KUKA

ready2_educate Level 1

Target Group: School and College Students

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Contents

3 Training module: Structure and function of a KUKA robot system

3.1 Overview

The following contents are explained in this training module:

- Robot basics
- Robot arm
- Robot controller

3.2 Robot basics

What is a robot?

- The term *robot* comes from the Slavic word *robota*, meaning *hard work*.
- According to the official definition of an industrial robot: “A robot is a freely programmable, program-controlled handling device”.
- The robot system thus also includes the controller and the operator control device, together with the connecting cables and software.

Fig. 3-1: Industrial robot

1 Controller ((V)KR C4 control cabinet)
2 Manipulator (robot arm)
3 Teach pendant (KUKA smartPAD)

Everything outside the system limits of the industrial robot is referred to as the *periphery*:

- Tooling (end effector/tool)
- Safeguard
- Conveyor belts

- Sensors
- Machines
- etc.

3.3 Robot arm of a KUKA robot

What is a manipulator?

- The manipulator is the actual robot arm.
- It consists of a number of moving rigid links that are linked together by means of axes.
- The individual axes are moved by means of targeted actuation of servomotors.
- These are linked to the individual components of the manipulator via reduction gears.

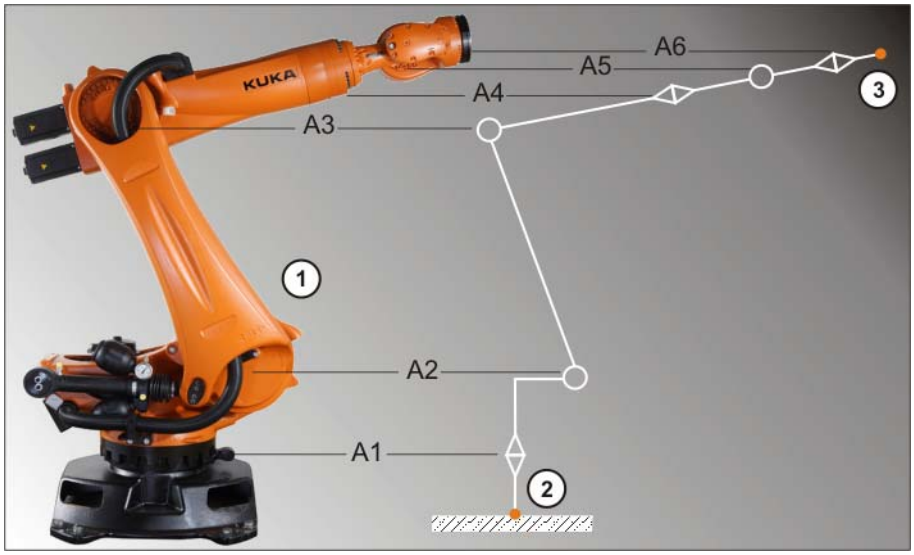

Fig. 3-2: Manipulator

1	Manipulator (robot arm)
2	Start of the kinematic chain: base of the robot (ROBROOT)
3	Free end of the kinematic chain: flange (FLANGE)
A1...A6	Robot axes 1 to 6

Overview of manipulator components

- The components of a robot arm consist primarily of cast aluminum and steel.
- In isolated cases, carbon-fiber components are also used.
- The individual components are numbered from bottom (robot base) to top (robot flange):

Fig. 3-3: Overview of manipulator components

1	Base frame	4	Link arm
2	Rotating column	5	Arm
3	Counterbalancing system	6	Wrist

Axes of the robot

Fig. 3-4: Axes of a KUKA robot

Excerpt from the technical data of manipulators from the KUKA product range:

- **Number of axes:**
  - *4 axes* for KR 40 PA
  - *6 axes* for standard vertical jointed-arm robots

- *7 axes* for lightweight robots
- **Reach:** from 0.54 m (KR 3 R540) to 3.9 m (KR 120 R3900 ultra K)
- **Weight:** from 23 kg (LBR iiwa 7 R800) to 4700 kg (KR 1000 Titan).
- **Accuracy:** 0.03 mm to 0.2 mm repeatability.

Axis 1	Axis 2	Axis 3
		

- The axis ranges of main axes A1 to A3 and wrist axis A5 of the robot are limited by means of mechanical end stops with a buffer.
- Additional mechanical end stops can be installed on the external axes.

