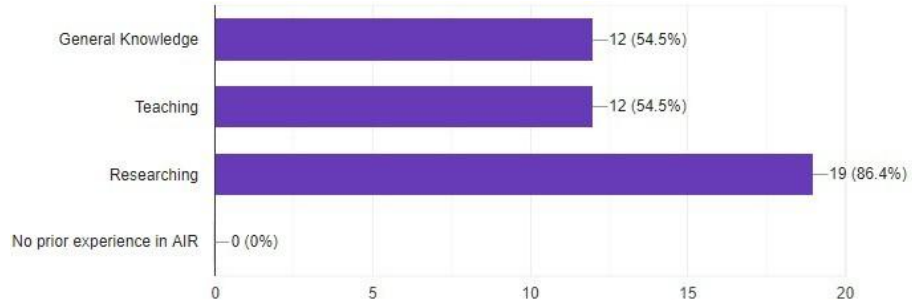


Figure 5.1. Instructors' experience in AIR

Most of the respondents reported that the curriculum that they teach has at least one course related to AIR such as introduction to machine learning, neural networks and fuzzy logic, introduction to robotics, control systems and sensing. For those who taught AIR related courses, they have used different types of assessment tools as shown in Figure 5.2.

Nonetheless, Figure 5.3 shows that most of the participants believe that the lack of equipmentand the lack of expertise are the main obstacles for teaching AIR courses. Also, 65% of the participants reported that their existing curriculum needs minor or major update in terms of AIR content, while 25% reported that they have already started updating their curriculum (Figure 5.4).

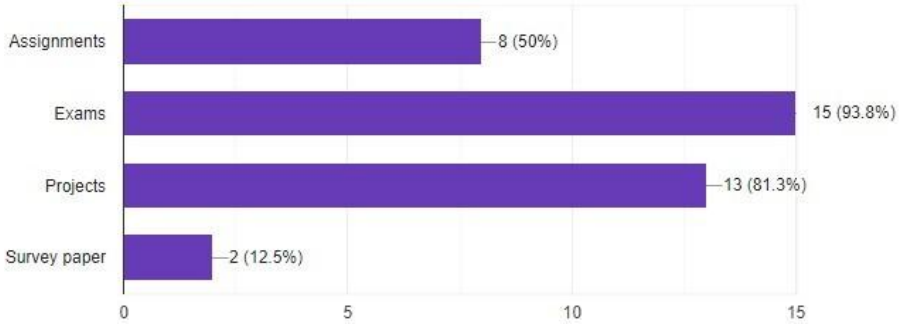


Figure 5.2. Assessment tools used by instructors

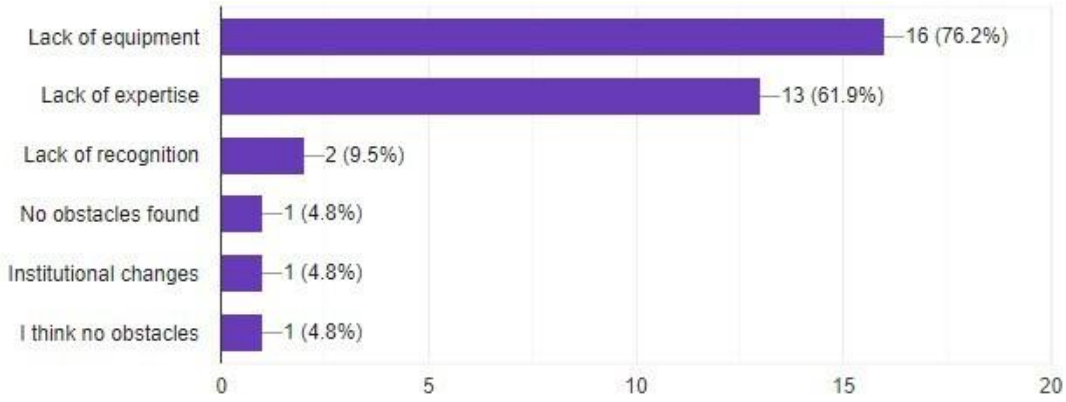


Figure 5.3. Obstacles in teaching AIR courses

For the purpose of updating existing curricula in order to cope with need for graduates with AIR expertise, the participants listed several AIR courses to be included in the curricula. These are listed in Table 5.1. Additionally, and in order to support AIR courses in the curricula, participants listed different types of equipment and software tools which are listed in Table 5.2. Generally, most of the responses required the availability high performance workstations with GPUs to support AI and data science. Additionally, robotics kits, arms and manipulators were alsolisted as required items to support robotics topics.

To address the lack of expertise in AIR, participants listed several topics in which they look for receiving training in. Some of the responses were general in nature while others were specific.A short list of the requested topics is given in Table 5.3.

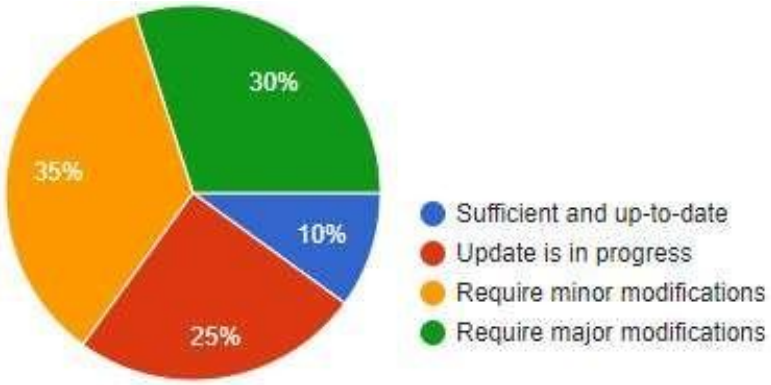


Figure 5.4. Current status of AIR curriculum

Table 5.1. List of Suggested Courses to Include in Curricula

Artificial Intelligence	• Introduction to Machine • Learning Optimization • Deep Learning • Advanced AI • Machine Vision • Natural Language Processing • Reinforcement Learning • Federated Learning • Feature Engineering
Data Science	• Data Mining • Big Data Analytics • Bioinformatics
Robotics	• Introduction to Robotics • Modeling and Simulation in Mechatronics • Concepts of Automatic Control • Internet of Things • Sensing, Actuation, & Navigation in Robots • Serial Manipulators: Modeling & Simulation • Parallel Manipulators: Modeling & Simulation • Autonomous Systems • Bio-robotics
Other	• Algorithms Programming • Signal Processing • Image Processing

Table 5.2. List of Equipment and Tools

- GPU accelerated workstations
- High-performance computers for AI
- Drones
- Robots, Mission Planners, autonomous robots, simulation tools
- Articulated Robots, Mobile Robots, UAVs
- Multi-DOF Industrial & Mobil Robots
- 3D Printers
- Robot Operating System (ROS)
- Robotics Kits
- AI-equipped robots

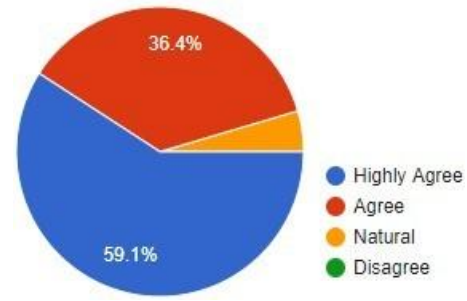
Table 5.3. List of Training Topics

- Machine learning
- Deep learning
- Time series prediction
- Applications of ML techniques in communication systems
- High computing hardware for AI
- Data analysis and coding AI algorithms
- Federated Learning
- Natural Languages processing
- Big data analysis
- Control Concepts
- Serial Manipulators
- Parallel Manipulators
- Drives and Automation

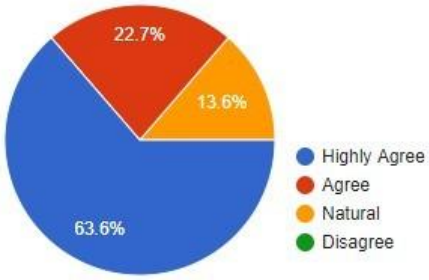
In terms of the impact of the availability of academic programs in AIR, around 84% of the participants agree with the fact that qualifying students in AIR will improve the employability. Additionally, there was a high level of agreement between participants on the positive impact of enhancing their AIR skills and the availability of the necessary AIR infrastructure in different aspects, such as advancing research, collaborating with industry,

securing funds and creating interdisciplinary research. Figure 5.5 shows the level of agreement on these aspects.

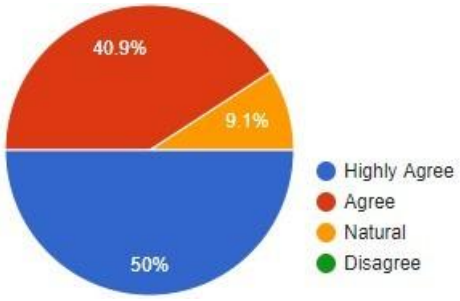
Given all AIR obstacles and the impact of AIR as recognized by the instructors, Figure 5.6 shows that around 96% of the participants reported that there is a need to establish specialized AIRprograms in Jordan and Lebanon, and all of them supported the fact that developing such programsin collaboration with European institutions would help in improving the quality of the programs and their graduates as shown in Figure 5.7.



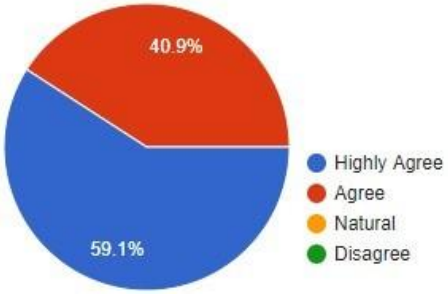
Advancing Research



Collaboration with Industry



Securing Funds



Enhancing Interdisciplinary Research

Figure 5.5. Level of agreement among participants on the impact of AIR

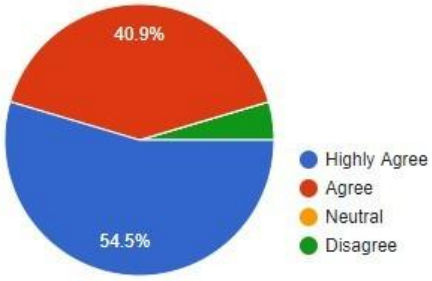


Figure 5.6. Level of agreement on establishingAIR programs

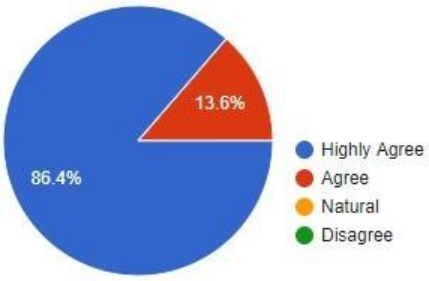


Figure 5.7. Level of agreement in collaborating with European institution to establish/update AIRprograms

Appendix A.1: Stakeholders' Survey

Surveying the needs for AI and Robotics expertise and professionals in Jordan and Lebanon

Dear respondent;

This survey is implemented within the framework of the Erasmus+ project "DeCAIR: Developing Curricula for Artificial Intelligence and Robotics". The project is aiming to improve existing computer, mechatronics, electrical, and mechanical engineering master's and bachelor's programs in the areas of AI and robotics (AIR). Additionally, DeCAIR will establish new master's program in AIR at University of Jordan, new bachelor's program in AIR at Tafila Technical University, and new track in AIR at Beirut Arab University. This will lead to graduating students able to meet the rising market demands for experts who can use AIR technologies to develop products and solve various problems facing modern societies.

We warmly ask you to spend around 10 minutes to answer the following questions. Your contribution is valuable for the achievement of the DeCAIR project objectives.

* Required

Participant Category

1. Please select your category *

Mark only one oval.

- ◯ Student *Skip to question 25*
- ◯ Instructor *Skip to question 39*
- ◯ Enterprise / Governmental Agency / Professional Organization

Enterprise / Governmental Agency / Professional Organization Survey

2. Name

3. Email address

4. Country

Mark only one oval.

- ◯ Jordan
- ◯ Lebanon
- ◯ Other: _____

5. Affiliation

6. Main Activities/Products/Services

7. Previous experience related to AIR

Check all that apply.

- ☐ Research
- ☐ Development
- ☐ Team member of AIR project
- ☐ Team Leader of AIR project
- Other: ☐ _____

8. For how many years have you been working in the AIR field?

Mark only one oval.

- ◯ 0
- ◯ 1-3
- ◯ 3-5
- ◯ More than 5

Adoption of AIR in organizations located in Jordan/Lebanon

9. How would you rate the adoption to AIR in your organization?

Mark only one oval.

- ◯ No plans for adoption
- ◯ Adopted AIR but still in the early stages
- ◯ Have been adopting AIR for more than 5 years

10. How do you think that adopting AIR will affect your organization activities?

Check all that apply.

- ☐ Improve the efficiency of current products
- ☐ Open the domain for new products
- ☐ Speedup the workflow in the company
- Other: ☐ _____

11. In your opinion, what are the key challenges/ impediments for AIR development and adoption in your organization?

Mark only one oval.

- ◯ Lack of Funding
- ◯ Lack of expertise
- ◯ Low recognition of the added value of AIR
- ◯ The management does not believe that AIR is important in the company working field
- ◯ None

12. What is the number of tech employees with knowledge/skills in the AIR domain in your organization?

Mark only one oval.

- ◯ 0
- ◯ 1-5
- ◯ 6-10
- ◯ 10-15
- ◯ 15-20
- ◯ More than 20

13. Did your organization take a forward step in developing the employees skills set in the field(s) of AIR in the last 5 years?

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Not Applicable

14. Does your organization have a training strategy for the current employees in AIR?

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Not Applicable

15. What are the techniques your organization is using to build capacity in the AIR domain?

Check all that apply.

- ☐ Hiring experts in AIR
- ☐ Training current employees
- ☐ Hiring fresh University graduates
- ☐ Not Applicable

Role of Universities in Jordan/Lebanon in strengthening the adoption of AIR?

16. How would you rate the adoption of AIR in Jordan/Lebanon?

Mark only one oval.

- ◯ High
- ◯ Medium
- ◯ Low

17. Do you agree that the demand for skillful graduates in the AIR domain will increase in the coming years?

Mark only one oval.

- Highly agree
- Agree
- Neutral
- Disagree

18. Do you agree that the availability of skillful graduates and professionals in the field of AIR will attract international companies to establish regional offices in Jordan/Lebanon?

Mark only one oval.

- Highly agree
- Agree
- Neutral
- Disagree

19. Do you think that having an up-to-date and well-equipped undergraduate and graduate programs will play a main role in improving collaboration between public/private sectors and the universities in Jordan/Lebanon?

Mark only one oval.

- Highly agree
- Agree
- Neutral
- Disagree

20. How would you rate the knowledge of university graduates in the AIR domain?

Mark only one oval.

- Excellent
- Average
- Poor

21. Do you agree that the universities should establish/upgrade AIR related programs to cover the increased demand in the AIR domain?

Mark only one oval.

- Highly agree
- Agree
- Neutral
- Disagree

22. In your opinion, which sectors do you believe will benefit from the improvement in the AIR programs in Jordan/Lebanon? *

Mark only one oval per row.

	Highly Agree	Agree	Neutral	Disagree
Manufacturing Quality				
Control Systems				
Agriculture				
Healthcare				
Pharmacy				
Education				
Management				
Security				

23. Based on your expertise, what are the AIR topics and related skills that university graduates should have to increase their employability in the field?

24. Other Comments

Student Survey

25. Name

26. Email

27. University/College

28. Country

Mark only one oval.

- Jordan
- Lebanon
- Other:

29. Major

30. Level of Study

Mark only one oval.

- ◯ Undergraduate
- ◯ Graduate

31. What is the main source of your AI knowledge?

Check all that apply.

- ☐ Online courses on MOOCs
- ☐ Local training courses
- ☐ AIR courses in the curriculum
- ☐ I do not have prior knowledge in AI

32. If your curriculum contains courses in AI and Robotics, then please list the names of these courses.

_____

33. If you took any courses in AI and Robotics, were they sufficient and up-to-date?

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ I did not take any courses in AI and Robotics

34. What were the teaching methodologies in the AIR courses that you took?

Check all that apply.

- [ ] Theoritical
- [ ] Project-based
- [ ] Assignments
- [ ] Exams
- [ ] Other: _____

35. How would you rate the lab equipment that is available in your institution to support the AIR courses in your curriculum?

Mark only one oval.

- ◯ Up-to-date
- ◯ Average
- ◯ Poor
- ◯ My institution does not have specialized AIR labs
- ◯ Not applicable, no AIR courses in my curriculum

36. How do you rate the demand of graduates with sufficient knowledge in AIR in your country?

Mark only one oval.

- ◯ High
- ◯ Medium
- ◯ Low
- ◯ Can not tell

37. Do you agree that the universities in your country should open specialized programs in AI and Robotics?

Mark only one oval.

- ◯ Highly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree

38. Other Comments

Instructor Survey

39. Name

40. Email

41. Institution

42. Department

43. Country

Mark only one oval.

- Jordan
- Lebanon
- Other: _____

Untitled Section

44. What is your experience in AI and Robotics?

Check all that apply.

- [ ] General Knowledge
- [ ] Teaching
- [ ] Researching
- [ ] No prior experience in AIR

45. If you have prior experience in AI and Robotics, then please specify your experience domain.

46. Does your curriculum contain courses on AI and Robotics? If yes, please list the names of these courses.

47. If you taught AIR courses before, then what tools did you use for assessment?

Check all that apply.

- [ ] Assignments
- [ ] Exams
- [ ] Projects
- [ ] Survey paper

48. In your opinion, what are the obstacles of teaching AIR courses in your institution?

Check all that apply.

- [ ] Lack of equipment
- [ ] Lack of expertise
- [ ] Lack of recognition
- [ ] Other: _____

49. What is the status of AI and Robotics courses in your curriculum?

Mark only one oval.

- ◯ Sufficient and up-to-date
- ◯ Update is in progress
- ◯ Require minor modifications
- ◯ Require major modifications

50. In your opinion, what courses and labs should be included in the curricula of AI and Robotics related programs?

51. In your opinion, what equipment should be available to support AI and Robotics related programs?

52. If you are offered to get training courses in AI and Robotics, what topics would be of greatest importance and interest to you?

53. Do you agree that qualifying students in AI and Robotics will increase their employability?

Mark only one oval.

- Highly Agree
- Agree
- Natural
- Disagree

54. Do you agree that enhancing AI and Robotics skills of students and faculty members and supporting them with specialized equipment/labs will result in practical research and projects which solve real life problems?

Mark only one oval.

- Highly Agree
- Agree
- Natural
- Disagree

55. Do you agree that qualifying faculty members in AI and Robotics will open the door to collaborate with the industry to solve their problems?

Mark only one oval.

- Highly Agree
- Agree
- Natural
- Disagree

56. Do you agree that qualifying faculty members in AI and Robotics may help them in securing research funds from different national and international funding agencies?

Mark only one oval.

- Highly Agree
- Agree
- Natural
- Disagree

57. Do you agree that qualifying faculty members in AI and Robotics may create opportunities for interdisciplinary research projects (i.e. apply AI and Robotics in the field of medicine, agriculture, pharmacy etc..)

Mark only one oval.

- Highly Agree
- Agree
- Natural
- Disagree

58. Do you agree that the universities in your country should open specialized programs in AI and Robotics?

Mark only one oval.

- Highly Agree
- Agree
- Neutral
- Disagree

59. Do you agree that the collaboration with the European universities specialized in AI and Robotics would help in improving the quality of the AI and Robotics programs in terms of teaching and preparing high quality graduates?

Mark only one oval.

- Highly Agree
- Agree
- Natural
- Disagree

60. Other comments

Appendix A.2: Stakeholders' Survey DetailedResults

Surveying the needs for AI and Robotics expertise and professionals in Jordan and Lebanon

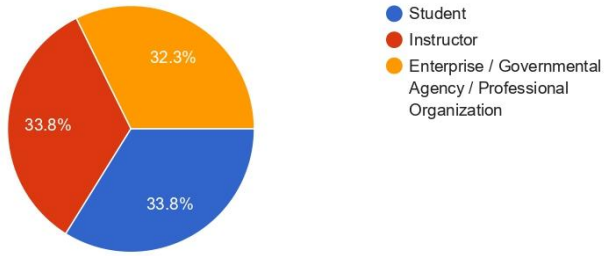
65 responses

Publish analytics

Participant Category

Please select your category

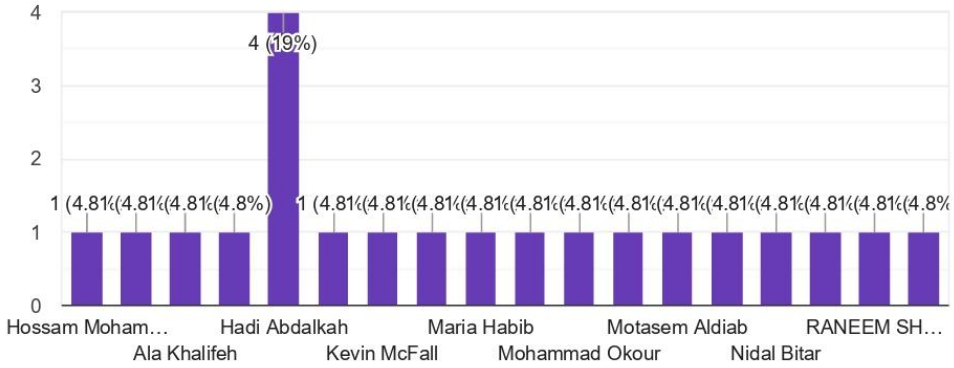
65 responses



Enterprise / Governmental Agency / Professional Organization Survey

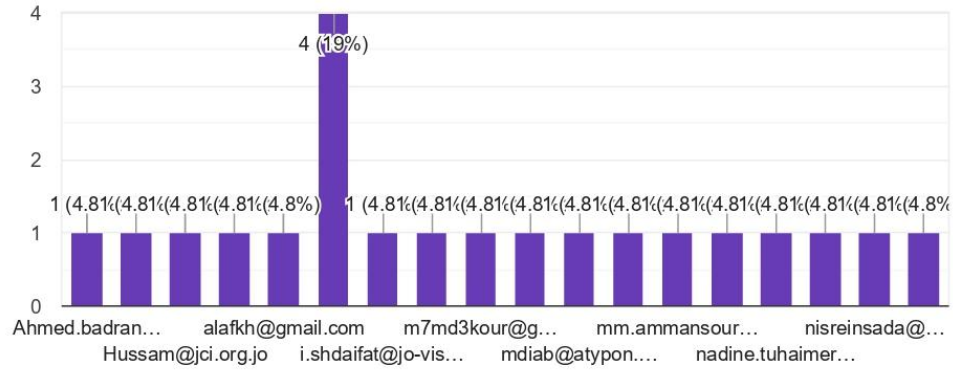
Name

21 responses



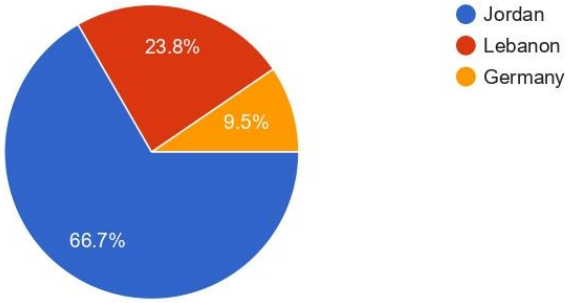
Email address

21 responses



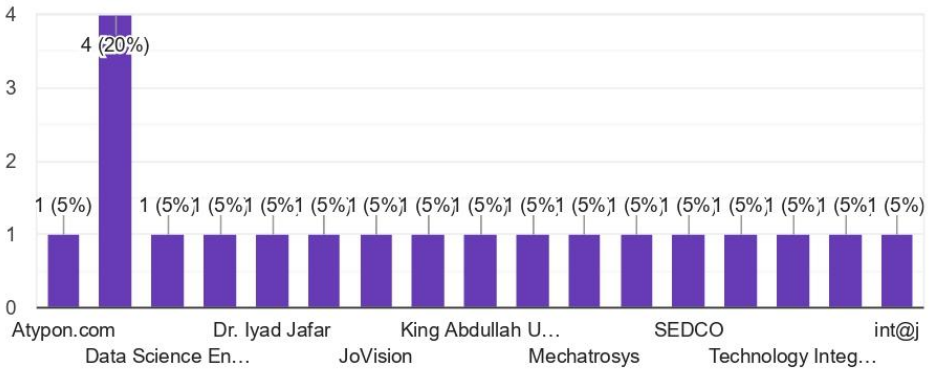
Country

21 responses



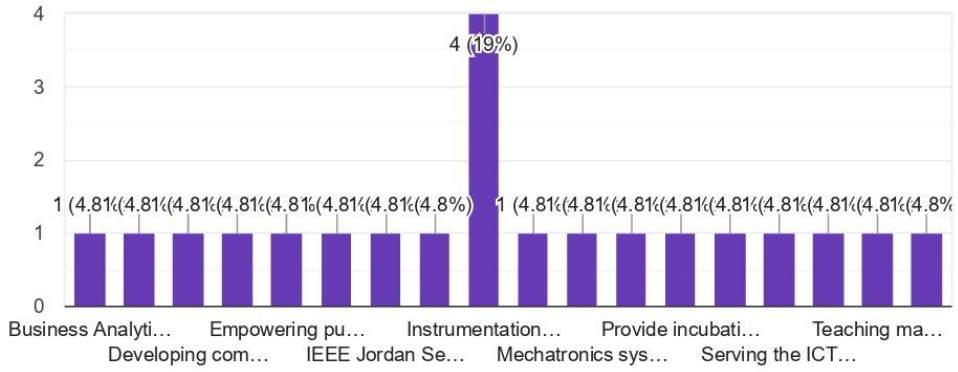
Affiliation

20 responses



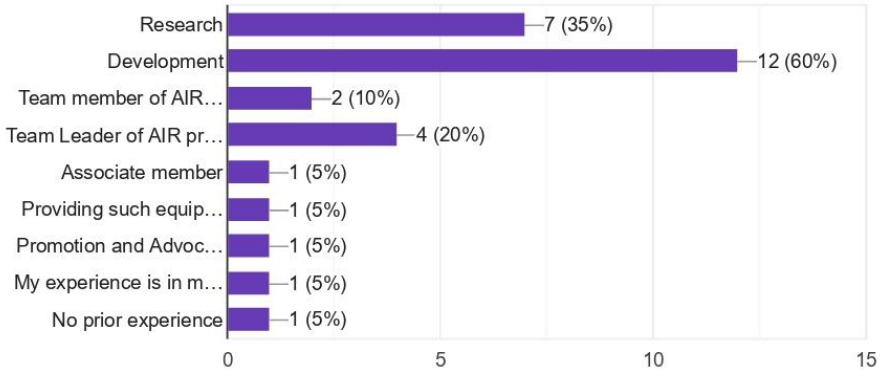
Main Activities/Products/Services

21 responses



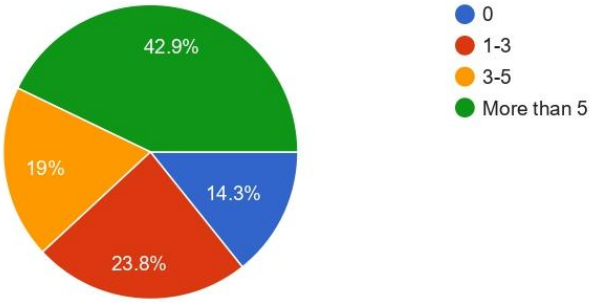
Previous experience related to AIR

20 responses



For how many years have you been working in the AIR field?

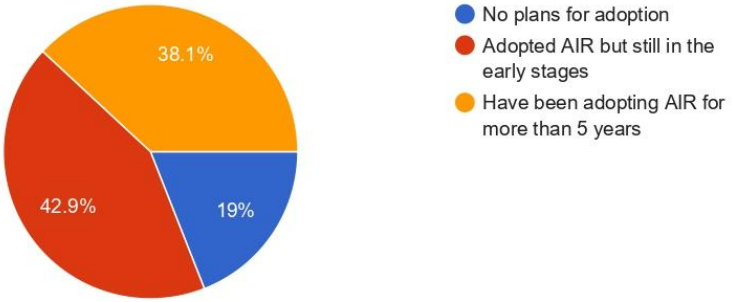
21 responses



Adoption of AIR in organizations located in Jordan/Lebanon

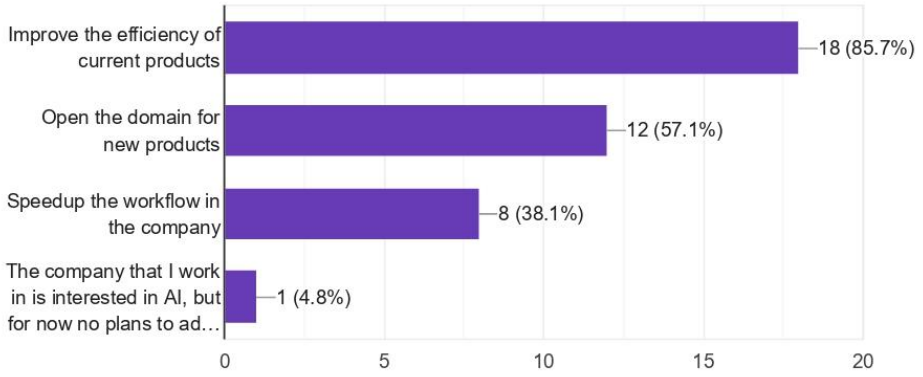
How would you rate the adoption to AIR in your organization?

21 responses



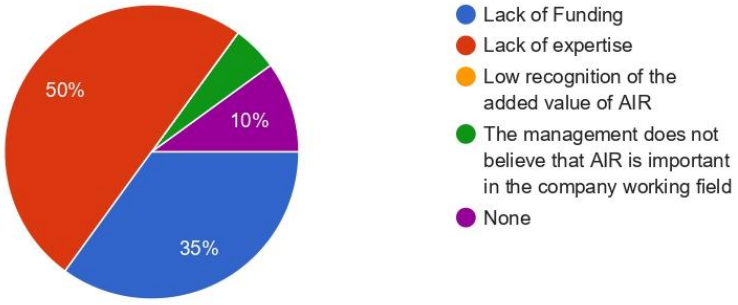
How do you think that adopting AIR will affect your organization activities?

21 responses



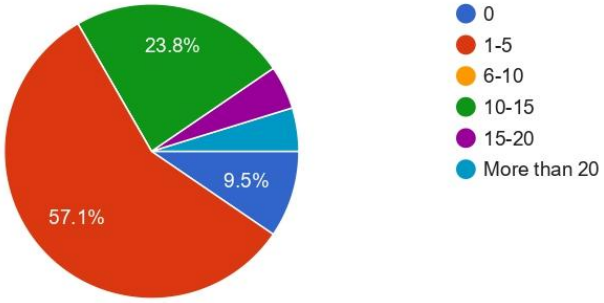
In your opinion, what are the key challenges/ impediments for AIR development and adoption in your organization?

20 responses



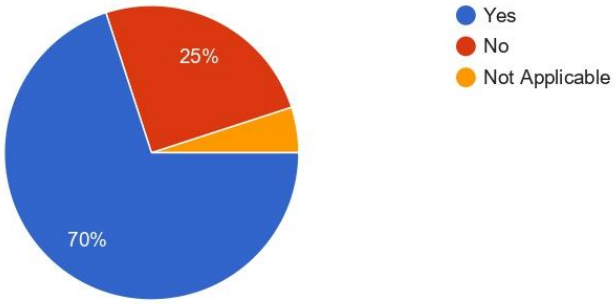
What is the number of tech employees with knowledge/skills in the AIR domain in your organization?

21 responses



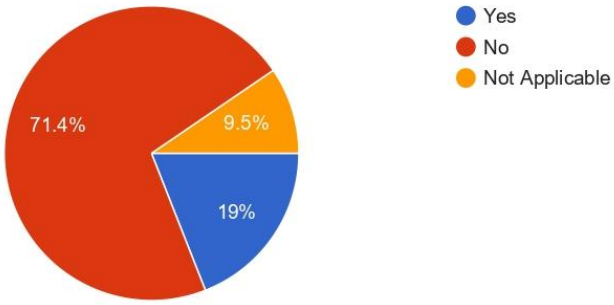
Did your organization take a forward step in developing the employees skills set in the field(s) of AIR in the last 5 years?

20 responses



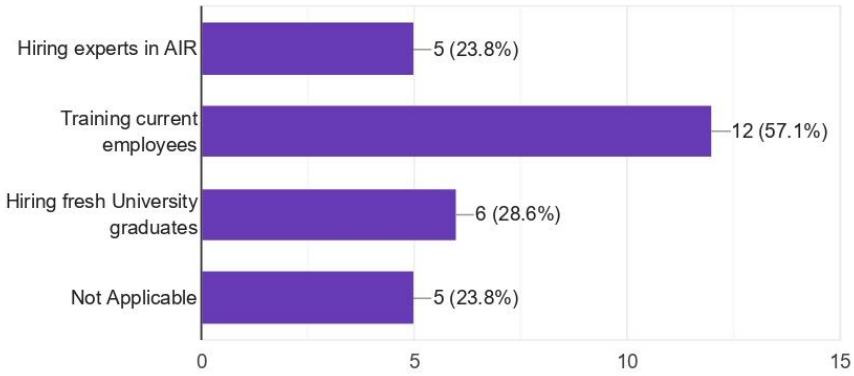
Does your organization have a training strategy for the current employees in AIR?

21 responses



What are the techniques your organization is using to build capacity in the AIR domain?

