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MASTER CLASS

INTRODUCTION TO INDUSTRIAL ROBOTICS

Project "Developing Innovative Science Outreach for Vocational Education to Encourage STEM Careers and Education", ref. no. 2017-1-BG01-KA202-036327

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DISCOVER PROJECT

Contents

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Introduction

HOW TO USE THIS RESOURCE

This Master Class is an on-campus learning and orientation experience for high school students, combining visits to a Robotics lab with an informative interactive talk on scientific topics related to computer programming and Robotics. It should be planned so that it can take place within the university and use available labs or other equipment.

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Activity concept and lesson plan

THEME OF THE CLASS	Introduction to Industrial Robotics and basic robot programming and operation.
LEVEL OF DIFFICULTY / AGE OF STUDENTS	This Master Class is targeted at students of upper secondary education that need not have any experience in robot programming. The idea is to show the possible area of use and basic programming concepts of robots, so the level of difficulty can be characterized as low to medium.
REQUIRED PRIOR KNOWLEDGE	The students can be secondary school students with a technical or general profile (if students are from general secondary schools, the preferred target group is classes with a profile in Mathematics or Physics). Students should be able to easily understand basic robot programming concepts.
TIME REQUIRED FOR IMPLEMENTATION	3 to 4 astronomical hours
INSTRUCTORS	The activity should be implemented by university teachers or research institute staff with experience in robotics and in teaching introductory robot programming courses.
KNOWLEDGE GAINED AND COMPETENCIES DEVELOPED - STUDENTS	Students who complete the Master Class will be able to: • recognise the difference between industrial and service robots • understand the approach to robots' classification • understand and explain basic concepts related to industrial robot operation and programming.
KNOWLEDGE GAINED AND COMPETENCIES DEVELOPED - SCHOOL TEACHERS	Assuming that the accompanying teachers are teachers in Maths, Physics or Technical Subjects, they will learn the basics of robot operation and programming (just like the students). By observing the teaching process, they will also develop skills to teach introductory robotics concepts to their students.
KNOWLEDGE GAINED AND COMPETENCIES DEVELOPED - UNIVERSITY STAFF OR UNIVERSITY STUDENTS	To effectively conduct this Master Class, the involved university teaching staff or university students will be able to develop their robot programming skills and understand how robots could be used as examples in introductory programming.

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MATERIALS NEEDED FOR IMPLEMENTATION OF THE ACTIVITY

Projector and computer with Internet connection for the purpose of presentation during the lecture part in this Master Class.

Operational robotic stands (cells) where students can learn how to operate and program the robot.

BREAKDOWN OF ACTIVITIES

This Master Class is divided into 3 parts:

1. Informative talk/Lecture: This part should take place in a lecture room or amphitheatre of the organizing university or research institution, so that the students can have the feeling of how it is to be a university student or a researcher. This part should start with a brief discussion of the previous experience of students in robotics. Then, the brief history of robotics should be presented, followed by introduction into robot structure and operation, programming techniques. During this phase, theoretical concepts should be exemplified with examples of utilization of robots in the industry.

2. Hands-on activity/Lab visit: This part should take place in a robotics laboratory. The hands-on activity should include the following steps:

Step 1 – The students are divided into groups of 2-5 persons (depending on the number of available robots and the number of participating students).

Step 2 – A short introduction to the robots available in the lab

Step 3 – The groups are invited to operate a robot and to write a short program, using various functions of the robot. Exact tasks will depend on the actual configuration of robotics stand(s) available in the laboratory.

3. Self-reflection on the part of students: This part can take place in a lecture room or possibly in the laboratory. Each group in turn is invited to report on the difficulties they have faced and how they solved problems that have arisen. After the students' presentations, the organizers close the meeting providing additional links and information for those that want to learn more on the topics of the Master Class.

