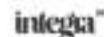# MIND

Erasmus+ strategic partnership for Higher Education

DEVELOPMENT OF MECHATRONICS SKILLS AND INNOVATIVE LEARNING METHODS FOR INDUSTRY 4.0

IO5 REPORT

Project Title	**Development of mechatronics skills and innovative learning methods for Industry 4.0** **2019-1-RO01-KA203-063153**
Output	**IO5 – Collection of didactic videos aiming to improve mechatronics skills**
Date of Delivery	**May 2021**
Authors	**The leader of this intellectual output is STU and following partners are implicated in the realization: UTCN, UNI, UPT and CC.**
Version	**V5, 25.05.2021**

Contents

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1   Introduction, objectives, and tasks of IO5

Mechatronics represents a symbiosis of technical fields such as mechanics, electronics, control systems and computer systems. Mechatronics aims to develop new device concepts with built-in artificial intelligence algorithms.

The main goal of the MIND project is to develop the skills of mechatronics and innovative method training for Industry 4.0 to meet the requirements of employers to prepare qualified students with interdisciplinary skills in mechatronics, IT and excellent soft skills for developing Industry 4.0 concepts.

We are convinced that short videos can effectively complement lectures on mechatronics (Fig.1). They will lead to increased student interest. The main reason to use didactic videos to develop mechatronics skills is that the media will appeal to all students' senses and help them better process the information they receive. Video content helps teachers motivate students because it brings real life to the classroom, and a complete communication context represents the language. And instead of taking up more lessons (traditional care for the professor), they help save the teaching role. We believe that the involvement of students in mechatronics will increase in short video clips [MES17].
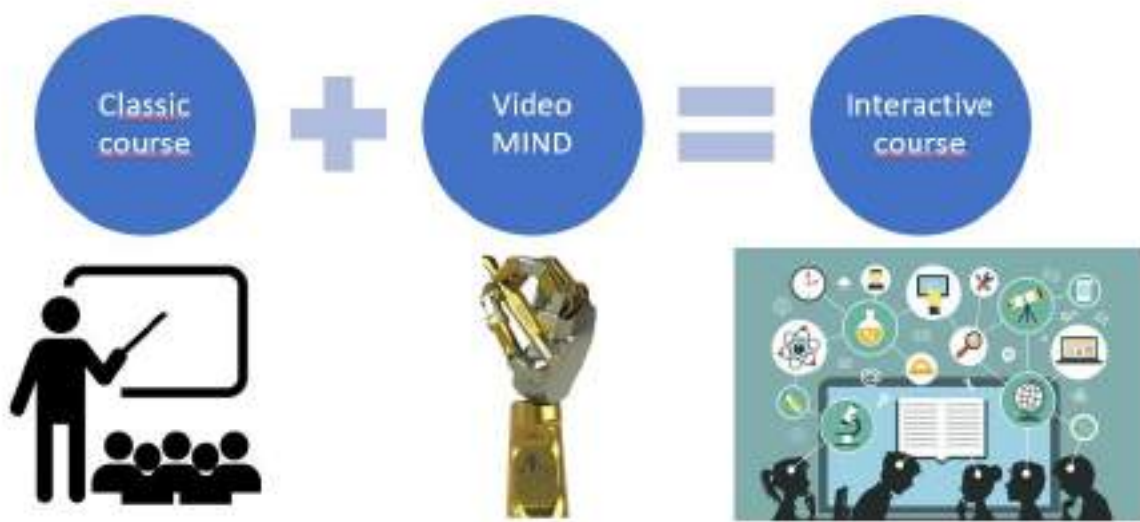

Fig.1. Description of IO5 concept [www02], [www03]

A teacher will select videos to reinforce mechanical and electronic concepts by taking a mechatronics course. We consider this to be two to four short videos that last from 30 to 120 seconds. The most effective for involvement is 120 seconds, which are regularly given after students' 20 minutes of the lecture [CHO19]. We believe in videos

(1) will motivate them to participate in a mechatronics class,

(2) to improve their understanding; and

(3) help them memorize concepts and

(4) motivate them to examine the curriculum outside the classroom.

All digital training media are compiled in a central library for direct access, significantly reducing course preparation time. Participants are provided with a set of related material for each session, but instructors can also create new media for tests or questionnaires as needed to complete courses or training [FER11].

The following partners were involved in the development of IO5: STU, UTCN, UNI, UPT

The specific tasks of IO5 are:

Collection of didactic videos covering critical elements of mechatronics:

- Video covering modelling and simulation of mechatronic systems
- Video covering sensors and actuators used in mechatronics
- Video about software and data acquisition from sensors
- Examples of mechatronic hardware include Arduino and Raspberry Pi hardware.

Each participant in this intellectual output will contribute to its result. The entire project partners will be constantly available via mobile phones. Each participant in this scholarly output will organize regular project meetings (Skype). Communication and cooperation will be ensured by intensive use of the Internet and e-mail contact. STU assumes responsibility for collecting, organizing and uploading materials for the project website and partners to submit the translated version promptly.
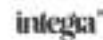
2 Requirements, according to target groups

Because the leading target group is students of mechatronics and related fields, the first step was to create a questionnaire for them. Students expressed an interest in an easier way to acquire the necessary skills for mechatronics students from the Technical University of Cluj-Napoca and to have the ability to evaluate their knowledge in this area at the end of each section.