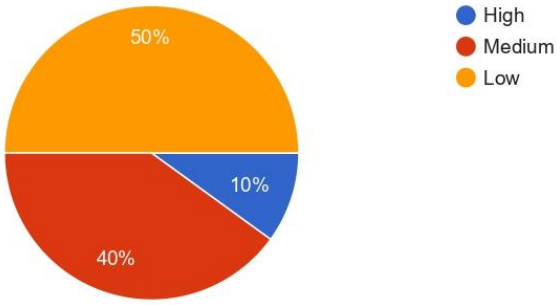
21 responses



Role of Universities in Jordan/Lebanon in strengthening the adoption of AIR?

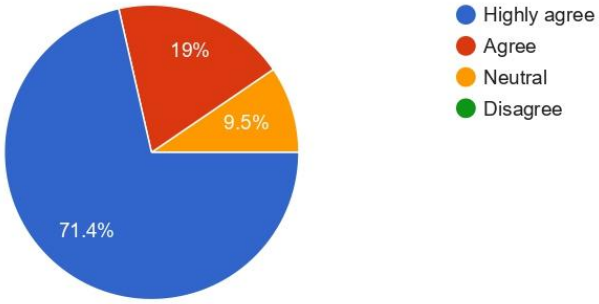
How would you rate the adoption of AIR in Jordan/Lebanon?

20 responses



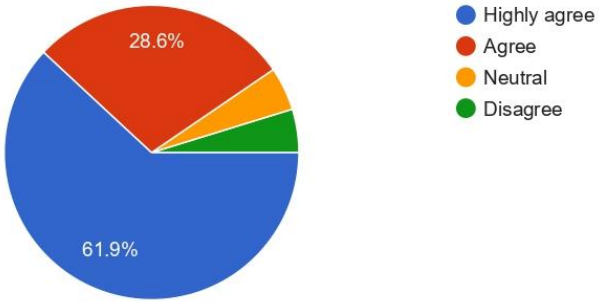
Do you agree that the demand for skillful graduates in the AIR domain will increase in the coming years?

21 responses



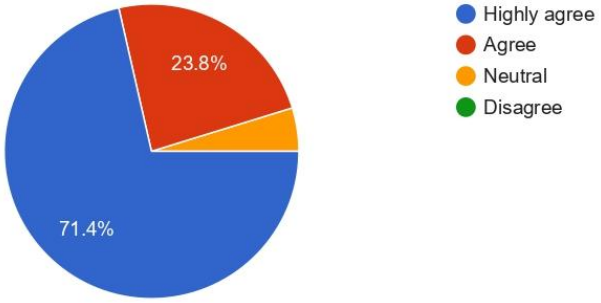
Do you agree that the availability of skillful graduates and professionals in the field of AIR will attract international companies to establish regional offices in Jordan/Lebanon?

21 responses



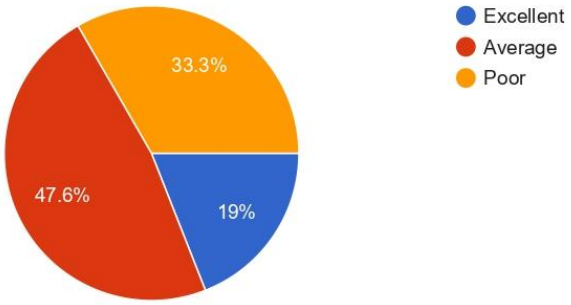
Do you think that having an up-to-date and well-equipped undergraduate and graduate programs will play a main role in improving collaboration between public/private sectors and the universities in Jordan/Lebanon?

21 responses



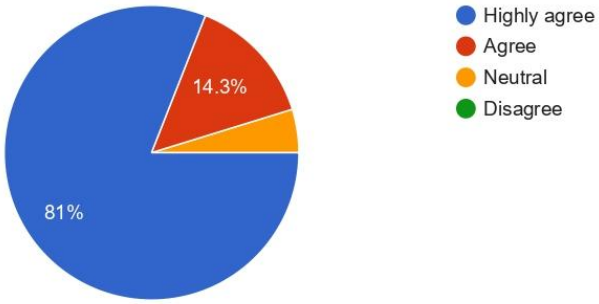
How would you rate the knowledge of university graduates in the AIR domain?

21 responses

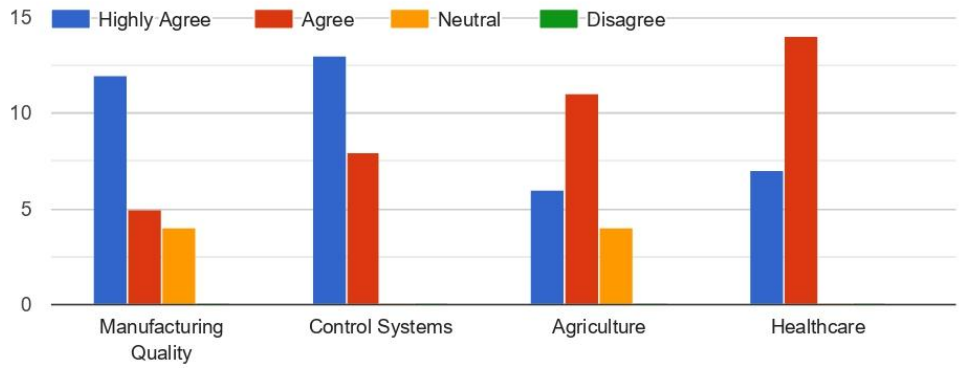


Do you agree that the universities should establish/upgrade AIR related programs to cover the increased demand in the AIR domain?

21 responses



In your opinion, which sectors do you believe will benefit from the improvement in the AIR programs in Jordan/Lebanon?



Based on your expertise, what are the AIR topics and related skills that university graduates should have to increase their employability in the field?

17 responses

Decision making algorithms/Computer vision/Mdern Automation/Quality control base technic

X

programming

More hand on experience to be able to bridge between theory and practice

Any of them. There is great demand for this in industry across the board. From my experience from an undergraduate Mechatronics Engineering program, students are most commonly hired because of their ability to advance industrial automation.

Enhance the students knowledge in both math and programming skills to come up with AI and their tools

Practical projects, training on joint venture projects with the local market

Other Comments

5 responses

Feel free to reach out to me if there are any way NVIDIA can contribute to your project.

Students needs more intensive internship programs before graduation.

Well done and thanks for your great efforts...
My recomendation is that it is important to invest in up skilling the faculty members in universities to deliver up to date curricula for students

Practice at least 50% not only theory

I highly encourage and recommend starting this graduate-level master program.

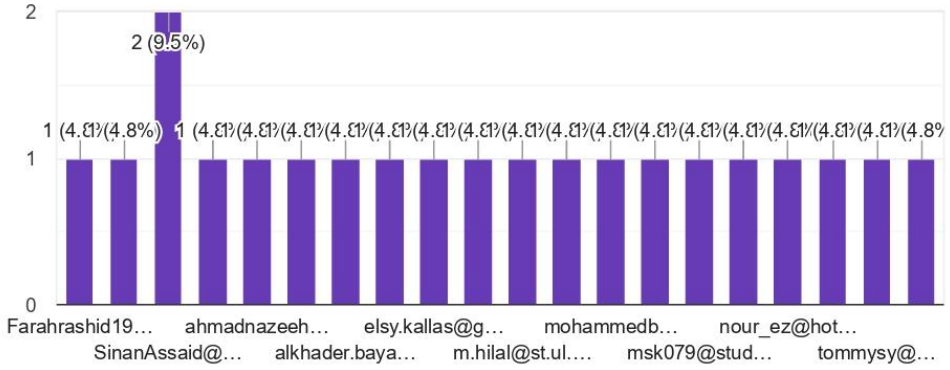
Student Survey

Name

21 responses

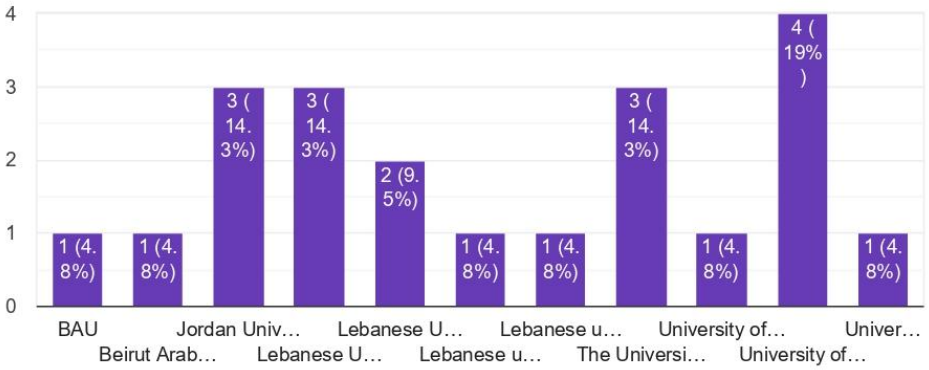
Email

21 responses



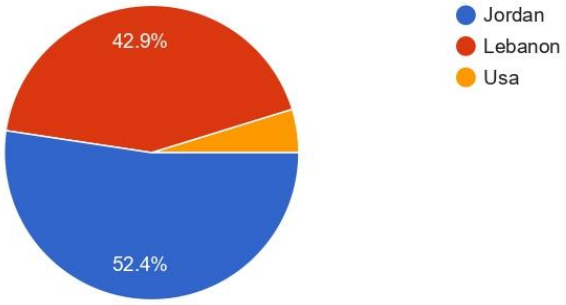
University/College

21 responses



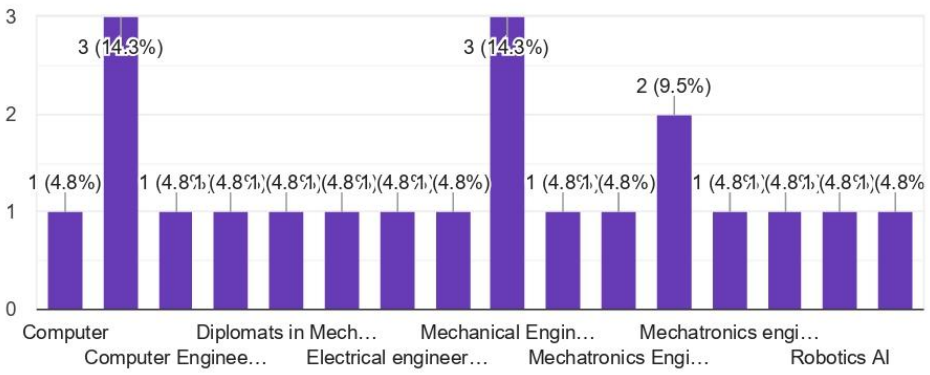
Country

21 responses



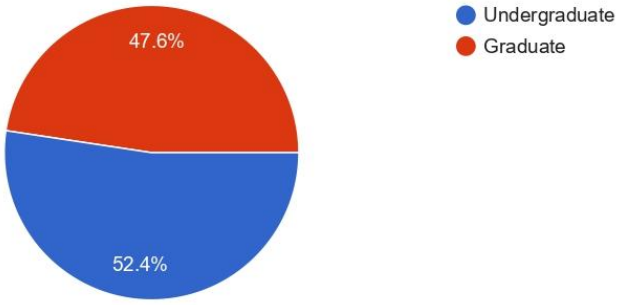
Major

21 responses



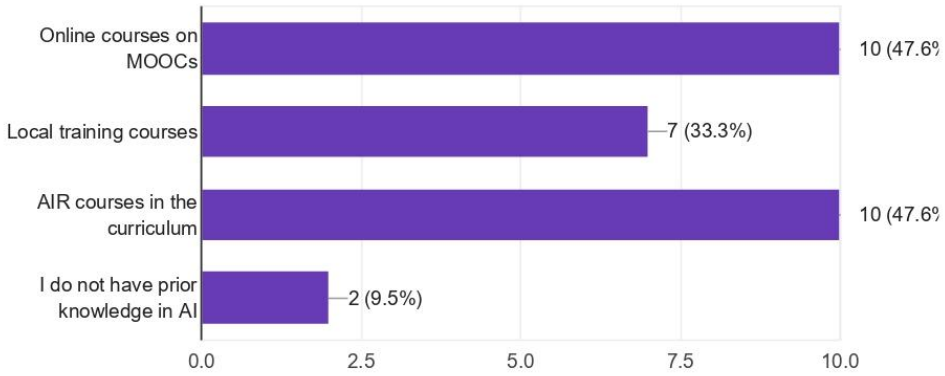
Level of Study

21 responses



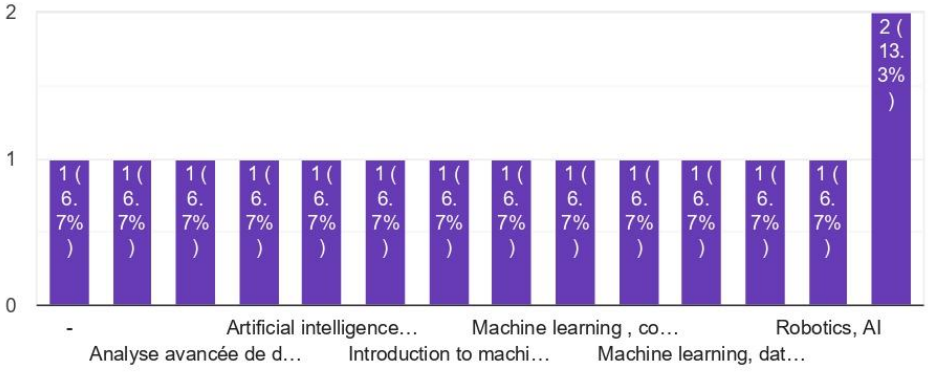
What is the main source of your AI knowledge?

21 responses



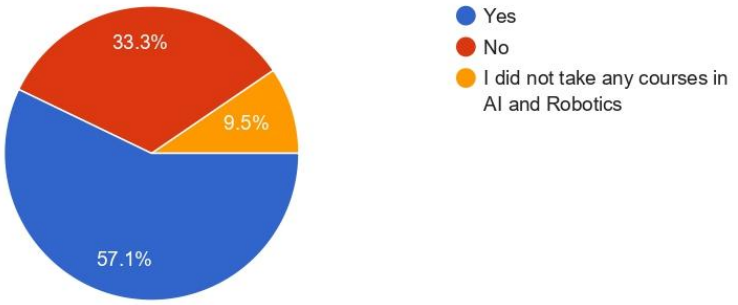
If your curriculum contains courses in AI and Robotics, then please list the names of these courses.

15 responses



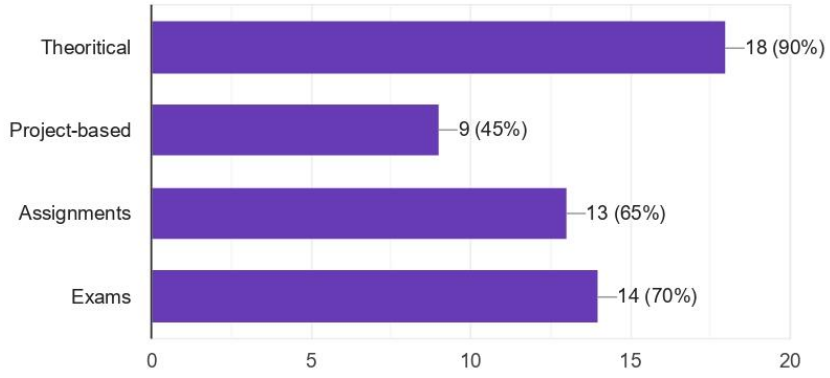
If you took any courses in AI and Robotics, were they sufficient and up-to-date?

21 responses



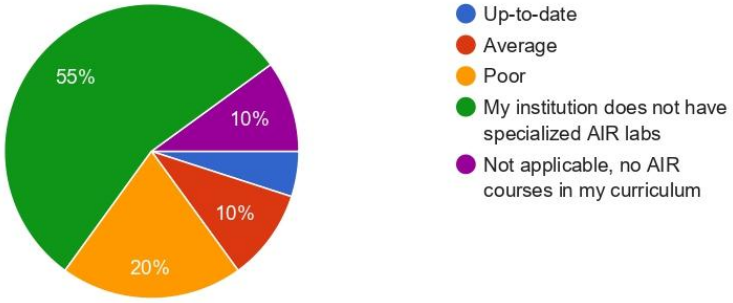
What were the teaching methodologies in the AIR courses that you took?

20 responses



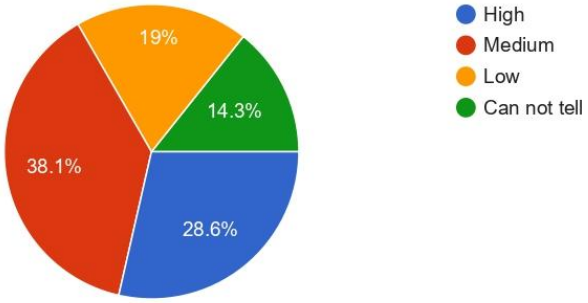
How would you rate the lab equipment that is available in your institution to support the AIR courses in your curriculum?

20 responses



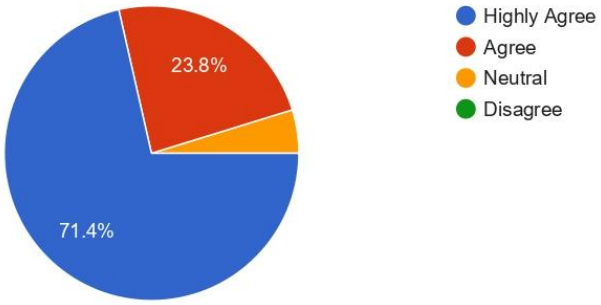
How do you rate the demand of graduates with sufficient knowledge in AIR in your country?

21 responses



Do you agree that the universities in your country should open specialized programs in AI and Robotics?

21 responses



Other Comments

6 responses

Robotics is taught from a mechanical engineering perspective rather than systems engineering and is more focused on mathematical theoretical procedures rather than an applied practical approach and that is wrong and irrelevant to the job market.

I think there should be more talk about AIR during the introductory computer courses of the university to help students see the reasons behind the hype early on in their studies and get excited to form communities and clubs to learn more about the topics.

Thank your for this kind invitation

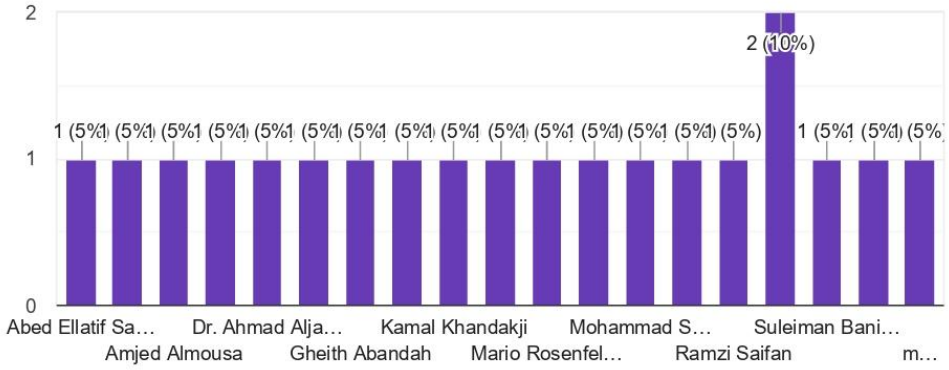
Thank you for this workshop, it was really informative and important. We hope to meet again, for open discussions, webinars and even collaborative researches/projects between the universities in Lebanon and Jordan. God bless your efforts.

I am not sure about other universities, or even if people can learn in universities these days because of the economical crisis.

Instructor Survey

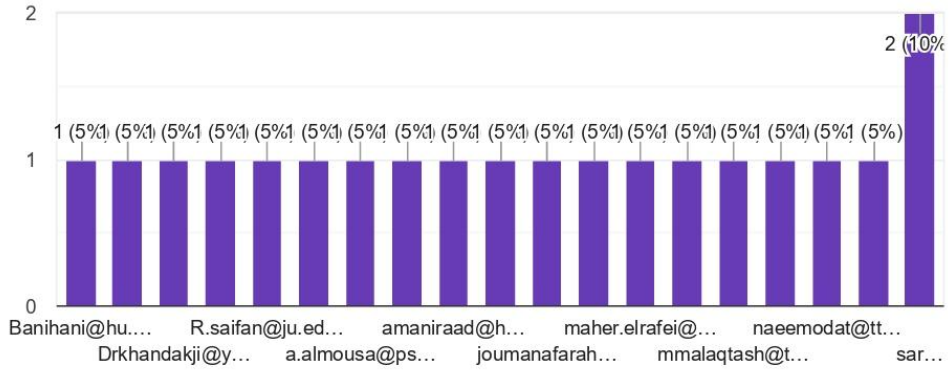
Name

20 responses



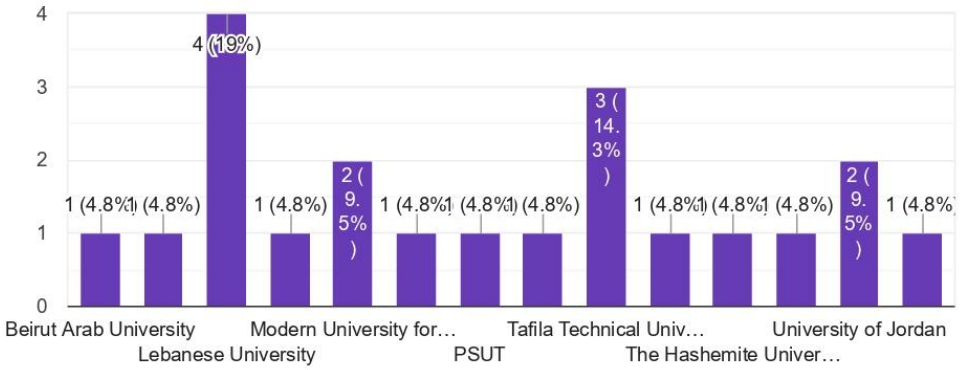
Email

20 responses



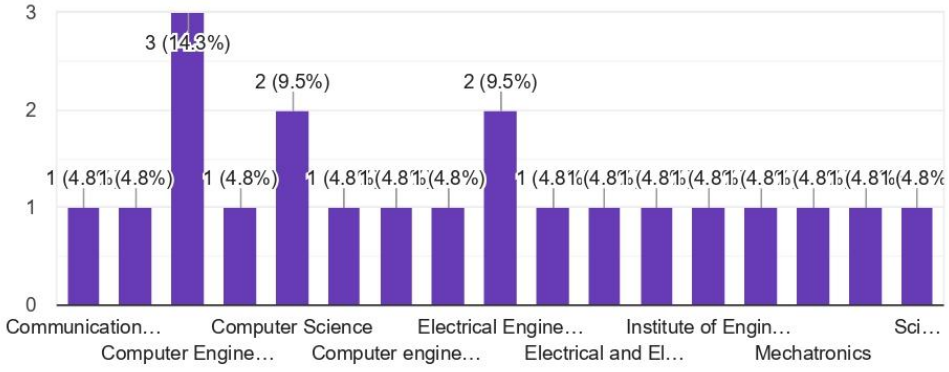
Institution

21 responses



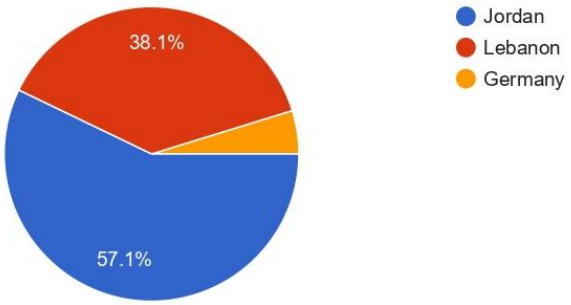
Department

21 responses



Country

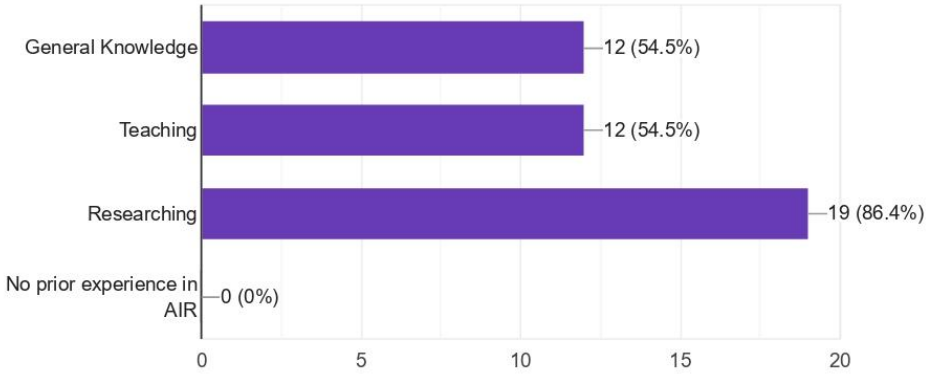
21 responses



Untitled Section

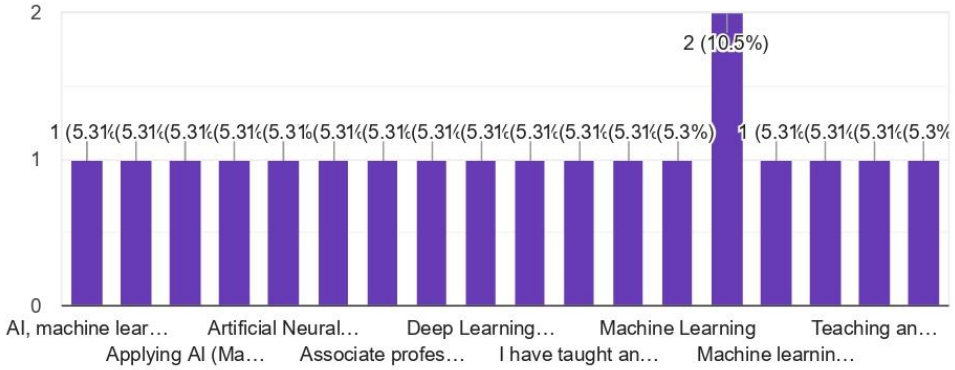
What is your experience in AI and Robotics?

22 responses



If you have prior experience in AI and Robotics, then please specify your experience domain.

19 responses



Does your curriculum contain courses on AI and Robotics? If yes, please list the names of these courses.

20 responses

Yes

Yes. AI, NN, Fuzzy Logic, and Programming for AI

yes AI for industrial control

Robotics, Machine Learning

Introduction to Robotics, AI

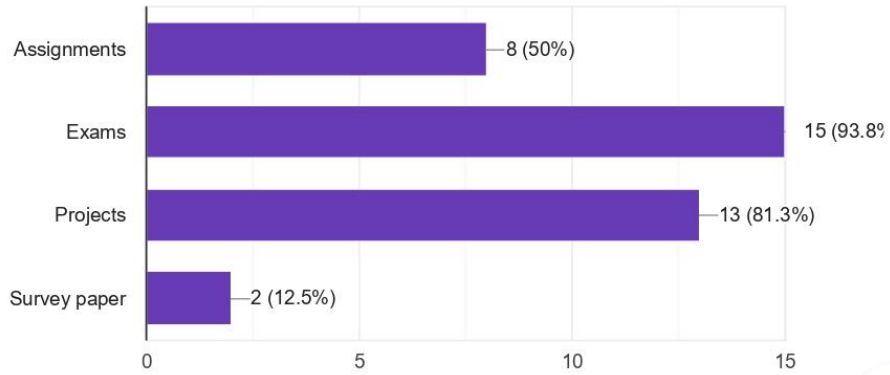
Machine Learning
Data Mining
Non Linear control applied to Robotics

Introduction to AI, Machine Learning, Deep Learning, Natural Language Processing, Neural Network, Fuzzy Logic, Robotics, Games

Exemplarily: Modeling and Simulation in Mechatronics, Concepts of Automatic Control,

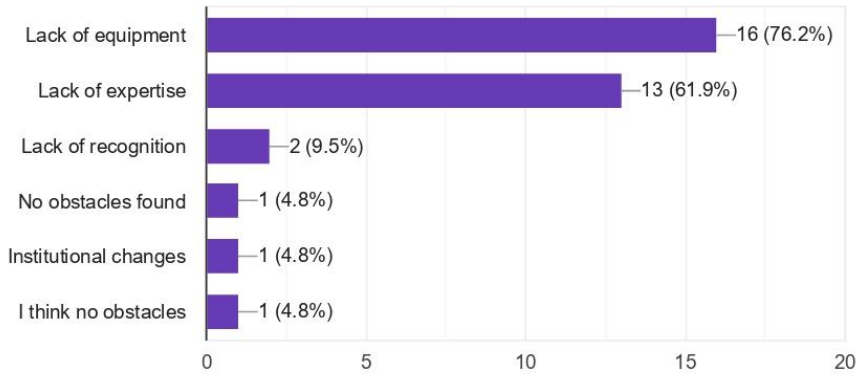
If you taught AIR courses before, then what tools did you use for assessment?

16 responses



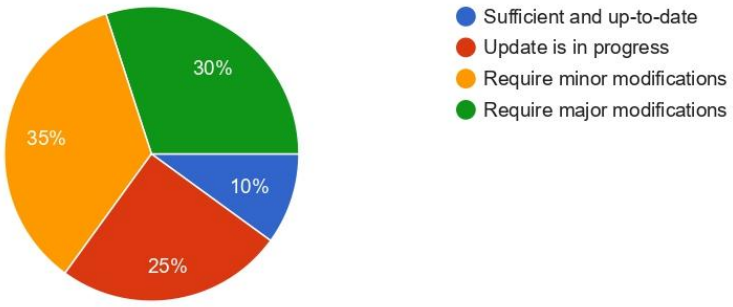
In your opinion, what are the obstacles of teaching AIR courses in your institution?

21 responses



What is the status of AI and Robotics courses in your curriculum?

20 responses



In your opinion, what courses and labs should be included in the curricula of AI and Robotics related programs?

15 responses

Machine learning & Data science

Robotics lab , machine learning lab

Signal porcessing, image processing, Deep Learning Lab

We need to introduce lab sessions that include the latest frameworks in ML

Advanced AI and Robotics design

Robotic Lab
Deep Learning Lab
ROS based development environment Lab

Practical Labs that use the latest kits for AI and labs that should include some robots and manipulators.

Modeling and Simulation in Mechatronics, Concepts of Automatic Control, Deep Learning

In your opinion, what equipment should be available to support AI and Robotics related programs?

17 responses

Specialized SW & HW equipment

labs with powerful PCs

GPU accelerated workstations

High-performance computers for AI

Drones , different types of robots,

Deep Learning Tools
GPU
Robots, Mission Planners, autonomous robots simulation tools

Kits from NVIDIA and mini Robots

Articulated Robots, Mobile Robots, UAVs, computer stations

If you are offered to get training courses in AI and Robotics, what topics would be of greatest importance and interest to you?

18 responses

Machine learning & Deep learning

Image segmentation techniques. Big data analysis

Time series prediction, Deep Learning using Pytorch, Model deployment

Applications of ML techniques in communication systems

All

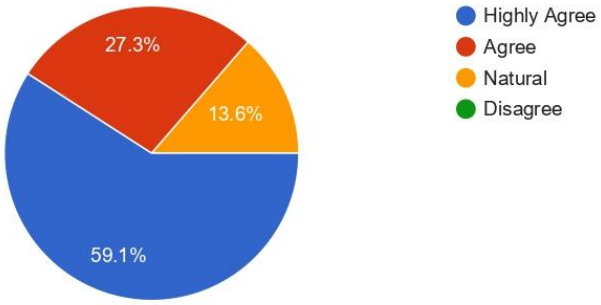
AI

Deep Learning tools
Serial and parallel manipulators
ROS development environment
autonomous robots path planning

DNN, High computing hardware for AI

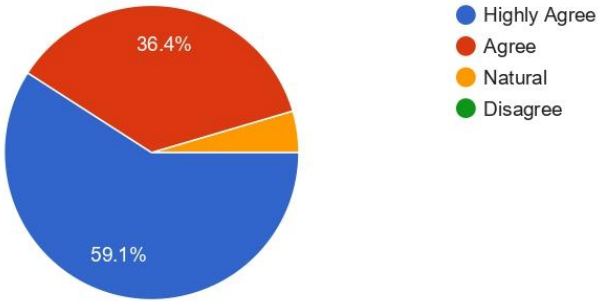
Do you agree that qualifying students in AI and Robotics will increase their employability?

22 responses



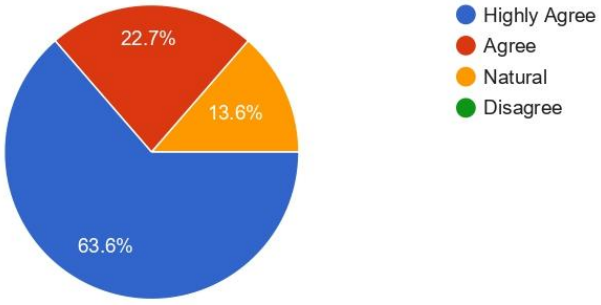
Do you agree that enhancing AI and Robotics skills of students and faculty members and supporting them with specialized equipment/labs will result in practical research and projects which solve real life problems?

22 responses



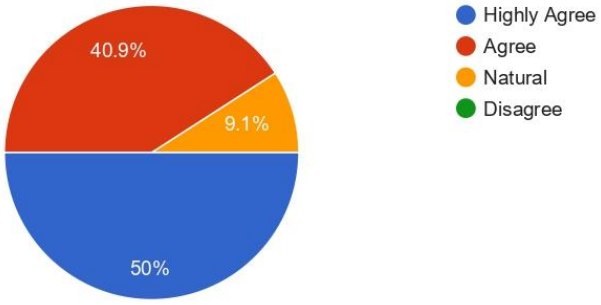
Do you agree that qualifying faculty members in AI and Robotics will open the door to collaborate with the industry to solve their problems?

