NETKOM 4.0

Netcompetence For A Digitized Working World 4.0

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RBZ
ECKENER-SCHULE

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Intellectual Outcome O1

Collaborating robots in Industry 4.0

This document contains a result from the NetKOM_4.0_v2 project.

It was created by the RBZ Eckener-Schule Flensburg.

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Course / Curriculum - Pilot course /module

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General information on the NetKom_4.0_v.2 project

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1 Introduction

Collaborative robots (cobots) are a key function in the development towards Industry 4.0. Cobots enable human-robot collaboration (HBR), combining human skills and abilities with the precise functions of a robot. The reasons for using these cobots include demographic change, ergonomic considerations, lack of skilled workers and necessary productivity gains. Due to their small size, cobots are expected to be used in many industries, especially those that have no previous experience with robotics. Accordingly, there is a high demand for skilled workers who are able to integrate collaborative robots, especially into existing processes. In addition to the requirements regarding the operation and programming of these devices, there is also a need for the analysis and evaluation of existing processes as well as the ability to coordinate the introduction of a robot in projects. Since collaborative robots no longer have any protective devices or can work directly with humans, there are special requirements for the design of workplaces to ensure the safety and health of employees.

The target group for this learning unit is teachers, especially in the context of technical vocational education and training. It is being tested in the training course for state-certified technicians specialising in mechatronics at the technical college.

The underlying didactic concept for the learning unit is based on a holistic approach. It corresponds to the didactic learning field concept, in which interdisciplinary learning takes place starting from the work orientation. This is to be understood in such a way that the possible use of a cobot in a production environment is considered holistically in the learning unit with the participation of a wide range of specialist colleagues. (This includes e.g. elements of production process analysis, project management, work planning, programming of different use cases, etc.).

At the centre of the learning unit is an existing collaborative industrial robot arm (UR5) from the company Universal Robots.

The development of the learning unit is embedded in the development of an innovative spatial concept. It is characterised by the fact that the robot is accessible for diverse learning groups, i.e. beyond the previously intended target group. The concept claims to guarantee easy accessibility for a broad team of colleagues as well as high availability. Overall, the intention is to achieve a high frequency of use of the acquisition and thus the greatest possible impact of the learning tool.

2 Production automation with cobots in SMEs

2.1 Exemplary cobot automations

To identify occupational requirements in connection with the integration of collaborative robots in industrial processes, exemplary automation projects in the cooperation company LOGO tape were analysed. LOGO tape is an internationally active, medium-sized company that specialises in the production of adhesive tape and film products as well as packaging and printing solutions (cf. Wesselmann, 2020). Among other things, the company has committed itself to continuously investing in the occupational health and safety of its employees and to increasing the efficiency of its production processes (cf. ibid.). To support these goals, collaborative robots have been used for the first time since 2018. The following three examples show exemplary process automation with collaborative robots from Universal Robots.

1. Palletising products

The first cobot use in the company aims to take over the palletising of products. In the previous production process, this monotonous activity was done manually by employees. The products packed in cartons at the end of the production process reach the robot on a conveyor belt. After pressing a start button (see illustration), the robot begins to automatically pack up to two pallets with cartons.

Figure 2-1: Palletising products with a cobot

The project is characterised by its simplicity. All that is needed for implementation is a simple pick-and-place programme and a vacuum gripper with suction cups to pick up the carton.

2. Product packaging

   Another automation step at the end of the production is the automatic packaging of the products. This was also done manually, which could cause damage to health due to the repetitive activities. The integration of a cobot is more complex. For example, a gripper had to be constructed that can grasp different end products (cf. Figure 2-2). The process provides for a product check after this step. A comparative weighing can be used to determine whether any faulty packaging (empty carton) is included.

Figure 2-2: Picking up rolls of adhesive tape for packing in cartons

Mechanical centring is carried out using the angle plate before the products are packed in the carton (see Figure 2-3 and Figure 2-4).

Figure 2-3: Mechanical centring in the packaging process

One requirement of the automation solution is to identify different product sizes as well as cartons and to take them into account in the packaging process.

Figure 2-4: Placement of the products in the box

3. Packing of heavy adhesive rolls

The third example project involves another packaging task. The adhesive rolls to be packaged are larger and heavier, which leads to fatigue during manual packaging. The cobot automation is more complex and also includes the application of a product label before the actual packaging in the carton takes place. When developing the solution, the higher weight on the gripper with an additional long lever arm had to be taken into account in the parameterisation (see Figure 2-5).

Figure 2-5: Packaging of heavy adhesive rolls

2.2 Work process for the presentation of professional tasks and requirements

Based on work analyses and expert interviews, the work tasks for the introduction and subsequent operation of an automation solution using cobots are presented in a generic work process. The process follows an abstracted structure through the steps PLAN (planning aspects), BUILD (develop and implement the solution) and RUN (operate the cobot automation).