Students need concrete and explicit materials. If they want to study on their own, they must be able to understand the basic concepts.

Requirements for uploaded videos should be short but concise. The first part of the video is a brief introduction to the discussed topic and then the practical part of demonstrating the device or software implementation of the concept. After completing each video, students have the opportunity (if they wish) to complete a short quiz about the content they watched. The examination should be simple, easy to meet and provide them with an objective view of their acquired knowledge of the material studied.

If something is unclear, they can always watch the videos again and find more details in the courses.

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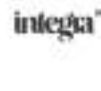
3 *Overview of the video collection*

As it was presented in previous chapter, the MIND video collection is divided in four main groups (Fig.2), which were chosen for covering the interdisciplinary connections of the Mechatronics subject.
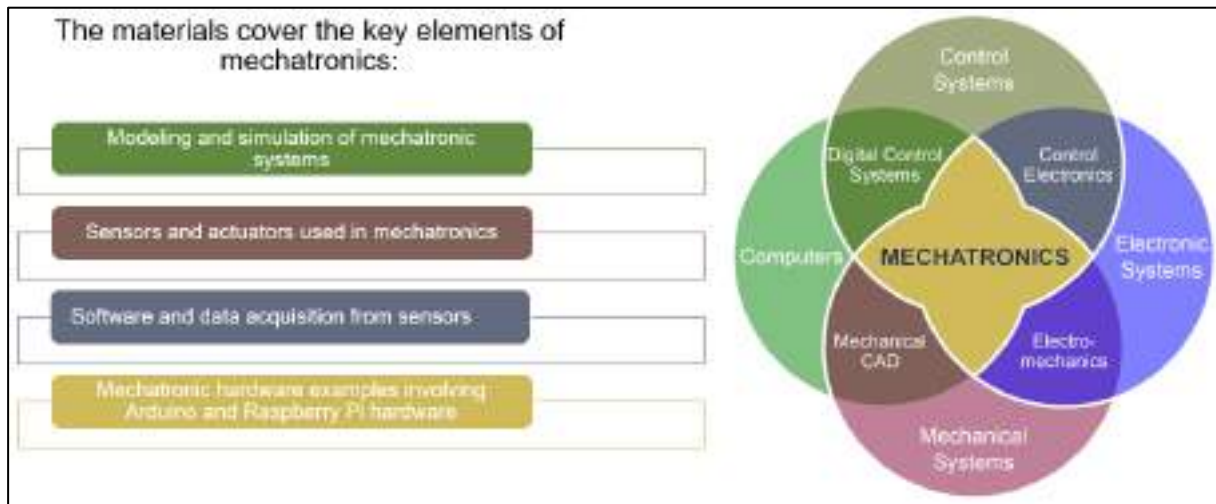

Fig.2. The main topics for MIND video collection [www01]

During the project meetings was decided to work on a PowerPoint template (Fig.3), in order to be filled by the partners involved in this Intellectual Output with the relevant information for the chosen topics and later the PowerPoint template will be converted into a video [OLI10].
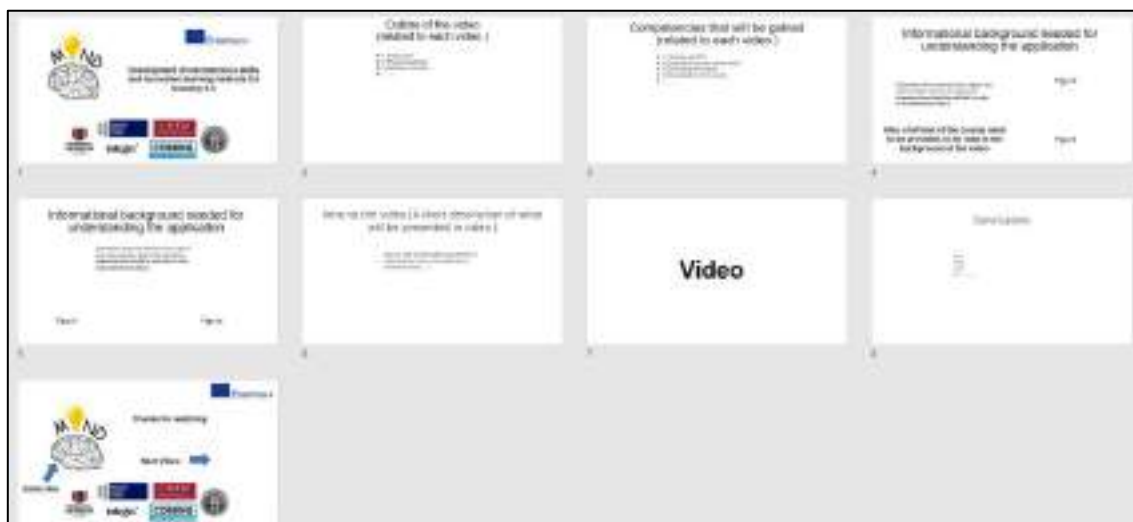

Fig.3 PowerPoint template

Every MIND video has following structure:

- Intro with project logo

- Outline of the video

- Theoretical background needed for understanding the application presented in the video

- A description of the hardware that will be presented

- Conclusion

- Outro

3.1   Video covering modelling and simulation of mechatronic systems

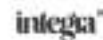- **Virtual robot control with haptic feedback**

The current video presents the development and functional testing of a hardware-software tool for testing the suitability of certain actuator types as joints for an exoskeleton. The approach explored is to replace the brake/pot combination with a single unit (a smart servo) which can provide position sensing and (active) feedback in the same package. Because this being active feedback a slave robot is required to be able to test and prove the concept. For this task, a virtual environment was considered that could simulate and traffic data from a robot scene.