22 responses



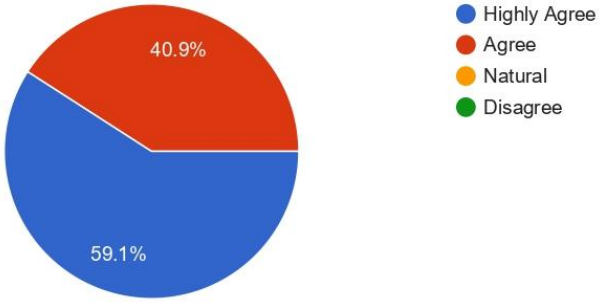
Do you agree that qualifying faculty members in AI and Robotics may help them in securing research funds from different national and international funding agencies?

22 responses



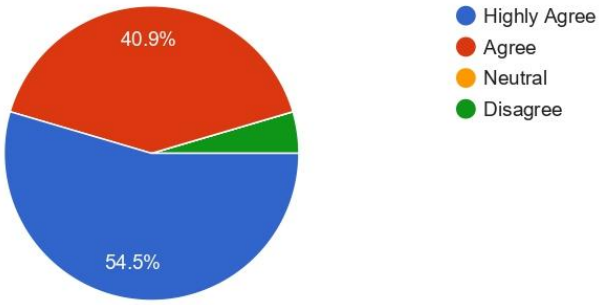
Do you agree that qualifying faculty members in AI and Robotics may create opportunities for interdisciplinary research projects (i.e. apply AI and Robotics in the field of medicine, agriculture, pharmacy etc..)

22 responses



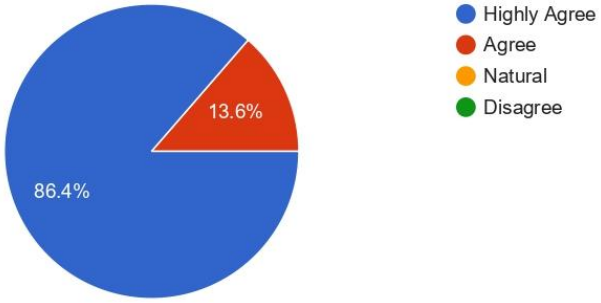
Do you agree that the universities in your country should open specialized programs in AI and Robotics?

22 responses



Do you agree that the collaboration with the European universities specialized in AI and Robotics would help in improving the quality of the AI and Robotics programs in terms of teaching and preparing high quality graduates?

22 responses



Other comments

2 responses

A master program in Jordan may not be of interest to Jordanians at the current time .. may be in the next (10) years especially that governmental policies and regulations will take some time to be polished and modified for the industrial sector.

The program we have at TTU is AI only. Robotics are not included in any other programs. I suggest to add Robotics either to the curriculum of AI or Mechatronics program.

Appendix B: Surveying M.Sc. Programs Report

DeCAIR: Developing Curricula for Artificial Intelligence andRobotics

Report on Surveying International M.Sc. Programs in AI and Robotics

Activity Information:

Work Package	WP1 – Surveys and Needs Identification
Task	1.2 Survey and evaluation of similar AI and robotics master Programs
Activity Coordinator	UJ (Ramzi Saifan)
Participating Partners	UJ, JUST, LU, UGR, UNIGE, UST, UNIPI
Objective(s)	Surveying international AIR M.Sc. programs to identify their main attributes in terms of curriculum, syllabi, resources, faculty members' expertise and collaboration with industry.
Due Date	March 7th

Instructions:

1. Activity coordinator is to coordinate with the focal point of JUST and LU to collectinformation of **eight** international AIR **M.Sc. programs**. EU partners may provide suggestions regarding the programs to survey.
2. Activity coordinator is to coordinate with EU partners to provide information about their AIR M.Sc. Programs.
3. Information to be collected for each program is the main attributes reported in Table 1.2.1, and files for the Curriculum and Syllabi.
4. Activity coordinator is responsible for gathering the collected files and store them to the ***Surveyed_MSC_Programs*** shared folder. The files for each program should be stored in a separate folder with the following syntax ***ProgramName_UniversityName***.
5. This report is to be prepared through collaboration of different partners and submitted tothe WP lead by the activity coordinator. Filled tables should be added to this report.

Summary and Recommendations:

In this report, we surveyed twenty-one AIR related master programs as a step towards achieving the first work package (i.e, the surveys work package) in the DeCAIR project. The surveyed programs are from diverse countries and universities, and are scattered among wide geographical areas. Specifically, we surveyed three programs from USA, two programs from Asia, and sixteen programs from Europe. Among the sixteen programs from Europe, there were 10 programs from the partner universities as shown in Table 1.

Table 1. List of Surveyed M.Sc. Programs

No	Program name	University	Country
1	MSc in Artificial Intelligence	Radboud University	Netherlands
2	MSc in Artificial Intelligence	University of Groningen	Netherlands
3	MSc in Engineering - Robot Systems (Advanced Robotics Technology/ Drones and Autonomous Systems)	University of SouthernDenmark	Denmark
4	MSc in Artificial Intelligence	University of Georgia	USA
5	MSc in Computer Science – Artificial Intelligence	University of Southern California	USA
6	MSc in Computer Science – Machine Learning	Columbia University	USA
7	MSC in Artificial Intelligence	Hong Kong university of science and technology	Hong Kong
8	MSc in Robotics and Autonomous Systems	Hong Kong university of science and technology	Hong Kong
9	MSc in Robotics	Ecole Polytechnique Fédérale de Lausanne (EPFL)	Switzerland
10	MSc in Robotics and Computation	University College London (UCL)	United Kingdom
11	Robotics, Cognition, Intelligence	Technical University ofMunich	Germany
12	Master in Computer Science	University of Granada	Spain
13	Master in Data Science and Computer Engineering	University of Granada	Spain
14	Master in Industrial Electronics	University of Granada	Spain
15	MSc in Data Science & Engineering – Artificial Intelligence Track	University of Genoa	Italy
16	MSc in Artificial Intelligence and Data Engineering	University of Pisa	Italy
17	MSc in Robotics And Automation Engineering	University of Pisa	Italy

18	MSc in Autonomous Systems	University of Stuttgart	Germany
19	MSc in Engineering Cybernetics	University of Stuttgart	Germany
20	MSc in Mechatronics	University of Stuttgart	Germany
21	MSc in Simulation Technology	University of Stuttgart	Germany

Generally, the master programs are focusing on one or two areas at most. For example, among the surveyed programs some of them are focusing on artificial intelligence (AI), some are focusing on Robotics, and some are more related to data science. But, since AI is needed in data science and robotics, the master programs in data science and robotics usually require one or more courses in AI.

On the other hand, several master programs are focusing on two disciplines like masterin data science and AI, or master in AI and robotics. In such programs, the students are required to register one to two fundamental courses in each discipline and one to two core courses in each discipline. Then the students may choose a minimum number of courses from one group out of two or more groups of courses. For example, the student who is enrolled in a master of AI and robotics, if he/she likes to focus more on AI, at least x courses from a set of AI courses must be studied. The same thing is applied on the student who studies master in AI and robotics and who would like to focus on robotics.

All of the surveyed master programs have two types of courses: mandatory and electives. Also, most of them are thesis based. Usually, the number of mandatory courses is less than the number of elective courses. Apparently, the mandatory courses are the minimum that the student must study. On the other hand, the elective courses are composed of a long list of courses, and the lists have a lot of variations among different universities. The student may choose the most suitable courses based on the pursued research and thesis. Similarly, the mandatory courses in different master programs at different universities are different. However, many programs share several mandatory courses. Also, the mandatory courses are based on whether the program is more focusing on AI, Robotics, or data science.

Table 2 summarizes the common mandatory courses among programs which are more related to AI. Also, the most frequent elective courses are shown. Table 3 shows the summary of master programs that are more related to Robotics. Regarding the data science programs, Table 4 summarizes them.

Regarding the research and teaching labs, each program at each university has several research labs and groups in the areas of AI, robotics, and/or data science. Regarding the teaching labs, the AI and data science master programs, do not have teaching labs other thana computer lab with strong and high specifications computers. But, the issue is different in robotics programs, which need robotics lab that allow the students to do their own testingand experiments.

Table 2: Summary of Mandatory and Elective Courses in AI Master Programs

Mandatory Courses	Most Common Elective Courses
Machine Learning	Advanced machine learning
Deep Learning	Speech processing and recognition
Applied Machine Learning or machine learning programming	Computational vision
Intelligent agents	Natural language processing
	Multi-agents systems
	Advanced artificial intelligence
	Ethics for AI
	Statistical machine learning
	Bayesian machine learning
	Advanced deep learning
	Deep reinforcement learning
	Probabilistic deep learning
	Cognitive engineering
	Introduction to data science
	Language modelling
	Handwriting recognition
	AI and the web
	Human computer interaction
	Knowledge based systems
	Decision making under uncertainty
	Introduction to computational learning theory
	Machine learning for data science
	Unsupervised learning

Table 3: Summary of Mandatory and Elective Courses in Robotics Master Programs

Mandatory Courses	Most Common Elective Courses
Database related course	Optimization methods and game theory
Data mining	Multimedia information retrieval and computer vision
Machine learning	Social media mining
Introduction to Data science	Data visualization
	Internet of things
	Large-scale computing
	Introduction to programming for data science
	Data mining: pre-processing and classification
	Data mining: unsupervised learning and anomaly detection
	System modelling and time series prediction
	Probabilistic graphical models
	Feature extraction in images
	Time series and mining of data streams
	Information retrieval and recommender systems
	Process mining
	Big data ii: big data analytics
	Soft computing: fuzzy sets and systems

Table 4. Summary of Mandatory and Elective Courses in Data Science MasterPrograms

Mandatory Courses	Most Common Elective Courses
Introduction to Robotics	Intelligent Systems
Machine Learning	Computational Intelligence
Computer Vision	Mechanics of Robots
Robot Sensing	Basics of Mobile Robotics
	Industrial and Applied Robotics
	Human Robot Interfaces
	Affective Computing and Human-Robot Interaction
	System Theory and Control Theory, Digital Control, Process Control, Control and Identification of Uncertain Systems
	Guidance and Navigation Systems
	Vehicle Dynamics
	Legged Robots
	Controlling Behavior in Animals and Robots
	Machine Learning for Visual Computing
	Multi-Agents Artificial Intelligence
	Introduction to Deep Learning
	Probabilistic and Unsupervised Learning
	Reinforcement Learning
	Supervised Learning
	Robot Vision and Navigation
	Robotic Sensing, Manipulation and Interaction
	Robotic Systems Engineering
	Motion Planning in Robotics
	Humanoid Robotic Systems
	Robotics 3D Vision
	Robot Perception and Learning
	Introduction to Drone Technology

Co-funded by the Erasmus+ Programme of the European Union

Surveyed M.Sc. Programs

Table 1.2.1 Attributes of Surveyed M.Sc. Programs

Number	1		
Program Name	MSc in Artificial Intelligence		
University	Radboud University		
Country	Nijmegen, Netherlands		
URL	https://www.ru.nl/courseguides/socsci/master/artificial-intelligence/		
Program Focus	☒ AI	☐ Data Science	☐ Robotics

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Credit Hours	120 European Credit Transfer and Accumulation System (ECTS) One EC is the equivalent of 28 hours of study (preparing for/attending classes, practical, exams, groupwork etc.). The program has two specialisations: • Cognitive Computing (CC) • Intelligent Technology (IT) Year 1 (Semester 1 and Semester 2; or Periods 1 through 4) • Foundation courses: 18 EC (Obligatory) • Specialisation selection core courses: 18 EC • Specialisation electives: 18 EC • Free electives 6 EC • Total 60 EC Year 2 (Semester 1 and Semester 2; or Periods 1 through 4) • Free electives: 15 EC • Option 1: Internship (15 EC) and Research Project (30 EC) • Option 2: Extended Research Project: 45 EC • Total 60 EC
AI Credit Hours	CC: 12 EC from Obligatory courses (That can be increased by 18 EC from Specialisation selection core courses and 18EC from Specialisation electives and 45 EC from Year 2) – **Maximum Total: 88 EC**
	IT: 12 EC (That can be increased by 18 EC from Specialisation selection core courses and 18 EC from Specialisation electives and 45 EC from Year 2) – **Maximum Total: 88 EC**

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Data Science Credit Hours	CC: 0 EC from Obligatory courses (That can be increased by 45 EC from Year 2) IT: 0 EC (That can be increased by 6 EC from electives and 45 EC from Year 2)
Robotics Credit Hours	CC: 0 EC from Obligatory courses (That can be increased by 6 EC from Specialisation electives and 45 EC from Year2) – **Maximum Total: 51 EC** IT: 0 EC (That can be increased by 6 EC from Specialisation selection core courses and 6 EC from Specialisationelectives and 45 EC from Year 2) – **Maximum Total: 57 EC**
AI Courses in Curriculum	1. Auditory Perception and Technology (Semester 1, 3 EC, IT Specialisation Elective) 2. Advanced Computational Neuroscience (Semester 2, 6 EC, CC Specialisation Elective) 3. Advanced Machine Learning (6 EC, CC Specialisation Elective, 4. Advanced Neuroscience Techniques (Semester 1, 6 EC, CC Specialisation Elective) 5. AI Research Colloquium (Semester 2, 3 EC, CC Specialisation Elective) 6. (The) Auditory System (3 EC) 7. (Automatic) Speech Recognition (Semester 2, 6 EC, IT Specialisation Elective) 8. Bayesian Networks (Semester 1, 6 EC, CC Specialisation Elective) 9. Brain Reading and Writing (Semester 2, 6 EC, IT and CC Specialisation Selection Core) 10. Capita Selecta AI (3 EC, Free Elective) 11. Capita Selecta AI (6 EC, Free Elective) 12. Cognition and Complexity (Semester 2, 6 EC, IT and CC Specialisation Elective) 13. Computational Neuroscience (3 EC, CC Specialisation Elective) 14. Computer Graphics and Computer Vision (Semester 2, 6 EC, IT Specialisation Selection Core, CC Specialisation Elective)

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	15. Ethics for AI (Semester 2, 6 EC, **Obligatory**) 16. Evolution and the Mind (Semester 1, 3 EC, CC Specialisation Elective) 17. Information Retrieval (Semester 1, 6 EC, IT Specialisation Elective) 18. Intelligent Systems in Medical Imaging (Semester 2, 6 EC, IT Specialisation Elective) 19. Intro to Language and Speech Technology (Semester 1, 6 EC, IT Specialisation Elective) 20. Machine Learning in Practice (Semester 2, 6 EC, **IT Obligatory**) 21. Natural Computing (Semester 2, 6 EC, CC Specialisation Elective)
	22. Neural Information Processing Systems (Semester 1, 6 EC, IT and CC Specialisation Elective) 23. Neuromorphic Computing (Semester 1, 6 EC, IT and CC Specialisation Elective) 24. Perception (Semester 1, 6 EC, CC Specialisation Elective) 25. Probabilistic Deep Learning (6 EC, IT Specialisation Elective, **CC Obligatory**) 26. Quantitative Brain Networks (Semester 2, 6 EC, CC Specialisation Elective) 27. Theoretical Foundations for Cognitive Agents (Semester 2, 6 EC, IT and CC Specialisation Elective)
Robotics Courses inCurriculum	1. Cognitive Robotics (Semester 1, 6 EC, IT and CC Specialisation Elective) 2. Human-Robot Interaction (Semester 1, 6 EC, IT Specialisation Selection Core) 3. Motor control (Semester 1, 6 EC, CC Specialisation Elective)

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Other Fundamental Courses	1. Advanced Academic & Professional Skills (Semester 1, 6 EC, **Obligatory**) 2. Design of Embedded Systems (Semester 1, 6 EC, IT Specialisation Elective) 3. Law in Cyberspace (Semester 1, 6 EC, IT Specialisation Elective) 4. Mind, Technology and Music (Semester 2, 6 EC, IT Specialisation Selection Core) 5. Neuroimaging I (Semester 1, 6 EC, IT and CC Specialisation Elective) 6. Neurophilosophy (Semester 2, 6 EC, IT Specialisation Elective) 7. New Media Lab (Semester 2, 6 EC, IT and CC Specialisation Selection Core) 8. Social Neurocognition (Semester 2, 6 EC, IT Specialisation Elective) 9. Text and Multimedia Mining (Semester 1, 6 EC, IT Specialisation Selection Core) 10. Upgrading the Human? (Semester 2, 6 EC, IT Specialisation Elective)
Teaching and Research Labs	NA
Research Groups	NA
Collaboration with Industry (List of sample projects)	NA
Summary and Notes	

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Number	2		
Program Name	MSc in Artificial Intelligence		
University	University of Groningen		
Country	Netherland		
URL	https://www.rug.nl/masters/artificial-intelligence/#!programme		
Program Focus	☒ AI	☐ Data Science	☐ Robotics
Credit Hours	120 European Credit Transfer and Accumulation System (ECTS)Most courses are worth 5 EC. One EC is the equivalent of 28 hours of study (preparing for/attending classes, practical, exams, groupwork etc.). The Artificial Intelligence programme has the following specializations: - Computational Intelligence and Robotics (CI&R) - Multi-Agent Systems (MAS) Structure: - General Mandatory Courses (60 ECTS): o 15 ECTS o Final Research Project AI (45 ECTS, with duration of one whole year) - CI&R Mandatory Courses (20 ECTS) - MAS Mandatory Courses (20 ECTS) - Elective Courses (40 ECTS)		

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AI Credit Hours	CI&R: 15 ECTs (That can be increased by 40 ECT from elective courses and 45 ECT from Final Research Project) Maximum Total: 100 ECT MAS: 35 ECTs (That can be increased by 40 ECT from elective courses and 45 ECT from Final Research Project) Maximum Total: 120 ECT
Data Science Credit Hours	CI&R: 0 ECTs (That can be increased by 5 ECT from elective courses and 45 ECT from Final Research Project) MAS: 0 ECTs (That can be increased by 5 ECT from elective courses and 45 ECT from Final Research Project)
Robotics Credit Hours	CI&R: 20 ECTs (That can be increased by 10 ECT from elective courses and 45 ECT from Final Research Project) Maximum Total: 75 ECT MAS: 0 ECTs (That can be increased by 10 ECT from elective courses and 45 ECT from Final Research Project) Maximum Total: 55 ECT
AI Courses in Curriculum	1. Design of Multi-Agent Systems (Semester 1, General Mandatory)
	2. Machine Learning (Semester 1, General Mandatory) 3. Arguing Agents (Semester 1, MAS Mandatory, CI&R Elective) 4. Cognitive Modelling: Basic Principles and Methods (Semester 1, MAS Mandatory, CI&R Elective) 5. Computational Social Choice (Semester 2, MAS Mandatory, CI&R Elective) 6. Logical Aspects of Multi-agent Systems (Semester 2, MAS Mandatory, CI&R Elective) 7. Deep Learning (Semester 2, General Mandatory) 8. Cognitive Engineering (Semester 1, Elective) 9. Introduction to Data Science (Semester 1, Elective) 10. Language Modelling (Semester 1, Elective)

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	11. Semantic Web Technology (Semester 1, Elective) 12. User Models (Semester 1, Elective) 13. Neural Networks and Computational Intelligence (Semester 1, Elective) 14. Applied Cognitive Engineering (Semester 2, Elective) 15. Computer Vision (Semester 2, Elective) 16. Natural Language Processing (Semester 2, Elective) 17. Handwriting Recognition (Semester 2, Elective)
Robotics Courses inCurriculum	4. Cognitive Robotics (Semester 1, CI&R Mandatory, MAS Elective) 5. Pattern Recognition (Semester 1, CI&R Mandatory, MAS Elective) 6. Robotics for AI (Semester 1, CI&R Mandatory, MAS Elective) 7. Handwriting Recognition (Semester 2, CI&R Mandatory) 8. Robotics for IEM (Semester 1, Elective) 9. Auditory and Visual Perception (Semester 1, Elective)
Other Fundamental Courses	11. Introduction Science and Policy (Semester 1, Elective) 12. Introduction Science and Business (Semester 1, Elective) 13. Skills in Science Communication (Semester 1, Elective) 14. Advanced Computer Graphics (Semester 1, Elective) 15. Computational Semantics (Semester 1, Elective) 16. Philosophy of Neuroscience (Semester 1, Elective) 17. Auditory Biophysics (Semester 2, Elective) 18. Cognitive Modelling: Complex Behaviour (Semester 2, Elective)

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	19. Computational Simulations of Language (Semester 2, Elective) 20. Fundamentals of Distributed Systems (Semester 2, Elective)
	21. Scientific Visualization (Semester 2, Elective) 22. Advanced Imaging Techniques (Semester 2, Elective) 23. Advanced self-organisation of social systems (Semester 2, Elective) 24. Computational Cognitive Neuroscience (Semester 2, Elective) 25. Language Technology Project (Semester 2, Elective) 26. Neuro-ergonomics (Semester 2, Elective)
Teaching and Research Labs	NA
Research Groups	1. Autonomous Perceptive Systems 2. Cognitive Modeling 3. Multi-Agent Systems 4. Robotics
Collaboration with Industry (List of sample projects)	NA - Only externally funded research projects by governmental programs and research foundations.
Summary and Notes	

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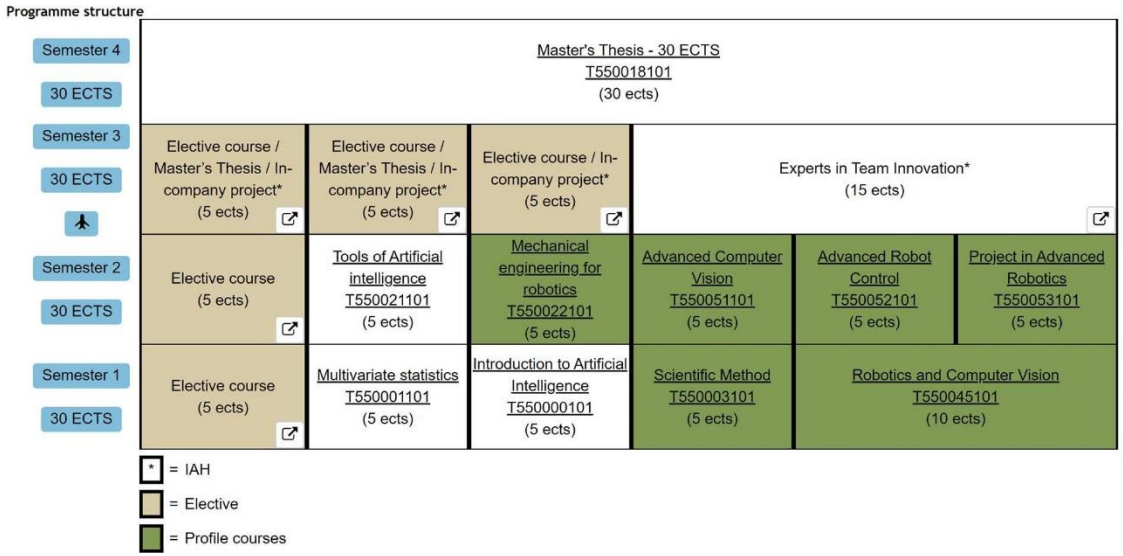
Number	3		
Program Name	MSc in Engineering - Robot Systems (Advanced Robotics Technology/Drones and Autonomous Systems)		
University	University of Southern Denmark		
Country	Odense, Denmark		
URL	https://www.sdu.dk/en/uddannelse/kandidat/robotteknologi?utm_source=Keystone&utm_campaign=Keystone&utm_medium=KeystoneListing		
Program Focus	☐ AI	☐ Data Science	☒ Robotics
Credit Hours	120 European Credit Transfer and Accumulation System (ECTS); Most courses are worth 5 ECTS.		

Number	3
Program Name	MSc in Engineering - Robot Systems (Advanced Robotics Technology/Drones and Autonomous Systems)
	The program has the following specializations: Advanced Robotics Technology (ART) Drones and Autonomous Systems (DAS) ART Structure:  DAS Structure:

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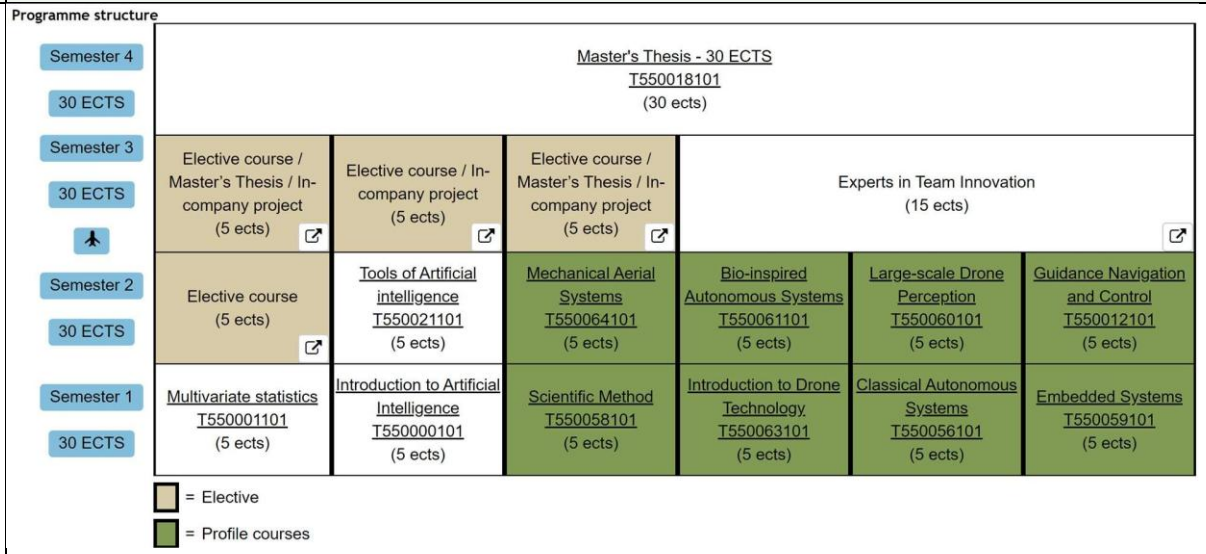
Number	3
Program Name	MSc in Engineering - Robot Systems (Advanced Robotics Technology/Drones and Autonomous Systems)
	 No list of Electives is provided.
AI Credit Hours	CAS: 10 Obligatory ECTS (That can be increased by 10 ECTS from elective courses and 15 ECTS from (elective courses OR additional Master's Thesis Credits OR In-company Project) and 15 ECTS from Experts in Team Innovation (or equivalent) and 30 ECTS from Master's Thesis. DAS: 10 Obligatory ECTS (That can be increased by 5 ECTS from elective courses and 15 ECTS from (elective courses OR additional Master's Thesis Credits OR In-company Project) and 15 ECTS from Experts in Team Innovation (or equivalent) and 30 ECTS from Master's Thesis.

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Number	3
Program Name	MSc in Engineering - Robot Systems (Advanced Robotics Technology/Drones and Autonomous Systems)
Data Science CreditHours	CAS: 5 Obligatory ECTS DAS: 5 Obligatory ECTS
Robotics Credit Hours	CAS: 25 Obligatory ECTS (That can be increased by 10 ECTS from elective courses and 15 ECTS from (elective courses OR additional Master's Thesis Credits OR In-company Project) and 15 ECTS from Experts in Team Innovation (or equivalent) and 30 ECTS from Master's Thesis. DAS: 35 Obligatory ECTS (That can be increased by 5 ECTS from elective courses and 15 ECTS from (elective courses OR additional Master's Thesis Credits OR In-company Project) and 15 ECTS from Experts in Team Innovation (or equivalent) and 30 ECTS from Master's Thesis.
AI Courses in Curriculum	10. Introduction to Artificial Intelligence (Semester 1, 5 ECTS, ART and DAS Obligatory) 11. Tools of Artificial Intelligence (Semester 2, 5 ECTS, ART and DAS Obligatory)
Robotics Courses in Curriculum	1. Robotics and Computer Vision (Semester 1, 10 ECTS, ART and DAS Obligatory) 2. Introduction to Drone Technology (Semester 1, 5 ECTS, DAS Obligatory) 3. Classical Autonomous Systems (Semester 1, 5 ECTS, DAS Obligatory) 4. Advanced Computer Vision (Semester 2, 5 ECTS, ART Obligatory) 5. Advanced Robot Control (Semester 2, 5 ECTS, ART Obligatory) 6. Project in Advanced Robotics (Semester 2,5 ECTS, ART Obligatory) 7. Mechanical Engineering for Robotics (Semester 2, 5 ECTS, ART Obligatory) 8. Guidance, Navigation, and Control (Semester 2, 5 ECTS, DAS Obligatory)

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Number	3
Program Name	MSc in Engineering - Robot Systems (Advanced Robotics Technology/Drones and Autonomous Systems)
	9. Large-scale Drone Perception (Semester 2, 5 ECTS, DAS Obligatory) 10. Bio-Inspired Autonomous Systems (5 ECTS, DAS Obligatory) 11. Mechanical Aerial Systems (Semester 2, 5 ECTS, DAS Obligatory)
Other Fundamental Courses	12. Multivariate Statistics (Semester 1, 5 ECTS, ART Obligatory) 13. Scientific Method (Semester 1, 5 ECTS, ART and DAS Obligatory) 14. Embedded Systems (Semester 1, 5 ECTS, DAS Obligatory)
Teaching and Research Labs	NA
Research Groups	SDU Robotics (https://www.sdu.dk/en/forskning/sdurobotics)
Collaboration with Industry (List of sample projects)	1. FlexDraperProduct (2018-2021) https://www.sdu.dk/en/forskning/sdurobotics/researchprojects/flexdraperproduct 2. Health Care Assisting Technology (2017-2020) https://www.sdu.dk/en/forskning/sdurobotics/researchprojects/health-cat 3. MADE Digital (2017-2020) https://www.sdu.dk/en/forskning/sdurobotics/researchprojects/made+digital …more at https://www.sdu.dk/en/forskning/sdurobotics/researchprojects
Summary and Notes	

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Number	4		
Program Name	MSc in Artificial Intelligence		
University	University of Georgia		
Country	USA		
URL	https://www.ai.uga.edu/ms-artificial-intelligence		
Program Focus	☒ AI	☐ Data Science	☐ Robotics
Credit Hours	30 Hours Structure: • 3 hours of Master's thesis • 2 hours of Master's research • At least 14 hours from the following groups: o 8 hours selected from Group A of courses o 6 hours selected from Group B of courses • The following courses must be included on the Program of Study unless specifically waived for a particular studentby that student's Advisory Committee and by the Graduate Coordinator: o PHIL/LING 6510 Deductive Systems (3 hours) o CSCI 6380 Data Mining (4 hours) or CSCI 8950 Machine Learning (4 hours) o CSCI/PHIL 6550 Artificial Intelligence (3 hours)		

	o ARTI 6950 Faculty Research Seminar (1 hour)
AI Credit Hours	7 Hours (That can be expanded to include 8 Hours from the group electives and 3 Hours from thesis and 2 hours from research) Maximum Total: 20 Units
Data Science CreditHours	0 Units (That can be expanded to include 8 Hours from the group electives and 3 Hours from thesis and 2 hours from research) Maximum Total: 13 Units
Robotics Credit Hours	0 Hours (That can be expanded to include 8 Hours from the group electives and 3 Hours from thesis and 2 hours from research) Maximum Total: 13 Units
AI Courses in Curriculum	28. CSCI 6380 Data Mining (4 hours) or CSCI 8950 Machine Learning (4 hours, Mandatory)
	29. CSCI/PHIL 6550 Artificial Intelligence (3 hours, Mandatory) 30. CSCI 6330 AI and the Web (4 hours, Group A) 31. CSCI 6360 Data Science II (4 hours, Group A) 32. CSCI/ARTI 6540 Symbolic Programming (3 hours, Group A) 33. CSCI 6560 Evolutionary Computing (4 hours, Group A) 34. CSCI 6800 Human Computer Interaction (4 hours, Group A) 35. CSCI 8050 Knowledge Based Systems (4 hours, Group A) 36. CSCI 8360 Data Science Practicum (4 hours, Group A) 37. CSCI 8380 Advanced Topics in Information Systems (4 hours, Group A)

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	38. CSCI/PHIL 8650 Logic and Logic Programming (4 hours, Group A) 39. CSCI 8920 Decision Making Under Uncertainty (4 hours, Group A) 40. CSCI/ENGR 8940 Computational Intelligence (4 hours, Group A) 41. CSCI 8945 Advanced Representation Learning (4 hours, Group A) 42. CSCI/ARTI 8950 Machine Learning (4 hours, Group A) 43. CSCI 8955 Advanced Data Analytics (4 hours, Group A) 44. CSCI 8960 Privacy-Preserving Data Analysis (4 hours, Group A) 45. FORS 8450 Advanced Forest Planning and Harvest Scheduling (3 hours, Group A) 46. LING 6570 Natural Language Processing (3 hours, Group A) 47. ARTI 8800 Directed Readings in Artificial Intelligence (Require permission of instructor) 48. ARTI 8000 Topics in Artificial Intelligence (Require permission of instructor)
Robotics Courses in Curriculum	49. CSCI/ARTI 6530 Introduction to Robotics (4 hours, Group A) 50. CSCI 8535 Multi Robot Systems (4 hours, Group A) 51. CSCI 8820 Computer Vision and Pattern Recognition (4 hours, Group A)
Other FundamentalCourses	27. PHIL/LING 6510 Deductive Systems (3 hours, Mandatory) 28. ARTI 6950 Faculty Research Seminar (1 hour, Mandatory) 29. CSCI 8860 Biomedical Informatics (4 hours, Group A) 30. ENGL 6885 Introduction to Humanities Computing (3 hours, Group A) 31. ENGL/LING 6886 Text and Corpus Analysis (3 hours, Group B) 32. EPSY 8130 Psycholinguistics (3 hours, Group B) 33. LING 6021 Phonetics and Phonology (3 hours, Group B)