USEFUL LINKS TO RESOURCES

International Federation of Robotics - https://ifr.org/

IFR YouTube channel:
https://www.youtube.com/channel/UCIdKFuqg5XxIPf_k2j4ZRfA

SUGGESTED FURTHER READING

https://blog.robotiq.com/bid/63528/what-are-the-different-types-of-industrial-robots

https://automatykaonline.pl/Artykuly/Robotyka/Roboty-przemyslowe-i-wspolpracujace

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Background knowledge sheet

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INTRODUCTION TO THE TOPIC

Robotics has emerged as a science, with its own subject of examination, purposes and objectives. It allows for the humanisation of human work, liberates the person from stressful and stereotypical activity and significantly increases work safety. However, robotics also has significant economic aspects, e.g. an increase in the quality and reliability of products and the stability of manufacturing processes, higher productivity of work, as well as an increase in the culture of manufacturing. Robotic devices enable wide flexibility of manufacturing and variability of products since industrial robots may flexibly modify their activity while such modifications are solved only at the level of programming.

IMPORTANCE TO DAILY LIFE/ ECONOMY /SOCIETY

Automation of production is becoming more and more common globally. As a result of changes taking place on the global market, manufacturers from various industrial sectors are forced to increase the range of production and the quality of products while reducing production costs. In the case of production companies, robotisation becomes necessity if these companies want to remain competitive on domestic and global markets.

DETAILED PRESENTATION ON THE TOPIC

An industrial robot, as defined in ISO 8373 is:

An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications:

- Reprogrammable: programmed motions or auxiliary functions may be changed without physical alterations
- Multipurpose: capable of being adapted to a different application with physical alterations
- Physical alterations: alteration of the mechanical structure or control system except for changes of programming cassettes, ROMs, etc.
- Axis: direction used to specify the robot motion in a linear or rotary mode

The typical industrial robots are still stationary machines, adapted and programmed to perform specific tasks. They can be classified on the grounds of their construction. The most popular are:

- 6-axis, human-like arm
- Cartesian, in which individual engines are usually used to position the robot in one out of three axes that are

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perpendicular to each other

- SCARA, equipped with three degrees of freedom, two of which are parallel to each other rotary axes, and one which allows for translational movement
- parallel (delta type), where the working tip is hung on more than one arm (and therefore has more than one kinematic loop)

Individual types of construction predestine robots of a given type for specific types of applications, although finally the recommended applications for the indicated machine also depend on other parameters, such as dimensions and reach of the robot, its lifting capacity, speed and even tightness.

Robotics is developing very fast, incorporating Mechatronics, electrical engineering and ICT technology. Therefore, the above presented features may soon be obsolete. Because of high work quality, robots are more often implemented into manufacturing systems. Despite nearly 100 years of history of industrial robots and a lot of progress in their development, they still cannot operate completely autonomously.

The application is the type of work the robot was designed for. Robots are created for specific applications or processes. Different applications will have different requirements about how robots are built. For example, a paint robot will require a large range of motion. On the other hand, the assembly robot will have a small work area, but it will be very precise and fast. Depending on the target application, the industrial robot will have a specific type of traffic, connection dimension, control right, software and accessory packages.

Here below are some typical applications for industrial robots:

- Welding
- Material handling
- Palletising
- Painting
- Assembly

There is also a range of robots whose application is directly targeted at assisting human beings in their work or in their everyday duties. The applications typically focus on tasks that are too difficult, hazardous, unpleasant or tedious for humans to perform, but are not related to industrial automation. These robots are called ‘service robots’. A large number of the service robots in operation are medical robots, defence robots, domestic robots (assisting with household chores) and research robots.

Service robots have requirements regarding safety and operation that differ from those of industrial robots. They are autonomous and need to interact with people in less structured or completely unstructured environments. For this reason, they need to be equipped with a variety

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of sensors and to follow more elaborate safety procedures.

The evolution of robots, marking progress from one robot generations to another is:

- 1st generation - reproduction robots that carry out given movement programs and can perform and repeat simple actions by themselves
- 2nd generation - robots equipped with a sensory system, meaning having "senses", thanks to which they respond to touch, sound signals, distinguish colours and shapes or otherwise react to stimuli from their external environment
- 3rd generation - robots equipped with a vision system that enables them to observe environmental changes and hear voice communication. Robots of this generation also have a technical layout of "artificial intelligence"
- 4th generation - adaptive control robots
- 5th generation - intelligent (smart) robots.