The processing and communication software interface is in charge of gathering, converting and providing the relevant data between the aforementioned components. The communication with the peripherals is time based, with a 20Hz target refresh frequency. The software interface is also in charge of the GUI that allows for: pairing of the servos with the robot joints, setting the force feedback amplification, opening and closing communication and displaying various useful runtime values. In order to be able to analyze the data streams this interface also logs the values for positions, torques, timestamps etc. in a CSV formatted file, for later use.

The video will show a teleoperation manipulation experiment where the user could grab one object and place it elsewhere in a virtual environment, using a force-feedback enabled serial-links device.

The controlling device is made using Dynamixel servo motors and a switch (for closing the gripper).

The key elements are the joint 3 (elbow) of the robot and the end-effector. Look for the "anti-gravity" motion of the motors in user hands as they receive force feedback signal from the virtual robot.
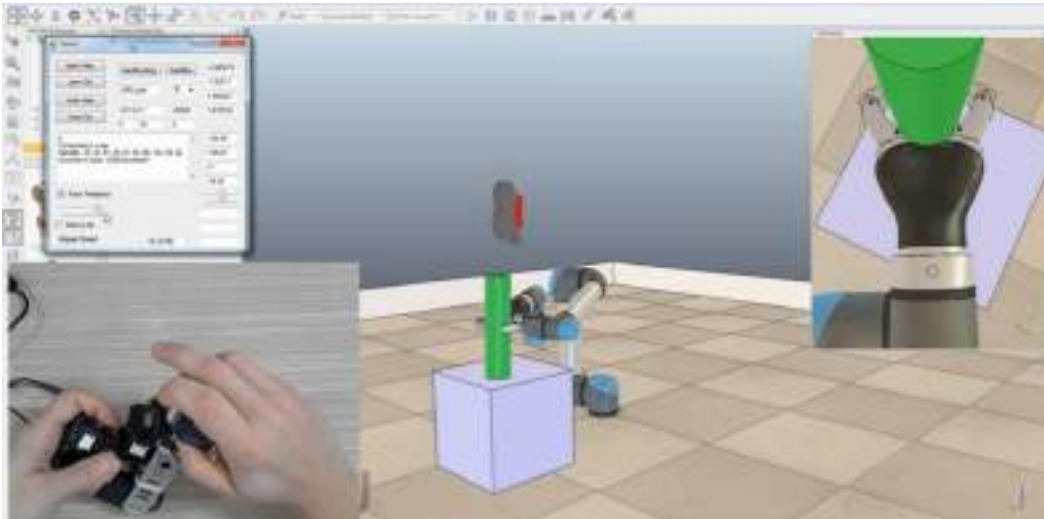

Fig.4. Virtual robot control with haptic feedback

- **Teleoperation of Kuka KR15 with Myo bracelet**

The human operator can control an industrial robot using two Myo armbands. With one armband he can control de X, Y, Z movement (Fig. 1) and with the second he can control de alpha orientation and open/close the gripper.
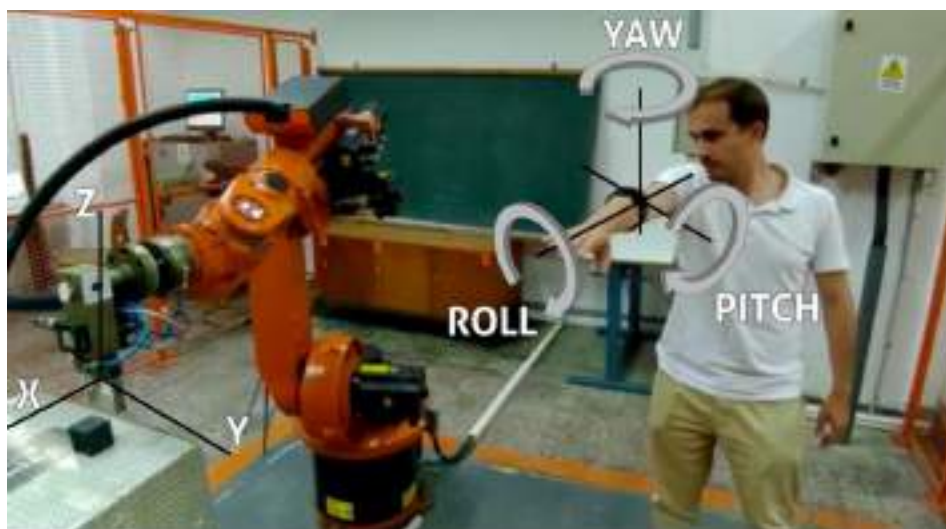

Fig.5. Teleoperation of Kuka KR15

The two Myo armbands are sending data to a laptop which is converted into positioning coordinates using a custom program created in Visual Studio.