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	34. LING 6022 Advanced Phonetics and Phonology (3 hours, Group B) 35. LING 6160 Compositional Semantics (3 hours, Group B) 36. LING 8120 Morphology (3 hours, Group B)
	37. LING 8150 Generative Syntax (3 hours, Group B) 38. LING 8160 Advanced Generative Syntax (3 hours, Group B) 39. LING 8180 Seminar in Phonetics/Phonology (3 hours, Group B) 40. PHIL/EETH 6250 Philosophy of Technology 41. PHIL/LING 6300 Philosophy of Language (3 hours, Group B) 42. PHIL 6310 Philosophy of Mind (3 hours, Group B) 43. PHIL 6410 Philosophy of Natural Science 44. PHIL/LING 6520 Model Theory (3 hours, Group B) 45. PHIL 6530 Philosophy of Math (3 hours, Group B) 46. PHIL/LING 8300 Seminar in Philosophy of Language (max of 3 hours, Group B) 47. PHIL 8310 Seminar in Philosophy of Mind (max of 3 hours, Group B) 48. PHIL 8500 Seminar in Problems of Logic (max of 3 hours, Group B) 49. PHIL 8600 Seminar in Metaphysics (max of 3 hours, Group B) 50. PHIL 8610 Epistemology (max of 3 hours, Group B) 51. PSYC 6100 Cognitive Psychology (3 hours, Group B) 52. PSYC 8240 Judgment and Decision Making (3 hours, Group B)
Teaching and ResearchLabs	• Evolutionary Computation and Machine Learning Lab http://ecml.uga.edu/

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Research Groups Collaboration withIndustry (List of sample projects)	• THINC lab http://thinc.cs.uga.edu/ • Heterogeneous Robotics (HeRo) Lab http://hero.uga.edu/ • CASPR Project https://www.ai.uga.edu/caspr-home
Summary and Notes	

Number	5		
Program Name	MSc in Computer Science – Artificial Intelligence		
University	University of Southern California		
Country	USA		
URL	https://viterbigradadmission.usc.edu/programs/masters/msprograms/computer-science/ms-computer-science-artificial-intelligence/		
Program Focus	☒ AI	☐ Data Science	☐ Robotics
Credit Hours	32 Units 12.5 hours of contact are required per unit. Structure: • Required Courses (20 units)		

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	• Group Electives – take three courses, one from each group (12 units) o Group 1 (Machine Learning & Deep Learning) o Group 2 (Natural Language Processing & Speech Recognition) o Group 3 (Computer Vision & Robotics) Students may use units of special topics courses CSCI 599 or CSCI 699 toward the group elective requirements with department approval. The list of available special topics include many courses that may fall under and beyond the listedgroups of electives (https://www.cs.usc.edu/academic-programs/courses/special-topics-courses/)
AI Credit Hours	12 Units (That can be expanded to include 8 Units from the group electives) Maximum Total: 20 Units
Data Science Credit Hours	0 Units
Robotics Credit Hours	8 Units (That can be expanded to include 4 Units from the group electives) Maximum Total: 12 Units
AI Courses in Curriculum	52. CSCI 561 Foundations of Artificial Intelligence (Required Course, 4 Units) 53. CSCI 566 Deep learning and Its Applications (Required Course, 4 Units) 54. CSCI 567 Machine learning (Required Course, 4 Units) 55. EE 546 Mathematics of High-Dimensional Data (Group 1 Elective, 4 Units) 56. EE 588 Optimization for the Information and Data Sciences (Group 1 Elective, 4 Units) 57. ISE 633 Large-Scale Optimization for Machine Learning (Group 1 Elective, 4 Units) 58. CSCI 544 Applied Natural Language Processing (Group 2 Elective, 4 Units)
	59. CSCI 662 Advanced Applied Natural Language Processing (Group 2 Elective, 4 Units)

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	60. EE 519 Speech Recognition and Processing for Multimedia (Group 2 Elective, 4 Units)
Robotics Courses inCurriculum	12. COMS W4733 Computational Aspects of Robotics (Selection Track Core Courses) 13. COMS W4733 Computational Aspects of Robotics (Elective) 14. MECS E6615 Advanced Robotic Manipulation (Elective) 15. CSCI 445 Introduction to Robotics (Group 3 Elective, 4 Units) 16. CSCI 545 Robotics (Group 3 Elective, 4 Units) 17. CSCI 677 Advanced Computer Vision (Group 3 Elective, 4 Units) 18. EE 569 Introduction to Digital Image Processing (Group 3 Elective, 4 Units)
Other Fundamental Courses	53. CSCI 570 Analysis of Algorithms (Required Course, 4 Units) 54. CSCI 571 Web Technologies (Required Course, 4 Units)
Teaching and Research Labs	https://viterbischool.usc.edu/shared-research-infrastructure/ Viterbi School Core Infrastructure • Center For Advanced Manufacturing (CAM) • John O'Brien Nanofabrication Laboratory • MOSIS VLSI Circuit Fabrication Facility • Structures and Materials Research Laboratory (SMRL) • USC Center for Peptide and Protein Engineering (CPPE) • USC-Lockheed Martin Quantum Computing Center • Investigator-Managed Viterbi School Shared Infrastructure • SLA Fast Prototyping Machine

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	• UltraLab Viterbi-Dornsife Shared Core Infrastructure • Core Center of Excellence in Nano Imaging (CNI) • Viterbi-Dornsife Machine Shop Other USC Core Infrastructure: • Complete Listing of USC Research Facilities • Biomedical Imaging
	• Biophysics Core • Compund Semiconductor Lab • Digital Archive & Media Resources • Dornsife Neuroimaging Center • Genomics • High Performance Computing Center • Medical and Biomedical Cores • Statistics Cores
Research Groups	Numerous Research Centers: https://viterbischool.usc.edu/research-centers/ • Artificial Intelligence for Social Good • Airbus Institute for Engineering Research (AIER) • Arid Climate and Water Research Center (AWARE) • Biomimicry for Synthesis of Smart Textiles • …

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Collaboration with Industry (List of sample projects)	https://viterbischool.usc.edu/faculty/faculty-research-resources/research-initiatives/ Programs: • Coulter Translational Research Partnership Program • Neuroscience Graduate Program • Women in Science and Engineering Funds: • Collaboration Fund • Zumberge Faculty and Research Innovation Fund • Core Instrumentation Fund • Collaborative Research in Regenerative Medicine Institutes with Funding Opportunities: • METRANS Transportation Center • Ming Hsieh Institute for Research • Southern California Clinical and Translational Science Institute (SC CTSI) • Southern California Environmental Health Sciences Center
Summary and Notes	

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Number	6		
Program Name	MSc in Computer Science – Machine Learning – Non-Thesis		
University	Columbia University		
Country	USA		
URL	https://www.cs.columbia.edu/areas/machine/		
Program Focus	☒ AI	☐ Data Science	☐ Robotics

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Credit Hours	30 Points (pts) Each point of academic credit requires a minimum of three hours work each week in a 14-week semester, typically divided into one hour of classroom instruction (with an hour of classroom instruction defined as at least 50 minutes) and two hours of independent work (which may include readings, problem sets, papers, individual or group projects, and so forth). Machine Learning track requires: • Breadth courses – 1 course (3pts) from Group 1 (Systems) – 1 course (3pts) from Group 2 (Theory) – 1 course (3pts) from Group 3 (AI and Applications) – 1 course (3pts) from either Group 1, 2, or 3 • Required Selection of Track courses (6pts) • Track Electives (6pts) • General Electives (6pts)
AI Credit Hours	9pts (That can be expanded to include 3pts from the breadth courses and 6pts from track electives) Maximum Total: 18pts
Data Science Credit Hours	3pts (That can be expanded to include 6pts from track electives) Maximum Total: 9pts
Robotics Credit Hours	3pts (That can be expanded to include 6pts from track electives) Maximum Total: 9pts

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AI Courses in Curriculum	61. COMS W4252 Introduction to Computational Learning Theory (Selection Track Core Courses) 62. COMS W4771 Machine Learning (Selection Track Core Courses) 63. COMS W4721 Machine Learning for Data Science (Selection Track Core Courses) 64. ELEN 4720 Machine Learning for Signals, Information and Data (Selection Track Core Courses) 65. COMS W4772 Advanced Machine Learning (Selection Track Core Courses)
	66. COMS 4773 Machine Learning Theory (Selection Track Core Courses) 67. COMS 4774 Unsupervised Learning (Selection Track Core Courses) 68. COMS 4775 Causal Inference (Selection Track Core Courses) 69. COMS W4731 Computer Vision (Selection Track Core Courses) 70. COMS W4705 Natural Language Processing (Selection Track Core Courses) 71. COMS W4701 Artificial Intelligence (Selection Track Core Courses) 72. COMS W4252 Introduction to Computational Learning Theory (Elective) 73. COMS W4772 Advanced Machine Learning (Elective) 74. COMS W4705 Intro to Natural Language Processing (Elective) 75. COMS W4731 Computer Vision (Elective) 76. COMS 6998 Machine Learning Personalization (Elective) 77. COMS W4776 Machine Learning for Data Science (Elective) 78. COMS E6253 Advanced Topics in Computational Learning Theory (Elective) 79. CSEE E6892 Bayesian Models in Machine Learning (Elective) 80. CSEE E6898 Large-Scale Machine Learning (Elective) 81. ECBM E4040 Neural Networks and Deep Learning (Elective)

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	82. ECBM E6040 Neural Networks and Deep Learning Research (Elective) 83. EECS E6691 Topics in Data-Driven Analysis & Comp: Advanced Deep Learning (Elective) 84. EECS E6699 Topics in Data-Driven Analysis and Computation: Mathematics of Deep Learning (Elective) 85. EECS E6720 Bayesian Models of Machine Learning (Elective) 86. EECS E6870 Speech Recognition (Elective) 87. EECS E6893 Big Data Analytics or Topics-Information Processing (Elective) 88. EECS E6895 Topic Adv Big Data Analytics (Elective) 89. EECS E6894Deep Learning for Computer Vision and Natural Language Processing (Elective) 90. ELEN 6885 Reinforcement Learning (Elective) 91. IEOR E8100 Big Data & Machine Learning (Elective) 92. IEOR E8100/4575 Reinforcement Learning (Elective) 93. STAT W4240 Data Mining (Elective) 94. STAT W4282 Linear Regression/Time Series Analysis (Elective) 95. STAT W4249 Applied Data Science (Elective) 96. STAT G4400 Statistical Machine Learning (Elective) 97. STAT W4640 Bayesian Statistics (Elective)
Robotics Courses inCurriculum	19. COMS W4733 Computational Aspects of Robotics (Selection Track Core Courses) 20. COMS W4733 Computational Aspects of Robotics (Elective) 21. MECS E6615 Advanced Robotic Manipulation (Elective)

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Other Fundamental Courses	55. COMS/STAT G6509/6701 Foundations of Graphical Models (Selection Track Core Courses) 56. CSOR W4246 Algorithms for Data Science (Elective) 57. COMS W4111 Introduction to Databases (Elective) 58. COMS W4737 Biometrics (Elective) 59. COMS W4761 Computational Genomics (Elective) 60. COMS E6111 Advanced Database Systems (Elective) 61. COMS E6232 Analysis of Algorithms II (Elective) 62. COMS E6717 Information Theory (Elective) 63. COMS E6735 Visual Databases (Elective) 64. COMS E6737 Biometrics (Elective) 65. COMS E6901 Projects in Computer Science (Elective) 66. CSEE E6898 Sparse Signal Modeling (Elective) 67. APMA E4990 Modeling Social Data (Elective) 68. BINF G4006 Translational Bioinformatics (Elective) 69. ELEN E6886 Sparse Representations and Higher Dimensional Geometry (Elective) 70. ELEN E6899 Topics in Information Processing: Autonomous Multi-Agent Systems (Elective) 71. IEOR E6613 Optimization I (Elective) 72. IEOR E8100 Optimization Methods in Machine Learning (Elective) 73. STAT W4201 Probability and Statistics/Advanced Data Analysis (Elective) 74. STAT W4700 Probability and Statistics (Elective) 75. STAT G6101 Statistical Modeling and Data Analysis I (Elective)

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	76. STAT G6104 Computational Statistics (Elective) 77. STAT GR8101 Topics in Applied Statistics: Applied Causality (Elective)		
Teaching and Research Labs	Computing Research Facilities: https://www.cs.columbia.edu/crf/		
Research Groups	NA		
Collaboration with Industry (List of sample projects)	NA		
Summary and Notes			
Number	7		
Program Name	MSC in Artificial Intelligence		
University	The Hong Kong university of science and technology		
Country	Hong Kong		
URL	https://prog-crs.ust.hk/pgprog/2021-22/mphil-phd-ai		
Program Focus	☒ AI	☐ Data Science	☐ Robotics
Credit Hours	15		
AI Credit Hours			

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Data Science Credit Hours	
Robotics Credit Hours	9
AI Courses in Curriculum	1. Advanced Artificial Intelligence (elective) 2. Machine Learning (elective) 3. Statistical Machine Learning (elective) 4. Bayesian Machine Learning (elective) 5. Advanced Deep Learning (elective) 6. Deep Reinforcement Learning (elective) 7. Topics in Artificial Intelligence (elective) 8. Topics in Machine Learning (elective) • (list of courses are attached with another file)
Robotics Courses inCurriculum	
Other Fundamental Courses	78. **Course Name** (Prerequisite Name) (obligatory/elective) 79. **Course Name** (Prerequisite Name) (obligatory/elective) 80. **…**
Teaching and Research Labs	**1. Introduction to Teaching and Learning in Higher :** The course aims to equip all full-time research postgraduate (RPg) students with basic teaching skills before assuming teaching assistant duties for the department. Good teaching skills can be acquired through learning and practice. This 10-hour mandatory training course provides all graduate teaching assistants (GTA) with the necessary theoretical knowledge withpractical opportunities to apply and build up their knowledge, skills and confidence in taking up their teachingduties. At the end of the course, GTAs should be able to (1) facilitate teaching in tutorials and laboratory

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	settings; (2) provide meaningful feedback to their students; and (3) design an active learning environment to engage their students. Graded PP, P or F.

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Research Groups	**1. Cross-disciplinary Research Methods I:** This course focuses on using various approaches to perform quantitative analysis through real-world examples. Students will learn how to use different tools in an interdisciplinary project and how to acquire new skills on their own. The course offers different modules that are multidisciplinary/multifunctional and generally applicable to a wide class of problems. **2. Cross-disciplinary Research Methods II:** This course focuses on using various approaches to perform quantitative analysis through real-world examples. Students will learn how to use different tools in an interdisciplinary project and how to acquire new skills on their own. The course offers different modules that are multidisciplinary/multifunctional and generally applicable to a wide class of problems. **3. Professional Development for Research Postgraduate Students:** This course aims at equipping research postgraduate students with transferrable skills conducive to their professional development. Students are required to attend 3 hours of mandatory training on Professional Conduct, and complete 12 hours of workshops, at their own choice, under the themes of Communication Skills, Research Competency, Entrepreneurship, Self-Management, and Career Development. Graded PP, P or F. **4. Artificial Intelligence Seminar I:** Series of seminars presenting research problems currently under investigation,presented by faculty, students, and visiting speakers. Students are expected to attend regularly. Graded P or F. **5. Artificial Intelligence Seminar II:** Series of seminars presenting research problems currently under investigation, presented by faculty, students, and visiting speakers. Students are expected to attend regularly. Continuation of AIAA 6101. Graded P or F. **6. MPhil Thesis Research:** Master's thesis research supervised by co-advisors from different disciplines. A successfuldefense of the thesis leads to the grade Pass. No course credit is assigned.
Collaboration with Industry (List of sample projects)	9. 10.
Summary and Notes	

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Number	8		
Program Name	MSc in Robotics and Autonomous Systems		
University	The Hong Kong university of science and technology		
Country	Hong Kong		
URL	https://prog-crs.ust.hk/pgprog/2021-22/mphil-phd-roas		
Program Focus	☐ AI	☐ Data Science	☒ Robotics
Credit Hours	15		
AI Credit Hours			
Data Science Credit Hours			
Robotics Credit Hours	9		
AI Courses in Curriculum	18. **Course Name** (Prerequisite Name) (obligatory/elective) 19. **Course Name** (Prerequisite Name) (obligatory/elective) 20. **…**		
Robotics Courses inCurriculum	22. Introduction to Robotics (elective) 23. Autonomous Mobile Robotics (elective) 24. Cloud Robotics and Autonomous Multi-Robot Systems (elective) 25. Human-Robot Interaction (elective)		

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	26. Robot Manipulation (elective) 27. Introduction to Aerial Robotics (elective) 28. Robot Perception and Learning (elective) • (list of courses are attached with another file)
Other Fundamental Courses	81. **Course Name** (Prerequisite Name) (obligatory/elective) 82. **Course Name** (Prerequisite Name) (obligatory/elective) 83. **…**
Teaching and Research Labs	1. **Introduction to Teaching and Learning in Higher :** The course aims to equip all full-time research postgraduate(RPg) students with basic teaching skills before assuming teaching assistant duties for the department. Good teaching skills can be acquired through learning and practice. This 10-hour mandatory training course provides all graduate teaching assistants (GTA) with the necessary theoretical knowledge with practical opportunities to apply and build up their knowledge, skills and confidence in taking up their teaching duties. At the end of the course, GTAs should be able to (1) facilitate teaching in tutorials and laboratory settings; (2) provide meaningful feedback to their students; and (3) design an active learning environment to engage their students. Graded PP, P or F.
Research Groups	5. **Cross-disciplinary Research Methods I:** This course focuses on using various approaches to perform quantitative analysis through real-world examples. Students will learn how to use different tools in an interdisciplinary project

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	and how to acquire new skills on their own. The course offers different modules that are multidisciplinary/multifunctional and generally applicable to a wide class of problems. 6. **Cross-disciplinary Research Methods II:** This course focuses on using various approaches to perform quantitative analysis through real-world examples. Students will learn how to use different tools in an interdisciplinary project and how to acquire new skills on their own. The course offers different modules that are multidisciplinary/multifunctional and generally applicable to a wide class of problems. 7. **Professional Development for Research Postgraduate Students:** This course aims at equipping research postgraduate students with transferrable skills conducive to their professional development. Students are required toattend 3 hours of mandatory training on Professional Conduct, and complete 12 hours of workshops, at their own choice, under the themes of Communication Skills, Research Competency, Entrepreneurship, Self-Management, and Career Development. Graded PP, P or F. 8. **Seminar in Robotics and Autonomous Systems:** Seminar topics presented by students, faculty and guest speakers. Students are expected to attend regularly and demonstrate proficiency in presentation in accordance withthe program requirements. Graded P or F. 9. **MPhil Thesis Research:** Master's thesis research supervised by co-advisors from different disciplines. A successful defense of the thesis leads to the grade Pass. No course credit is assigned.
Collaboration with Industry (List of sample projects)	1. 2.
Summary and Notes	

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Number	9		
Program Name	Master of Science in Robotics		
University	Ecole Polytechnique Fédérale de Lausanne (EPFL)		
Country	Switzerland		
URL	https://www.epfl.ch/education/master/programs/robotics/		
Program Focus	☒ AI	☐ Data Science	☒ Robotics
Credit Hours	120 ECTS		
AI Credit Hours	From 4 to 39 ECTS		
Data Science Credit Hours	From 0 to 14 ECTS		
Robotics Credit Hours	From 18 to 38 ECTS		
AI Courses in Curriculum	21. **Applied Machine Learning** (Linear Algebra, Probability & Statistics) (obligatory) 22. **Advanced Machine Learning** (Linear Algebra, Probability & Statistics) (elective) 23. **Deep Learning** (Linear Algebra, Differential Calculus, Python Programming, Probability & Statistics) (elective) 24. **Distributed Intelligent Systems** (Linear Algebra, Differential Calculus, Python Programming, Probability & Statistics, Programming Matlab, Python, C++) (elective) 25. **Fundamentals of Neuroengineering** (Neuroscience, Signal Processing, Machine Learning) (elective) 26. **Machine Learning Programming** (Applied Machine Learning) (elective) 27. **Intelligent Agents** (Artificial Intelligence) (elective)		

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Robotics Courses inCurriculum	29. **Basics of Mobile Robotics** (Introduction to Automatic Control, Introduction to Signal Processing) (obligatory) 30. Aerial Robotics (elective) 31. **Industrial and Applied Robotics** (Basics of Robotics, Control Systems I & II, Microtechnology Components I & II, Vibratory Systems) (elective) 32. **Evolutionary Robotics** (Programming Python, Java, C++) (elective) 33. **Haptic Human Robot Interfaces** (Basics of Robotics) (elective) 34. **Legged Robots** (Mobile Robots, Model Predictive Control) (elective) 35. **Controlling Behavior in Animals and Robots** (Neuroscience II: Cellular Mechanisms of Brain function)(elective)
Other Fundamental Courses	84. **Model Predictive Control** (Control Systems) (obligatory) 85. **Advanced Control Systems** (Control Systems, Numerical Control of Dynamic Systems) (elective) 86. **Industrial Automation** (Communication Networks) (elective) 87. Computer Vision (elective) 88. **Image Processing I** (Signals & Systems I & II) (elective) 89. **Image Processing II** (Image Processing I, Signals & Systems I & II, Linear Algebra, Analysis) (elective) 90. **Image Analysis and Pattern Recognition** (Introduction to Signal Processing, Image processing) (elective)

	91. Signal Processing for Functional brain Imaging (elective)
Teaching and Research Labs	2. **Learning Algorithms and Systems Laboratory (LASA)** (KUKA Light Weight Robot 4+, UR5 robotic arm, iCub humanoid robot, YuMi robot) 3. Laboratory of Intelligent Systems (LIS)

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Research Groups	10.
Collaboration with Industry (List of sample projects)	3. Second Hands 4. Crowdbot

Summary and Notes

This Robotics master's program at EPL provides education on the theory, technology and practice of intelligent robots, such as mobile robots, wearable robots, robotic manipulators, autonomous and brain-interfaced robots. In addition to classes spanning from electromechanical systems to advanced artificial intelligence, the program offers a large set of hands-on activities where students learn by designing, prototyping and validating robotic systems.

It extends over four semesters and is made up of individual modules that form the theoretical and methodological foundation for thorough practical training as detailed below:

- Basic compulsory modules (11 ECTS): Applied Machine Learning (4 ECTS), Basics of Mobile Robotics (4 ECTS), Model Predictive Control (3 ECTS).
- Optional courses and orientation (59 ECTS)
- Labs and Project I (14 ECTS): Robotics Practical (4 ECTS), Robotics Project I (10 ECTS).
- Project in social and human sciences (6 ECTS).
- Master's Thesis (30 ECTS).

This program is a part of the course of study of the "Learning Algorithms and Systems Laboratory (LASA)". This laboratory is organized into five research areas:

- Human-Robot Interaction
- Machine Learning with Application to Robotics
- Fast Adaptive Control
- Dexterous Manipulation and Grasping
- Computational Neuroscience and Cognitive Modeling

This program gives students a well-rounded education with practical experience, and will lead to careers in a wide range of fields where robotics technologies are increasingly adopted, such as: biomedical technologies; logistics and transportation; aviation and drones; autonomous cars; industry 4.0; smart houses; environmental technology. In addition, students can benefit from EPFL's strong innovation ecosystem to invent new systems and applications, and start up their own company.

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Number	10		
Program Name	Robotics and Computation MSc		
University	University College London (UCL)		
Country	United Kingdom		
URL	https://www.ucl.ac.uk/prospective-students/graduate/taught-degrees/robotics-computation-msc		
Program Focus	☐ AI	☐ Data Science	☒ Robotics
Credit Hours	180 ECTS		
AI Credit Hours	From 0 to 60 ECTS		
Data Science Credit Hours	From 0 to 45 ECTS		
Robotics Credit Hours	From 60 to 75 ECTS		
AI Courses in Curriculum	28. Machine Learning for Visual Computing (optional) 29. **Multi-Agents Artificial Intelligence** (Programming Python, Java, Probability, Statistics, Machine Learning, Deep Learning, TensorFlow or PyTorch or MXNet) (optional) 30. **Introduction to Machine Learning** (Calculus, Linear Algebra, Probability Theory, Programming Python)(elective) 31. **Introduction to Deep Learning** (Calculus, Linear Algebra, Probability Theory, Machine Learning, Programming Python or Julia) (elective) 32. **Probabilistic and Unsupervised Learning** (Calculus, Linear Algebra, Statistics, Computer Science, Programming Matlab or Octave) (elective) 33. **Reinforcement Learning** (Calculus, Probability, Linear Algebra, Programming Python) (elective) 34. **Supervised Learning** (Multivariable Calculus, Probability and Combinatorics, Linear Algebra) (elective)		

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Robotics Courses inCurriculum	36. Robot Vision and Navigation (obligatory) 37. **Robotic Control Theory and Systems** (Linear Algebra, Calculus, Programming C) (obligatory) 38. **Robotic Sensing, Manipulation and Interaction** (Programming C++, ROS, Matlab, Python) (obligatory) 39. **Robotic Systems Engineering** (Linux, Programming ROS, Python, Linear Algebra) (obligatory) 40. **Affective Computing and Human-Robot Interaction** (Machine Learning, Programming Matlab, Python, Java,C++) (elective)
Other Fundamental Courses	92. **Machine Vision** (Digital Imaging, Digital Image Processing) (optional) 93. **Numerical Optimization** (Linear Algebra, Analysis, Programming Matlab) (optional) 94. Acquisition and Processing of 3D Geometry (Linear Algebra) (optional)
Teaching and Research Labs	4.
Research Groups	11. 12.
Collaboration with Industry (List of sample projects)	5. 6.

Summary and Notes

This Robotics and Computation master's program at UCL provides an overview of robotic and computational tools for robotics and autonomoussystems as well as their main computational components: kinetic chains, sensing and awareness, control systems, mapping and navigation. Optional modules in machine learning, human-machine interfaces and computer vision help students grasp fields related to robotics more closely, while theproject thesis allows students to focus on a specific research topic in depth.

It extends over two semesters and is made up of individual modules that form the theoretical and methodological foundation for thorough practical training as detailed below:

- Compulsory modules (60 ECTS): Robot Vision and Navigation (15 ECTS), Robotic Control Theory and Systems (15 ECTS), Robotic Sensing, Manipulation and Interaction (15 ECTS), Robotic Systems Engineering (15 ECTS).
- Optional and Elective modules (60 ECTS)
- Master's Thesis (60 ECTS).

This programme prepares students to enter a robotics-related industry or any other occupation requiring engineering or analytical skills. Graduates with skills to develop new robotics solutions and solve computational challenges in automation are likely to be in demand globally.

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Number	11		
Program Name	Robotics, Cognition, Intelligence		
University	Technical University of Munich		
Country	Germany		
URL	https://www.tum.de/en/studies/degree-programs/detail/detail/StudyCourse/robotics-cognition-intelligence-master-of-science-msc/		
Program Focus	☒ AI	☐ Data Science	☒ Robotics
Credit Hours	120 ECTS		
AI Credit Hours	From 23 to 50 ECTS		
Data Science Credit Hours	From 8 to 35 ECTS		
Robotics Credit Hours	From 11 to 38 ECTS		

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AI Courses in Curriculum	35. **Basics of artificial Intelligence** (Basics: Algorithms and Data Structures, Discrete Structures) (obligatory) 36. **Machine Learning** (Linear Algebra for Computer Science, Analysis for Computer Science, Discrete Probability Theory) (obligatory) 37. **Human-Machine Communication I** (Boolean Algebra, Finite Automata, Mathematics I, Computer Technology,Signal Representation, Control Systems) (obligatory) 38. Cognitive Systems (obligatory) 39. Reinforcement Learning for Robotics (elective) 40. **Advanced Deep Learning for Computer Vision** (Analysis for Informatics, Linear Algebra for Informatics, Introduction to Deep Learning) (elective) 41. **Application of Knowledge-based Methods** (Techniques in Artificial Intelligence, Basic Courses in Informatics) (elective) 42. **Computational Intelligence** (Programming Matlab) (elective) 43. **Introduction to Deep Learning** (Analysis for Informatics, Linear Algebra for Informatics, Python) (elective) 44. **Machine Learning for Computer Vision** (Linear Algebra for Informatics, Probability Theory, statistical Modeling and Machine Learning) (elective) 45. **Advanced Deep Learning for Robotics** (Analysis for Computer, Linear Algebra for Computer, Introduction toDeep Learning) (elective) 46. **Human-Machine Communication II** (Human-Machine Communication I, Signals) (elective) 47. **Neural Engineering: Implants, Interfaces and Algorithms** (Computational Intelligence or Artificial Intelligenceor Machine Learning) (elective)
Robotics Courses inCurriculum	41. Motion Planning in Robotics (obligatory) 42. **Robotics** (Vector Algebra, Differential Calculus, Basic knowledge of physics) (obligatory) 43. Object-Oriented Modeling in Mechatronic Systems (elective)

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	44. **Assembly, Handling and Industrial Robots** (Technical Mechanics, Advanced Mathematics) (elective) 45. **Robot Dynamics** (Mechanics) (elective) 46. Sensor Guided Robotic Manipulation and Locomotion (Robotics) (elective) 47. **Orbit Dynamics and Robotics** (Mechanics, Control Systems, Basics of Astronautics) (elective) 48. **Advanced Concepts of Perception for Robotic Systems** (Robotics, Image Processing, Basics of Intelligent Robots, Programming C++) (elective) 49. Fundamentals of Human-Centered Robotics (Robotics, Control Systems) (elective) 50. Humanoid Robotic Systems (elective) 51. Modeling and Regulation of Humanoid Walking Robots (Control Engineering Fundamentals) (elective) 52. Introduction to Surgical Robotics (elective) 53. **Multi-Sensory Based Robot Dynamic Manipulation** (Linear Algebra, Robotics, Programming C++, ROS) (elective) 54. Programming and Control of Human Robot Interaction (Robotics) (elective) 55. Microtechnical sensors/actuators (elective) 56. **Mechatronic Device Technology** (Control Systems, Programming) (elective) 57. **Autonomous Navigation for Flying Robots** (Linear Algebra, Probability Theory, 3D Geometry, Python) (elective) 58. **Robotics 3D Vision** (Linear algebra, Calculus, Computer Vision II) (elective) 59. **Control of Modern Lightweight Robots** (Control Engineering Basics) (elective)
Other Fundamental Courses	95. **Computer Vision II: Multiple View** (Linear Algebra for Informatics, Analysis for Informatics) (obligatory)
Teaching and Research Labs	5. Chair of Robotics, Artificial Intelligence and Real Time Systems (Shunck LWA 4P Robot, ABB IRB 120 Robot, KUKA LBR iiwa Robot, Automated Bicycle, BeagleBone Black, Altera DE0 FPGA board, Raspberry Pi, Freescale i.MX 6 SoCs, Sensors (Cameras, Accelerometer, Gyroscope, Laser, Wheel-Encoders, IR))
Research Groups	13.

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Collaboration with Industry (List of sample projects)	7. Embodied Cognition in a Compliantly Engineered Robot (ECCEROBOT) 8. European Clearing House for Open Robotics Development (ECHORD)

Summary and Notes

The "Robotics, Cognition, Intelligence" master's program is a joint program of the Department of Informatics, Electrical Engineering, Information Technology and Mechanical Engineering of the Technical University of Munich.

It extends over four semesters and is made up of individual modules that form the theoretical and methodological foundation for thorough practical training as detailed below:

- Compulsory modules (57 ECTS): Basic knowledge in the three areas of robotics (11 ECTS), cognition (13 ECTS), intelligent autonomoussystems (18 ECTS), master's seminar (5 ECTS), master's internship (10 ECTS).
- Elective modules (33 ECTS): General fundamentals (6 ECTS) and Deepening in the fields of computer science, mechanical engineering and electrical engineering (27 ECTS).
- Master's Thesis (30 ECTS).