SCIENCE COMMUNICATION GUIDANCE TO INSTRUCTORS

- Share with the students your passion for robots. Start by sharing with them how you got into Robotics and why you like doing it.

- Establish your authority as an expert so that students feel confident about working with sophisticated machines under your instruction. However, avoid projecting a position of superiority.

- Ask the students about their prior knowledge of robots and programming in order to try to link the new knowledge with what the students already know.

- During the theoretical explanation, use examples from the real world, especially as they pertain to how robots influence the way people work and how they can achieve things that were previously not possible before.

- Try to make students curious about other ways of programming robots and other applications of robots.

- Tell students not just how to program the robot but also what (more sophisticated) functions can robots be programmed to perform. This would increase students' motivation by hinting to them that learning the basics now can help them do some really exciting stuff later.

- If you will be using visual material through a presentation or a handout, scale everything up in order to allow students to see clearly. For printing, print in colour, especially if there are schemes of robot parts.

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Lecture planning sheet

GOAL

The goal of the informative talk is to give students basic factual and theoretical knowledge on the history of robots and robotics, basic theoretical knowledge on what industrial robots are, basic theoretical knowledge on what service robots are and basic theoretical knowledge on why robotisation is important.

SETTING

The number of students will be limited by the plausible number that can be accommodated with the robotic lab during the second part of the Master Class. This part does not require special organization of space or division of learners into groups.

The duration of this part of the Master Class is between 40 and 60 minutes.

LOCATION FOR THE TALK/LECTURE

Lecture room

POSSIBILE INVOLVEMENT OF UNIVERSITY STUDENTS IN THE ACTIVITY

University students may undertake the responsibility to deliver the presentations, while university or research institution staff could coordinate the activity and the discussion with the students, especially in the beginning of the activity.

TIMING & RUN-DOWN

Phase no.	**Description of phase**	Time allocated
1	**Welcome words; clarification of the aim of the Master Class**	3-5 min
2	**Introduction to Robotics**	3-5 min
3	**The history of Robotics**	5-10 min
4	**Robots - terminology**	5-10 min
5	**Types of robots**	5-10 min
6	**Robot population in the world**	5-10 min
7	**Main producers** (the instructor could use internet to show the various types of robots produced by each producer)	5-10 min
8	**Closing**: the instructor should briefly present what will follow and what kind of activities the students will be involved in during the hands-on phase in the robotic lab.	5 min

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Hands-on activity/experiment planning sheet

GOAL	The goal of the hands-on activity is to familiarize students with robots, and give them the possibility of practical work with the robot. The visiting students and the accompanying teachers are invited to the robotic stand(s) and learn how to operate a robot. In the process, they are introduced to basic programming.
SETTING	The activity should take place in a robotics lab where the students work in groups of up to 5 persons per group depending on the available space.
LOCATION AND EQUIPMENT	The hands-on part of the Master class is expected to take place in a robotics lab within a university or a research organization. The students should be instructed in detail about safety procedures in the lab. If necessary, they have to wear protective gear. The host organization should carefully consider which of the robots available in the lab can be suitable to be operated by students. Regardless of this choice, lab staff or other staff members knowledgeable of robot operation should continuously oversee the work of the students.
POSSIBILE INVOLVEMENT OF UNIVERSITY STUDENTS IN THE ACTIVITY	The activity is designed to involve university students as facilitators, on the condition that they are knowledgeable of the operation of the robots in the lab. Volunteer students have to be instructed about safety procedures and to be capable of ensuring the observance of these procedures by the students. In case of lack of volunteers, this can be done by university staff. However, the involvement of university students is highly desirable as it will help the secondary students feel more comfortable and be able also to discuss with them other things beyond robotics.
CONTENT OF THE HANDS-ON ACTIVITY	During this activity, the secondary students will be given a short training how to operate, move and program the robot.

TIMING & RUN-DOWN OF THE HANDS-ON ACTIVITY

Phase no.	**Description of phase**	Time allocated
1	Organization of students into groups	5 min.
2	Basic information about the robots and training model of a given manufacturer: - types of robot - basic parameters (lifting capacity, working space)	10 min.