The video will show how any human operator, can control a Kuka KR15 industrial robot, using its hands. A practical application will be presented, in which a cube is moved in different positions.

Fig.6. Teleoperation of Kuka KR15

- **Collaborative remote control of virtual robotic manipulators**

The present work starts the development of a novel framework that will allow remote control of robotic manipulators. In particular, it deals with the hardware & software design aspects, related to the remote control of two virtual robotic manipulators.

For this type of control, the user should move the hands towards desired target positions. A Kinect for Xbox One will track the hands motion and recognize palms gestures and then forward this data to a virtual simulation environment (V-Rep) that animates a scene with two robotic manipulators, accordingly.

The video will show a collaborative manipulation experiment where the user could grab the two-colored cubes and place them elsewhere or could handover one cube, using the Kinect.

One of the authors – skeleton in the upper right corner – successfully manipulates 2 cubes in the virtual environment.

Pay attention to the robots end-effectors (suction cups), as they change color indicating activation. This can also be seen on the Kinect skeleton palms, changing color from green to red.
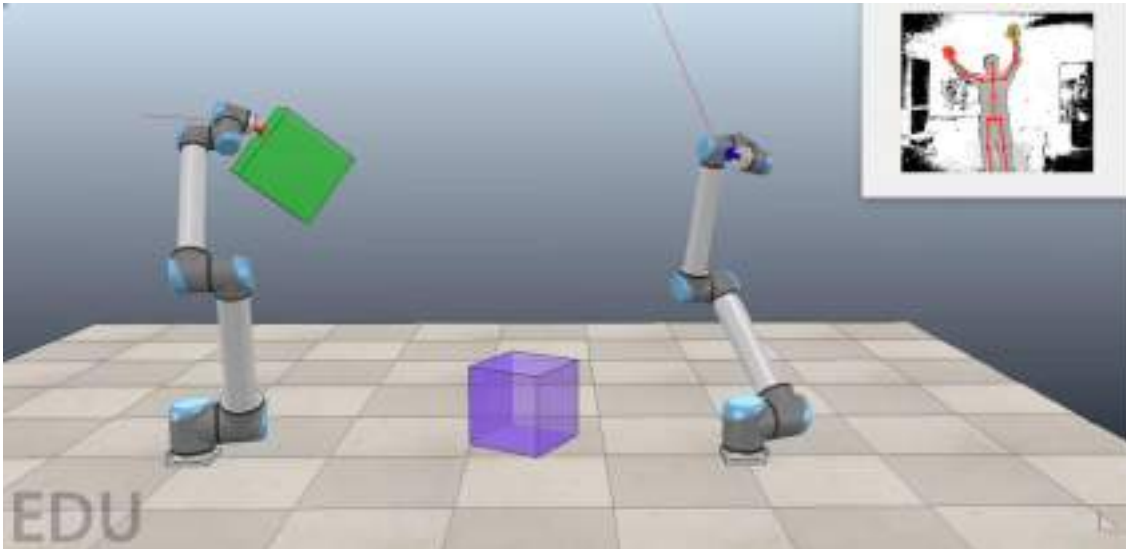

Fig.7. Collaborative remote control of virtual robotic manipulators

- **Eshed Robotec Conveyor Virtualization**

Working and programming the real conveyor in the Eshed Robotec FMS. Better understand the way this conveyor type works and its behavior. Manipulate the simulation application for different production data (piece ID, station manufacturing time etc.). Interpretation of the simulation results leading to the systems production efficiency calculus and a better schedule (short term production planning).