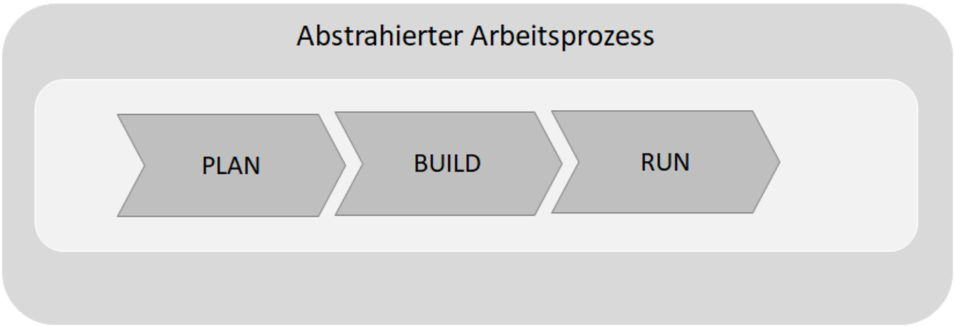
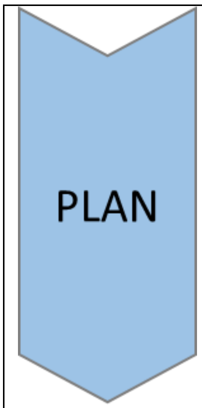


Figure 2-6: Abstracted work process to represent vocational work tasks

In the following table, the work tasks and their requirements are specified and provided with examples.

	Professionals can... analyse existing or new manufacturing processes to identify optimisation potential through the use of cobots. Identify processes to be automated: • Analyse previous process structure to identify problems in the current process (quality; throughput; injury, accidents, ergonomics, employee fatigue; environmental condition), • Identify sub-processes (e.g. packaging, palletising, quality assurance) that are suitable for automation by means of a cobot, evaluate them in terms of technical feasibility and economic efficiency, carry out preliminary costing, • Coordinate the introduction project with the company management. Tools, procedures and requirements in this task area: • Work observation procedures, time recording of processes, • Simulation of the automated sub-process with software, • Automated sub-process must not slow down the entire process chain (shift performance as indicator), • solution as cost-effective as possible. Carry out preliminary risk assessment and take it into account in planning • Evaluate space requirements, distances to people, etc..., • Environmental analysis, corrosion environment, explosion protection, etc. Select and procure suitable material • Perform cobot product comparison, • Determine gripper tools, sensors, other attachments, components, features etc. according to requirements, • If necessary, select PLC, • Create quotation requests,

	• Coordinate procurement with purchasing. Requirement: Observe company philosophy, e.g. use of standard parts from specified manufacturers. Create connection planning • Clarify electrical, pneumatic requirements, site requirements such as weight, working space.
BUILD	Develop an automated solution • manufacture, assemble, connect and commission mechanical, electrical and pneumatic components, • Carry out signal check. Carry out programming of the cobot • Prepare cobot (if necessary, reset passwords, delete old programmes, restore current software status), • Create, test and adjust the sequence programme with the operating panel, • If necessary, interlock cobot programme sequence with PLC programme, • Document programme in code, • Ensure unauthorised access to programme code, • Run test series parallel to the production process, revise solution. Implement cobot automation in the manufacturing process • Instruct/train operating personnel, • Implementation without interrupting the production process if possible. Create final documentation • Symbol table, • Programme schedule.
RUN	Carry out conversion of the production line • Carry out conversion of the robot to another system/production line • Load and test programmes for alternative production line • Complete risk assessment and carry out CE marking Optional: Evaluation of statistics on • Shift performance • Quality, repeatability, • Profitability etc. Carry out maintenance on the cobot • If necessary, update the software to ensure a uniform software status in the company.

2.3 Didactic implications

The experiences of the cooperation company regarding the use of cobots in the production process serve as a basis for the didactic conception of the learning tasks. The use of a cobot in the context of the automation solution includes comparable work tasks and requirements in principle, as they arise in the implementation of conventional robots. This requires comparable robot competences as well as competences to cope with the related tasks. A basic understanding of coordinate systems and travel paths and their programming, for example, is common to all robot variants. It follows that the task descriptions presented have a high relevance with regard to other tasks in the robot context and must therefore be taken into account in the context of training and further education.
Cobots are distinguished from conventional robots by their low-threshold introduction in connection with the low safety requirements. The robots used in the cooperation company are also characterised by the fact that they do not require, for example, annual maintenance contracts with manufacturers. The low maintenance requirements as well as the simple programming access were a weighty argument for the company to start automation with robots. Furthermore, the company sees the advantage of cobots compared to conventional robots in the fact that they do not destroy the products/environment in the event of a fault, as has been observed in practice with non-sensitive robots. The aspects mentioned are equally relevant in the context of a teaching environment, from which the selection of a cobot as a learning medium can be justified.

Furthermore, the sequence of operational cobot solutions shows an increase in complexity. The first cobot automation in the cooperating company was a simple "pick-and-place" task (cf. Fig. 2-1). The simply designed introduction produced immediate benefits and led to the acceptance of robots in operational processes in general. The following projects became more and more complex and used previous experience and solution approaches. Each automation solution represents an individual solution. The skilled worker is encouraged to shape his or her own work as well as the technology used as part of the solution development. This can contribute to higher job satisfaction. This learning process in the company environment can be transferred to the design of learning implementation. Simple "pick-at-place" tasks can serve as introductory learning tasks. Building on this, scenarios with extended requirements can be designed. Other learning areas from metalworking, automation technology, information technology, etc. can be linked and interlinked with the different learning requirements.