NOTICE

- If the robot or an external axis hits an obstruction or a buffer on the mechanical end stop or axis range limitation, this can result in material damage to the robot system.
- KUKA Roboter GmbH must be consulted before the robot system is put back into operation.

  The affected buffer must be replaced with a new one before robot operation is resumed.
- If the robot (or external axis) collides with a buffer at more than 250 mm/s, the robot (or external axis) must be exchanged or recommissioning must be carried out by KUKA Roboter GmbH.

3.4 (V)KR C4 robot controller

Who controls motion?

The manipulator is moved by means of servomotors controlled by the (V)KR C4 controller.

Fig. 3-5: (V)KR C4 control cabinet

Properties of the (V)KR C4 controller

- **(V)KR C4 controller**
  Robot controller (path planning): control of six robot axes plus up to three external axes.

Fig. 3-6: (V)KR C4 axis control

- **(V)KR C4 extended controller**
  Robot controller (path planning): control of six robot axes plus up to six external axes.

Fig. 3-7: (V)KR C4 extended axis control

- **Software-based controller**

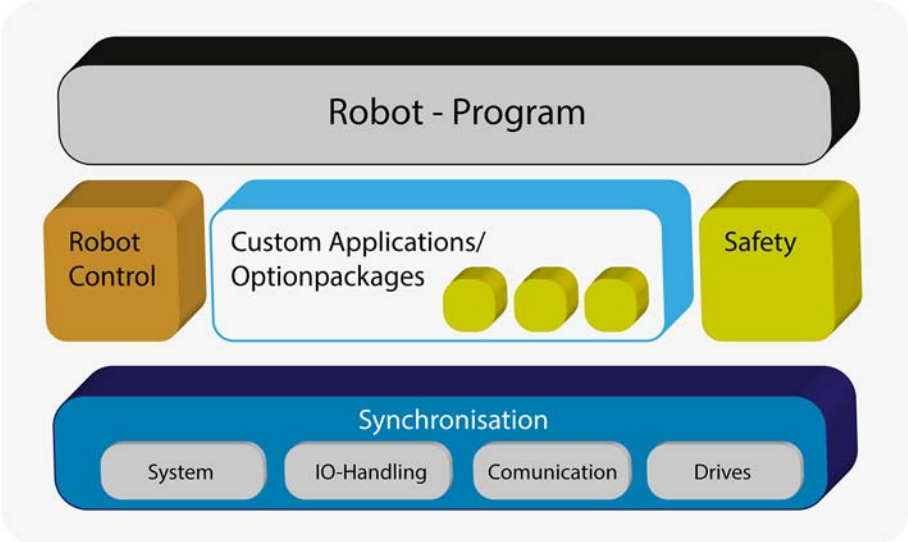

Fig. 3-8: Block model

- KR C4-based controllers work on a modular control concept.
- The **KPC**-*KUKA PC* plays a central role here.
- Robot programs access the required hardware interfaces via task-specific applications.
- In addition to **system-relevant applications** that are always available, the controller can also have **customer-specific applications** added to it.

The **system-relevant applications** include:

- **RC** (**R**obot **C**ontrol)
  KUKA kernel system of the robot controller
- **Safety**
  Integrated KUKA safety controller

The **customer-specific options** include (selection):

- **PLC**
  Soft PLC (KUKA.PLC in accordance with IEC61131) that can be integrated for general sequence control
- **XM** (e**X**tended**M**otion)
  Runtime system that can be integrated for a KUKA MotionControl library
- **Process control**
  General platform for integration of process controllers
  e.g. integration of vision capability

Communication options

Fig. 3-9: (V)KR C4 communication options

- Communication options via bus systems (e.g. ProfiNet, Ethernet IP, Interbus)
  - Programmable logic controllers (PLC)
  - Additional controllers
  - Sensors and actuators
- Communication options via network
  - Host computer
  - Additional controllers
  - Service notebook

3.5 Learning objective check

Revision questions

After this training module, these questions should no longer be a problem for you:

What are the components of a KUKA robot system?

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What is meant by peripheral equipment in this context?

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What distinctive points on the robot kinematic system are you familiar with?

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What system size can a standard KR C4 robot controller manage?

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6 Practical module: Operating the smartPAD and Navigator

6.1 Safety instruction

Hazards when working with a KUKA robot system

There are always certain residual risks from a robot system. Correct operator control and observation of the safety-relevant aspects is thus essential for safe operation.

Mechanical hazards:

- A KUKA robot is **always stronger than you**.
- The path of a robot is **not foreseeable in all cases**.