Conveyor has a plastic chain that moves and transport carriages continuously. In stopping position on conveyor, each carriage stops, it's ID is read, if there is no loading/unloading command, it goes on, else the carriage stays until the command is executed. Transfer carriages carry the symbol to differentiate the part ID (diamond: ID1, star: ID2). Carriages have different colors, depending on their ID. Tcurent is a global variable to count the simulation time. Tp2, Tp3 is the current time, equal with: Tcurent+Operation time at station EMCO or SCORA .
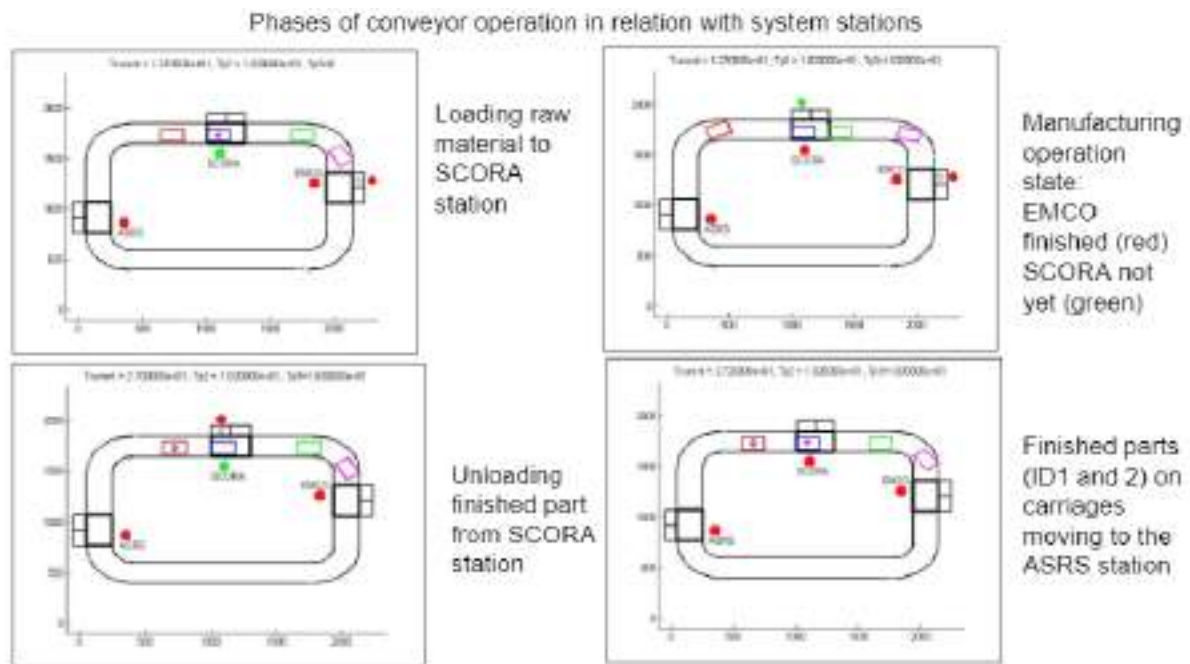
Fig.8. Eshed Robotec Conveyor Virtualization

Students might experiment the simulation program with different input production data. Students will calculate different efficiency parameters, for whole system or single station. The project can be developed toward an optimal scheduling production planning, by using MATLAB neural networks and deep learning facilities. By using a distributed control system in Eshed Robotec System, it is possible to develop a cyber-physical system, for education purposes.

Fig.9 GUI interface for Eshed Robotec Conveyor Virtualization

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3.2 Video covering sensors and actuators used in mechatronics

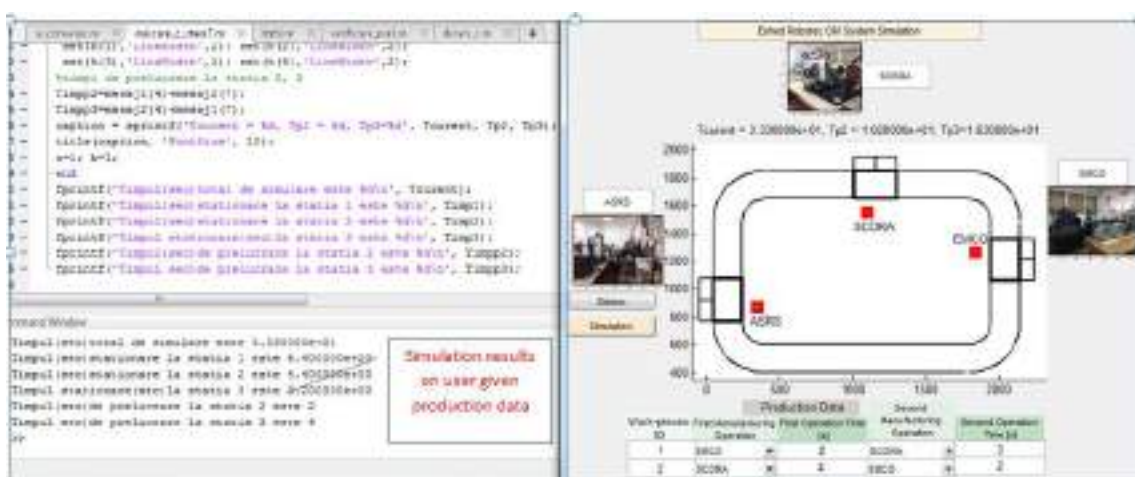A series of videos were developed for presenting the basic concepts of pneumatic systems and actuators:

- **Video 1**

In the given video, we first see the device for the treatment of compressed air, the compressed air distribution block, the control valve 3 / 2NC with a button and the directly controlled single-acting pneumatic extension cylinder.

The task:

Use the button to control the extension and retraction of the single-acting cylinder

Acquired competencies:

- understanding of the activity
  ◦ pneumatic systems,
  ◦ the term single-acting cylinder
  ◦ direct control
  ◦ push-button operated 3/2 NC valve
- basics of valve marking (3/2, 4/2, 5/2, NC, NO, …)
- practical skills in connecting pneumatic systems
- reading diagrams of pneumatic systems

- **Video 2**

In the given video, we first see the device for the treatment of compressed air, the distribution block of compressed air, the control valve 3 / 2NC with a button by which we control a pneumatically operated monostable NC valve and indirectly controlled single-acting pneumatic extension cylinder

The task:

Use the button to control the extension and retraction of the single-acting cylinder, the implementation of indirect control of the single-acting cylinder

Acquired competencies:

- understanding of the activity
- pneumatic valves
- direct and indirect control
- marking of pneumatic elements on the diagram

- **Video 3**

In the given video, we first see a device for the treatment of compressed air, a distribution block of compressed air, 2x control valves 3 / 2NC with a button, which controls a pneumatically operated bistable valve and an indirectly controlled double-acting pneumatic cylinder.