The analysis of the operational cobot sample projects shows that the focus is on the core tasks for the production of cobot automation. Adjacent tasks are only considered in a subordinate way in the day-to-day work of the company. The creation of documentation, more in-depth profitability analyses, ergonomics considerations and the effects of human-robot collaborations can be considered in greater depth within the framework of a school implementation. Here, schools can fulfil their educational mandate in the context of company work.

In this approach, the development of learning tasks is oriented towards the work process presented. At the same time, the individual learning sequences follow action-oriented concepts in their inner structure.

2.4 Assignment of learning tasks

PLAN	P1: Analyse complex sorting and packing processes P1.1: Explain the importance of robots in Industry 4.0 P1.2: Apply methods for process analysis P2: Procurement of a cobot P2.1: Perform purchase price calculation P2.2: Carry out utility analysis P3: Work out the basics of machinery safety
BUILD	B1: Carry out installation and setup of a cobot B2: Create a simple pick and place solution B3: Create pallet loading and transport solution
RUN	R1: Carry out process evaluation and optimisation based on a network plan R2: Carry out risk assessment

3 Learning tasks for production automation with cobots

3.1 Moodle course as carrier of the learning tasks

The learning tasks for production automation using Cobot are compiled as a course in the learning management system "Moodle". The entire course is available for download and can be imported on any Moodle platform. With the help of a guest account, the course can be viewed on the Moodle server of the Eckener School: https://moodle.esfl.de/course/view.php?id=4762 .

3.2 Tasks for PLAN

P1: Analyse complex sorting and packing processes

Didactic notes for course section P1.1 and P1.2

Overall, the robotic course is divided into three categories: Plan, Build and Run. This course structure follows the natural logic of automating work processes with cobots. The aim of this course is to enable students to analyse a work process, install a cobot and then operate it.

The planning section (P1 to P3) first deals with the basics of robotics and the question of whether a process is generally suitable for automation or whether this makes economic sense.

In order for this to happen, basic knowledge in the field of robot technology is necessary, among other things. These basics are addressed in the course section P 1.1. The course section thus serves as a general introduction to the topic of robotics in the classroom.

Starting with a brief overview of the term "Industry 4.0", the course then deals with the use of robots in this context. Building on this, basic concepts of robotics are dealt with. Upon completion of this section of the course, the vocational students will be able to classify the topic of robotics in the context of Industry 4.0 and have initial basic theoretical knowledge in the field of robot technology.

The Moodle function "Lesson" was used for the implementation. Here, information (texts, pictures, graphics and videos) is presented in a fixed order and these are combined with short tests (assignments, multiple choice). Due to this structure, the course can be used for individual (online) preparation.

The course section is exemplary and serves primarily as an example. It can (and should) be adapted and extended. The course shows how texts are combined with videos, graphics and pictures with short tests. If the teacher adapts the lesson, this content can be changed and added to as desired.

Learning objectives:

The students analyse complex sorting and packing processes to identify potential for optimisation through the use of cobots.

Indicators:

- Analyse a sorting and packing process
- Define sub-processes as "operations
- Draw up a list of operations with current times ("duration")

- Set up a network to map the current process
- Compare the actual and calculated lead time
- Identify sub-processes (from the network) whose automation is particularly effective.
- Use of CAP systems (Computer Aided Planning)

Chapter 2.3 "Didactic implications" already refers to the complexity of real work processes. In the sense of the learning field idea in the vocational school system, manufacturing processes can be simplified, but should simulate essential aspects of complexity - e.g. interdependence or diversity - as real as possible. In this sense, the following teaching format can support the achievement of the learning objective indicators mentioned.

Possible teaching format:

The students

- carry out the process themselves,
- record times and
- document the work steps appropriately (operation list).

Modern media technology (photo and video) is used for analysis and documentation. The students reproduce sub-processes and take into account work routes in order to determine realistic sub-process times.

Working in a group facilitates the

- Simulate,
- Observe how
    - Consider,
    - Photographing or filming,
    - and describing,
- and time recording.

P2: Procurement of cobots

In the planning part, the focus is on economic aspects, among other things. In P2, two methods from the field of procurement are integrated into the planning for the use of a cobot in the production process.

The subject area of procurement plays a major role in business administration lessons for future technicians. Various procedures for time and quantity planning are presented. With regard to the procurement of operating resources, a purchase price calculation offers a link to the case study. Using the example of the cobot, the calculation scheme with the technical terms is presented in learning section P2.1. The calculation is carried out in a task with reference to the case study. In addition, the technical knowledge is tested in the form of a Moodle test. The test can be repeated as often as desired and the result can be included in the oral grade.

In addition to the various procedures for time and quantity planning presented in class for the prospective technicians, a method for supplier selection is presented in P2.2.

After a short introduction about other criteria besides price and delivery time, the students are given the task of carrying out a utility analysis.

The task is student-centred and designed as group work. The teacher does not explain the utility analysis in advance, but gives information on how to do it. Therefore, the task requires a high degree of self-organisation and discussion within the groups. The aim is for the students themselves to recognise the advantages and disadvantages of this method, which becomes clear at the latest when the solution is presented and compared. In addition, other possible applications for a utility analysis can be identified, e.g. deciding between different production processes, products, special software, etc. The students can also discuss alternative forms of presentation, e.g. subdivision into categories or a different scale of points.