Electrical hazards:

- A robot is an electrical machine with **hazardous voltages and currents**.

Safety when working at the mobile training cell

A number of fundamental rules apply when working in the practical modules:

- The instructions issued by the course instructor must be observed.
- Do not perform any actions that you are uncertain about. If in doubt, ask the course instructor.
- The course instructor determines the maximum motion velocity of the robot. This velocity must not be exceeded under any circumstances.
- If in doubt, always press the EMERGENCY STOP button on the smartPAD or on the cell immediately. This safety facility is not merely there for decoration, but to be used. It is better to press the EMERGENCY STOP button too often rather than not often enough.
- The EMERGENCY STOP button is locked in place when the training cell is left.
- The person holding the smartPAD is responsible for the robot cell and for their colleagues. Do not act recklessly or in a way that could result in injuries to other participants in your group or damage to the robot system. In return, the other participants in your group are under the obligation to follow your instructions.
- If the robot is moved, the eyes and concentration of all persons at this cell must be focused on the robot. Furthermore, no extraneous activities are allowed during this time. The current motion velocity has no bearing on this.
- Every program must be tested after any modification. The path of the robot is dependent, among other factors, on the velocity that has been set! It is thus not possible to assume that the robot will behave in the same way at T1 100% as at T2 75%, for example. Testing must therefore be carried out step by step: Always increase the velocity one step at a time until the value specified by the course instructor has been reached. Only then may you switch to automatic mode (once again with the value specified by the course instructor and not simply 100%) and allow the program to run automatically. This procedure must be followed even if only a small modification has been made to the program, as the robot motion cannot always be predicted.

DANGER

- In the absence of functional safety equipment and safeguards, the robot system can cause personal injury or material damage.
- If safety equipment or safeguards are dismantled or deactivated, the robot system may not be operated.

Safety when working with the KUKA ready2_educate training cell

The KUKA ready2_educate training cell has a pneumatic gripper. This can exert a force that is hazardous to humans. In some practical modules, you will have to load a component into the gripper by hand.

Fig. 6-1: Clamping components

DANGER

- When using the gripper system there is a risk of crushing and cutting.
- Great care must therefore be taken when clamping manually.

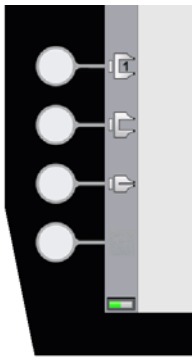

Fig. 6-2: Gripper keys

- The gripper can be opened and closed in T1 mode using the two status keys at the bottom left-hand side of the smartPAD.
- The enabling switch must be pressed for this.

What to do in case of an accident

In the event of an accident, the following procedure should generally be followed:

1. Secure the accident site
2. Fetch help
3. Rescue injured persons and provide first aid

What this specifically means in the case of an accident at the training cell is:

- **Secure the accident site**
  Stop the robot (EMERGENCY STOP, switch off the power supply to the laboratory, pull out the plug, etc.) and depressurize pneumatic components if applicable (disconnect compressed air supply). In the case of accidents with electric current, switch off the power supply. Do not enter the danger area yourself, however. Your own safety has top priority. It does not help anybody if you get yourself knocked down, for example, while trying to rescue an unconscious person from an area in which a machine is still active.
- **Fetch help**
  Notify the responsible first aider (generally the course instructor) and the emergency services. Also warn other people who could still be endangered.
- **Rescue injured persons and provide first aid**
  If the injured person has been trapped by the robot, release him from this situation by using the available method for moving the manipulator without the robot controller. Do not reactivate the robot controller under any circumstances! Perform first aid until the responsible first aider or emergency services arrive.

Options for moving the manipulator without the robot controller

The following options are available for moving the manipulator after an accident or malfunction:

- Release device (optional)
  The release device can be used for the main axis drive motors and, depending on the robot variant, also for the wrist axis drive motors.