The task:

Use the button to control the extension and retraction of the double-acting cylinder, the implementation of indirect control of the double-acting cylinder utilizing a bistable valve and two buttons.

Acquired competencies:

- understanding of the activity
  ◦ monostable valve,
  ◦ bistable valve
- pneumatic valves
- direct and indirect control
- marking of pneumatic elements on the diagram

- **Video 4**

In the given video, we first see the device for the treatment of compressed air, the distribution block of compressed air, 1x control valves 3 / 2NC with a button, which controls a pneumatically operated monostable NC valve and indirectly controlled double-acting pneumatic cylinder

The task:

Use the button to control the extension and retraction of the double-acting cylinder, the implementation of indirect control of the double-acting cylinder utilizing a monostable valve and one button.

Acquired competencies:

- understanding of the activity
  ◦ monostable valve,
  ◦ bistable valve
- pneumatic valves
- direct and indirect control
- marking of pneumatic elements on the diagram

- **Video 5**

In the video, we first see a device for compressed air treatment, compressed air distribution block, 1x 3 / 2NC control valves with a button, which control a pneumatically operated bistable valve, mechanically - pulley-operated 3/2 NC valve as an end position sensor and indirectly controlled double-acting pneumatic cylinder
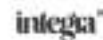
The task:

Use the button to control the extension and retraction of the double-acting cylinder, the implementation of indirect control of the double-acting cylinder utilizing a bistable valve, the end position sensor (pulley) and one button

Acquired competencies:

• understanding of the activity
  ◦ monostable valve,
  ◦ bistable valve
  ◦ end position sensor
• pneumatic valves
• direct and indirect control
• marking of pneumatic elements on the diagram

- **Video 6**

In the given video, we first see a device for compressed air treatment, compressed air distribution block, 3x control valves 3 / 2NC with a button, which we use pneumatically, logic valve AND, logic valve OR controlled bistable valve, mechanically - pulley controlled 3/2 NC valve as end position sensor and indirectly operated double-acting pneumatic cylinder

The task:

Use the button to control the extension of the double-acting cylinder.

Acquired competencies:

• understanding of the activity
  ◦ monostable valve,
  ◦ bistable valve
  ◦ end position sensor
  ◦ logic valve OR
  ◦ AND logic valve
• pneumatic valves

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• direct and indirect control

• marking of pneumatic elements on the diagram

- **Video 7**

In the given video, we first see a device for compressed air treatment, compressed air distribution block, 1x 3 / 2NC control valves with pneumatic button, logic valve AND, logic valve OR controlled bistable valve, mechanically - pulley controlled 3/2 NC valve as end position sensor and indirectly operated double-acting pneumatic cylinder

The task:

Use the button to control the extension of the double-acting cylinder.

Acquired competencies:

- • understanding of the activity
  - ◦ monostable valve,
  - ◦ bistable valve
  - ◦ end position sensor
  - ◦ logic valve OR
  - ◦ AND logic valve
- • pneumatic valves
- • direct and indirect control
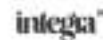- • marking of pneumatic elements on the diagram

- **Video 8**

In the given video we first see a device for compressed air treatment, compressed air distribution block, 2x control valves 3 / 2NC with a button, which we use pneumatically, logic valve AND, logic valve OR controlled bistable valve, mechanically - pulley controlled 3/2 NC valve as end position sensor and indirectly operated double-acting pneumatic cylinder

The task:

The button to control the extension of the double-acting cylinder the extension must be realized simultaneously by pressing two buttons (two-hand control), the insertion of the cylinder is realized by the end position sensor, realization of indirect control of the double-acting cylinder by bistable valve.

Acquired competencies:

- • understanding of the activity

◦ monostable valve,

◦ bistable valve

◦ end position sensor

◦ logic valve OR

◦ AND logic valve

◦ two-hand operation

• pneumatic valves

• direct and indirect control

• marking of pneumatic elements on the diagram

- **Video 9**

In the given video, we first see a device for compressed air treatment, compressed air distribution block, 2x control valves 3 / 2NC with a button, which we use pneumatically, logic valve AND, logic valve OR controlled bistable valve, mechanically - pulley controlled 3/2 NC valve as end position sensor and indirectly operated double-acting pneumatic cylinder.
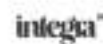
The task:

The button to control the extension of the double-acting cylinder must be realized simultaneously by pressing two buttons (two-hand control). The insertion of the cylinder is recognized by the end position sensor, the realization of indirect control of the double-acting cylinder by a bistable valve.