This section is intended for classroom teaching, but can also be adapted for online teaching. In this case, group rooms can be set up in the video conferencing system and the task can be worked on in the groups via screen sharing.

Learning objectives:

The students

- distinguish terms related to a purchase price calculation, such as purchase allowance, purchase discount, purchase costs,
- carry out a purchase price calculation using spreadsheet software,
- identify criteria that are relevant for supplier selection,
- carry out a utility analysis with the help of spreadsheet software,
- identify advantages and disadvantages as well as possible applications of utility analysis.

P3: Basics of machinery safety

This section provides an introduction to the basics of machinery safety. This includes general information on the EU Machinery Safety Directive and the CE marking procedure as well as aspects relevant to the purchasing/planning process.

On the one hand, this is relevant for the educational institution when a cobot learning environment is installed for the first time. On the other hand, students are shown the need to consider machinery safety when installing cobots in companies. Aspects of machinery safety, i.e. the CE marking process, are then further introduced in the RUN phase, although they should be considered in all three phases PLAN, BUILD and RUN.

This section is designed for classroom teaching, but can also be adapted for online teaching.

Learning objectives:

The students

- describe the motivation for (machine) safety,
- distinguish between occupational safety and safety of machinery,
- identify the relevant national law based on the European directives on machinery safety,
- explain the scope and main purpose of the CE marking and the Machinery Directive,
- distinguish between the terms "machine" and "partly completed machinery" in the sense of the Machinery Directive and name the resulting requirements for the purchase of a cobot.

3.3 Tasks for BUILD

B1: Installation and configuration of a UR 5

The entry into robot programming is via the online course provided free of charge by Universal Robots. Registration is required for participants. The processing of all modules requires an effort of approx. 3h. Upon completion, the students will be able to carry out the setup of the robot.

B2: Create Simple Pick and Place Solution

The learning tasks presented are suitable for learners in dual initial training in professions where automation plays a role. These include industrial mechanics, cutting mechanics and construction mechanics.

The tasks teach the basic handling of a UR robot arm. The learners are to acquire the following skills by means of six tasks that build on each other:

- Programming a movement sequence using the appropriate movement types and taking into account boundary conditions such as the shape and position of the workpiece,
- Connecting several sensors to the robot's controller and integrating the sensor signals into the programme sequence,
- Use ready-made programme blocks, in this case the palette function.

The tasks use a parts chute with sensors and small, round workpieces made of steel. The components for the parts chute come from the 3D printer and are shown below. The STL. Files for these components are linked behind the illustrations in the Moodle course and can be reprinted.

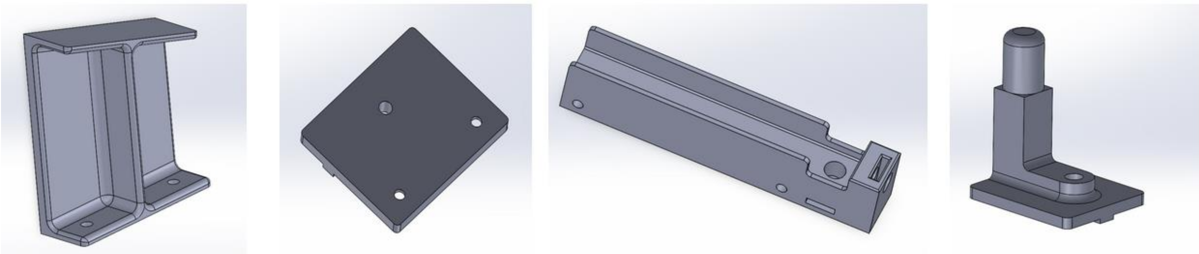


Figure 3-1: Components for the parts chute

The tasks are meant to simulate a classic sorting task that often occurs in industrial manufacturing. To complete all tasks, learners normally need at least 10 hours.

B3: Create pallet loading and transport solution

The following learning task in particular brings together the previously acquired competences. The task contains a higher complexity and additionally integrates aspects of sensor technology, drives with their control and UR programming. The task requires laboratory equipment that includes a conveyor belt in addition to the robot (see Figure 3-1). The conveyor belt drive is controlled by a frequency converter.