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	- application areas - basic differences between successive control systems	
3	Launching the robot	10 min.
4	Operation mode with industrial robot - manual work / programming, testing, automatic operation	10 min
5	Coordinate systems	10 min
6	Tool: - idea, declaration, definition	10 min
7	Programming: - logic instructions - positioning instructions	10 min
8	Basics of robot operation	10 min
9	The robot's movement capabilities	10 min
10	Simple robot programs	10 min
11	Programming the robot trajectory	10 min
12	Editing / correcting the program	10 min
13	Conclusions and farewell	5 min.

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Annex I: Knowledge Resource

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ABOUT ROBOTS

Since intelligence appeared in the universe, creatures blessed with its gifts started using simple tools to achieve specific results faster and easier than they could by using only what nature equipped them with. Today we know that some bird species can creatively use simple tools, e.g. sticks to get food. Not only can they use tools, but they can also make them. They learn how to do it by observing each other. Human beings not only can learn from each other, but they can also pass on that knowledge over time.

People invented different ways to preserve and transfer knowledge to future generations. This allowed them to creatively develop the first simple tools. Over time, people put together more complex structures – mechanical devices. While the simple tool can be considered as an extension of the hand and all activities related to their use need to be carried out by humans and powered by muscles, the mechanical devices perform simple tasks in a totally independent way by using the power generated by external sources.

But even these solutions have their limitations. Each device is designed to perform specific tasks. It is therefore inflexible because either it is difficult to adapt to do something else or its adaptation is too time-consuming, costly and economically inefficient to be justifiable. For example, the packaging machine can never be able to be used as a welding machine.

The first machines have been developed to perform tasks that either require much more power than that provided by human muscles or are hazardous to humans or are performed in unsafe conditions. Over time people started to build devices to perform easier tasks, too, not because they require much power but because they are repetitive, monotonous and tedious to humans.

Robots represent by far the highest degree of evolution of the tools used by man. They are autonomous (to some extent), programmable, reconfigurable and flexible in terms of the ease of adaptation to perform a new task.

The concept of robot describes autonomously operating devices that can receive information from the environment through sensors and influence their environment through effectors. Returning to the example quoted above, the robot can both be used for packaging parts and for welding. One robot can even perform both tasks at the same stand even though not at the same time.

Robotics is a field of science dedicated to the design and construction of robots. This science covers a very wide range of knowledge, from mechanics, electrics, electronics, to the theory of control and artificial intelligence and cognitive science aimed at modelling cognitive abilities, ways of thinking and behaviour of animals or people. Recently, even sociology and education have started using robots.

The term “robot” is generally supposed to have been used for the first time in a play written in 1921 by a Czech writer. The year 1921 is therefore considered as the year zero of the history of modern robotics. It should be highlighted here that the term robot was first used in the science-fiction literature describing artificially produced, simplified versions of the man intended to perform hard labour, while the first mechanical construction was, as we know it today, a typical industrial robot. The first prototype of the industrial robot was developed only in 1958, and three years later mass production of these robots was launched.

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There is currently no one single coherent definition of robot succinctly describing all possible and existing structures. As mentioned above, the beginnings of robotics focused on developing manipulators for industry. The first official definition of a robot refers to such solutions.

INDUSTRIAL ROBOT BRANDS

There are many industrial robot brands. The largest ones produce a complete range of robots for different applications at different sizes. The smallest companies usually target a specific size or application range. Examples of industrial robot brands are:

- Fanuc (https://www.fanuc.com)
- Motoman (https://www.motoman.com)
- ABB (https://new.abb.com)
- Kuka (https://www.kuka.com)
- Denso (https://www.densorobotics.com)
- Adept (http://onexia.com/adept/index.html)
- Comau (https://www.comau.com)
- Kawasaki (https://robotics.kawasaki.com)
- OTC Daihen (https://www.daihen-usa.com)
- Universal Robots (https://www.universal-robots.com)
- Staubli (https://www.staubli.com)
- Mitsubishi (https://www.mitsubishielectric.com/fa/products/rbt/robot/index.html)
- Epson (https://epson.com › industrial-robots-factory-automation)
- Yamaha (https://www.yrginc.com)
- Nachii (www.nachirobotics.com)