Acquired competencies:

• understanding of the activity

◦ monostable valve,

◦ bistable valve

◦ end position sensor

◦ logic valve OR

◦ AND logic valve

◦ two-hand operation

• pneumatic valves

• direct and indirect control

• marking of pneumatic elements on the diagram

- **Video 10**

In the given video, we first see a device for compressed air treatment, compressed air distribution block, 1x 3 / 2NC control valves with pneumatic button, logic valve AND, logic valve OR controlled bistable valve, mechanically - pulley controlled 3/2 NC valve as end position sensor and indirectly controlled double-acting pneumatic cylinder, throttle valves, timer

The task:

Using the button to control the extension of the double-acting cylinder, the extension must be realised by pressing the button. In the extended position, the cylinder remains a specific set time (timer). The insertion of the cylinder is recognised by the end position sensor, the realisation of the indirect control of the double-acting cylinder utilising a bistable valve. Throttle valves regulate the speed of movement of the cylinder.
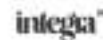
Acquired competencies:
- understanding of the activity
  ◦ monostable valve,
  ◦ bistable valve
  ◦ end position sensor
  ◦ logic valve OR
  ◦ AND logic valve
  ◦ two-hand operation
  ◦ flow restriction, throttle valves
  ◦ timer
- pneumatic valves
- direct and indirect control
- marking of pneumatic elements on the diagram

- **Video 11**

In the given video, we first see a device for compressed air treatment, compressed air distribution block, 2x control valves 3 / 2NC with a button, which we use pneumatically, logic valve AND, logic valve OR controlled bistable valve, mechanically - pulley controlled 3/2 NC valve as end position sensor and indirectly controlled double-acting pneumatic cylinder,

The task:

Use the button to control the extension of the double-acting cylinder.

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Acquired competencies:
- understanding of the activity
  - monostable valve,
  - bistable valve
  - end position sensor
  - logic valve OR
  - AND logic valve
  - two-hand operation
  - control from two places
- pneumatic valves
- direct and indirect control
- marking of pneumatic elements on the diagram

- **Video 12**

In the given video, we first see a device for compressed air treatment, compressed air distribution block, 1x 3 / 2NC control valves with pneumatic button, logic valve AND, logic valve OR controlled bistable valve, mechanically - pulley directed 3/2 NC valve as end position sensor and indirectly controlled double-acting pneumatic cylinder,

The task:

Use the button to control the extension of the double-acting cylinder extension. The insertion of the cylinder is realized by the end position sensor, the realization of the indirect control of the double-acting cylinder utilizing a bistable valve.

Acquired competencies:
- understanding of the activity
  - monostable valve,
  - bistable valve
  - end position sensor
  - throttle valve
- pneumatic valves
- direct and indirect control
- marking of pneumatic elements on the diagram

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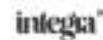
3.3 Video about software and data acquisition from sensors

- **Quanser QUBE-Servo 2**

This video is dedicated for understanding how an encoder works and how data from the encoder can be obtained. The encoder data represents the input for a PID controller for positioning the pendulum straight up and keeps it up in case of an external disturbance.

Fig.10. Quanser QUBE-Servo 2

- **Screw recognition using image processing techniques**

This video will present main functions in MATLAB that are used for image processing. Also, will be presented the possibility of creating GUI standalone application and integrating the image processing techniques in it.
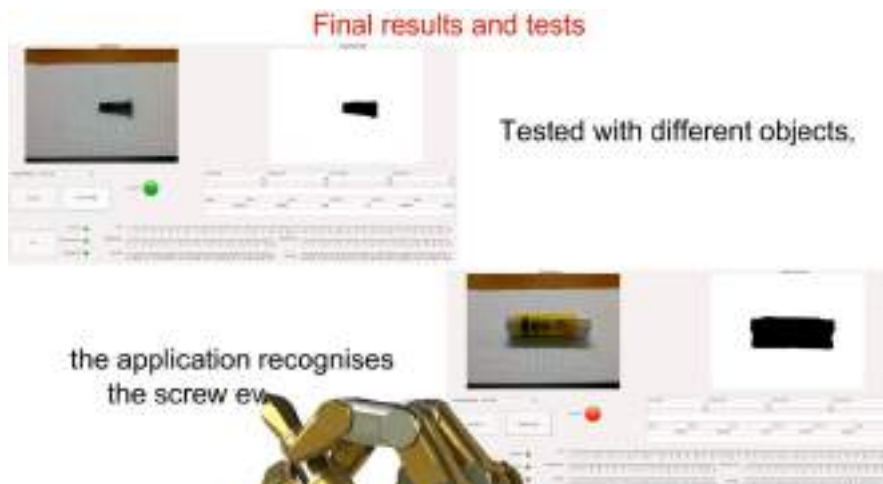

Fig.11. GUI interface for screw recognition

3.4 Examples of mechatronic hardware include Arduino and Raspberry Pi hardware

In this category will be included complex mechatronics systems, that will require the understandings of the topics explained in previous chapters. This collection of the videos will present the possibility of integration of the sensors, actuators and the control of the system will be provided by an Arduino board or Raspberry Pi.

- **The intelligent roof window**

The actuation is performed by means of the linear actuator type Actuonix L 12, which allows a maximum force of 80 N with the maximum stroke of 100 mm. For the automatic control of the window was conceived and assembled a system based on: the board Arduino Mega ADK, the sensor BME280, used for the acquisition of data regarding temperature, pressure and humidity, the phototransistor PT15-21C/TR8, which measures the light intensity.

An appropriate code was written in order to control the closing and opening of the window at given values of ambient light intensity, humidity, temperature and pressure.