This program is a part of the course of study of the "Chair of Robotics, Artificial Intelligence and Real-Time Systems". This chair is organizedinto four research areas:

- Human Robot Interaction and Service Robotics
- Medical Robotics
- Cognitive Robotics
- Cyber-Physical / Embedded Systems

After the completion of this program, good future employment prospects are predicted in the fields of automation technology for the aviation and aerospace industries, microelectronics industry, intelligent environments, pharmaceutical and chemical industries and large- scale research institutions. Graduates of the program will be qualified to move into employment in a range of high-level roles, including:

- Conception and realization of complex systems
- Project management and development of new software based products
- Conception and development of new systems from application areas such as automation technology, the automobile industry, engineering, information technology, real-time systems, web-services and infrastructures
- Research and teaching in research institutes, universities, and continuing education environments
- Consulting

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Number	12		
Program Name	Master in Computer Science		
University	University of Granada		
Country	Spain		
URL	https://masteres.ugr.es/ing-informatica/		
Program Focus	☒ AI	☒ Data Science	☒ Robotics
Credit Hours	102 ECTS offered - 72 ECTS for the Master degree		
AI Credit Hours	6 ETCS		
Data Science Credit Hours	30 ECTS		
Robotics CreditHours	8 ETCS		
AI Courses inCurriculum	1. Computational Intelligence (obligatory) 2. Cloud Computing: Fundamentals and Infrastructures (obligatory) 3. Cloud Computing: Services and Applications (obligatory) 4. Intelligent Systems for Management in Companies (obligatory) 5. Intelligent Data Processing (obligatory) 6. Applications of Advanced Computational Mathematics (obligatory)		

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	7. Graphical Visualisation Techniques: Medical Applications (elective)
Robotics Courses in Curriculum	1. Home Automation (elective) 2. Critical Systems (elective)
Other Fundamental Courses	**1.** Planning and Management of Computer Projects (obligatory) **2.** Company Internships (elective) **3.** Company Engineering Projects (elective) **4.** Development of Software Systems Based on Components and Services (obligatory) **5.** Development and Evaluation of Interactive Software Systems (obligatory) **6.** Virtual Environments (obligatory) **7.** Systems Administration and Security (elective) **8.** Information Management in Mobile Devices (elective) **9.** Information Management on The Web (elective) **10.** Mobile Internet (elective) **11.** Web-Based Software Systems (elective) **12.** Master Thesis (obligatory)
Teaching and Research Labs	1. No special labs available
Research Groups	1. Approximate Reasoning and Artificial Intelligence (ARAI) 2. Computer Vision Group (CVG)

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	3. Computational Intelligence (CI) 4. Intelligent Databases and Information Systems (IdBIS) 5. Intelligent Systems Groups (ISG) 6. Models of Decision and Optimization (MODO) 7. Soft Computing and Intelligent Information Systems (SCI2S) 8. Uncertainty Treatment in Artificial Intelligence (UTAI) 9. Visual and Information Processing (VIP) 10. Circuits and Systems for Information Processing (CASIP) 11. Concurrent Systems (SC) 12. Group of Specification, Development and Software Evolution (GEDES) 13. Graphic Computers and Virtual Reality (INGREVI) 14. Signals, Telematics and Communications (STC) 15. Smart Wireless Applications and Technologies Group (SWAT)
Collaboration with Industry (List of sample projects)	1. None related directly with Master
Summary and Notes	

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Number	13		
Program Name	Master in Data Science and Computer Engineering		
University	University of Granada		
Country	Spain		
URL	https://masteres.ugr.es/datcom/		
Program Focus	☒ AI	☒ Data Science	☒ Robotics
Credit Hours	127 ECTS offered - 60 ECTS for the Master degree		
AI Credit Hours	95 ETCS		
Data Science Credit Hours	95 ECTS		
Robotics Credit Hours	32 ETCS		

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AI Courses in Curriculum	48. Introduction to Data Science (obligatory) 49. Introduction to Programming for Data Science (elective) 50. Data mining: pre-processing and classification (elective) 51. Data Mining: Unsupervised Learning and Anomaly Detection (elective) 52. High Performance Computing for Classification and Optimisation (elective) 53. Computational biology with big data-omics and biomedical engineering (elective) 54. System modelling and time series prediction (elective) 55. Probabilistic graphical models (elective) 56. Feature Extraction in Images (elective) 57. Time Series and Mining of Data Streams (elective) 58. Information Retrieval and Recommender Systems (elective) 59. Data mining: Advanced Aspects (elective) 60. Social Media Mining (elective) 61. Process Mining (elective) 62. Big data II: Big Data analytics (elective) 63. Soft computing: Fuzzy Sets and systems (elective) 64. Soft Computing Techniques for Learning and Optimisation. Neural Networks and Metaheuristics,evolutionary and bio-inspired programming (elective) 65. Computer Vision (elective)
Robotics Courses inCurriculum	60. Introduction to Programming for Computer Engineering (elective) 61. Embedded systems and hw/sw co-design (elective) 62. Internet of things (elective) 63. High performance architectures for vision (elective) 64. Mechatronics and aerospace systems (elective) 65. Computational neuroscience and neuroengineering (elective)

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	66. Bio-inspired vision systems (elective) **67.** Mobile robotics and neuro-robotics (elective)
Other Fundamental Courses	96. Entrepreneurship and knowledge transfer (obligatory) 97. Research Methodology (elective) 98. Secure servers (elective) 99. High Performance Computing (elective) 100. Web server engineering (elective) 101. High performance signal processing in biomedicine (elective) 102. Big data I: Cloud computing and massive data storage (elective) 103. Applications of Data Science and Intelligent Technologies (elective) 104. Master Thesis (obligatory)
Teaching and Research Labs	6. No special labs available
Research Groups	14. Approximate Reasoning and Artificial Intelligence (ARAI) 15. Computer Vision Group (CVG) 16. Computational Intelligence (CI) 17. Intelligent Databases and Information Systems (IdBIS) 18. Intelligent Systems Groups (ISG) 19. Models of Decision and Optimization (MODO) 20. Soft Computing and Intelligent Information Systems (SCI2S) 21. Uncertainty Treatment in Artificial Intelligence (UTAI) 22. Visual and Information Processing (VIP) 23. Circuits And Systems for Information Processing (CASIP)
Collaboration with Industry (List of sample projects)	9. None related directly with Master
Summary and Notes	

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Number	14		
Program Name	Master in Industrial Electronics		
University	University of Granada		
Country	Spain		
URL	https://masteres.ugr.es/electronicaindustrial/		
Program Focus	☐ AI	☐ Data Science	☒ Robotics
Credit Hours	78 ECTS offered - 60 ECTS for the Master degree		
AI Credit Hours	0 ETCS		
Data Science Credit Hours	0 ECTS		
Robotics Credit Hours	20 ETCS		
AI Courses in Curriculum	1.		
Robotics Courses inCurriculum	**1.** Digital Control of Mechatronic Systems (obligatory) **2.** Mobile Robotics (obligatory) **3.** Design and Construction of Non-Tripulated Vehicles (elective) **4.** Aerospace Electronics, Applications to Small Satellites (elective) **5.** Power Electronics for Electric Traction Vehicles (elective) **6.** Biomedical Electronics Systems (elective)		

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Other Fundamental Courses	**1.** Digital Control for Power Electronics (obligatory) **2.** Industrial Electronics: Emerging Components, Power Systems, Market and Perspective (obligatory) **3.** Modeling and Management of Energy Storage Systems (obligatory) **4.** Advanced Digital Design (obligatory) **5.** Systems with Integrated Processors (obligatory) **6.** Development of Portable Instrumentation (elective) **7.** Development of Technological Innovation (elective) **8.** Tcad Design of Integrated Circuits (elective) **9.** Advanced Project Management (elective) **10.** Advanced Image Processing for Industrial Applications (elective) **11.** Security in Electronic Systems (elective) **12.** External Internships (elective)
Teaching and Research Labs	**1.** Advanced Electronics Laboratory **2.** Basic Electronics Laboratory
Research Groups	1. Cirtuits And Systems for Information Processing (CASIP) 2. Research Group on Electronic Devices (GRIDE) 3. Digital Techniques, Digital TECniques (DiTEC)
	4. Nanoelectronics Research Group (GIN) 5. Nanostructures, quantum properties and technological applications (NPCAT) 6. Electrical and Chemical Sensing Solutions (ECSENS) 7. Pervasive Electronics advanced research laboratory (PEARL)
Collaboration with Industry (List of sample projects)	2. None related directly with Master
Summary and Notes	

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Number	15		
Program Name	Master of Science - Data Science & Engineering – Artificial Intelligence Track		
University	UNIGE		
Country	Italy		
URL	https://www.unige.it/ (a)		
Program Focus	■ AI	☐ Data Science	☐ Robotics
Credit Hours	120 CFU = 3000 student hours (b) (c)		
AI Credit Hours	54 CFU = 1350 student hours		
Data Science Credit Hours	15 CFU = 375 student hours		
Robotics Credit Hours	0		
AI Courses in Curriculum	1. MACHINE LEARNING - CFU 9 - Obligatory 2. DIGITAL SIGNAL & IMAGE PROCESSING - CFU 9 - Obligatory 3. ADVANCED MACHINE LEARNING - CFU 9 - Obligatory 4. SPEECH PROCESSING AND RECOGNITION - CFU 6 - Obligatory 5. COMPUTATIONAL VISION - CFU 6 – Obligatory 6. WELL-BEING TECHNOLOGIES - CFU 6 – Elective 7. NATURAL LANGUAGE PROCESSING - CFU 6 – Obligatory 8. MULTIAGENTS SYSTEMS - CFU 6 – Obligatory		

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Data Science Courses in Curriculum	1. LARGE-SCALE COMPUTING - CFU 9 – Obligatory 2. DATA VISUALIZATION - CFU 6 – Obligatory
Robotics Courses in Curriculum	NONE
Other Fundamental Courses	1. ADDITIONAL USEFUL KNOWLEDGE - CFU 3 – Obligatory 2. COMPUTATIONAL NEUROENGINEERING - CFU 6 - Elective 3. TOPICS IN COMPUTER SCIENCE - CFU 6 - Elective 4. HIGH PERFORMANCE COMPUTING - CFU 9 – Obligatory 5. DATA PROTECTION & PRIVACY - CFU 6 – Elective
Teaching and Research Labs	1. Lab SW1: 32PC workstations for training at all levels (BSc and MSc) 2. Lab SW2: 24 PC workstations for training at all levels (BSc and MSc) 3. Research Group Labs: Advanced workstations and HPC facilities including NVIDIA GPUs, biosensors and wearable and ambient sensors
Research Groups (d)	1. Artificial intelligence 2. Data Science and Engineering 3. Secure and Reliable Systems 4. Human-Computer Interaction
	5. Science and Technology for Health 6. Robotics and Autonomous Systems 7. Systems Engineering

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Collaboration with Industry (e) (List of sample projects)	1. Company : LEONARDO - Topic: Technological support 2. Company : CETENA - Topic: Technological support 3. Company : GENOA Municipality - Topic: Technological support 4. Company : CAP - Topic: Technological support 5. Sponsor : EC - Project name: Daydream 6. Sponsor : CINI - Project name: ELISE 7. Sponsor : EC - Project name: Jemaro 8. Sponsor : EC - Project name: IENE 9. Sponsor : Union Des Partner Industries Ferroviaires - Project name: OPTIMA 10. Sponsor : EU ESF - Project name: SENIOR

Summary and Notes

(a) Complete info available at https://courses.unige.it/10852, https://servizionline.unige.it/unige/stampa_manifesto/MF/2020/10852.html

(b) The Italian Credit system is based on the CFU (Credito Formativo Universitario) corresponding to 25 student hours. 1 CFU = 1 ECTS (European Credit Transfer and Accumulation System). Each Department decides about the number of hours of lecture corresponding to one CFU. The DIBRIS -Dept of Informatics, Bioengineering, Robotics and Systems Engineering assigns 8 hours of lecture to one CFU.

(c) The weight of the FINAL DISSERTATION is 6 CFU.

(d) The research groups at DIBRIS are informal aggregation of researchers. The reported list is not exhaustive .

(e) The technological transfer is also operated trough 10 active spin-offs of the DIBRIS: BIO3DMATRIX, LCAIR, DOCSPACE, HEALTHROPY,GERMINA, LOGNESS, SCREENNEURO FARM, TALOS, TESEO, VEGA RESEARCH LABORATORIES, ZENA BYTE.

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Number	16		
Program Name	Artificial Intelligence and Data Engineering		
University	University of Pisa		
Country	Italy		
URL	https://computer.ing.unipi.it/aide-lm		
Program Focus	☒ AI	☒ Data Science	☐ Robotics
Credit Hours	120		
AI Credit Hours	30-40		
Data Science Credit Hours	24-34		
Robotics Credit Hours	6		
AI Courses in Curriculum	66. Data Mining and Machine Learning (None) (obligatory) 67. Computational Intelligence and Deep Learning (None) (obligatory) 68. Process Mining and Intelligence (None) (obligatory) 69. Symbolic and Evolutionary Artificial Intelligence (None) (obligatory) 70. Process Mining and Intelligence ng (None) (obligatory)		
Robotics Courses inCurriculum	68. Robotica e Macchine Intelligenti (None) (elective)		

Other Fundamental Courses	105. **Cloud Computing** (None) (obligatory) 106. Large-Scale and Multi-Structured Databases (None) (obligatory) 107. Business and Project Management (None) (obligatory) 108. Optimization Methods and Game Theory (None) (obligatory) 109. Multimedia Information Retrieval and Computer Vision (None) (obligatory) 110. Performance Evaluation of Computer Systems and Networks (None) (elective) 111. Mobile and Social Sensing Systems (None) (elective) 112. Distributed Systems and Middleware Technologies (None) (elective) 113. Internet of Things (None) (elective)
Teaching and Research Labs	7. **Networking and Cloud Computing Lab** (List of major equipment, if available) 8. **CyberSecurity Lab** (List of major equipment, if available) 9. Data Science and Engineering Lab 10. Lab Cloud Computing, Big Data & Cybersecurity
Research Groups	24. 25.
Collaboration with Industry (List of sample projects)	10. 11.
Summary and Notes	

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Number	17		
Program Name	Robotics And Automation Engineering		
University	University of Pisa		
Country	Italy		
URL	http://www.aut.ing.unipi.it/index.php		
Program Focus	☐ AI	☐ Data Science	☒ Robotics
Credit Hours	120		
AI Credit Hours	0-12		
Data Science Credit Hours			
Robotics Credit Hours	66-84		
AI Courses in Curriculum	71. Intelligent Systems (None) (elective) 72. Computational Intelligence (None) (elective)		
Robotics Courses inCurriculum	69. Mechanics of Robots (None) (obligatory) 70. System Theory and Control Theory (None) (obligatory) 71. **Digital Control** (None) (obligatory) 72. **Process Control** (None) (obligatory) 73. Control and Identification of Uncertain Systems (None) (obligatory) 74. **Robotics** (None) (obligatory) 75. Aerospace Robotics (None) (elective)		

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	76. Underwater Systems (None) (elective) 77. Cybernetic and Physiological Systems (None) (elective) 78. Guidance and Navigation Systems (None) (obligatory)
Other Fundamental Courses	114. Probability and Stocastic Processes (None) (obligatory) 115. Electronic Systems for Robotics and Automation (None) (elective) 116. Real Time Systems (None) (elective) 117. Control of energy systems (None) (elective) 118. Mechanics and Mechatronics Laboratory (None) (elective) 119. **Vehicle Dynamics** (None) (elective) 120. Modelling and simulation of discrete event systems (None) (elective)
Teaching and Research Labs	11. **Advanced Manufacturing** (1 Franka Panda Robot, 1 UR10, Universal Robot, 1 LGV forklift, 1 XL SteelRobotnik) 12. **Aerial Robotics Lab** (4 Drones, Vicon Motion Tracking System with 10 cameras, 2 Camera Stabilizing gimbal) 13. **Manipulation and Grasping Lab** (2 LWR-II Kuka arms, 2 Franka Panda Emika, 3 Pisa IIT soft hands) 14. **Hands and Haptics Lab** (2 Pisa IIT soft hands, 1 DLR hand, Phantom and Delta Robots, Wearable devices)
	15. **Underwater Robotics Lab** (Zeno Underwater robot, sensors for underwater communication) 16. **Soft Robotics Lab** (Variable Stiffness Actuators, soft robots, soft materials)
Research Groups	26. 27.
Collaboration with Industry (List of sample projects)	12. 13.
Summary and Notes	

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Number	18		
Program Name	Autonomous Systems, M.Sc.		
University	University of Stuttgart		
Country	Germany		
URL	https://www.uni-stuttgart.de/en/study/study-programs/Autonomous-Systems-M.Sc./		
Program Focus	☒ AI	☐ Data Science	☒ Robotics
Credit Hours	3600		
AI Credit Hours	(in total 3780h offered)		
Data Science CreditHours	(in total 5130h offered)		
Robotics Credit Hours	(in total 3330h offered)		
AI Courses inCurriculum	1. Laboratory Big Data Machine Learning 3CP 2. Aspects of Autonomous Systems (obligatory) 6CP 3. Concepts of Automatic Control 6CP 4. Detection and Pattern Recognition 6CP 5. Distributed Systems 6CP 6. Distributed Systems II 6CP 7. Intelligent cyber-physical Systems 6CP 8. Machine Learning 6CP		

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	9. Smart Cities and Internet of Things 6CP 10. Dependability intelligent distributed automation systems 6CP 11. Reinforcement Learning() 6CP 12. Deep learning 6CP 13. Concepts of Automatic Control 6CP 14. Deep Learning Applications for Communications 3CP 15. Project Automatic Control 3CP 16. Internship System Dynamics 3CP 17. Optimal Control 6CP 18. Robust Control 6CP 19. Nonlinear Control 6CP 20. Model Predictive Control 6CP 21. Numerical Optimization and Optimal Control 6CP 22. Flat Systems 6CP 23. Statistical Learning and Stochastic Control 6CP

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Robotics Courses inCurriculum	1. Control Technology of Machine Tools and Industrial Robots 6CP 2. Applications of Robot Systems 6CP 3. Design of robot systems 3CP 4. Modeling, Analysis and Design of Advanced Kinematics 6CP 5. Computational Dynamics for Robotics 6CP 6. Trajectory Generation 3CP 7. Probabilistic Planning 6CP 8. Robots – Applications in Service Robotics 6CP 9. Practical Laboratory Automation() 3CP 10. Laboratory Project Computer Vision for Robotics 3CP 11. Laboratory Project Service Robotics 3CP 12. Automation Engineering II 6CP 13. Basic Principles of Modeling and Simulation 6CP 14. Robotics I 6CP 15. Modeling and Analysis of Automation Systems 6CP 16. Modeling and Identification of Dynamical Systems 6CP 17. Machine Dynamics 6CP 18. Modeling and Simulation in Mechatronics 6CP 19. Robotics I 6CP 20. Dynamics of Mechanical Systems 6CP 21. Nonlinear Dynamics of mechanical Systems 6CP

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Other FundamentalCourses	1. Automated and Connected Driving I + II 6CP 2. Systems Engineering II 6CP 3. Digital Signal Processing 6CP 4. Discrete Optimization 6CP 5. Optimization 6CP 6. Communications II 6CP 7. Computer architecture and computer organisation 6CP 8. Real-time Concepts for Embedded Systems 6CP 9. Laboratory Course Software Engineering 6CP 10. Statistical and Adaptive Signal Processing 6CP 11. Computer Vision 6CP 12. Correspondence Problems in Computer Vision 6CP
	13. Optical Sensor Engineering for Autonomous Systems 6CP 14. Advanced Mathematics for Signal and Information Processing 6CP 15. Automotive radar systems for autonomous driving 3CP 16. Computer Engineering II 6CP 17. Communications III 6CP 18. Embedded Controller and Data Networks in Vehicles 6CP 19. Data Engineering 6CP 20. Software Engineering for Real-Time Systems 6CP 21. Industrial Automation Systems 6CP 22. Technologies and methods of software systems II 6CP 23. Cloud Computing: Concepts and Technologies 6CP 24. Design of Digital Systems 6CP 25. Software System Safety 3CP

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	26. Digital Image processing 3CP 27. Distributed Parameter Systems 6CP 28. Convex Optimization 6CP 29. Dynamic Filtering 6CP 30. Uncertainty Quantification 6CP
Teaching and Research Labs	17. Laboratory – Institute of Engineering and Computational Mechanics 18. Laboratory – Institute for Systems Theory and Control 19. Practical Trainings – Institute for System Dynamics 20. Laboratory – Institute for Control Engineering of Machine Tools and Manufacturing Units 21. Laboratory – Institute for Nonlinear Mechanics 22. Machine Learning & Robotics Lab – IPVS 23. SOLA – Software Lab University of Stuttgart
Research Groups	28. Institute of Engineering and Computational Mechanics 29. Institute for Systems Theory and Control 30. Institute for System Dynamics 31. Institute for Control Engineering of Machine Tools and Manufacturing Units 32. Institute for Nonlinear Mechanics 33. Institute for Parallel and Distributed Systems 34. Fraunhofer IPA
Collaboration withIndustry (List of sample projects)	Only exemplarily: ZF Friedrichshafen, Bosch, Porsche, Daimler, Trumpf, Rexroth, Festo, …
Summary and Notes	

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The master's program Autonomous Systems was newly developed and started in the winter semester 2019/2020, so there are no graduates yet. The program can be seen as mixture of the other three programs mentioned above, i.e., it offers more AI courses than e.g. the Mechatronics program, but on the other hand it is less research-oriented than the Simulation Technology program, i.e., it considers more practical aspects. There are no compulsorycourses in this program, but thematic blocks from which the students chose their elective courses.

The University of Stuttgart mainly offers four Master of Science programs in AI and robotics. Their main features are summarized in the following table and further information about the courses in AI and robotics is provided. Note that the official teaching language for all four programs is German, although some courses are offered in English. There are virtually no obligatory courses in any of the four programs, meaning that each student can choose specialization subjects and courses according to their interests. Therefore, it is not possible to give an explicit number of credit hours in the following tables since this depends heavily on the subjects chosen. Thus, we have rather indicated the number of all credit hours of subjects that are offered. Of course, students cannot take all subjects.

It is assumed that the students have a strong theoretical background in mathematics, programing and modeling. Typically, most master students have obtained their bachelor's degree at the University of Stuttgart such that the master courses build on the corresponding bachelor's degree. However, since the programs we are dealing with have many similarities, students have the opportunity to change from one bachelor's program to another master's program without any additional effort.

In general, the Mechatronics program and the Engineering Cybernetics program belong to the engineering science programs. However, in a broader sense, both programs are also categorized as applied mathematics programs, especially the Engineering Cybernetics program. In both programs, students choose two different specialization subjects, giving them the opportunity to take courses in AI and robotics. Note that there is a lot of overlap with respect to the specialization subjects. Usually, one specialization subject is offered by one institute. Thus, each institute can teach its corresponding research expertise. In addition, this structure provides an incentive for institutes to attract highly qualified students to their research through exceptional teaching.

In order to strengthen the practical knowledge of the students, the courses are complemented by mandatory practical trainings, e.g., in the laboratories. Inaddition, the curriculum includes a minimum twelve-week industrial internship, often extended to six months as this is common practice in industry.

The Autonomous Systems program and the Simulation Technology program are cross-faculty programs. Therefore, students can choose a wide range of specialization subjects which include AI and robotics, but also, for instance, physics. Especially in the Simulation Technology program, a strong

theoretical background is required since the program is research-oriented. Both programs focus on theoretical aspects which are complemented by

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technical trainings. However, an industrial internship, as obligatory in the Mechatronics and Engineering Cybernetics program, is not required in these programs.

For general robotic studies, the Mechatronics M.Sc. program at the University of Stuttgart is recommended, as it covers a wide range of robotics problems based on fundamental knowledge in mathematics, programming and modeling. In addition, various practical trainings complement the theoretical courses. If a special focus is placed on general system dynamics and control engineering problems, the Engineering Cybernetics program is recommended. In this program, specialization subjects and additional courses in AI can also be chosen.

If the student's interests lie in the field of AI, the Simulation Technology or Autonomous Systems program is recommended. These study programs offer many specialization subjects and courses in AI, but also in robotics. The Simulation Technology program in particular is very research-oriented and therefore offers fewer practical aspects. The study program Autonomous Systems is newly developed, it started in the winter term 2019/2020.

Note that all possible elective courses are considered below in terms of credit hours, although a student obviously cannot choose all of them within his orher program. Furthermore, many of the courses listed below are part of a specialization subject such that not every course can be combined with every other. As noted above, we would like to iterate that the programs have many courses in common.

It is worth pointing out that that international studies are generally encouraged. There are additional double degree programs (e.g., with Chalmers University of Technology and Toyohashi University of Technology) which cover similar courses in AI and robotics. Students can also spend a semester abroad at the university's or institute's partners.

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Number	19		
Program Name	Engineering Cybernetics, M.Sc.		
University	University of Stuttgart		
Country	Germany		
URL	https://www.uni-stuttgart.de/en/study/study-programs/Engineering-Cybernetics-M.Sc./		
Program Focus	☒ AI	☐ Data Science	☒ Robotics
Credit Hours	3600		
AI Credit Hours	in total 4050h offered		
Data Science Credit Hours	in total 5490h offered		
Robotics Credit Hours	in total 3960h offered		
AI Courses inCurriculum	1. Machine Learning 6CP 2. Introduction to Distributed Artificial Intelligence 3CP 3. Reinforcement Learning 6CP 4. Statistical Learning and Stochastic Control 6CP 5. Deep learning 6CP 6. Concepts of Automatic Control (obligatory) 6CP		

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	7. Optimal Control 6CP 8. Robust Control 6CP 9. Nonlinear Control 6CP 10. Numerical Optimization and Optimal Control 6CP 11. Flat Systems 6CP 12. Machine Learning in System Dynamics 3CP 13. Model Predictive Control 6CP 14. Topics in Autonomous Systems and Control 6CP 15. Theoretical and Methodological Foundations of Autonomous Systems 6CP 16. Introduction to Adaptive Control 3CP 17. Networked Control Systems 6CP 18. Analysis and Control of Multi-agent Systems 3CP 19. Advanced Methods in Systems and Control Theory 3CP 20. Optimization and Optimal Control 6CP 21. Human-Computer Interaction 6CP 22. Detection and Pattern Recognition 6CP 23. Basic Principles of Artificial Intelligence 6CP
	24. Seminar – Computer Science 1 3CP 25. Similarity Mechanics Engineering and Artificial Intelligence 3CP 26. Matrix Computations in Signal Processing and Machine Learning 3CP 27. Deep Learning Applications for Communications 3CP

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Robotics Courses in Curriculum	1. Modeling and Simulation in Mechatronics 6CP 2. Dynamics of Mechanical Systems 6CP 3. Computational Dynamics for Robotics 6CP 4. Non-linear Dynamics 6CP 5. Modeling and Identification of Dynamical Systems 6CP 6. Dynamics of Discrete-Event Systems 6CP 7. Vehicle Dynamics 3CP 8. Flexible Multibody Systems 6CP 9. Optimization of Mechanical Systems 3CP 10. Practical Laboratory Applied Dynamics 3CP 11. Selected Problems of Dynamics 3CP 12. Selected Problems of Mechanics 3CP 13. Control Technology of Machine Tools and Industrial Robots 6CP 14. Control Engineering 6CP 15. Applications of Robot Systems 3CP 16. Practical Laboratory Automation 3CP 17. Hydraulics and Pneumatics in Control Technology 3CP 18. Control Architecture and Communication Technology 3CP 19. Applied Control Systems in Manufacturing Facilities 3CP 20. Robots – Applications in Service Robotics 3CP 21. Robots – Application in Industry 3CP

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	22. Design of robot systems 3CP 23. Modeling, Analysis and Design of Advanced Kinematics 6CP 24. Automation Engineering 3CP 25. Object-oriented modeling and simulation 6CP 26. Internship System Dynamics 3CP 27. Trajectory Generation 3CP 28. Robotics I 6CP 29. Robotics II 6CP
	30. Flight Mechanics 3CP 31. Flight Control 3CP 32. Nonlinear Dynamics of mechanical Systems 6CP 33. Nonsmooth Dynamics 6CP 34. Workshop Nonlinear Mechanics 3CP 35. Miscellaneous Topics in Mechanics 3CP 36. Nonlinear Structural Dynamics 6CP 37. Computational Dynamics for Robotics 6CP 38. Dynamics and Control of Legged Locomotion 3CP 39. Electrical Machines I 6CP 40. Automation Engineering II 6CP 41. Practical Course Robotics 6CP
Other Fundamental	1. Distributed Parameter Systems (obligatory) 6CP

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Courses	2. Model Reduction of Mechanical Systems 3CP 3. Uncertainty Quantification 6CP 4. Control Architecture and Communication Technology 6CP 5. Dynamic Filtering 6CP 6. Convex Optimization 6CP 7. Stochastic processes and modeling 6CP 8. Introduction into Chaostheory 6CP 9. Dynamics of non-smooth models 3CP 10. Nonlinear Programming 3CP 11. Methods of System Simulation and Analysis 3CP 12. Estimation Methods 3CP 13. Discretization Methods 3CP 14. Mechanics of Nonlinear Continua 6CP 15. Higher Analysis 9CP 16. Functional Analysis 9CP 17. Dynamics Systems 9CP 18. Partial Differential Equations (Modeling, Analysis, Simulation) 9CP 19. Introduction to Optimization 9CP 20. Stochastic Processes 9CP 21. Differential Geometry 9CP

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	22. Nonlinear Partial Differential Equations 9CP 23. Linear Matrix Inequalities in Control 9CP 24. Functional Analysis 2 9CP 25. Data Science in Production Technology 3CP 26. Automated and Connected Driving I+II 6CP 27. Computer Vision 6CP 28. Higher Mathematics IV for Cyberneticists 6CP 29. Efficient Programming 6CP
Teaching and Research Labs	1. Laboratory – Institute of Engineering and Computational Mechanics 2. Laboratory – Institute for Systems Theory and Control 3. Practical Trainings – Institute for System Dynamics 4. Laboratory – Institute for Control Engineering of Machine Tools and Manufacturing Units 5. Laboratory – Institute for Nonlinear Mechanics 6. Machine Learning & Robotics Lab - IPVS
Research Groups	1. Institute of Engineering and Computational Mechanics 2. Institute for Systems Theory and Control 3. Institute for System Dynamics 4. Institute for Control Engineering of Machine Tools and Manufacturing Units 5. Institute for Nonlinear Mechanics 6. Institute for Parallel and Distributed Systems

	7. Fraunhofer IPA
Collaboration with Industry (List of sample projects)	Only exemplarily: ZF Friedrichshafen, Bosch, Porsche, Daimler, Trumpf, Rexroth, Festo, …

Summary and Notes

As in the Mechatronics program, students choose two specialization subjects (18CP each). Many of the specialization subjects, especially in robotics, are similar to the subjects offered in the Mechatronics program. However, there are some additional subjects that have their focus more on a strong theoreticaland research background of engineering problems. Thus, there are more AI courses offered than in the Mechatronics program.

Note that in total only two explicit courses are mandatory (Concepts of Automatic Control and Distributed Parameter Systems). All other courses are chosen from various prescribed thematic blocks, for example, Advanced Control.

The University of Stuttgart mainly offers four Master of Science programs in AI and robotics. Their main features are summarized in the following table and further information about the courses in AI and robotics is provided. Note that the official teaching language for all four programs is German, although some courses are offered in English. There are virtually no obligatory courses in any of the four programs, meaning that each student can choosespecialization subjects and courses according to their interests. Therefore, it is not possible to give an explicit number of credit hours in the following tables since this depends heavily on the subjects chosen. Thus, we have rather indicated the number of all credit hours of subjects that are offered. Of course, students cannot take all subjects.

It is assumed that the students have a strong theoretical background in mathematics, programing and modeling. Typically, most master students have obtained their bachelor's degree at the University of Stuttgart such that the master courses build on the corresponding bachelor's degree. However, sincethe programs we are dealing with have many similarities, students have the opportunity to change from one bachelor's program to another master's program without any additional effort.

In general, the Mechatronics program and the Engineering Cybernetics program belong to the engineering science programs. However, in a broader

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sense, both programs are also categorized as applied mathematics programs, especially the Engineering Cybernetics program. In both programs, students choose two different specialization subjects, giving them the opportunity to take courses in AI and robotics. Note that there is a lot of overlap with respect to the specialization subjects. Usually, one specialization subject is offered by one institute. Thus, each institute can teach its corresponding research expertise. In addition, this structure provides an incentive for institutes to attract highly qualified students to their research through exceptional teaching.

In order to strengthen the practical knowledge of the students, the courses are complemented by mandatory practical trainings, e.g., in the laboratories. Inaddition, the curriculum includes a minimum twelve-week industrial internship, often extended to six months as this is common practice in industry.

The Autonomous Systems program and the Simulation Technology program are cross-faculty programs. Therefore, students can choose a wide range of specialization subjects which include AI and robotics, but also, for instance, physics. Especially in the Simulation Technology program, a strong theoretical background is required since the program is research-oriented. Both programs focus on theoretical aspects which are complemented by technical trainings. However, an industrial internship, as obligatory in the Mechatronics and Engineering Cybernetics program, is not required in these programs.

For general robotic studies, the Mechatronics M.Sc. program at the University of Stuttgart is recommended, as it covers a wide range of robotics problems based on fundamental knowledge in mathematics, programming and modeling. In addition, various practical trainings complement the theoretical courses.If a special focus is placed on general system dynamics and control engineering problems, the Engineering Cybernetics program is recommended. In this program, specialization subjects and additional courses in AI can also be chosen.

If the student’s interests lie in the field of AI, the Simulation Technology or Autonomous Systems program is recommended. These study programs offer many specialization subjects and courses in AI, but also in robotics. The Simulation Technology program in particular is very research-oriented and therefore offers fewer practical aspects. The study program Autonomous Systems is newly developed, it started in the winter term 2019/2020.

Note that all possible elective courses are considered below in terms of credit hours, although a student obviously cannot choose all of them within his orher program. Furthermore, many of the courses listed below are part of a specialization subject such that not every course can be combined with every other. As noted above, we would like to iterate that the programs have many courses in common.

It is worth pointing out that that international studies are generally encouraged. There are additional double degree programs (e.g., with Chalmers

University of Technology and Toyohashi University of Technology) which cover similar courses in AI and robotics. Students can also spend a semester abroad at the university’s or institute’s partners.