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Annex II: Co-Creation

University Students

<table>
<tr><td colspan="2">Selection</td></tr>
<tr><td colspan="2">The following university students can be involved in the design and delivery of the activity:
- Students of Mechatronics or Engineering, in any year of studies, as long as they are knowledgeable in the field of Industrial Robotics.
- Students should be selected by the faculty member responsible for the activity and should have worked with this faculty member before (in class or in educational outreach activities).
The selected students should stand out for their science communication skills rather than their excellence and academic achievement per se.</td></tr>
<tr><td>Role (in order of relevance)</td><td>Guidance</td></tr>
<tr><td>Pedagogical co-designers of learning, teaching and assessment; facilitators in hands-on and lab experiments</td><td>The selected university students:
- should work together with high school students during the practical activity and help them use Arduino to develop the weather station
- should participate in the assessment of student performance during the course and in the evaluation of the effectiveness of the training
- should also be actively engaged in the self-reflection phase, staying with the student team in which they worked.</td></tr>
<tr><td>Mentors of SE VET students</td><td>The selected university students can be asked to share their contacts with bright or motivated high school students who may want to learn more about Robotics. The possibility of involving high school students in teams working on university projects or contests in the field of Robotics or Mechatronics should be explored.</td></tr>
<tr><td>Consultants in planning and designing the learning and teaching process</td><td>The selected university students should be fully engaged in the design of the hands-on activity in order to ensure that the tasks would be manageable for younger students without prior experience with robots.
Students can be given the task to prepare the Power Point presentation for the activity, as well as any handouts and supporting materials. They should, however, do this on the basis of clear instructions from the faculty member</td></tr>
</table>

	who will lead the course.
Co-researchers contributing to subject-based research	The selected university students can be asked to design detailed guidelines for practical activities involving work with the robots. They should be instructed to keep the level of difficulty close to the skills and knowledge of high school students.

High School Teachers (supporting role is suitable for teachers in Computer Science or Physics)

Consultants in planning and designing the learning and teaching process	The accompanying teachers should have the leading role in selecting trainees from among the students. They should be approached in advance and consulted about the relevance of the presented examples and the level of difficulty of the theoretical presentation (in view of the intended group of trainees). Special attention should be paid to the selection of manageable practical tasks and the avoidance of tasks that have no relevance to the compulsory curriculum. Teachers should be consulted about the best way to draw parallels and to link the content of the course to the compulsory curriculum.
Pedagogical co-designers of learning, teaching and assessment; facilitators in hands-on and lab experiments	The accompanying teachers should work together with high school students during the practical activity in order to help them operate the robots, as well as provide clarification to those of them that have failed to understand the presented material or apply it in practice. Most teachers would be in position in which they themselves will operate robots for the first time. They should be given the chance to learn themselves. High School teachers should be the primary source of feedback about the effectiveness of the training. They will also be in the best position to assess the performance of their students. Teachers should play a central role in maintaining discipline during the activity. Teachers should be specially instructed about safety rules in the Robotics Lab. Safety instruction most likely would be given to the

	students by the Lab staff or the Master Class instructor. However, teachers should be tasked with monitoring functions during the activity in order to ensure that safety instructions are strictly observed by the students.

University-high school partnerships

This course in particular would be a suitable addition to study programs in secondary schools with a profile in Engineering, Mathematics, or the Natural Sciences. It can be the beginning of a series of extra-curricular courses on Mechatronics or Robotics. If there is such an interest, contact between the accompanying teachers and the university should be made well in advance and the course should be planned as part of a larger set of topics. The course can be combined with workshops organized at the school by visiting university lecturers. One particular high school teacher or administrator and one particular university faculty member should be tasked with the organization of this Master Class and they should act as contact persons and "boundary spanners" in future activities. For further collaboration to be planned, it is advisable that an educational manager from the school attend (part of) the Master Class in order to witness the effectiveness of the training. If this is not possible, then a report on the achieved results and the satisfaction of students should be presented to the school management, together with a proposal for further collaboration.

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