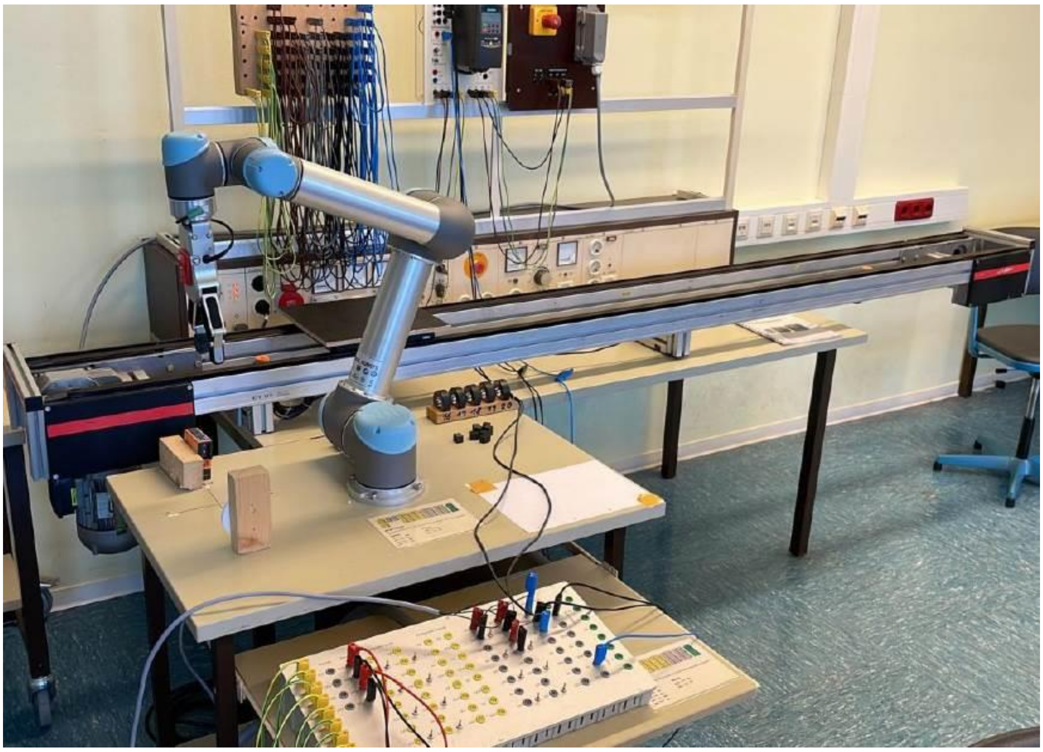


Figure 3-2: Exemplary laboratory set-up for the learning task "pallet loading and transport

Learning objectives:

Students can realise a complex sorting and packaging process with the help of the robot. In addition to the programming task, suitable documentation must be prepared.

Work order:

Create a programme for pallet loading with the UR5. The pallet is to be positioned in the loading position with a conveyor belt and moved to the removal position after being loaded with 9 cans (3x3). In addition to the UR5 with two-finger gripper and the conveyor belt, optical and inductive sensors as well as a frequency converter (Siemens Micromaster) are available.

The following elements shall be documented:

- Programming the UR5,
- Parameterisation of the Siemens Micromaster,
- Wiring diagram for sensors, UR5 and frequency inverter.

The following technology scheme is provided to complete the task:

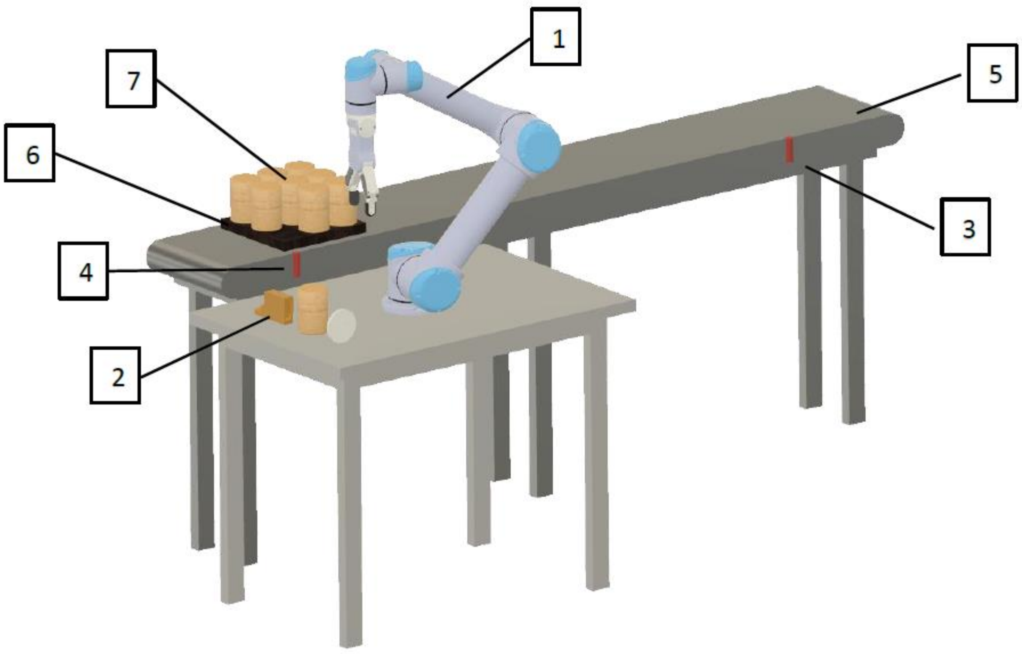


Figure 3-3: Technology diagram for the learning task "pallet loading and transport".

Position	Naming
1	Articulated arm robot UR5
2	Light barrier
3	Inductive proximity switch BG1
4	Inductive proximity switch BG2
5	Conveyor belt
6	Pallet
7	Wooden cylinder (9 pieces)

Figure 3-4: Components of the technology scheme

Functional description:

The articulated arm robot UR5 takes wooden cylinders from a material store and positions them on a pallet, which is located on a conveyor belt. When the pallet is full, it is transported away from the conveyor belt. After 20 seconds, the empty pallet is moved back to the starting position and loaded again. The limit switches BG1 and BG2 indicate when the pallet is in front of the robot and can be loaded or when it can be unloaded. The palletising programme stops if there is no pallet in front of the cobot and continues as soon as the corresponding signal is present. Whether there is material in the material store is checked by a light barrier.