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Number	20		
Program Name	Mechatronics, M.Sc.		
University	University of Stuttgart		
Country	Germany		
URL	https://www.uni-stuttgart.de/en/study/study-programs/Mechatronics-M.Sc-00001./		
Program Focus	☐ AI	☐ Data Science	☒ Robotics
Credit Hours	3600		
AI Credit Hours	in total 2700h offered		
Data Science Credit Hours	in total 5040h offered		
Robotics Credit Hours	in total 4860h offered		

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AI Courses in Curriculum	• Concepts of Automatic Control 6CP • Optimal Control 6CP • Robust Control 6CP • Nonlinear Control 6CP • Model Predictive Control 6CP • Networked Control Systems 6CP • Analysis and Control of Multi-agent Systems 3CP • Statistical Learning and Stochastic Control 6CP • Multivariable Control 3CP • Introduction to Adaptive Control 3CP • Advanced Methods in Systems and Control Theory 3CP • Numerical Optimization and Optimal Control 6CP • Flat Systems 6CP • Machine Learning in System Dynamics 3CP • Dependability intelligent distributed automation systems 6CP • Detection and Pattern recognition 6CP • Deep learning 6CP • Matrix Computations in Signal Processing and Machine Learning 3CP
Robotics Courses inCurriculum	1. Flexible Multibody Systems 6CP 2. Control Technology of Machine Tools and Industrial Robots 6CP 3. Modeling and Simulation in Mechatronics 6CP

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	4. Optimization of Mechanical Systems 3CP 5. Modeling and Identification of Dynamical Systems 6CP
	6. Simulation Engineering 6CP 7. Design and manufacturing of micro- and nanoelectronic systems 6CP 8. Control Engineering 6CP 9. Applications of Robot Systems 6CP 10. Applied Control Systems in Manufacturing Facilities 6CP 11. Modeling, Analysis and Design of Advanced Kinematics 6CP 12. Robots – Applications in Service Robotics 6CP 13. Control Architectures and Communication Technology 3CP 14. Design of robot systems 3CP 15. Vehicle Dynamics 3CP 16. Dynamics of Discrete-Event Systems 6CP 17. Selected Problems of Mechanics 3CP 18. Automation Engineering 3CP 19. Object-oriented modeling and simulation 3CP 20. Trajectory Generation 3CP 21. Dynamics of Mechanical Systems 6CP 22. Nonlinear Dynamics of Mechanical Systems 6CP 23. Nonsmooth Dynamics 6CP

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	24. Computational Dynamics for Robotics 6CP 25. Dynamics and Control of Legged Locomotion 6CP 26. Discretization Methods 3CP 27. Electrical Machines I 6CP 28. Electrical Machines II 6CP 29. Electronic Motor 6CP 30. Practical Laboratory Automation 3CP 31. Project Automatic Control 3CP 32. Practical Laboratory Applied Dynamics 3CP 33. Internship System Dynamics 3CP 34. Workshop Nonlinear Mechanics 3CP
Other Fundamental Courses	1. Parallel Systems 6CP 2. Numerical Methods for Dynamics 6CP 3. Uncertainty Quantification 6CP 4. Model Reduction of Mechanical Systems 3CP
	5. Embedded Systems Engineering 6CP 6. Technologies and methods of software systems II 6CP 7. Computer architecture and computer organisation 6CP 8. Digital Signal Processing 6CP 9. Communications Transmission I 6CP

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	10. Design of Digital Systems 6CP 11. Convex Optimization 6CP 12. Stochastic processes and modeling 6CP 13. Electrical Signal Processing 6CP 14. Real-Time Data Processing 6CP 15. Distributed Parameter Systems 6CP 16. Dynamic Filtering 6CP 17. Mechanics of Nonlinear Continua 6CP 18. Basics of Micro Technology 6CP 19. Electronic Components in Microsystems Technology 3CP 20. Computer Engineering 6CP 21. Automation Engineering 6CP 22. System Concept and System Programming 6CPa. 23. Communication Networks Architecture and Design 6CP 24. Performance Modeling and Simulation 6CP 25. Network Security 3CP 26. Mobile Network Architecture Evolution 3CP 27. Statistical and Adaptive Signal Processing 6CP 28. Advanced Mathematics for Signal and Information Processing 6CP 29. Communications Transmission I 6CP 30. Communications III 6CP

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Teaching and Research Labs	1. Laboratory – Institute of Engineering and Computational Mechanics 2. Laboratory – Institute for Systems Theory and Control 3. Practical Trainings – Institute for System Dynamics 4. Laboratory – Institute for Control Engineering of Machine Tools and Manufacturing Units 5. Laboratory – Institute for Nonlinear Mechanics
Research Groups	**1.** Institute of Engineering and Computational Mechanics **2.** Institute for Nonlinear Mechanics
	3. Institute for Systems Theory and Control **4.** Institute for System Dynamics **5.** Institute for Control Engineering of Machine Tools and Manufacturing Units **6.** Fraunhofer IPA
Collaboration with Industry (List of sample projects)	Only exemplarily: ZF Friedrichshafen, Bosch, Porsche, Daimler, Trumpf, Rexroth, Festo, …

Summary and Notes

This study program is interdisciplinary in nature to prepare students to master any complex technological process. In addition to in-depth modules which also deal with AI and robotic topics, students choose two out of over twenty specialization subjects. It is important to highlight that there is no mandatorycourse in the program. However, there is a strong emphasis on robotics in most of the specialization subjects. The specialization subjects are supplemented by practical trainings. In addition, a minimum twelve-week industrial internship is part of the curriculum. The master's thesis and another student research project are completed in both specialization subjects.

The University of Stuttgart mainly offers four Master of Science programs in AI and robotics. Their main features are summarized in the following table and further information about the courses in AI and robotics is provided. Note that the official teaching language for all four programs is German,

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although some courses are offered in English. There are virtually no obligatory courses in any of the four programs, meaning that each student can choose specialization subjects and courses according to their interests. Therefore, it is not possible to give an explicit number of credit hours in the following tables since this depends heavily on the subjects chosen. Thus, we have rather indicated the number of all credit hours of subjects that are offered. Of course, students cannot take all subjects.

It is assumed that the students have a strong theoretical background in mathematics, programing and modeling. Typically, most master students have obtained their bachelor's degree at the University of Stuttgart such that the master courses build on the corresponding bachelor's degree. However, since the programs we are dealing with have many similarities, students have the opportunity to change from one bachelor's program to another master's program without any additional effort.

In general, the Mechatronics program and the Engineering Cybernetics program belong to the engineering science programs. However, in a broader sense, both programs are also categorized as applied mathematics programs, especially the Engineering Cybernetics program. In both programs, students choose two different specialization subjects, giving them the opportunity to take courses in AI and robotics. Note that there is a lot of overlap with respect to the specialization subjects. Usually, one specialization subject is offered by one institute. Thus, each institute can teach its corresponding research expertise. In addition, this structure provides an incentive for institutes to attract highly qualified students to their research through exceptional teaching.

In order to strengthen the practical knowledge of the students, the courses are complemented by mandatory practical trainings, e.g., in the laboratories. Inaddition, the curriculum includes a minimum twelve-week industrial internship, often extended to six months as this is common practice in industry.

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The Autonomous Systems program and the Simulation Technology program are cross-faculty programs. Therefore, students can choose a wide range of specialization subjects which include AI and robotics, but also, for instance, physics. Especially in the Simulation Technology program, a strong theoretical background is required since the program is research-oriented. Both programs focus on theoretical aspects which are complemented by technical trainings. However, an industrial internship, as obligatory in the Mechatronics and Engineering Cybernetics program, is not required in these programs.

For general robotic studies, the Mechatronics M.Sc. program at the University of Stuttgart is recommended, as it covers a wide range of robotics problems based on fundamental knowledge in mathematics, programming and modeling. In addition, various practical trainings complement the theoretical courses. If a special focus is placed on general system dynamics and control engineering problems, the Engineering Cybernetics program is recommended. In this program, specialization subjects and additional courses in AI can also be chosen.

If the student's interests lie in the field of AI, the Simulation Technology or Autonomous Systems program is recommended. These study programs offer many specialization subjects and courses in AI, but also in robotics. The Simulation Technology program in particular is very research-oriented and therefore offers fewer practical aspects. The study program Autonomous Systems is newly developed, it started in the winter term 2019/2020.

Note that all possible elective courses are considered below in terms of credit hours, although a student obviously cannot choose all of them within his orher program. Furthermore, many of the courses listed below are part of a specialization subject such that not every course can be combined with every other. As noted above, we would like to iterate that the programs have many courses in common.

It is worth pointing out that that international studies are generally encouraged. There are additional double degree programs (e.g., with Chalmers University of Technology and Toyohashi University of Technology) which cover similar courses in AI and robotics. Students can also spend a semester abroad at the university's or institute's partners.

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Number	21		
Program Name	Simulation Technology, M.Sc.		
University	University of Stuttgart		
Country	Germany		
URL	https://www.uni-stuttgart.de/en/study/study-programs/Simulation-Technology-M.Sc./		
Program Focus	☒ AI	☒ Data Science	☒ Robotics
Credit Hours	3600		
AI Credit Hours	(in total 4950h offered)		
Data Science Credit Hours	(in total 8640h offered)		
Robotics Credit Hours	(in total 3600h offered)		
AI Courses inCurriculum	1. Basic Principles of Artificial Intelligence 6CP 2. Introduction to Feedback Control Systems 6CP 3. Multivariable Control 3CP 4. Feedback Control Systems and Control Engineering 6CP 5. Concepts of Automatic Control 6CP 6. Optimal Control 6CP		

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	7. Robust Control 6CP 8. Nonlinear Control 6CP 9. Detection and Pattern Recognition 6CP 10. Machine Learning 6CP 11. Model Predictive Control 6CP 12. Numerical Optimization and Optimal Control 6CP 13. Flat Systems 6CP 14. Statistical Learning Theory 9CP 15. Linear Control Theory 9CP 16. Multivariable Control 3CP 17. Reinforcement Learning 6CP 18. Theoretical and Methodological Foundations of Autonomous Systems 6CP 19. Robust Control 9CP 20. Networked Control Systems 6CP 21. Control and System Design 6CP 22. Matrix Computations in Signal Processing and Machine Learning 3CP 23. Statistical Learning and Stochastic Control 6CP
	24. Deep learning for NLP 3CP 25. Deep learning 6CP 26. Deep Learning for Speech and Language Processing 6CP 27. Analyzing Software using Deep Learning 6CP

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Robotics Courses in Curriculum	1. Basic Principles of Modeling and Simulation 6CP 2. Advanced Mechanics I 6CP 3. Advanced Mechanics II 6CP 4. Machine Dynamics 6CP 5. Modeling and Simulation in Mechatronics 6CP 6. Flexible Multibody Systems 6CP 7. Optimization of Mechanical Systems 6CP 8. Non-linear Dynamics 6CP 9. Modeling and Identification of Dynamical Systems 6CP 10. Biorobotics 6CP 11. Robotics I 6CP 12. Stochastic and Statistical Topics in Modeling and Simulation 6CP 13. Dynamic Systems 9CP 14. Dynamics of Mechanical Systems 6CP 15. Nonlinear Dynamics of mechanical Systems 6CP 16. Design of robot systems 3CP 17. Modeling, Analysis and Design of Advanced Kinematics 6CP 18. Computational Dynamics for Robotics 6CP 19. Dynamics and Control of Legged Locomotion 6CP 20. Advanced Topics in Machine Learning 6CP

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	10. Partial Differential Equations (Modeling, Analysis, Simulation) 9CP 11. Introduction to Optimization 9CP 12. Stochastic Processes 9CP 13. Software Engineering 6CP 14. Discrete Optimization 6CP 15. Computer Vision 6CP 16. Distributed Parameter Systems 6CP 17. Convex Optimization 6CP 18. Numerics for High Performance Computing 3CP 19. Dynamic Filtering 6CP 20. Virtual Engineering 6CP 21. Linear Matrix Inequalities in Control 9CP 22. Programming Paradigms 6C 23. Nonlinear Programming 3CP 24. System Dynamics 3CP 25. Optimization 6CP 26. Fundamentals of Scientific Computing 6CP 27. High Performance Computing 6CP 28. Selected Topics of Scientific Computing 6CP 29. Efficient Programming 6CP 30. Advanced Seminar Computer Science 3CP

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	31. Practical Course Visual Computing 6CP 32. Functional Analysis 2 9CP 33. Introduction to Scientific Programming 6CP 34. Seminar: Mathematical Modelling(elective) 6CP 35. Advanced Simulation Methods 6CP 36. Computer Science Selection VI: Concepts of Programming Languages, Operating Systems 9CP 37. Discretization Methods 3CP 38. Parallel Numerics 6CP 39. Scientific Computing 9CP 40. Introduction to model order reduction of mechanical systems 6CP 41. Cloud Computing: Concepts and Technologies 6CP 42. Methods in Simulation Technology 3CP

	43. Automated and Connected Driving I+II 6CP 44. Cognitive Computing 3CP 45. Uncertainty Quantification 6CP 46. Mathematical Image Processing 9CP

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Teaching and Research Labs	1. Laboratory – Institute of Engineering and Computational Mechanics 2. Laboratory – Institute for Systems Theory and Control 3. Practical Trainings – Institute for System Dynamics 4. Laboratory – Institute for Control Engineering of Machine Tools and Manufacturing Units 5. Laboratory – Institute for Nonlinear Mechanics 6. Machine Learning & Robotics Lab – IPVS 7. SOLA – Software Lab University of Stuttgart
Research Groups	1. Institute of Engineering and Computational Mechanics 2. Institute for Systems Theory and Control 3. Institute for System Dynamics 4. Institute for Control Engineering of Machine Tools and Manufacturing Units 5. Institute for Nonlinear Mechanics 6. Institute for Parallel and Distributed Systems 7. Fraunhofer IPA
Collaboration with Industry (List of sample projects)	Only exemplarily: ZF Friedrichshafen, Bosch, Porsche, Daimler, Trumpf, Rexroth, Festo, …
Summary and Notes	

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The Simulation Technology program is very interdisciplinary and free-form, as it is cross-faculty. Thus, students can choose from a wide range of courses and thus take courses which cover robotics and AI topics. Notice that this program is very research oriented, but offers more courses in AI than, for instance, the Mechatronics program.

The University of Stuttgart mainly offers four Master of Science programs in AI and robotics. Their main features are summarized in the following table and further information about the courses in AI and robotics is provided. Note that the official teaching language for all four programs is German, although some courses are offered in English. There are virtually no obligatory courses in any of the four programs, meaning that each student can choose specialization subjects and courses according to their interests. Therefore, it is not possible to give an explicit number of credit hours in the following tablessince this depends heavily on the subjects chosen. Thus, we have rather indicated the number of all credit hours of subjects that are offered. Of course, students cannot take all subjects.

It is assumed that the students have a strong theoretical background in mathematics, programing and modeling. Typically, most master students have obtained their bachelor's degree at the University of Stuttgart such that the master courses build on the corresponding bachelor's degree. However, since the programs we are dealing with have many similarities, students have the opportunity to change from one bachelor's program to another master's program without any additional effort.

In general, the Mechatronics program and the Engineering Cybernetics program belong to the engineering science programs. However, in a broader sense, both programs are also categorized as applied mathematics programs, especially the Engineering Cybernetics program. In both programs, students choose two different specialization subjects, giving them the opportunity to take courses in AI and robotics. Note that there is a lot of overlap with respect to the specialization subjects. Usually, one specialization subject is offered by one institute. Thus, each institute can teach its corresponding research expertise. In addition, this structure provides an incentive for institutes to attract highly qualified students to their research through exceptional teaching.

In order to strengthen the practical knowledge of the students, the courses are complemented by mandatory practical trainings, e.g., in the laboratories. Inaddition, the curriculum includes a minimum twelve-week industrial internship, often extended to six months as this is common practice in industry.

The Autonomous Systems program and the Simulation Technology program are cross-faculty programs. Therefore, students can choose a wide range of specialization subjects which include AI and robotics, but also, for instance, physics. Especially in the Simulation Technology program, a strong theoretical background is required since the program is research-oriented. Both programs focus on theoretical aspects which are complemented by technical trainings. However, an industrial internship, as obligatory in the Mechatronics and Engineering Cybernetics program, is not required in these

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programs.

For general robotic studies, the Mechatronics M.Sc. program at the University of Stuttgart is recommended, as it covers a wide range of robotics problems based on fundamental knowledge in mathematics, programming and modeling. In addition, various practical trainings complement the theoretical courses. If a special focus is placed on general system dynamics and control engineering problems, the Engineering Cybernetics program is recommended. In this program, specialization subjects and additional courses in AI can also be chosen.

If the student's interests lie in the field of AI, the Simulation Technology or Autonomous Systems program is recommended. These study programs offer many specialization subjects and courses in AI, but also in robotics. The Simulation Technology program in particular is very research-oriented and therefore offers fewer practical aspects. The study program Autonomous Systems is newly developed, it started in the winter term 2019/2020.

Note that all possible elective courses are considered below in terms of credit hours, although a student obviously cannot choose all of them within his orher program. Furthermore, many of the courses listed below are part of a specialization subject such that not every course can be combined with everyother. As noted above, we would like to iterate that the programs have many courses in common.

It is worth pointing out that that international studies are generally encouraged. There are additional double degree programs (e.g., with Chalmers University of Technology and Toyohashi University of Technology) which cover similar courses in AI and robotics. Students can also spend a semester abroad at the university's or institute's partners.

Appendix C: Surveying B.Sc. Programs Report

DeCAIR: Developing Curricula for Artificial Intelligence andRobotics

Report on Surveying International B.Sc. Programs in AI and Robotics

Activity Information:

Work Package	WP1 – Surveys and Needs Identification
Task	1.3 Survey and evaluation of AI and Robotics courses in similar bachelor programs
Activity Coordinator	TTU (Murad Alaqtash)
Participating Partners	TTU, UJ, BAU, UGR, UNIGE, UST, UNIPI
Objective(s)	Surveying international B.Sc. programs that are specialized in AIR c significant AIR component to identify their main attributes in te curriculum, syllabi, resources, faculty members' expertise and collaboration with industry.
Due Date	March 7th

Instructions:

1. Activity coordinator is to coordinate with the focal point of UJ and BAU to collect information of **eight** international AIR **B.Sc. programs**. EU partners may provide suggestions regarding the programs to survey.
2. Activity coordinator is to coordinate with EU partners to provide information about their AIR B.Sc. Programs.
3. Information to be collected for each program is the main attributes reported in Table 1.3.1, and files for the Curriculum and Syllabi.
4. Activity coordinator is responsible for gathering the collected files and store them to the ***Surveyed_BSC_Programs*** shared folder. The files for each program should be stored in a separate folder with the following syntax ***ProgramName_UniversityName***.
5. This report is to be prepared through collaboration of different partners and submitted tothe WP lead by the activity coordinator. Filled tables should be added to this report.

Summary and Recommendations:

Different international AIR related B.Sc. programs were explored. Eventually, 11 bachelor programs from USA, Europe, and Asia were selected for this survey. According to the comprehensive and intensive search, it is clearly noticed that the majority of undergraduate programs are either computer science or electrical and computer engineering programs with minors or concentrations offer a set of AIR courses.

In general, the following courses are common between all programs:

- Introduction to Artificial Intelligence
- Machine Learning
- Natural Language processing
- Image processing and Computer Vision
- Introduction to Intelligent Robotic Systems/Autonomous Robotics

The University of Stuttgart mainly offers three Bachelor of Science programs in AI and robotics. Their main features are summarized in the following table and further information is provided regarding the courses in AI and robotics. Note that the official teaching language for all three programs is German, although some courses are offered in English.

In general, the emphasis in the first (especially four) semesters is on building a strong theoretical background for the students. To this end, and to provide a broad basic knowledge, the focus there is on mathematics, programming, and modeling. These points are also covered by the courses at the Institute of Engineering and Computational Mechanics and furthermore show our research work. After the first semesters, a wide range of specialization subjects is offered. Many of these are in robotics and AI. The strong theoretical backgroundof the students is complemented by various practical trainings, especially in the Mechatronics and Engineering Cybernetics program. Those practical trainings are often integrated in the lecture course and carried out in the institute's own laboratories.

For general robotic studies, the Mechatronics B.Sc. program at the University of Stuttgart is recommended, as it covers a wide range of robotics problems based on fundamental knowledge in mathematics, programming and modeling. In addition, various practical trainings complete the theoretical courses.

If special attention is paid to general system dynamics and control engineering problems, the Engineering Cybernetics program is recommended. There is much overlap between this program and the Mechatronics program, especially in the area of robotics. Based on a strong mathematical background, some courses are attended together with mathematicians andphysicists, students may continue to choose courses in AI.

The third recommended program is Simulation Technology. This program is research- oriented and involves almost all faculties of the University of Stuttgart. Therefore, students can choose almost any course, with many of them covering robotics and AI.

Note that subsequently, all possible elective courses are considered in terms of credit hours, although of course a student cannot choose all of them within their program.

Surveyed Programs

Table 1.3.1 Attributes of Surveyed B.Sc. Programs

Number	1	
Program Name	Computer science with artificial intelligence BSc (Hons)	
University	University of Nottingham Malaysia	
Country	UK, China, Malaysia	
URL	https://www.nottingham.edu.my/Study/Undergraduate-courses/Computer-Science/Computer-Science-with-Artificial-IntelligenceBSc-Hons.aspx	
Program Nature	☒ General program with AI component ☐ General program with Data Science component ☐ General program with Robotics component	☐ Specialized program in AI ☐ Specialized program in Data Science ☐ Specialized program in Robotics
Total Credit Hours	1+3 years	
AI Credit Hours	21	
Data Science Credit Hours	-	
Robotics Credit Hours	3	

AI Courses in Curriculum	1. Fundamentals of Artificial Intelligence (obligatory) 2. Artificial Intelligence Methods (obligatory) 3. Language and Computation (obligatory) 4. Computer Vision (obligatory) 5. Designing Intelligent Agents (obligatory) 6. Artificial Intelligence Methods (obligatory) 7. Language and Computation (obligatory)
Robotics Courses inCurriculum	1. Autonomous Robotic Systems (obligatory)
Fundamental Courses toSupport AIR	1. Computer Fundamentals (obligatory) 2. Databases and Interfaces (obligatory) 3. Mathematics for Computer Scientists (obligatory) 4. Programming and Algorithms (obligatory) 5. Programming Paradigms (obligatory) 6. Software Engineering (obligatory) 7. Systems and Architecture (obligatory) 8. Algorithms Correctness and Efficiency (obligatory) 9. Operating Systems and Concurrency (obligatory) 10. Software Engineering Group Project (obligatory) 11. Software Maintenance (obligatory) 12. Software Specification (elective)

	13. C++ Programming (elective)
Teaching and Research AIRLabs	
Research Groups	1. Computer Vision, 2. Evolutionary Computation, 3. Hypermedia, 4. Intelligent Reasoning Agents, 5. Machine Learning, 6. Neural Computation and 7. Operational Research.
Collaboration with Industry (List of sample projects)	1. 2.
Summary and Notes	
Computer science with artificial intelligence is a computer science program with more specialist skills and knowledge in artificial intelligence (AI). In addition to fundamental computer science modules, the course covers topics including computer vision, expert systems, heuristic optimisation, the historyand philosophy of artificial intelligence, intelligent agents, machine learning, neural networks and other intelligent systems. The Foundation in Science (2 or 3 semesters full-time) is 1+3 year programme that results in direct progression to the undergraduate programs. This rigorous programme provides students with a strong academic background that will result in enhanced language, mathematics, critical thinking and studyskills.	

Number	2	
Program Name	Intelligent Sys Engineering BS	
University	INDIANA UNIVERSITY BLOOMINGTON	
Country	USA	
URL	https://engineering.indiana.edu/programs/bs-intelligent-systems-engineering/index.html	
Program Nature	☒ General program with AI component ☐ General program with Data Science component ☐ General program with Robotics component	☐ Specialized program in AI ☐ Specialized program in Data Science ☐ Specialized program in Robotics
Total Credit Hours	120 (4 Years)	
AI Credit Hours	12	
Data Science Credit Hours	6	
Robotics Credit Hours	3	

AI Courses in Curriculum	https://igps.iu.edu/sisaadm-prd/maps/view/d8d4dc49-d8b2-4e19-8575-5e66b75003cb https://bulletins.iu.edu/iub/sice/2020-2021/undergraduate/courses/engineering.shtml https://bulletins.iu.edu/iub/sice/2020-2021/undergraduate/courses/computer-science.shtml 1. Intelligent Systems I 2. Intelligent Systems II 3. High Performance Computing (Elective) 4. Engineering Cloud Computing (Elective) 5. Data Representation (Elective) 6. Big Data Analytics (Elective) 7. Big Data Applications (Elective) 8. Scientific Visualization (Elective) 9. Introduction to Artificial Intelligence (Elective) 10. Game Development (Elective) 11. Principles of Machine Learning (Elective) 12. Introduction to Computer Vision (Elective) 13. Interactive Graphics (Elective)
Robotics Courses in Curriculum	1. Embedded Systems (Elective) 2. Autonomous Robotics (Elective)

Fundamental Courses toSupport AIR	1. Engineering Innovation & Design 2. Engineering Computer Architectures 3. Software Systems Engineering 4. Computer Systems Engineering 5. Engineering Cyber-Physical Systems 6. Systems, Signals & Control 7. Statistics 8. Advanced Undergraduate Engineering Mathematical Methods 9. Digital Design With FPGAS 10. Introduction To Modeling And Simulation 11. Engineering Networks 12. Engineering Operating Systems 13. Engineering Distributed Systems (Elective) 14. Image Processing (Elective)
Teaching and Research AIRLabs	
Research Groups	
Collaboration with Industry (List of sample projects)	
Summary and Notes	
After completing the 120 hrs program, students can choose a concentration program with additional 30 hrs. the concentrations are: Bioengineering Computer Engineering/Cyber-Physical Systems, and Nanoscale Systems Engineering. Students may obtain a minor degree by successfully completing five courses totaling a minimum of 15 hrs. minors are Human-Centered Computing , Human-Computer Interaction/Design, , Virtual Reality, Animal-Computer Interaction, Computer Science, and Intelligence Studies. https://bulletins.iu.edu/iub/sice/2020-2021/undergraduate/degree-programs/certificates-minors.shtml	

Number	3	
Program Name	B.Sc. in Artificial Intelligence	
University	Carnegie Mellon University	
Country	USA	
URL	https://www.cs.cmu.edu/bs-in-artificial-intelligence/curriculum	
Program Nature	☐ General program with AI component ☐ General program with Data Science component ☐ General program with Robotics component	☒ Specialized program in AI ☐ Specialized program in Data Science ☒ Specialized program in Robotics
Total Credit Hours	120	
AI Credit Hours	4 core + 2 elective courses	
Data Science Credit Hours	Elective courses can be offered in the data science field.	
Robotics Credit Hours	2 elective courses	
AI Courses in Curriculum	1. Concepts in Artificial Intelligence 2. Introduction to AI: Representation and Problem Solving 3. Introduction to Machine Learning 4. Take one of the following courses:	

	a. Introduction to Natural Language Processing b. Introduction to Computer Vision
Robotics Courses inCurriculum	
Fundamental Courses toSupport AIR	- Decision Making and Robotics Cluster o Neural Computation (15-386) http://www.cnbc.cmu.edu/~tai/nc17.html o Autonomous Agents (15-482) http://www.cs.cmu.edu/~15482-f19/index.html o Truth, Justice and Algorithms (15-483) o Cognitive Robotics (15-494) https://www.cs.cmu.edu/afs/cs/academic/class/15494-s19/index.html o Strategic Reasoning for AI (new) o Planning Techniques for Robotics (16-350) http://www.cs.cmu.edu/~maxim/classes/robotplanning/ o Mobile Robot Programming Laboratory (16-362) http://www.cs.cmu.edu/~alonzo/teaching/16x62/16x62.html o Robot Kinematics and Dynamics (16-384) - Machine Learning Cluster o Deep Reinforcement Learning and Control (10-403) http://www.andrew.cmu.edu/course/10-403/ o Intermediate Deep Learning (10-417) https://andrejristeski.github.io/10417-20/ o Machine Learning for Structured Data (10-418) http://www.cs.cmu.edu/~mgormley/courses/10418/about.html o Machine Learning for Text Mining (11-441) http://www.cs.cmu.edu/~yiming/MLTM-f20-index.htm o Introduction to Deep Learning (11-485) https://deeplearning.cs.cmu.edu/S21/index.html o Advanced Data Analysis (36-402) https://www.stat.cmu.edu/~cshalizi/uADA/15/ - Perception and Language Cluster o Search Engines (11-442) o Speech Processing (11-492)

	o Computational Perception (15-387) o Computational Photography (15-463) o Vision Sensors (16-421) - Human-AI Interaction Cluster o Design of Artificial Intelligence Products (05-317) https://hcii.cmu.edu/courses/design-ai-products-and-services o Human-AI Interaction (05-318) http://www.humanaiclass.org/ o Designing Human-Centered Systems (05-391) o Human-Robot Interaction (16-467)
Teaching and Research AIR Labs	
Research Groups	**https://www.ml.cmu.edu/research/ https://www.ri.cmu.edu/**
Collaboration with Industry (List of sample projects)	3. 4.
Summary and Notes	
This program is specialized in AI and have many courses in AI and Robotics and data science This program is supported by other departments like Computer Science Department, Human-Computer Interaction Institute, Institute for Software Research, Language Technologies Institute, Machine Learning Department and Robotics Institute.	

Number	4	
Program Name	B.S. in Computer Science & Engineering: Artificial Intelligence/Robotics Track Option	
University	University of Minnesota	
Country	USA	
URL	https://cse.umn.edu/cs/ba-bs https://cse.umn.edu/cs/track-electives#AI	
Program Nature	☒ General program with AI component ☐ General program with Data Science component ☒ General program with Robotics component	☐ Specialized program in AI ☐ Specialized program in Data Science ☐ Specialized program in Robotics
Total Credit Hours	120	
AI Credit Hours	At least 4 courses to fulfill the requirements for the track and the students can select from clusters of courses in all thesedomains	
Data Science Credit Hours		
Robotics Credit Hours		

AI Courses in Curriculum	- CSCI 4511W - Introduction to Artificial Intelligence (4 cr) https://www-users.cs.umn.edu/~gini/4511/ - CSCI 5512 - Artificial Intelligence II (3 cr) http://vision.psych.umn.edu/users/schrater/schrater_lab/courses/AI2/ - CSCI 5561 - Computer Vision (3 cr) https://www-users.cs.umn.edu/~hspark/csci5561_F2020/csci5561.html - CSCI 5521 - Introduction to Machine Learning (3 cr) https://www-users.cselabs.umn.edu/classes/Fall-2020/csci5521-001/index.php?page=syllabus - CSCI 5523 - Introduction to Data Mining (3 cr) https://canvas.umn.edu/courses/98222 - CSCI 5525 - Machine Learning (3 cr) https://zstevenwu.com/courses/f19/csci5525/
Robotics Courses inCurriculum	- CSCI 5551 - Introduction to Intelligent Robotic Systems (3 cr) http://mars.cs.umn.edu/classes/csci5551/ - CSCI 5552 - Sensing and Estimation in Robotics (3 cr) http://mars.cs.umn.edu/classes/csci5552/ - CSCI 5715 - From GPS and Virtual Globes to Spatial Computing (3 cr) http://classinfo.umn.edu/?shekhar+CSCI5715+Fall2016
Fundamental Courses toSupport AIR	
Teaching and Research AIRLabs	
Research Groups	- Artificial Intelligence, Robotics, and Vision Lab - Interactive Robotics and Vision Laboratory - Visual Information Processing Lab - Computational Perception and Action Lab - Applied Motion Lab https://cse.umn.edu/cs/robotics-AI?field_category_target_id=7046

Collaboration with Industry (List of sample projects)	5. 6.
Summary and Notes	
Choose at least 4 if your goal is to “complete” a track. Core course (choose at least 2) CSCI 4511W - Introduction to Artificial Intelligence (4 cr)CSCI 5512 - Artificial Intelligence II (3 cr) CSCI 5551 - Introduction to Intelligent Robotic Systems (3 cr)CSCI 5561 - Computer Vision (3 cr) Other track courses CSCI 4707 - Practice of Database Systems (3 cr) CSCI 5521 - Introduction to Machine Learning (3 cr)CSCI 5523 - Introduction to Data Mining (3 cr) CSCI 5525 - Machine Learning (3 cr) CSCI 5552 - Sensing and Estimation in Robotics (3 cr) CSCI 5715 - From GPS and Virtual Globes to Spatial Computing (3 cr)LING 5801 - Computational Linguistics (4 cr) PSY 5018H - Math Models Human Behavior (3 cr) PSY 5036W - Computational Vision (3 cr)	

Number	5	
Program Name	B.Sc. in Computer Science, Intelligent Systems track	
University	Columbia University	
Country	USA	
URL	https://www.cs.columbia.edu/education/undergraduate/ https://mice.cs.columbia.edu/c/d.php?d=253	
Program Nature	☒ General program with AI component ☐ General program with Data Science component ☒ General program with Robotics component	☐ Specialized program in AI ☐ Specialized program in Data Science ☐ Specialized program in Robotics
Total Credit Hours	7 courses (21 units)	
AI Credit Hours	5	
Data Science Credit Hours	1	
Robotics Credit Hours	1	
AI Courses in Curriculum	- COMS W4701 Artificial Intelligence http://www.cs.columbia.edu/~kathy/cs4701/ - COMS W4705 Natural Language Processing http://www.cs.columbia.edu/~mcollins/cs4705-spring2019/ - COMS W4706 Spoken Language Processing http://catalog.barnard.edu/search/?P=COMS%20W4706 - COMS W4731 Computer Vision http://w4731.cs.columbia.edu/	

	- COMS W4771 Machine Learning http://www.cs.columbia.edu/~verma/classes/ml/index.html
Robotics Courses inCurriculum	- COMS W4733 Computational Aspects of Robotics https://www.cs.columbia.edu/~allen/F19/
Fundamental Courses to Support AIR	
Teaching and Research AIR Labs	- Robotics Laboratory http://www.cs.columbia.edu/robotics/
Research Groups	
Collaboration with Industry (List of sample projects)	
Summary and Notes	

Number	6	
Program Name	B.Sc. in Artificial Intelligence	
University	University of Groningen	
Country	Netherland	
URL	https://www.rug.nl/bachelors/artificial-intelligence/?lang=en#!programme	
Program Nature	☐ General program with AI component ☐ General program with Data Science component ☐ General program with Robotics component	☒ Specialized program in AI ☐ Specialized program in Data Science ☐ Specialized program in Robotics
Total Credit Hours	180 European Credit Transfer and Accumulation System (ECTS)An academic year consists of 60 European Credits (ECs). Most courses are worth 5 EC. One EC is the equivalent of 28 hours of study (preparing for/attending classes, practical, exams, groupwork etc.). Bachelor Project (10 EC, Year 3, Elective) Minor Electives (15 EC, Year 3, Obligatory)	
AI Credit Hours	50 ECs (can be further extended through 15 EC of elective courses and 10 EC of Bachelor Project) Maximum Total: 75 EC	
Data Science Credit Hours	10 ECs (can be further extended through 15 EC of elective courses and 10 EC of Bachelor Project) Maximum Total: 35 EC	
Robotics Credit Hours	5 ECs (can be further extended through 15 EC of elective courses and 10 EC of Bachelor Project)	

	Maximum Total: 30 EC
AI Courses in Curriculum	5. Artificial Intelligence I (Year 1, Obligatory) 6. Introduction to Artificial Intelligence (Year 1, Obligatory) 7. Introduction to Logic (Year 1, Obligatory) 8. Introduction to the Brain (Year 1, Obligatory) 9. Advanced Logic (Year 2, Obligatory) 10. Architectures of Intelligence (Year 2, Obligatory) 11. Knowledge and Agent Technology (Year 2, Obligatory) 12. Language and Speech Technology (Year 2, Obligatory) 13. Neural Networks (Year 2, Obligatory) 14. Practicals in e.g. Language and Speech Technology… (Year 2, Obligatory) 15. Artificial Intelligence II (Year 3, Obligatory)
Robotics Courses in Curriculum	1. Autonomous Systems (Year 1, Obligatory) 2. Practicals in e.g. Autonomous Systems, Knowledge Technology… (Year 2, Obligatory)

Fundamental Courses toSupport AIR	1. Algorithms and Data Structures in C (Year 1, Obligatory) 2. Basic Scientific Skills (Year 1, Obligatory) 3. Calculus (Year 1, Obligatory) 4. Cognitive Psychology, Logic (Year 1, Obligatory) 5. General Linguistics (Year 1, Obligatory) 6. Imperative Programming (Year 1, Obligatory) 7. Linear Algebra and Multivariable Calculus (Year 1, Obligatory) 8. Object-Oriented Programming (Year 2, Obligatory) 9. Philosophy of Cognitive Science (Year 2, Obligatory) 10. Signals and Systems (Year 2, Obligatory) 11. Statistics (Year 2, Obligatory)
Teaching and Research AIRLabs	NA
Research Groups	8. Autonomous Perceptive Systems 9. Cognitive Modeling 10. Multi-Agent Systems 11. Robotics
Collaboration with Industry (List of sample projects)	NA - Only externally funded research projects by governmental programs and research foundations.
Summary and Notes	

Number	7	
Program Name	B.Sc. in Robotics and Intelligent Systems	
University	Jacobs University	
Country	Germany	
URL	https://www.jacobs-university.de/study/undergraduate/programs/robotics-and-intelligent-systems	
Program Nature	☐ General program with AI component ☐ General program with Data Science component ☐ General program with Robotics component	☒ Specialized program in AI ☐ Specialized program in Data Science ☒ Specialized program in Robotics
Total Credit Hours	180 European Credit Transfer and Accumulation System (ECTS)An academic year consists of 60 European Credits (ECs). Most courses are worth 5 EC. One EC is the equivalent of 28 hours of study (preparing for/attending classes, practical, exams, groupwork etc.). **First Year:** Students select introductory modules with a total of 45 EC from the **CHOICE** area of a variety of study programs, of which 22.5 EC will be from their intended major. **Second Year:** Students take modules with a total of 45 EC from in-depth, discipline-specific **CORE** modules. **Third Year:** RIS students take 15 EC of major-specific and major-related **Specialization** modules to consolidate their knowledge at the current state of research in areas of their choice. **Jacobs Track:** An important feature of Jacobs University's educational concept, runs parallel to the disciplinary modules across all study years and is an integral part of the study program. Students are required to take 20 EC in the **Methods** area.	