Fig. 6-3: Release device

- Brake release device (option)
  The brake release device is designed for robot variants whose motors are not freely accessible.
  Example for AGILUS:

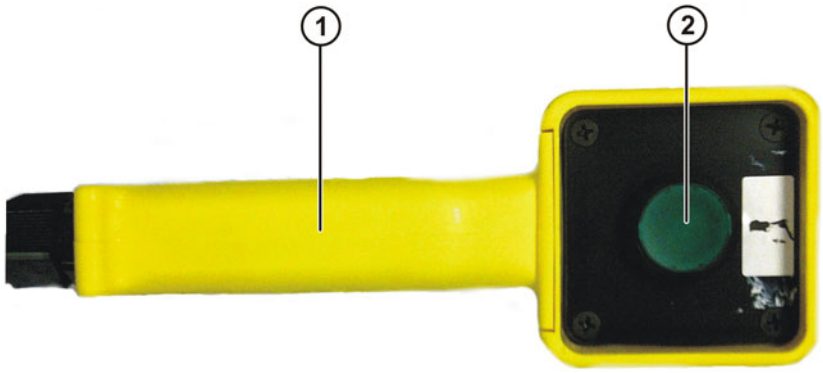

Fig. 6-4: Hand-held device

1 Hand-held device 2 Pushbutton S1

- Moving the wrist axes directly by hand

  There is no release device available for the wrist axes of variants in the low payload category. This is not necessary because the wrist axes can be moved directly by hand.

The options are only for use in exceptional circumstances and emergencies, e.g. for freeing people.

Information about the options available for the various robot models and about how to use them can be found in the assembly and operating instructions for the robot or requested from KUKA Roboter GmbH.

⚠ CAUTION The motors reach temperatures during operation which can cause burns to the skin. Contact must be avoided. Appropriate safety precautions must be taken, e.g. protective gloves must be worn.

The KUKA ready2_educate training cell comes equipped with either the KR 3 R540 or the KR 6 R700. The brake release device option is available for these robot types. If you have a different robot type, please contact the department responsible for information about the options for moving the robot axes.

Safety questions

Before commencing the practical exercises, you must first answer these safety questions and receive clearance from the course instructor to start the practical module.

What is the maximum velocity at which the robots are allowed to move?

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What action do you take if the robot moves unpredictably and there is a risk of a collision?

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You have the smartPAD in your hand and want to test a program in T1 mode with the safety gates open. You notice that your colleague is leaning against the cell with his back to the robot and staring at his cellphone. What do you do?

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You notice damage or a modification to the training cell that could have a detrimental effect on the safety equipment. What do you do?

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How can you move the robot without a controller?

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What do you do in the event of an accident?

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6.2 Exercise: smartPAD and Navigator

Aim of the exercise

On successful completion of this exercise, you will be able to carry out the following activities:

- Operating the smartPAD
- Working correctly with the Navigator
- Working in projects, archiving programs
- Selecting programs, performing a BCO run and starting programs

Precondition

- Training module: Working with the Navigator
- Safety instruction with answering of safety questions

Safety instructions

You must test every program before operation. The procedure for a program test is always the same.

- **T1**
  Test your program in T1 mode, increasing the velocity up to 100%.
- **T2**
  Test your program in T2 mode, gradually increasing the velocity up to the maximum velocity specified by the course instructor (% or m/s). Always increase the velocity in small steps only, as the path may vary depending on the velocity.
- **AUT**
  Now you can use your program in AUT mode up to the maximum tested velocity.

■If a program is not tested thoroughly enough, or not tested at all, this can result in injury to persons and damage to property!

Ensure that the correct Tool and Base settings are used. If the tool is modified, components on the application plate are shifted or a new form is loaded into the clamping fixture, Tool and Base must be recalibrated.

Working in the practical modules

In the following exercises, you will always be working on a project of your own. At the start of the subsequent practical module, please always check whether the correct project is selected. You will not be reminded of this in the following practical modules. If a different project has been activated in the meantime, the course instructor will help you to change back to your project.

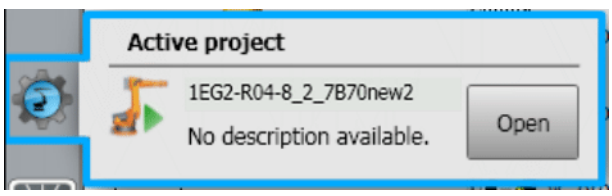

Fig. 6-5: Active project

If you have created contents using KUKA.OfficeLite, the simplest way of transferring them to the robot controller is to use a KUKA USB stick.

Task description

1. Together with the course instructor, create a copy of the base project and rename it with your name.
2. Ensure that operating mode T1 is set.
3. Navigate to the Programs folder and select the program module *Demo()*.

4. Test the program. Caution: During the first program test, or if the program is restarted during the motion, the robot performs a BCO run.
5. Run the program in automatic mode.
6. Deselect the program again.
7. Create an archive of your project on the KUKA USB stick with the setting “All”.