The conveyor belt is driven by a three-phase motor, which in turn is controlled by a frequency converter (Siemens Micromaster). The frequency converter is controlled via digital inputs which are directly addressed by the UR5. When setting the parameters, it is important to ensure that the conveyor belt is started and braked in such a way that no cans fall over.

In addition to retro-reflective sensors and inductive proximity sensors on the conveyor belt, switches and buttons are also available on the UR5 (see technology diagram).

Use the relevant manufacturer documentation to obtain further information.

3.4 Tasks for RUN

R1: Carry out process evaluation and optimisation based on a network plan.

Learning objectives:

Students undertake process evaluation and optimisation using a network diagram

- Customise the operation list,
- Record current throughput times,
- Determine a new lead time,
- Evaluate and carry out a performance review.

Didactic considerations:

- The production process can be simplified but should reflect crucial aspects of complexity in the lab or classroom.
- The students should - the basis can be the learning field principle in the German vocational education system - work together on the task "Analysis of a work process with subsequent optimisation" in different defined roles. These could result from the subject areas e.g.
  - Mechanics,
  - Automation and
  - Business Administration.
- The results of the group work should be presented and evaluated together. This can be done both in the group and in front of the teacher.

R2: Assessment of machinery safety

In the last phase RUN, the focus is on the implemented system. At the latest in this phase, the previous machinery safety considerations should be compiled in order to complete the CE marking process newly introduced in P3. In this phase or - if possible - in the BUILD phase, tests should be carried out to check whether the risk assessment is adequate and the measures defined lead to the desired result.

In this section, the process of CE marking is described in more detail in relation to the implementation of a robot in a learning environment or - with regard to the future professional activity of the students - in a company. In addition, practical aspects are also considered.

With regard to the preparation of further teaching, a risk assessment can be included depending on the learning level of the students. For example, a risk assessment for a cobot could (partly) be done together with the class. Alternatively, the students could do this as a group work and present their results.

The lesson is designed for classroom teaching but can also be adapted for online teaching.

Learning objectives:

The students:

- describe the process of CE marking,
- identify the main issues related to this process using the example of the implementation of a robot,
- explain the process of risk assessment,
- identify aspects to be considered during the risk assessment process.

4 Examination scenarios

The learning tasks developed are enriched by various performance assessments (tests) in order to give the participants individual feedback on their level of performance and to give them the opportunity to reflect on their learning process and to make it more sustainable accordingly. Various Moodle test tools are used for this purpose (see Moodle course).

In the following section, a task to be realised in practice is presented as an examination object. The subtasks lead to observable results and can exemplarily reflect the competence requirements of the examinees identified in the process. The focus is particularly on problem- and action-oriented requirements. The intention is to design the type of tasks with the inclusion of the real robot in such a way that, on the one hand, it is embedded in complex action contexts, but the examinees can produce multi-layered performances to solve them.

The tasks were tested within the framework of a final examination task in the course of education for state-certified mechatronics technicians specialising in operating technology. The processing time is 60 minutes.

Initial situation:
Your customer has purchased a UR5e or UR3e collaborative robot with 2-finger gripper for a palletising task. It is your task to set up and install the robot for use according to customer specifications.

Figure 4-1: Examination structure of UR5

Customer specifications:
The robot is to pick up nine product units and place them on a pallet in a 3x3 format. The packaging process runs automatically after the sequence is started by pressing **button I** (see Figure 4-2) and ends after palletising is complete. The sequence can be restarted by pressing **button I** again. The rotary switch is designed as a latching "free-drive button".

Since the customer cannot provide light barriers due to delivery delays, this is to be simulated for programming by the **push-button II.**

The light barrier should signal the presence of a product unit for the process. If a product unit is present at the pick-up location, **push-button II** must be pressed and held.

Figure 4-2: Control panel for the examination task

Work order:

a) During the preparation time, develop a rough programme plan in key words or outline the programme sequence.

b) Program the robot according to customer requirements.

c) Check the programmed packaging process for function.

Rating:

The evaluation is carried out jointly on the basis of a test protocol in accordance with the customer's requirements.

5 Collaborating robots at school

A recurring challenge in the school environment is to use media visibly and efficiently in the teaching context. In practice, it can be observed that expensive media equipment is purchased but unfortunately not used much in the classroom. The following example shows one approach to this problem. For this purpose, two laboratory rooms were designed to meet the demands in the field of automation technology and robotics and to be as accessible as possible for many vocational education programmes.

Requirement for the rooms:

- Spatially bundle the existing components of robotics and automation technology in order to be able to process maintenance and servicing work more efficiently.
- Making it easy to link the areas of sensors, actuators, PLC control and robotics.
- Create a place of learning that provides the most practical working environment possible for the students.
- Enable students to work independently and safely (confront dangers from electricity, cobots and PLC models).
- All components can also be used individually in other learning spaces of the school.
- Develop a cross-disciplinary teaching concept, e.g. to offer elective courses.

1.1 Room concept

The planning provides for two rooms with 12 workstations each, which have an appropriate energy and IT supply.