AI Credit Hours	20 EC (can be further extended by 7.5 EC through CHOICE and Specialization modules) Maximum Total: 27.5 EC
Data Science Credit Hours	0 ECs (can be further extended by 5 EC through Methods modules) Maximum Total: 5 EC
Robotics Credit Hours	35 ECs (can be further extended by 17.5 EC through CHOICE and Specialization modules) Maximum Total: 52.5 EC
AI Courses in Curriculum	16. CHOICE Module: Introduction to Robotics and Intelligent Systems (Year 1, 7.5 EC, Common for AI, andRobotics) 17. CORE Module: RIS Project (Year 2, 5 EC, Common for AI, and Robotics) 18. CORE Module: RIS Lab (Year 2, 5 EC, Common for AI and Robotics) 19. CORE Module: Machine Learning (Year 2, 5 EC) 20. CORE Module: Artificial Intelligence (Year 2, 5 EC)
Robotics Courses inCurriculum	1. CHOICE Module: Introduction to Robotics and Intelligent Systems (Year 1, 7.5 EC, Common for AI, andRobotics) 2. CORE Module: RIS Project (Year 2, 5 EC, Common for AI, and Robotics) 3. CORE Module: RIS Lab (Year 2, 5 EC, Common for AI, and Robotics) 4. CORE Module: Robotics (Year 2, 5 EC) 5. CORE Module: Automation (Year 2, 5 EC) 6. CORE Module: Embedded Systems (Year 2, 5 EC) 7. CORE Module: Control Systems (Year 2, 5 EC) 8. CORE Module: Computer Vision (Year 2, 5CP) 9. Specialization: Human Computer Interaction (Year 3, 5 EC)

	10. Specialization: Marine Robotics (Year 3, 5 EC)
Fundamental Courses toSupport AIR	12. CHOICE Module: Programming in C and C++ (Year 1, 7.5 EC) 13. CHOICE Module: Algorithms and Data Structures (Year 1, 7.5 EC) 14. CORE Module: Software Engineering (Year 3, 7.5 EC) 15. CORE Module: Databases and Web Services (Year 3, 7.5 EC) 16. CORE Module Operations Research (Year 3, 5 EC) 17. CORE Module: PCB design and measurement automation (Year 3, 5 EC) 18. CORE Module: Information Theory (Year 3, 5 EC) 19. Specialization from MATH: Stochastic Processes (Year 3, 5 EC) 20. Specialization from MATH: Stochastic Methods Lab (Year 3, 7.5 EC) 21. Specialization: Optimization (Year 3, 5 EC) 22. Specialization: Distributed Algorithms (Year 3, 5 EC) 23. Specialization: Computer Graphics (Year 3, 5 EC) 24. Specialization: Web Application Development (Year 3, 5 EC) 25. Specialization: Digital Design (Year 3, 5 EC) 26. Methods: Calculus and Linear Algebra I (5 EC) 27. Methods: Calculus and Linear Algebra II (5 EC) 28. Methods: Probability and Random Processes (5 EC)
Teaching and Research AIR Labs	NA

Research Groups	NA
Collaboration with Industry (List of sample projects)	NA – Only externally funded research projects by governmental programs and research foundations.
Summary and Notes	

Number	8	
Program Name	Machine Intelligence and Robotics (MIR) 3 years (Another 4 years program is also offered)	
University	University for Information Science and Technology	
Country	Macedonia	
URL	http://uist.edu.mk/academics/bachelors/aitmir/	
Program Nature	☐ General program with AI component ☐ General program with Data Science component ☐ General program with Robotics component	☒ Specialized program in AI ☐ Specialized program in Data Science ☒ Specialized program in Robotics
Total Credit Hours	180 European Credit Transfer and Accumulation System (ECTS)An academic year consists of 60 European Credits (EC). Most courses are worth 6 ECT.	

	One EC is the equivalent of 28 hours of study (preparing for/attending classes, practical, exams, groupwork etc.).
AI Credit Hours	12 ECTs (can be further extended through 30 ECT of elective courses) Maximum Total: 42 ECT
Data Science Credit Hours	0 ECTs (can be further extended through 6 ECT) Maximum Total: 6 ECT
Robotics Credit Hours	6 ECT
AI Courses in Curriculum	21. Artificial Intelligence (Year 3, Obligatory) 22. Natural Language Processing (Elective) 23. Data Mining (Elective) 24. Pattern Recognition (Elective) 25. Data, Information, and Knowledge Engineering (Elective) 26. Computer Vision (Elective)
Robotics Courses inCurriculum	3. Basics of robotics (Year 2, Obligatory) 4. Sensors and Actuators (Year 2, Obligatory)

Fundamental Courses toSupport AIR	29. Introduction to Programming (Year 1, Obligatory) 30. Mathematics 1 (Year 1, Obligatory) 31. Physics (Year 1, Obligatory) 32. Discrete Mathematics (Year 1, Obligatory) 33. Object Oriented Programming (Year 1, Obligatory) 34. Mathematics 2 (Year 1, Obligatory) 35. Script Programming (Year 1, Obligatory) 36. Introduction to electric circuits (Year 1, Obligatory) 37. Mathematics 3 (Year 2, Obligatory) 38. Digital Logic Circuits (Year 2, Obligatory) 39. Signals and systems (Year 2, Obligatory) 40. Microprocessors (Year 2, Obligatory) 41. Control Theory 1 (Year 3, Obligatory) 42. Probability and Statistics (Year 3, Obligatory) 43. Programmable Logical Controllers (Year 3, Obligatory) 44. A large pool of 75 Major Elective courses (See PDF files, each of 6 ECT)
Teaching and Research AIRLabs	NA
Research Groups	NA – Two centers are available in the institution: 1. The Center for Intellectual Property and Technology Transfer (supported with a grant under The European Commission's Seventh Framework Programme) 2. The Center for BioEngineering

Collaboration with Industry (List of sample projects)	NA
Summary and Notes	

Number	8	
Program Name	Machine Intelligence and Robotics (MIR) 4 years (Another 3 years program is also offered)	
University	University for Information Science and Technology	
Country	Macedonia	
URL	http://uist.edu.mk/academics/bachelors/aitmir/	
Program Nature	☐ General program with AI component ☐ General program with Data Science component ☐ General program with Robotics component	☒ Specialized program in AI ☐ Specialized program in Data Science ☒ Specialized program in Robotics
Total Credit Hours	240 European Credit Transfer and Accumulation System (ECTS)An academic year consists of 60 European Credits (ECs). Most courses are worth 6 ECTs. One EC is the equivalent of 28 hours of study (preparing for/attending classes, practical, exams, groupwork etc.).	

AI Credit Hours	12 ECTs (can be further extended through 30 ECs of elective courses and 6 ECTs of Diploma Work)
Data Science Credit Hours	0 ECTs (can be further extended through 6 ECTs of elective courses and 6 ECTs of Diploma Work)
Robotics Credit Hours	18 ECTs (can be further extended through 6 ECTs of Diploma Work)
AI Courses in Curriculum	27. Artificial Intelligence (Year 3, Obligatory) 28. Machine Learning (Year 4, Obligatory) 29. Natural Language Processing (Elective) 30. Data Mining (Elective) 31. Pattern Recognition (Elective) 32. Data, Information, and Knowledge Engineering (Elective) 33. Computer Vision (Elective)
Robotics Courses inCurriculum	5. Basics of robotics (Year 2, Obligatory) 6. Sensors and Actuators (Year 2, Obligatory) 7. Automotive Control Systems (Year 4, Obligatory)

Fundamental Courses toSupport AIR	45. Introduction to Programming (Year 1, Obligatory) 46. Mathematics 1 (Year 1, Obligatory) 47. Physics (Year 1, Obligatory) 48. Discrete Mathematics (Year 1, Obligatory) 49. Object Oriented Programming (Year 1, Obligatory) 50. Mathematics 2 (Year 1, Obligatory) 51. Script Programming (Year 1, Obligatory) 52. Introduction to electric circuits (Year 1, Obligatory) 53. Mathematics 3 (Year 2, Obligatory) 54. Digital Logic Circuits (Year 2, Obligatory) 55. Signals and systems (Year 2, Obligatory) 56. Microprocessors (Year 2, Obligatory) 57. Control Theory 1 (Year 3, Obligatory) 58. Probability and Statistics (Year 3, Obligatory) 59. Programmable Logical Controllers (Year 3, Obligatory) 60. Control Theory 2 (Year 4, Obligatory) 61. Virtual and Augmented Reality (Year 4, Obligatory) 62. Communication Protocols (Year 4, Obligatory) 63. A large pool of 75 Major Elective courses (each of 6 ECTs)
Teaching and Research AIRLabs	NA

Research Groups	NA – Two centers are available in the institution: 3. The Center for Intellectual Property and Technology Transfer (supported with a grant under The European Commission's Seventh Framework Programme) 4. The Center for BioEngineering
Collaboration with Industry (List of sample projects)	NA
Summary and Notes	

Number	9	
Program Name	Mechatronics, B.Sc.	
University	University of Stuttgart	
Country	Germany	
URL	https://www.uni-stuttgart.de/en/study/bachelor-programs/mechatronics-b.sc./	
Program Nature	☒ General program with AI component ☒ General program with Data Science component ☒ General program with Robotics component	☐ Specialized program in AI ☐ Specialized program in Data Science ☐ Specialized program in Robotics

Total Credit Hours	5400
AI Credit Hours	450 obligatory + 90 elective
Data Science Credit Hours	1260 obligatory + 900 elective
Robotics Credit Hours	1530 obligatory + 1800 elective
AI Courses in Curriculum	34. Introduction to Feedback Control Systems (obligatory) 6 CP 35. Control Engineering (obligatory) 6 CP 36. Project Work: Engineering Cybernetics (obligatory) 3 CP 37. Multivariable Control (elective) 3CP
Robotics Courses inCurriculum	1. **System Dynamics** (obligatory) 3 CP 2. **Machine Dynamics** (obligatory) 6 CP 3. Electrical Drives (elective) 6 CP 4. Technologies and Methods of Software Systems I (elective) 6 CP 5. Information Technology in Production (elective) 6 CP 6. Programming and Software Development (obligatory) 9 CP 7. Applied Mechanics I (obligatory) 6 CP 8. Applied Mechanics II + III (obligatory) 12 CP 9. Numerical Methods for Dynamics (obligatory) 6 CP 10. Industrial Automation I (obligatory) 6 CP 11. Digital Signal Processing (elective) 6 CP

	12. Design and manufacturing of micro- and nanoelectronic systems (elective) 6 CP 13. Control Technology of Machine Tools and Industrial Robots (elective) 6 CP 14. Dynamics of Mechanical Systems (elective) 6 CP 15. IT architectures for production applications (elective) 6 CP 16. Non-linear Dynamics (elective) 6 CP 17. Dynamics of Discrete-Event Systems (elective) 6 CP 18. Measurement Engineering (obligatory) 3 CP
Fundamental Courses toSupport AIR	1. Advanced Mathematics I-III (obligatory) 27 CP 2. Foundations of Software Engineering (obligatory) 6 CP 3. Basics of Information Processing (elective) 6 CP 4. Modeling, Simulation and Optimization Processes (elective) 6 CP 5. Data Structures and Algorithms (obligatory) 9 CP 6. Simulation Methods for Dynamic Systems (elective) 6 CP 7. Stochastic Systems (elective) 6 CP 8. Technical Computer Science I (elective) 6 CP
Teaching and Research AIRLabs	1. Laboratory – Institute of Engineering and Computational Mechanics 2. Laboratory – Institute for Systems Theory and Control 3. Practical Trainings – Institute for System Dynamics 4. Laboratory – Institute for Control Engineering of Machine Tools and Manufacturing Units 5. Laboratory – Institute for Nonlinear Mechanics

Research Groups	1. Institute of Engineering and Computational Mechanics 2. Institute for Nonlinear Mechanics 3. Institute for Systems Theory and Control 4. Institute for System Dynamics 5. Institute for Control Engineering of Machine Tools and Manufacturing Units
Collaboration with Industry (List of sample projects)	Only exemplarily: ZF Friedrichshafen, Bosch, Porsche, Daimler, Trumpf, Rexroth, Festo, …
Summary and Notes	
This study program is interdisciplinary in nature to prepare students to master any complex technological process. However, there is a strong emphasis onrobotics, also in the obligatory courses. This program covers much of the basic knowledge in robotics and is therefore recommended as a robotics bachelor's degree at the University of Stuttgart. Additionally, students can choose courses to gain further in-depth knowledge also in the field of AI. Notice that the first four semesters aim to build a strong theoretical background for students. After that, a wide range of specialization subjects is offered.	

Number	10
Program Name	Engineering Cybernetics, B.Sc.
University	University of Stuttgart
Country	Germany

URL	https://www.student.uni-stuttgart.de/en/study-programs/Engineering-Cybernetics-B.Sc-00001./	
Program Nature	☒ General program with AI component ☒ General program with Data Science component ☒ General program with Robotics component	☐ Specialized program in AI ☐ Specialized program in Data Science ☐ Specialized program in Robotics
Total Credit Hours	5400	
AI Credit Hours	360 obligatory + 990 elective	
Data Science Credit Hours	990 obligatory + 3150 elective	
Robotics Credit Hours	1350 obligatory + 2430 elective	
AI Courses in Curriculum	1. Introduction to Feedback Control Systems (obligatory) 6 CP 2. Introduction to Engineering Cybernetics (obligatory) 3 CP 3. Multivariable Control (obligatory) 3 CP 4. Control Engineering (elective) 6 CP 5. Basic Principles of Artificial Intelligence (elective) 6 CP 6. Computer Science II (elective) 6 CP 7. Nonlinear Programming (elective) 3 CP 8. Machine Learning (elective) 6 CP 9. Reinforcement Learning (elective) 6 CP	
Robotics Courses inCurriculum	1. Machine Dynamics (elective) 6 CP	

	2. Dynamics of Mechanical Systems (elective) 6 CP 3. Applied Mechanics I-III (obligatory) 18 CP 4. Applied Mechanics IV (elective) 6 CP 5. Numerical Methods for Dynamics (obligatory) 6 CP 6. Measurement Engineering I (obligatory) 3 CP 7. Non-linear Dynamics (elective) 6 CP 8. Dynamics of Discrete-Event Systems (elective) 6 CP 9. Electrical Signal Processing (obligatory) 6 CP 10. Introduction to Electrical Engineering I (obligatory) 3 CP 11. Introduction to Electrical Engineering II (elective) 3 CP 12. System Dynamics and Simulation Methods for Dynamic Systems (obligatory) 9 CP 13. Measurement Engineering in Automation (elective) 3 CP 14. **Robotics I** (elective) 6 CP 15. Robots – Applications in Service Robotics (elective) 3 CP 16. Control Technology of Machine Tools and Industrial Robots (elective) 6 CP 17. Flight Mechanics (elective) 3 CP 18. **Flight Control** (elective) 3 CP 19. Satellite Control (elective) 3 CP 20. Modeling and Simulation in Mechatronics (elective) 6 CP 21. Selected Problems of Mechanics (elective) 3 CP 22. Electrical Drive Systems (elective) 12 CP

Fundamental Courses toSupport AIR	1. Advanced Mathematics I-III (obligatory) 27 CP 2. Probability Theory and Statistics (obligatory) 6 CP 3. **Analysis I-III** (elective) 27 CP 4. Linear Algebra and Analytical Geometry 1 (elective) 9 CP 5. Stochastic Systems (elective) 6 CP 6. Stochastic processes and modeling (elective) 6 CP 7. Real-Time Data Processing (elective) 6 CP 8. Parallel Systems (elective) 6 CP 9. Introduction to Software Engineering (elective) 6 CP 10. Foundations of Software Engineering (elective) 6 CP 11. Computer Vision (elective) 6 CP 12. Computer Networks (elective) 6 CP 13. Technologies and Methods of Software Systems I (elective) 6 CP 14. IT architectures for production applications (elective) 6 CP 15. Introduction to Information Security (elective) 6 CP 16. Control Architectures and Communication Technology (elective) 3 CP
Teaching and Research AIRLabs	1. Laboratory – Institute of Engineering and Computational Mechanics 2. Laboratory – Institute for Systems Theory and Control 3. Practical Trainings – Institute for System Dynamics 4. Laboratory – Institute for Control Engineering of Machine Tools and Manufacturing Units 5. Laboratory – Institute for Nonlinear Mechanics

	6. Machine Learning & Robotics Lab - IPVS
Research Groups	1. Institute of Engineering and Computational Mechanics 2. Institute for Systems Theory and Control 3. Institute for System Dynamics 4. Institute for Control Engineering of Machine Tools and Manufacturing Units 5. Institute for Nonlinear Mechanics 6. Institute for Parallel and Distributed Systems
Collaboration with Industry (List of sample projects)	Only exemplarily: ZF Friedrichshafen, Bosch, Porsche, Daimler, Trumpf, Rexroth, Festo, …
Summary and Notes	
The emphasis of this program is more on a strong theoretical and mathematical background of engineering problems. Especially general system dynamicsand control problems are covered. However, there is a strong overlap with the courses offered in the Mechatronics program, although many of them areelective courses for this program. In addition, further courses in Data Science and AI are offered.	

Number	11	
Program Name	Simulation Technology, B.Sc.	
University	University of Stuttgart	
Country	Germany	
URL	https://www.uni-stuttgart.de/en/study/study-programs/Simulation-Technology-B.Sc./	
Program Nature	☒ General program with AI component ☒ General program with Data Science component ☒ General program with Robotics component	☐ Specialized program in AI ☐ Specialized program in Data Science ☐ Specialized program in Robotics
Total Credit Hours	5400	
AI Credit Hours	450 obligatory + 3780 elective	
Data Science Credit Hours	1800 obligatory + 9720 elective	
Robotics Credit Hours	540 obligatory + 5220 elective	
AI Courses in Curriculum	1. Introduction to Simulation Technology 1 (obligatory) 6 CP 2. Introduction to Computer Science (obligatory) 9 CP 3. Basic Principles of Artificial Intelligence (elective) 6 CP 4. Theoretical Computer Science (elective) 6 CP 5. **Algorithmics** (elective) 6 CP	

	6. Theoretical Fundamentals of Computer Science (elective) 12 CP 7. Algorithms and Computability (elective) 6 CP 8. Introduction to Feedback Control Systems (elective) 6 CP 9. Feedback Control Systems and Control Engineering (elective) 6 CP 10. Concepts of Automatic Control (elective) 6 CP 11. **Robust Control** (elective) 6 CP 12. Nonlinear Control (elective) 6 CP 13. Detection and Pattern Recognition (elective) 6 CP 14. Computer Vision (elective) 6 CP 15. Machine Learning (elective) 6 CP 16. Programming Paradigms (elective) 6 CP 17. Multivariable Control (elective) 3 CP 18. Computed Networks (elective) 6 CP 19. Distributed Systems (elective) 6 CP 20. Linear Control Theory (elective) 9 CP 21. Statistical Learning and Stochastical Control (elective) 6 CP 22. **Deep learning** (elective) 6 CP

Fundamental Courses toSupport AIR	1. **Analysis I-II** (obligatory) 18 CP 2. Advanced Analysis for Simulation Technology I (obligatory) 9 CP 3. Advanced Analysis for Simulation Technology II (obligatory) 6 CP 4. Data Structures and Algorithms (obligatory) 6 CP 5. Fundamentals of Experimental Physics I-II (obligatory) 15 CP 6. Statistics and Optimization for Simulation Technology (obligatory) 6 CP 7. Numerical Mathematics 1 (elective) 9 CP 8. Numerical Mathematics (elective) 9 CP 9. Numerical Fundamentals (elective) 6 CP 10. Numerical Mathematics for SimTech (elective) 6 CP 11. Numerical and Stochastic Fundamentals (elective) 9 CP 12. Linear Algebra and Analytical Geometry I-II (elective) 18 CP 13. Probability Calculus (elective) 9 CP 14. Higher Analysis (elective) 9 CP 15. Functional Analysis (elective) 9 CP 16. Partial Differential Equations (elective) 9 CP 17. Computability and Complexity (elective) 6 CP 18. Stochastic Systems (elective) 6 CP 19. Discrete Optimization (elective) 6 CP 20. Nonlinear Partial Differential Equations (elective) 9 CP 21. Introduction to the numerics of partial differential equations (elective) 9 CP

	22. Advanced Numerics of Partial Differential Equations (elective) 9 CP 23. Computer Basics (elective) 6 CP 24. Fundamentals of Experimental Physics III-IV (elective) 15 CP 25. Theoretical Physics I-IV (elective) 36 CP 26. Computer Organization (elective) 12 CP 27. Fundamentals of Scientific Computing (elective) 6 CP 28. High Performance Computing (elective) 6 CP 29. Stochastic processes and modeling (elective) 6 CP 30. Analytical Methods (elective) 6 CP 31. Theoretical and Methodological Foundations of Autonomous Systems (elective) 6 CP 32. Functional Analysis (elective) 9 CP 33. Parallel Numerics (elective) 6 CP 34. Stochastical Processes II (elective) 9 CP 35. Introduction to stochastical partial differential equations (elective) 6 CP
	36. Introduction into Chaostheory (elective) 6 CP 37. Numerical Simulation (elective) 6 CP 38. Asymptotic Analysis (elective) 9 CP 39. Foundations of Computer Engineering (elective) 6 CP 40. Theoretical Computer Science III (elective) 6 CP 41. Data Processing for Engineers and Scientists (elective) 6 CP 42. Numerical Mathematics for Differential Equations (elective) 9 CP

	43. Mathematical Image Processing (elective) 9 CP
Teaching and Research AIRLabs	1. Laboratory – Institute of Engineering and Computational Mechanics 2. Laboratory – Institute for Systems Theory and Control 3. Practical Trainings – Institute for System Dynamics 4. Laboratory – Institute for Control Engineering of Machine Tools and Manufacturing Units 5. Laboratory – Institute for Nonlinear Mechanics 6. Machine Learning & Robotics Lab – IPVS 7. SOLA – Software Lab University of Stuttgart
Research Groups	1. Institute of Engineering and Computational Mechanics 2. Institute for Systems Theory and Control 3. Institute for System Dynamics 4. Institute for Control Engineering of Machine Tools and Manufacturing Units 5. Institute for Nonlinear Mechanics 6. Institute for Parallel and Distributed Systems
Collaboration with Industry (List of sample projects)	Only exemplarily: ZF Friedrichshafen, Bosch, Porsche, Daimler, Trumpf, Rexroth, Festo, …
Summary and Notes	
The Simulation Technology program is very interdisciplinary and free-form. Thus, the students can choose from a wide range of courses and thus also take courses which cover robotics and AI topics. Notice that this program is very research oriented.	

Appendix D: Surveying Training Needs Report

DeCAIR: Developing Curricula for Artificial Intelligence andRobotics

Report on Surveying Training Needs and Capabilities

Activity Information:

Work Package	WP1 – Surveys and Needs Identification
Task	1.4 Identifying training needs for staff members in universities of Partner Countries
Activity Coordinator	UJ (Musa Alyaman)
Participating Partners	TTU, UJ, JUST, LU, BAU, UGR, UNIGE, UST, UNIPI
Objective(s)	• Identify AIR training needs of faculty members in universities of Partner Countries • Identify training capabilities of partners in Program Countries • Specify tentative topics for the training courses
Due Date	March 10th

Instructions:

1. Activity coordinator is to communicate with the focal point of JUST, TTU, LU and BAU and request each of them to fill Table 1.4.4 about Preliminary List Courses Needed by universities of Partner Countries.
2. Activity coordinator is to communicate with EU partners and request each of them to fill Table 1.4.5 about Preliminary List of Suggested Courses to be delivered by universities in Program Countries to the DeCAIR Project.
3. This report is to be prepared through collaboration of different partners and submittedto the WP lead by the activity coordinator. Filled tables should be added to this report.

Summary and Recommendations:

The training needs and capabilities in both program (Table 1.4.4) and partner universities (Tables 1.4.5) were collected and analyzed. Several training courses were considered as a step towards achieving the first work package (i.e. Surveys work package) in the DeCAIR project. The average number of targeted faculty members in Partner Countries is 20 for each university. The surveyed training courses are laid under three main training areas; AI, Data Science and Robotics.

AI

Generally, the needed AI related training courses focus on six areas ranging from basic to advanced levels. In Basic level, mainly two training courses were requested: "Introduction to AI and Machine Learning" and "Neural Network fundamentals". At the intermediate level, mostly two training courses were requested: "Deep Learning" and "Reinforcement Learning". Finally, in advanced level; essentially two training courses were reported: "Natural Language Processing" and "Computer Vision".

On the other hand, the partners from Program Countries offered several AI related training courses which focus on six areas range from basic to advanced levels. In Basic level; three training courses were reported: "Introduction to AI and Machine Learning", "Neural Network Fundamentals" and "Fuzzy Logic Fundamentals". At the intermediate level, one training course was reported: "Deep Learning". Finally, in advanced level; essentially two training courses were reported: "Natural Language Processing" and "Computer Vision". These courses are offered by University of Granada (UGR) and University of Genoa (UNIGE).

Table 1.4.1 summaries the needed training topics in AI listed from most to least wanted and the name of EU partner who offers these topics.

Table 1.4.1 List of Requested AI Topics

#	AI Topic	JU	JUST	TTU	LU	BAU	Offered by
1	Machine Learning	X	X	X	X	X	UGR
2	Deep Learning	X	X	X	X	X	UGR/UNIGE
3	Reinforcement Learning			X	X	X	
4	Introduction to AI	X	X	X			UNIGE
5	Computer Vision	X		X	X		UNIGE
6	Natural Language Processing	X		X			UNIGE

7	Neural Network	X		X			UNIGE
8	Fuzzy Logic			X			UNIGE
9	Intelligent Embedded Systems			X			
10	Pattern Recognition				X		
11	Federated Learning and Block chain					X	
12	Feature Engineering					X	
13	Generative Adversarial Networks					X	
14	AI in Security	X					
15	Knowledge Representation and Reasoning	X					
16	Multi-agent Systems and Game Theory	X					
17	AI in Games			X			
18	Machine learning techniques for Internet of Things				X		
19	Meta-heuristics and Natural Inspired Optimization						UGR

Data Science

Generally, the requested Data Science related training courses focused on three areas ranging from basic to advanced levels. In basic level; one training course was reported: “Introduction to Data Science”. Additionally, in intermediate level, one training courses was reported: “Data Analysis and Visualization”. Finally, in advanced level; one training courses was reported: “Big Data Analysis”.

On the other hand, universities in Program Countries offered Data Science related training courses that focus on three areas ranging from basic to advance levels. In basic level;one training course was reported: “Introduction to Data Science”. Additionally, in intermediate level, one training courses was reported: “Data Visualization”. Finally, in advanced level; one training courses was reported: “Large scale Data Management” .These courses offered are offered by UGR and UNIGE.

Table 1.4.2 summaries the needed training topics in Data Science listed from most to least wanted and

the name of EU partner who offers these topics.

Table 1.4.2 List of Requested Data Science Topics

#	Data Science Topic	JU	JUST	TTU	LU	BAU	Offered by
1	Data Science Fundamentals	X		X		X	UNIGE
2	Big Data Analytics Fundamental and tools	X				X	UNIGE
3	Statistical Data Science	X					
4	Data Mining				X		
5	Multi-Label classification				X		
6	Decision under uncertainties				X		
7	Python for AI and Data Science			X			UNIGE
8	Data pre-processing and visualization						UGR

Robotics

Generally, the requested Robotics related training courses focused on four areas ranging from basic to advanced levels. In basic level; mainly two training courses were reported: “Introduction to Robotics” and “Robot Control fundamentals”. Additionally, in intermediate level, one training course was reported: “Robot Programming”. Finally, in advanced level; one training course was reported: “Advanced Robotic Control”.

On the other hand, universities from Program Countries offered Robotics related training courses that focus on six areas ranging from basic to advanced levels. In basic level; mainly four training courses were reported: “Introduction to Robotics” and “Robot Control fundamentals”, “Introduction to Mobile and Distributed Robots” and “Building non- Expensive Robot”. Additionally, in intermediate level, two training courses were reported: “ROS Programming” and “Robot Modelling”. Finally, in advanced level; essentially two training courses were reported: “Controlling UAV” and “Distributed Control of SwarmRobots”. These courses offered by three universities; UNIPI, UST and UGR.

Table 1.4.3 summaries the needed training topics in Robotics listed from most to leastwanted and the name of EU partner who offers these topics.

Table 1.4.3 List of Requested Robotics Topics

#	Robotics Topic	JU	JUST	TTU	LU	BAU	Offered by
1	Fundamental of robotics	X	X	X	X	X	UGR/ UNIPI(3)/ UST(3)
2	Advance robotics systems control	X	X	X	X		UNIPI/UST
3	Programming methods forRobotics	X			X	X	UNIPI
4	Ethical Standards in AI and Robotics	X	X				
5	Autonomy in Robotic Systems	X					
6	Human Robot Interaction	X					
7	Sensors and Actuators					X	UNIPI
8	AI and Mobile Robots			X			
9	Introduction to Automatic Control /Linear / Non-Linear						UNIPI(3)
10	Flexible One-Arm-Robot						UST
11	Regulation of a Spherical Pendulum						UST
12	Controller Design for a Model Railway						UST
13	Balanced Ball on Rim						UST
14	Control of a UAV						UST
15	External tracking of robots in a laboratory environment						UST
16	Distributed Control of a Swarm of Mobile Robots						UST

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AIR Training Needs in Universities of Partner Countries

Note: A total of 19 training courses are to be conducted in the project. Please list any topic you feel it is necessary to improve your expertise even if it is a fundamental course. List the topics in different categories from basic to advanced. Try to be specific in the topics you list. You can add rows as you need.