The video shows the structure of the intelligent roof window:

- Window in closed position.

- The actuating mechanism is located on one side of the window frame.

- The control system is started.

- The system allows the measuring the pressure, temperature and humidity by activating the phototransistor, this gives a signal to open the window.

Fig.12. Intelligent roof actuating system

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- **Active knee prosthesis**

In this video, the synthesis of the geared linkage will be explained. In order to avoid the disadvantages of the inverted slider-crank it is recommended to use a geared linkage and a linear displacement actuator. The geared linkage contains an inverted slider-crank as basic structure connected in parallel with a gear train. One of the gears is connected with the slider of the basic structure and performs a planetary motion. The control of the system electro-pneumatic system (fig.13) will be made with an Arduino Board.
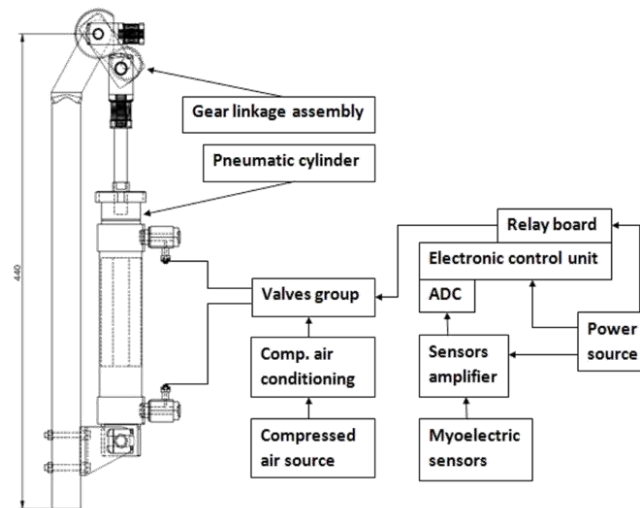

Fig.13. Active knee prosthesis scheme

Fig.14. Active knee prosthesis prototype

- **3D printed gripper**

In this video, the mechanical design of a 3D printed gripper will be explained. The Gripper will have just two positions: open and closed, and these two positions can be switched using two buttons. The wiring for connecting a stepper motor will be covered.
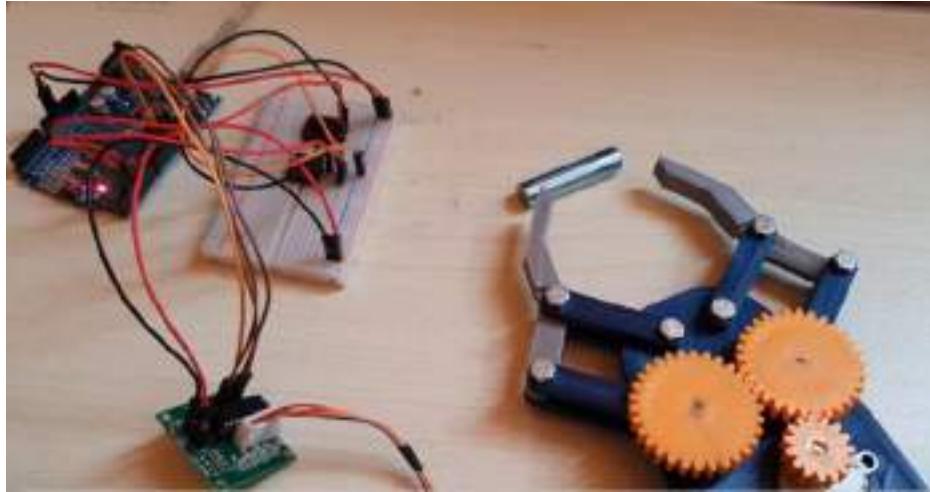

Fig.15. 3D printed gripper

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4   Conclusion

The MIND Video collection was developed as complementary material for the classic course for making it more interactive and interesting for the students. This report was written for giving an overview of the main four topics and describing some videos that were developed by MIND Project team.

This collection of videos explains the basics of all pylons of mechatronics: mechanical design, electronics, sensors, programming, and signal acquisition. The last series will combine all the knowledge gained form previous chapter and involve them into complex mechatronics systems that are controlled using developing boards as Arduino or Raspberry Pi.

The recorded videos must meet current standards as well as future trends, such as Industry 4.0; it must be student-centred, with an emphasis on what students learn in a problem-based learning environment; and it must take into account an integrated approach.

It's also critical that students are taught how to address more challenges rather than didactic ones. Students must choose the subjects that are most relevant to their personal development and career choices.
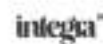
Literature

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[OLI10]   de Oliveira Miguel, P.V., Murari, C.A.F. and Barreto, G., (2010), April. Didactic videos about basic concepts on alternating current circuits. In IEEE EDUCON 2010 Conference (pp. 1941-1946). IEEE.

[www01]   https://qph.fs.quoracdn.net/main-qimg-0a31da7be125c544213f00d417f5d0e3

[www02]   https://cirl.etoncollege.com/wp-content/uploads/sites/4/2021/01/Online-Learning.png

[www03]   https://dataexpertise.org/wp-content/uploads/2021/02/Teaching_icon-2.png