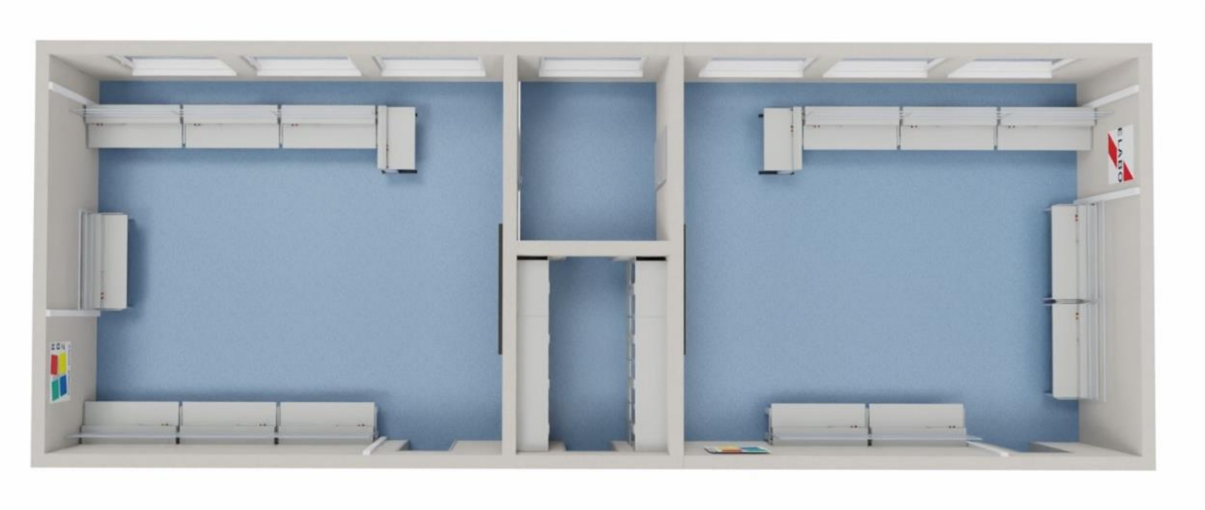


Figure 5-1 Room concept: Room D311 and Room D313

PLCs and their peripherals can be attached to the workstations. All workstations are equipped with network connections that allow access to the robots or FESTO systems placed in the centre of the room.

In room D311, the three UR3e are equipped with the MPS modules (Modular Production System) from FESTO and also offer the possibility of using PLC learning carriers (cf. Figure 5-2). With the 6 different MPS stations and the UR3 robots, it is possible to use the components individually as well as in networked operation (production line).

Figure 5-2 FESTO Didactics MPS conveyor system with expansion modules (from left: 1. stacking magazine, 2. drilling and depth testing, 3. turning components, 4. RFID reading, writing and ejection)

The modules can all be used individually or, as shown here, as an entire production process. Programming via the TIA portal with a 1200 PLC with touch panel.

Room D313 is assigned the UR5e with a conveyor line (technician project from the ERASMUS programme) and the operation of motor test benches is also planned here. In terms of robotics, the room is the focal point for programming and mapping work processes. It contains the corresponding sensors, actuators, robots and motor control.

Both rooms are equipped with a Clevertouch board system and will be equipped with a portable camera system in the future so that they can also be used as hybrid learning rooms. It will be possible for pupils to operate and programme the robots in hybrid learning forms, partly from a distance. Feedback is provided via live image transmission.

The distance between the row of desks in front of the windows is a result of the requirements of the school authorities in order to allow access to the windows for cleaning work (cf. Figure 5-1).

Figure 5-3 Mounting frame with sliding rails, height-adjustable teacher's desk

The mounting frames on the desks can be moved forward on a rail. The teacher's desk is height-adjustable and equipped with all media interfaces. A floor tank is installed in the centre of the room to supply the robots and FESTO modules with power, network and compressed air. The supplier of the laboratory furniture is ELABO.

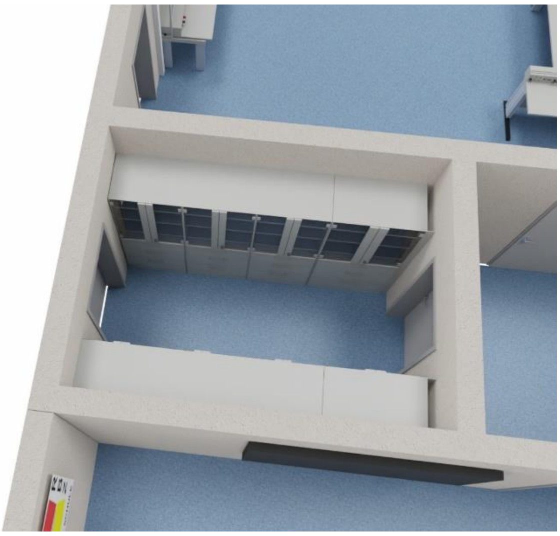


Figure 5-4 Intermediate space for storage of components

A storage room between rooms D311 and D313 is used to store additional robot and PLC components.

5.1 Collaborating robots

In total, collaborative robots from Universal Robot are currently available in the following versions: UR3e (3x present); UR5e (1x present) and UR10e (1x present).

Figure 5-5 UR3e, UR5e and UR10e from supplier Universal Robot

The UR3e and the UR5e are used in rooms D311 and D313 for the compulsory elective courses as well as the learning field lessons in the various training occupations. The UR10e is intended for use in the metal sector in the area of machine placement, etc. The frames for the PLC, touch screen and FESTO modules as well as the robot tables and plug-in panels of the URs are the school's own developments and were made in-house.