Table 1.4.4 Preliminary List Courses Needed by University of Jordan

Partner Name	University of Jordan	
Targeted Program(s)	• B.Sc. in Computer Engineering (Existing) • B.Sc. in Mechatronics Engineering (Existing) • M.Sc. in Computer Engineering and Networks (Existing) • M.Sc. in AI and Robotics (to be established)	
Number of Targeted Faculty Members	20	
AI Topics to be Covered in Training		
Topic		Priority (High, Medium, Low)
Artificial Intelligence In Python (Basic)		High
Machine Learning (Basic)		High
Artificial Neural Networks Applications and Deep Learning (Intermediate)		High

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Natural Language Processing (Intermediate)	High
AI in Security (Advanced)	Medium
Knowledge Representation and Reasoning (Advanced)	Low
Multi-Agent Systems and Game Theory (Advanced)	Low
Data Science Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
Data Science Fundamentals: Concepts, Importing, Cleaning, Manipulation, Visualization of Data	High
Statistical Data Science	High
Big Data Analytics Fundamentals and Tools (Hadoop, Spark, Tableau…)	High
Robotics Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
Fundamentals of Robotics	High

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Partner Name	University of Jordan
Robotics Control	High
Artificial Intelligence and Machine Learning for Robotics	High
Programming Methods for Robotics	Low
Human-Robot Interaction	Medium
Machine Vision for Robotics	Medium
Autonomy in Robotic Systems	High
Ethical Standards in Artificial Intelligence and Robotics	High
Other Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
Summary and Notes	

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Table 1.4.4 Preliminary List Courses Needed by University of Science and Technology

Partner Name	University of Science and Technology
Targeted Program(s)	Master Program
Number of Targeted Faculty Members	10
AI Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
Deep learning in Engineering Applications	High
Machine Learning impact on the fourth industrial revolution	Medium
Advanced training in using Microsoft Azure for AI	Medium
Python Programming for AI with Microsoft Azure	High
Data Science Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
Robotics Topics to be Covered in Training	

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Topic	Priority (High, Medium, Low)
Advanced Robotics systems	Medium
Robots impact on the fourth industrial revolution	High
Warehouse Robots Design and Control	High
Other Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
Summary and Notes	

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Table 1.4.4 Preliminary List Courses Needed by Tafila Technical University

Partner Name	Tafila Technical University
Targeted Program(s)	Intelligent systems engineering
Number of Targeted Faculty Members	8
AI Topics to be Covered in Training	

Topic	Priority (High, Medium, Low)
Introduction to AI	Low
Neural Networks	High
Deep Learning	High
Deep Reinforcement Learning	High
Fuzzy Logic	Medium
Machine Learning	High
Computer Vision	High
Natural Language Processing	High
Intelligent Embedded Systems	High

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AI on edge	High
Data Science Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
Data Exploration and Analytics	High
Artificial Intelligence in Games	High
Python for AI and Data Science	High
Robotics Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
Robot Principles And Design	High
Robot Intelligent Control	High
Ai And Mobile Robots	High
Other Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
Summary and Notes	

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16 courses are needed as training topics in this project:
14 with high priority, 1 has a medium priority and 1 has a low priority.

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Table 1.4.4 Preliminary List Courses Needed by Lebanese University

Partner Name	Lebanese University
Targeted Program(s)	Master in Robotics and Intelligent Systems – Electrical Engineering – Mechanical Engineering
Number of Targeted Faculty Members	25
AI Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
Machine Learning / Deep learning	High
Reinforcement learning	High
Pattern recognition	Medium
Data Science Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
Data mining	High
Multi-label classification	High
Decisions under uncertainties	Medium

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Robotics Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
Computer vision	High
Serial, parallel and cable-driven robots	High
ROS-based development approaches	High
UAV dynamics and control	Medium
Other Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
Machine learning techniques for the Internet of Things	High
Machine-to-Machine Communications	High
Summary and Notes	

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Table 1.4.4 Preliminary List Courses Needed by Beirut Arab University

Partner Name	Beirut Arab University
Targeted Program(s)	Computer Engineering
Number of Targeted Faculty Members	10
AI Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
1. Applied Machine Learning, Basic Level 2. Reinforcement Learning, Advanced Level 3. Deep Learning, Advanced Level 4. Deep Reinforcement Learning, Advanced Level 5. Federated Learning, Advanced Level 6. Blockchain for Federated Learning, Advanced Level 7. Feature Engineering, Advanced Level 8. Generative Adversarial Networks, Advanced Level	1. High 2. Medium 3. High 4. High 5. High 6. Medium 7. High 8. High
Data Science Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)

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9. Data Science Fundamentals, Basic Level 10. Data Analysis with Python, Basic Level 11. Modern Software Tools for Data Science (R, Python, SAS, etc.), Basic Level	9. High 10. Medium 11. Medium
Robotics Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
12. Introduction to Robotics, Basic Level	12. Medium
13. Robotics Programming, Basic Level	13. Medium
14. Sensors and Actuators, Advanced Level	14. Medium
Other Topics to be Covered in Training	
Topic	Priority (High, Medium, Low)
Summary and Notes	

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AIR Training Capabilities in Universities of Program Countries

Note: A total of 19 5-day training courses are to be delivered by EU partners with the following distribution: six courses by UNIGE, five courses by UNIPI, five courses by UGR and three courses by UST. Please fill the table with the list of courses that you plan to deliver. You may list more than the required number of courses. List these courses from basic to advanced.

Table 1.4.5 Preliminary List of Suggested Courses to be delivered by UNIGE to the DeCAIR Project

Partner Name	UNIGE		
Partner Main Expertise	■AI	☐ Data Science	☐ Robotics
AI Topics to be Covered in Training			
Topic			Required Background and Resources
Fuzzy Logic & Evolutionary Computation			basic
Neural Networks			basic
Deep Learning			advanced
Computer Vision			medium
Introduction to Artificial Intelligence			basic
Natural Language Processing			basic
Data Science Topics to be Covered in Training			

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Topic	Required Background and Resources
Introduction to Data Science	basic
Large scale Data Management	advanced
Robotics Topics to be Covered in Training	
Topic	Required Background and Resources
Other Topics to be Covered in Training	
Topic	Required Background and Resources
Introduction to Python Language Programming	basic
Summary and Notes	
The proposed possible courses are more than six. The consortium will select the six more suitable	

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Table 1.4.5 Preliminary List of Suggested Courses to be delivered by UGR to the DeCAIR Project

Partner Name	University of Granada		
Partner Main Expertise	☒ AI	☒ Data Science	☒ Robotics
AI Topics to be Covered in Training			
Topic			Required Background and Resources
Meta-heuristics and Nature-Inspired Optimization			None
Data Science Topics to be Covered in Training			
Topic			Required Background and Resources
Data Pre-processing and Visualization			None
Machine Learning Foundations			Basics on data management
Deep Learning and Advanced Machine Learning			Machine Learning basics
Robotics Topics to be Covered in Training			
Topic			Required Background and Resources
Fundamentals of Intelligent Robotics and Control			None

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Other Topics to be Covered in Training	
Topic	Required Background and Resources
Summary and Notes	

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Table 1.4.5 Preliminary List of Suggested Courses to be delivered by UNIPI to the DeCAIR Project

Partner Name	University of Piza		
Partner Main Expertise	☐ AI	☐ Data Science	☒ Robotics
AI Topics to be Covered in Training			
Topic			Required Background and Resources
Data Science Topics to be Covered in Training			
Topic			Required Background and Resources
Robotics Topics to be Covered in Training			
Topic			Required Background and Resources
Introduction to Automatic Control			Linear Algebra
Introduction to System Theory and Linear Control			Linear Algebra & Automatic Control

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Introduction to Nonlinear Control	Previous courses
Introduction to Robotics	Previous courses
Introduction to Mobile Robotics (ground, aerial and underwater robotics)	
Introduction to Distributed Robotic Systems	
Introduction to ROS and Matlab Simulink	
Introduction to Sensors and Actuators for Robotics	
Introduction to Modelling and Simulation of Discrete Event Systems	Probability theory
Other Topics to be Covered in Training	
Topic	Required Background and Resources
Summary and Notes	

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Table 1.4.5 Preliminary List of Suggested Courses to be delivered by UST to the DeCAIR Project

Partner Name	University of Stuttgart		
Partner Main Expertise	☐ AI	☐ Data Science	☒ Robotics
AI Topics to be Covered in Training			
Topic			Required Background and Resources
-			
Data Science Topics to be Covered in Training			
Topic			Required Background and Resources
-			
Robotics Topics to be Covered in Training			
Topic			Required Background and Resources
			Required Background: Basic understanding ofmechatronic systems and their dynamics, modeling, the control of mechanic systems
Basic			

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Building Non-expensive and Custom-Build Wheeled Mobile Robots	Required Background (R.-B.): kinematics of mobile robots, practical mechatronics experience (soldering, programming) Resources (R.): metal workshop, laser cutter, soldering station
Mobile Robot Motion Control	R.-B.: First knowledge in mobile robotics R.: multiple different wheeled mobile robots with different kinematics
Robot Kinematics (Articulated Robot)	R.-B.: theoretical knowledge of articulated robots R.: 6-DOF robot (Schunk)
Kinematics of Wheeled Mobile Robots	R.-B.: - R.: practical examples (omnidirectional and differentially driven)
Intermediate	
Flexible One-Arm-Robot	R.-B.: knowledge in flexible multi bodysystems R.: flexible one-arm robot in the ITM-lab
Regulation of a Spherical Pendulum	R.-B.: general knowledge in applied dynamics and machine dynamics R.: 3D pendulum in the ITM-lab (“Expo-Pendulum”)

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Controller Design for a Model Railway	R.-B.: basic knowledge in control theory (PID controllers) R.: railway in the ITM-lab
Balanced Ball on Rim	R.-B.: basic knowledge in modeling mechanical systems and in control theory (LQR), basic knowledge of microprocessors R.: corresponding set-up in the ITM-lab
Advanced	
Control of a UAV	R.-B.: advanced knowledge in modeling and control R.: multiple quadcopters in the ITM-lab
External tracking of robots in a laboratory environment	R.-B.: basic knowledge in communication R.: external tracking system in the ITM-lab
Distributed Control of a Swarm of Mobile Robots	R.-B.: basic knowledge in modeling and advanced knowledge in (distributed) controlR.: multiple mobile robots in the ITM-lab, tracking system
Other Topics to be Covered in Training	
Topic	Required Background and Resources

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-	

Summary and Notes
The Institute of Engineering and Computational Mechanics offers several practical trainings in WP 7 (summer 2023). These trainings will all be conducted in the laboratory of the institute at the University of Stuttgart using the given resources and facilities in Stuttgart. The focus is on providing practical knowledge and experience in the field of robotics. This includes, but is not limited to, programming of an articulated robot, analyzing the different kinematics of wheel-driven mobile robots, controlling mobile robots and UAVs, and designing and manufacturing custom mobile robots.

Appendix E: Surveying Facilities and Labs Report

DeCAIR: Developing Curricula for Artificial Intelligence andRobotics

Report on Surveying Facilities and Labs

Activity Information:

Work Package	WP1 – Surveys and Needs Identification
Task	1.5 Survey of facilities and equipment
Activity Coordinator	JUST (Wafa Batayneh)
Participating Partners	TTU, UJ, JUST, LU, BAU, UGR, UNIGE, UST, UNIPI
Objective(s)	• Assessment of existing facilities and equipment inuniversities of Partner Countries • Identifying the initial list of equipment to be ordered • Surveying equipment in universities of Program Countries
Due Date	March 10th

Instructions:

1. Activity coordinator is to communicate with the focal point of UJ, TTU, LU and BAU andrequest each of them to fill Table 1.5.1 and Table 1.5.2.
2. Activity coordinator is to communicate with EU partners and request each of them to fillTable 1.5.3.
3. This report is to be prepared through collaboration of different partners and submitted tothe WP lead by the activity coordinator. Filled tables should be added to this report.

Summary and Recommendations:

In this task the main objectives were the assessment of existing facilities and equipment in universities of Partner Countries and Program Countries. This was accomplished through collecting and analyzing the following listed surveys:

1. Assessment of Existing Labs in the Universities of Partner Countries
2. Preliminary List of Needed Equipment to Order through DeCAIR Project
3. Detailed List for Labs Equipment in Universities of Program Countries

The first survey considers the assessment of existing labs in the universities of Partner Countries, namely; UJ, JUST, TTU, LU and BAU (Table 1.5.1). The collected information shows large variation between the partners in terms of existing equipment, but they all agree on that the available equipment in the labs is of low to medium specifications with high priority to upgrade most of the existing equipment. Generally, they agreed that the existing equipment are sufficient for teaching the basic courses; however, they are not suitable for teaching and research purposes in AI and Robotics which require much higher specifications. Some of the existing labs can be upgraded with better equipment to serve AI and Robotics needs. In other cases, there is a need to create new labs with modern high-end equipment that can be ordered through the DeCAIR project.

The second survey is about collecting information regarding the preliminary list of needed equipment to be ordered through the DeCAIR Project by the Partner Countries, namely; UJ, JUST, TTU, LU and BAU (Table 1.5.2). The collected information shows high priority for upgrading most of the existing equipment, in addition to the need to order new equipment that will serve AI and Robotics program needs, or new lab with modern high-end equipment can be established through the DeCAIR project.

In the third survey, the information about the available AIR equipment in the universities of Program Countries, namely; UGR, UNIGE, UST, UNIPI (Table 1.5.3) is collected. The collected information shows that most of these equipment is necessary and important for AI and Robotics labs, and it provide us with ideas to upgrade and establish labs in Jordanianand Lebanese universities.

In conclusion, the collected surveys gave a clear idea on the list of existing equipment, and the list of potential equipment that can be provided through the DeCAIR Project. In addition to a list of existing equipment in the EU Universities of Program Countries, which provide us with different ideas on AI and Robotics equipment that will be beneficial for the partner universities. At this point we can move to the next work packages with a clear viewof the existing and needed equipment for each partner university.

Assessment of Existing Labs and Preliminary List of Needed Equipment in Universities of Partner Countries

Table 1.5.1 Assessment of Existing Labs

Partner Name	The University of Jordan	
Targeted Program(s)	B.Sc. in Computer Engineering (Existing) B.Sc. in Mechatronics Engineering (Existing) M.Sc. in Computer Engineering and Networks (Existing)M.Sc. in AI and Robotics (to be established)	
Existing Labs Supporting AI and Data Science		Priority to Upgrade (High, Medium, Low)
Lab Name 1	List of major equipment	
Existing Labs Supporting Robotics		Priority to Upgrade (High, Medium, Low)
Embedded Systems Lab	Intel(R) Core(TM) 2 Quad CPU Q9550 @2.83GHz, 2 GB RAM500 GB HDD 25 Kit of Microchip 1427bww Kits for PIC16F877A	Low
Other Existing Labs Supporting AIR		Priority to Upgrade (High, Medium, Low)
Computer Applications Lab	21 PCs - Intel(R) Core(TM) 2 Quad CPU Q9550 @2.83GHz (4 CPU, 4GB RAM, 500GB HDD)	Medium

Digital Logic Lab	Intel(R) Core(TM) 2 Quad CPU Q9550 @2.83GH, 2 GB RAM500 GB HDD 25 Kit of FPGAs (Altera FPGA-DE2_70)	Low
Computer Design Lab	1 PC Intel(R) Core(TM) 2 Quad CPU Q9550 @ 2.83 GHz, 2 GB RAM 500 GB HDD 20 PCs Intel(R) Core(TM) 2 Duo CPU E8400 @ 3.00 GHz, 2 GB RAM 256 GB HDD	Medium
Computer Networks Labs	21 PCs Intel(R) Core(TM) i5- 4440 CPU @ 3.1 GHz, 8.00 GB RAM, 500 GB HDD	Low
Summary and Notes		
Available equipment in the labs in the Computer Engineering Department are of low to medium specifications. Generally, they are sufficient for teaching the basic computer engineering courses; however, they are not suitable for teaching and research purposes in AI and data science which require much higher specifications. Some of the existing labs can be upgraded with better equipment to serve AI needs, or a new lab with modern high-end equipment can be established through the DeCAIR project.		

Table 1.5.1 Assessment of Existing Labs

Partner Name	JUST	
Targeted Program(s)	Master of Science in Mechanical Engineering - Mechatronics	
Existing Labs Supporting AI and Data Science		Priority to Upgrade (High, Medium, Low)
Mechatronics Lab	*1)* Fuzzy Logic Kit *2)* DC motor Control kit by Quaner *3)* Rotary Inverted Pendulum kit by Qanser *4)* Twin Rotor Helicopter by Feedback	High
Existing Labs Supporting Robotics		Priority to Upgrade(High, Medium, Low)
Mechatronics Lab	*1)* Twin Rotor Helicopter by Feedback *2)* Electro-pneumatic and Electro-hydraulic kits by FESTO *3)* Embedded systems kits by Sparkfun	Low
Robotics and Intelligent systems	*1)* Motion tracking system from VICON *2)* Industrial Serial Manipulator from KUKA *3)* Quadrotor	High

Other Existing Labs Supporting AIR		Priority to Upgrade(High, Medium, Low)
Lab Name 1	List of major equipment	
Lab Name 2	List of major equipment	
Summary and Notes		

Table 1.5.1 Assessment of Existing Labs

Partner Name	Tafila Technical University	
Targeted Program(s)		
Existing Labs Supporting AI and Data Science		Priority to Upgrade (High, Medium, Low)
N/A	N/A	High
N/A	N/A	High
Existing Labs Supporting Robotics		Priority to Upgrade (High, Medium, Low)

N/A	N/A	High
N/A	N/A	High
Other Existing Labs Supporting AIR		Priority to Upgrade (High, Medium, Low)
N/A	N/A	High
N/A	N/A	High
Summary and Notes		

Table 1.5.1 Assessment of Existing Labs

Partner Name	Lebanese University	
Targeted Program(s)	Master in Robotics and Intelligent SystemsMechanical Engineering Electrical Engineering	
Existing Labs Supporting AI and Data Science		Priority to Upgrade (High, Medium, Low)
Computer Lab	Computers	Low

Signal Processing Lab	Data Acquisition System	Low
Existing Labs Supporting Robotics		Priority to Upgrade(High, Medium, Low)
Lab Name 1Flying Robots lab	Flying Robots (Drones): Quadrotors, Hexarotors and Octorotors	Medium
Robotic Lab	Robotic serial arm	High
Other Existing Labs Supporting AIR		Priority to Upgrade(High, Medium, Low)
Control Lab	Control system	Low
Signal Processing Lab	Acquisition system	Low
Signal Processing Lab	Computer Vision	Medium
Summary and Notes		

Table 1.5.1 Assessment of Existing Labs

Partner Name	Beirut Arab University
Targeted Program(s)	Computer Engineering

Existing Labs Supporting AI and Data Science		Priority to Upgrade (High, Medium, Low)
Digital Systems Laboratory (DSL)	Computers (8 units), advanced 8086 microprocessor trainer (5 units), digital input/output module (6 units), matrix led module (8 units), seven segment module (8 units), matrix key pad module (7 units), programmable interrupt controller module (8 units), LCD display module (8 units), stepper motor module (5 units), 8 channel 8 bit ADC module (6 units), digital/analog module (8 units), DC motor controller module (4 units), traffic light module (8 units), elevator module (6 units), DSP starter kit (5 units), ezdsp kit (1 unit), PIC programmer USB (6 units), picstart plus (3 units), flash starter kit (5 units), Digilent Spartan 3E-starter (1 unit), Telemasse (8 units), IC tester (2 units), digital logic lab – main board (6 units), basic gate experiment module (6 units), combinational logic circuit experiment module (30 units), clock generator circuit experiment module (6 units), sequence logic circuit experiment module (12 units), memory circuit experiment module (12 units), converter circuit experiment module (12 units)	High
Software Laboratory (SWL)	Computers (including desktops, screens, keyboards and mouse) (30 units), VGA splitter (1 unit), projector (1 unit), Network switches (2 units), rack (1 unit) Software (Windows 8.1, Microsoft Office 2013, Microsoft Visual Studio 2010, CiscoPacket Tracer 7.0, Arena 13.9); Visual Studio; MATLAB; LabVIEW; Quartus Prime	High
Existing Labs Supporting Robotics		Priority to Upgrade(High, Medium, Low)

Digital Systems Laboratory (DSL)	Same as above	High
Software Laboratory (SWL)	Same as above	High
Control and Industrial Electronics Laboratory (CIEL)	DC motor trainer (1 unit), AC position control (1 unit), DC position control (1 unit), DC motor speed control system (1 unit), inverter (1 unit), liquid level and temperature control level (1 unit), automation board (3 units)	High
Other Existing Labs Supporting AIR		Priority to Upgrade(High, Medium, Low)
Communications Laboratory (COML)	Spectrum analyzer (1 unit), network analyzer (1 unit), power meter E4418A (1 unit), power meter NRP2 (1 unit), computer (9 units), Dc power supply (6 units), propagation setup (1 unit), acoustic measurement impedance (1 unit), oscilloscope (6 units), bench for analog and digital kit (1 unit), frequency generator (2 units), waveform generator (6 units), current generator (1 unit), digital oscilloscope (3 units)	High
Measurement and Electronics Laboratory (MEL)	Oscilloscope (16 units), power supply (16 units), A-V meter DC & AC (2 units),frequency generator (17 units)	High
Summary and Notes		

Preliminary List of Needed Equipment to Order through DeCAIR Project

Table 1.5.2 Preliminary List of Equipment to Order through DeCAIR Project

Partner Name	University of Jordan	
Targeted Program(s)	B.Sc. in Computer Engineering (Existing) B.Sc. in Mechatronics Engineering (Existing) M.Sc. in Computer Engineering and Networks (Existing) M.Sc. in AI and Robotics (to be established)	
Item	Quantity	Estimated Cost (Euros)
High-end workstations (many cores and dedicated GPUs)	2	23000
High-spec PCs with dedicated GPUs	10	10000
Laptops for teaching purposes	8	8000
Smartboards for classrooms	4	4000
Robotic manipulator	1	16000
Autonomous ground robot	1	11000
Autonomous air vehicle	1	17000
Ground control station	1	6000
	Total	95,000

Table 1.5.2 Preliminary List of Equipment to Order through DeCAIR Project

Partner Name	JUST	
Targeted Program(s)	Master of Science in Mechanical Engineering - Mechatronics	
Item	Quantity	Estimated Cost (Euros)
Laptops for teaching purposes	4	5000
Smartboards for classrooms	1	1000
BALL BALANCING TABLE 2-DoF Control Platform for Teaching and Research	1	6000
LINEAR INVERTED PENDULUM 2-DoF Control Platform for Advanced Control Teaching and Research	1	6000
BALL AND BEAM 1 DOF Control Platform for Teaching and Research	1	6000
DELTA ROBOT 3-DoF Vision Guided Robotic Platform for Teaching and Research	1	6000
STEWART PLATFORM 6-DoF sophisticated motion system for robotics and controls	1	6000

1-DOF COPTER Flight simulation control unit for teaching and research	1	6000
High-Performance Autonomous Ground Robot for Indoor Labs	1	6000
QUANSER MECHATRONIC SYSTEMS BOARD with ELVIS III	1	6000
	Total	54,000

Table 1.5.2 Preliminary List of Equipment to Order through DeCAIR Project

Partner Name	Tafila Technical University		
Targeted Program(s)	Intelligent Systems Engineering Computer Engineernig		
Item		Quantity	Estimated Cost (Euros)
A GPU Server with an Intel Dual CPU Xenon Processor (Silver or Gold), 512 GB DDR4-RAM, 4 TB SSD hard disc and 4 to 8 free slots for GPU accelerator cards. Initially two slots can be occupied with a GeForce RTX 2080 Ti, similar to the workstations or with one or two business GPU cards such as a Nvidia Tesla V100S (16 GB). The new Nvidia A100 Tensor Core graphics processor also offers a powerful alternative. Theremaining free slots are left for future expansion. The server is not placed in the laboratory, but centrally in the data center of the university. The server can be used on top of the AI workstations, if dedicated computing power is required.		1	15000

AI WORKSTATIONS , CPU Intel Core i9-9900KF, 8 x 3.6 GHz RAM DDR-4, 2 x 16 GB , SSD 1 500 GB, GPU GB GeForce RTX 2080 Ti, 11 GB (lab workstations)	15	15000
Jetson Nano Developer Kit	10	1000
NVIDIA Jetson Xavier NX Developer Kit	10	4000
NVIDIA Jetson AGX Xavier devekopment kit	10	6000
Raspberry Pi CSI Camera	10	400
JetBot AI robot platform	10	1000
Google Coral Dev Board	10	3000
6-axis Industrial robot arm (6-digree of freedom)	4	12000
Humanoid Robot	3	7000
unmanned Aerial Vehicle (UAV),	6	3000
unmanned Ground vehicle (UGV)	4	5000
Legos and constructible robots	4	3000
Robot simulation software	1	1000
Total price		
	Total	76400

Table 1.5.2 Preliminary List of Equipment to Order through DeCAIR Project

Partner Name	Lebanese University	
Targeted Program(s)	Master in Robotics and Intelligent System- Electrical Engineering- Mechanical Engineering	
Item	Quantity	Estimated Cost (Euros)
PIXKIT - Autonomous Driving Development Kit:	1	23.000
Ainstein Automotive Safety Radar T-79	1	3500
High-resolution lidar sensors	1	3500
3D Scanning Bundle	1	500
Industrial-level Blue Light 3D Scanner	1	1000
ViperX 300 Robot Arm 6DOF	1	5000
	Total	36,500

Table 1.5.2 Preliminary List of Equipment to Order through DeCAIR Project

Partner Name	Beirut Arab University	
Targeted Program(s)	Computer Engineering	
Item	Quantity	Estimated Cost (Euros)
High-Performance Computing Systems	1	5000
FPGA Training Boards	12	5000
High-Performance FPGA Board	1	8000
GPUs	2	3000
Raspberry Pi Kits and Accessories	12	5000
Automation and Robotics Laboratory Kits	12	8000
Software Laboratory (MATLAB Toolboxes)	99 Users – Academic License	2000
	Total	36000 Euros

Facilities and Labs in Universities of Program Countries

Table 1.5.3 Detailed List for Labs Equipment in Universities of Program Countries

Partner Name	University of Pisa		
Partner Main Expertise	☐ AI	☐ Data Science	☐ Robotics
Labs Supporting AI and Data Science			
Lab Name 1	List of major equipment		
Lab Name 2	List of major equipment		
Labs Supporting Robotics			
UNIPI AERIAL ROBOTICS LAB	Quadcopter Tarot frame for general purpose autonomous mission research Hexacopter Flame Wheel frame for general purpose autonomous mission research2 Quadcopter for indoor flight tests Camera Stabilizing gimbal prototype (1DOF)Camera Stabilizing gimbal (3DOF) fixed wing autonomous vehicleCrazyflie nano quadcopter Intel Ready-to-Fly Drone Dji Phantom 3 advanced DroneDucted Fan Drone Prototype Vicon Motion Tracking System with 10 cameras		

UNIPI MANIPULATION LAB	2 Kuka Light Weight Robot LWR-II, robotic arms3 Franka Panda Emika, robotic arms 1 UR10, Universal Robot, robotic arm6 Pisa/IIT soft hand 1 DLR II Hand, 10 ATI-nano 17, 6-axis force sensors, ATI Industries 10 Electronic boards for controlling DC motors and signal acquisition a dual-arm robot on a two-wheeled mobile base provided with a stereo-camera to be used as a tele-operatedplatform to perform lab tests BIOPAC MP35 general Purpose
	2 Virtual Reality sets Oculus Rift
UNIPI MOBILE ROBOTICS LAB	6 Autonomous remotely controlled 1:8 scale model car6 small mobile robots with arduino Autonomous Forklift, Toyota Robotnik STEEL XL, mobile robot Zeno, underwater autonomous vehicle
Labs Supporting AIR	
Lab Name 1	List of major equipment
Lab Name 2	List of major equipment
Summary and Notes	

Table 1.5.3 Detailed List for Labs Equipment in Universities of Program Countries

Partner Name	University of Stuttgart – Institute of Engineering and Computational Mechanics		
Partner Main Expertise	☒ AI	☐ Data Science	☒ Robotics
Labs Supporting AI and Data Science			
Lab – ITM	optical tracking system, multiple wheeled mobile robots, unmanned aerial vehicles, …		
Labs Supporting Robotics			
Lab – ITM	multiple wheeled mobile robots, unmanned aerial vehicles, articulated robot, flexible one-arm-robot, driving simulator with active motion platform, micro-mechanical oscillation inducer, (large) Expo-pendulum, active vibration absorber, model railway, optical lenses, spring-damper combination on a hydraulic test bench, balancedball on rim, machine foundation test bed, laser cutter, soldering stations, laservibrometer, 3D printer		
Metal workshop - ITM	turning machines (4x), milling machines (2x), drilling machines (2x), band saw, circular metal saw, trimming saw, metal band saw, belt and disc sander		
Labs Supporting AIR			
	See above		
Summary and Notes			

Our laboratory at the Institute of Engineering and Computational Mechanics at the University of Stuttgart (Germany) offers a variety of different devices and test benches as well as excellent measuring instruments. Many of the robotic tests were designed in-house and the required parts were manufactured in our metal workshop by trained employees. This includes, for example, mobile robots or aerial vehicles. The excellent setup is complemented by high- quality external components such as a visual tracking system, a single-arm robot and much more. Further details can also be found online on our website, see https://www.itm.uni-stuttgart.de/en/institute/laboratory/ and https://www.itm.uni-stuttgart.de/en/institute/metalworkshop/.

Table 1.5.3 Detailed List for Labs Equipment in Universities of Program Countries

Partner Name	University of Granada		
Partner Main Expertise	☒ AI	☒ Data Science	☒ Robotics
Labs Supporting AI and Data Science			
Computing for AI and DS	A cluster of six HPC multi-GPU multi-CPU nodes: • Titán (2 x procesador Intel® Xeon® E5-2630 v4, 4 x Nvidia Geforce GTX Titan X Pascal core GP102) • Atenea (2 x procesador Intel® Xeon® E5-2630 v4, 4 x Nvidia Geforce GTX Titan Xp core GP102.) • Zeus (2 x procesador Intel® Xeon® E5-2630 v4 @2.20GHz, 4 x Nvidia Geforce RTX 2080 Ti) • Hera (2 x procesador Intel® Xeon® Silver 4114 @ 2.20GHz, 4 x Nvidia Geforce RTX Titan RTX 24GBGDDR6) • NVIDIA DGX1 (Dual 20-Core Intel Xeon E5-2698 v4 2.2 GHz, 8x NVIDIA Tesla V100 32GB) • NVIDIA DGX1 (Dual 20-Core Intel Xeon E5-2698 v4 2.2 GHz, 8x NVIDIA Tesla V100 32GB)		

	• Access to supercomputers, MareNostrum (BSC) and Picasso (University of Málaga)
Labs Supporting Robotics	
Robotics	4 drones with a cage for flight tests. • Ryze Tello y Parrot Mambo • Parrot Disco (fixed wing) • DJI Mavic Pro • Hexacopters for assembly (pieces: autopilot Pixhawk, motors, propellers, batteries, etc.) 4 educational robots, 2*Scorbot ER 4u and 2*ER V+ 18 educational mobile robots: 1*DonkeyCar with HQ camera, 1*Koala with laser, 6*Kephera II/III with US, 10*Zumo Robot 3*Pixy for robot vision
Hardware and printed circuits	• Circuit board plotters: LPKF ProtoMat S103 • ABS plastic 3D printing center: Stratasys Dimension Elite.
	• Electroplating machine for via plating on multilayer PCBs: LPKF model MiniContac RS (220x330 mmPCBs). • LPKF solder mask exposure and solder mask exposure machine. • JCB AR5800 hot air soldering/desoldering station. • Semi-automatic assembly machine for SMD components: • Pick&Place model LPKF-ProtoPlace (components with footprint up to sizes 0201). • Ultrasonic cleaning station: Kerry Guyson (4-liter tank). • Oscilloscope: Rigol DS6062, 2 channels 600Mhz, 5GSa/s.

	• Signal generator: Rigol DG5071. 70Mhz, 1GSa/s
Labs Supporting AIR	
Lab Name 1	List of major equipment
Lab Name 2	List of major equipment
Summary and Notes	

Table 1.5.3 Detailed List for Labs Equipment in Universities of Program Countries

Partner Name	University of Genoa (UNIGE)		
Partner Main Expertise	☒ AI	☒ Data Science	☐ Robotics
Labs Supporting AI and Data Science			
DIBRIS-Software 1 and Software 2	32+24 PC workstations for training at all levels (BSc and MSc) in software, data science and computing (including HPC) subjects		
DIBRIS research facilities	Training of students at the master's level are mostly done in research laboratories where they are involved in research projects and have access to the specific project's equipment.		

Licenses for relevant software tools and platforms	Mathworks Matlab "Total Academic Headcount"Microsoft Office 365 Microsoft Education (includes licenses for operating systems, programming platforms and tools, Machine Learning Server, and other software)
Labs Supporting Robotics	
Lab Name 1	List of major equipment
Lab Name 2	List of major equipment
Labs Supporting AIR	
Lab Name 1	List of major equipment
Lab Name 2	List of major equipment
Summary and Notes	