Since the school already has appropriate models and the students should be able to work as openly as possible, ready-made solutions from teaching material manufacturers were ruled out for the room concept, as these are closed systems that could only be adapted or changed to a limited extent or not at all. In the developed room concept, however, the focus is on this, so that an own solution is developed and implemented.

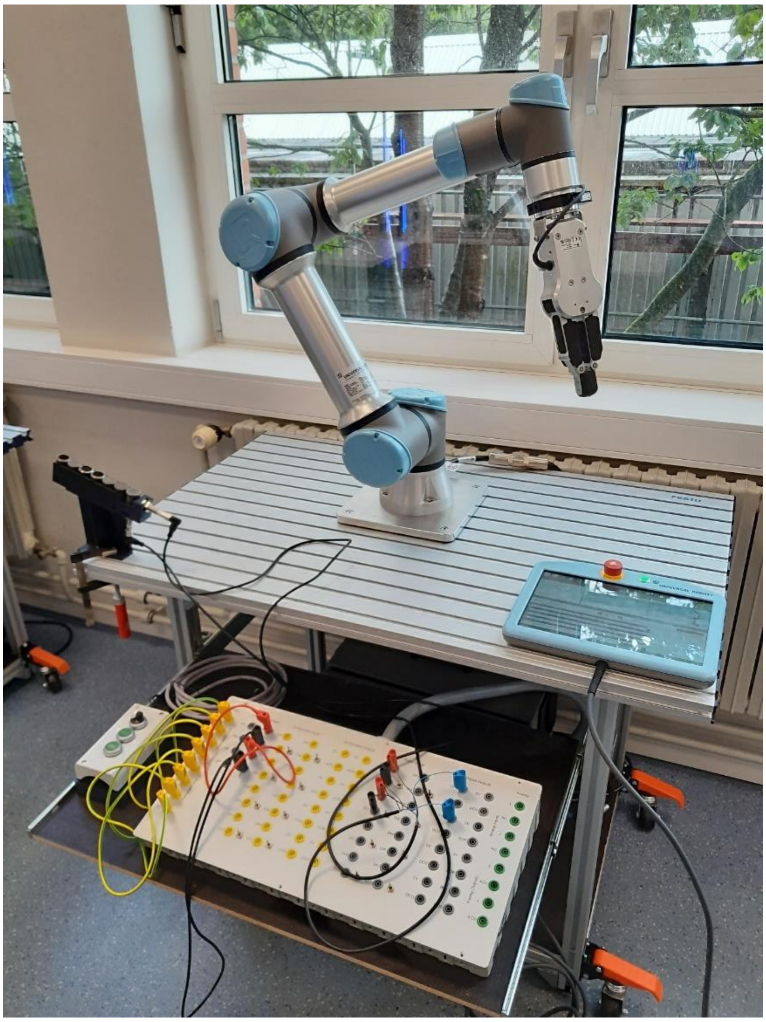


Figure 5-6 Robot trolley with I/O access possibility (own design)

All robots have a trolley (own design). This is equipped with a plug-in board that makes all inputs and outputs of the robot usable without opening the control unit. In Figure 5-6, the robot table is equipped with a material chute (2 inductive proximity sensors) and an external control unit (2x buttons and a rotary switch).

Figure 5-7 URx with conveyor belts

MPS conveyors from FESTO are available for all UR3e and UR5e, which can either be "hard" wired or operated with the robot via Profinet and a PLC.

5.2 Grippers and lifters

The robots can be equipped with different grippers and lifters. The following illustration shows the acquired grippers. They enable a variety of uses and correspondingly diverse design of learning tasks.

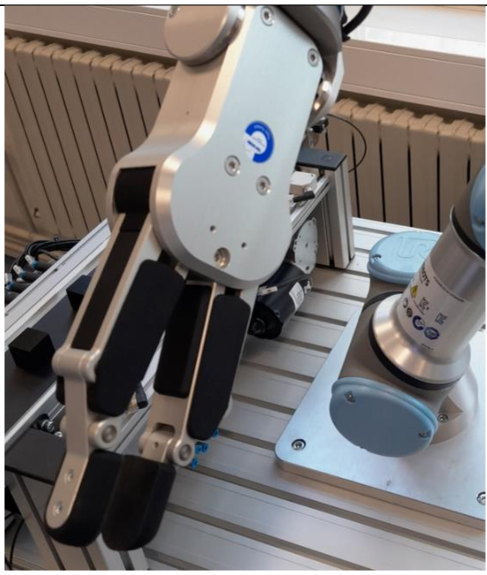
 Parallelgripper from the company OnRobot	 Suction lifter from the company OnRobot
 „Softgripper“ from the company OnRobot	 2-finger-gripper from the company OnRobot

Figure 5-8 Grippers and lifters

The various grippers are all equipped with quick-change couplings that enable tool-free changing.

In addition, the school has an "Eye-Cam" system from the company OnRobot, which enables optical component recognition and thus offers an extension of the "Pick 'n' Place" applications.

In addition, a "TRACE" system from WandelBots has been purchased, which enables "freehand teaching" of waypoints. This is needed for applications such as welding or gluing.

Bibliography

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