MANUAL
Connecting ArtiMinds RPS to a KUKA KRC4

Setup and usage of a KUKA robot with ArtiMinds RPS

Version 1.11

January 16th, 2023

Contact

Support: support@artiminds.com
Sales: sales@artiminds.com

Content

1. Prerequisites

1.1. Supported platforms

Currently the controller generation KR C4 and KR C5 are supported, running KUKA.SystemSoftware (KSS) up to version 8.6.8 (KR C4) and 8.7.3 (KR C5). Newer versions may work, but have not been fully verified yet.

1.2. Required technology packages

The following technology packages are required for basic ArtiMinds RPS usage:

- KUKA.DirectoryLoader: Required to transfer and start programs on the robot
- KUKA.EthernetKRL: Required to send and receive data over network.
  Attention:
  - o For KSS < 8.5 the EthernetKRL Version 2.2.9 had a bug that affected ArtiMinds RPS communication. Either upgrade or downgrade to Version 2.2.7
  - o For KSS > 8.5 the EthernetKRL Version 3.1.0 had a bug that affected ArtiMinds RPS communication. Please upgrade to a newer version.
  - ⇨ The listed versions cause blocking of the used communication ports, resulting in an error in *KRC\Roboter\log\EthernetKRL\EKI*.log* like:
    ```
    CTcpSock: Socket *** on port **** failed to bind with code 48
    ```

The following technology packages are required for force guided motions:

- KUKA.RobotSensorInterface (RSI): Required for sensor adaptive motions.
  Attention: For KSS 8.5 the versions older than 4.0.9.3190 of RSI had a bug that affected ArtiMinds RPS code.
- KUKA.ForceTorqueControl: Required to connect to a Force-Torque Sensor

Please consult your KUKA sales representative to obtain the required technology packages. KUKA.WorkVisual or "Main (Menu) -> Start-up -> Add-on Software" (German KUKA "Hauptmenü -> Inbetriebnahme -> Zusatz-software") on the robot teach pendant (KUKA SmartPad) can be used to verify the installed technology packages on the KUKA controller.

Additional system requirements about the ArtiMinds RPS can be obtained in the document "ArtiMinds RPS - Installation and technical information for use in corporate IT environments".

1.3. Basic network setup

Physically connect the KUKA robot and the computer that runs the ArtiMinds RPS to the same network (Ethernet recommended, no WLAN) e.g. by using a network switch.

Often computer and network switch are able to set suitable IP addresses automatically. If static IP addresses are used (recommended), please make sure that the robot and computer are in the same network.

The IP address of the KUKA robot can be configured on the KUKA teach pendant by clicking on the "(Main) Menu" button (KUKA robot icon), then "Start-up -> Network Configuration" (German KUKA: "Hauptmenü -> Inbetrienahme -> Netzwerk"). Setting is only visible if logged in as Expert/Administrator user (default password "kuka") and no program is selected.

On the computer the IP address is set in the "Windows Control Panel -> Network and Sharing Center" (Windows 7 or newer). Here you can see an overview of all network adapters. Click on the network adapter that is connected to the KUKA and then on "Properties" to verify or alter the IP address of the computer.

Optional one can use the Windows command shell (opening the Windows start menu and typing in "cmd.exe") and execute the command "ping IP_ADDRESS_OF_THE_ROBOT" to verify that the connection is working. Replace IP_ADDRESS_OF_THE_ROBOT with the IP address of your robot, for example "ping 192.168.2.10".
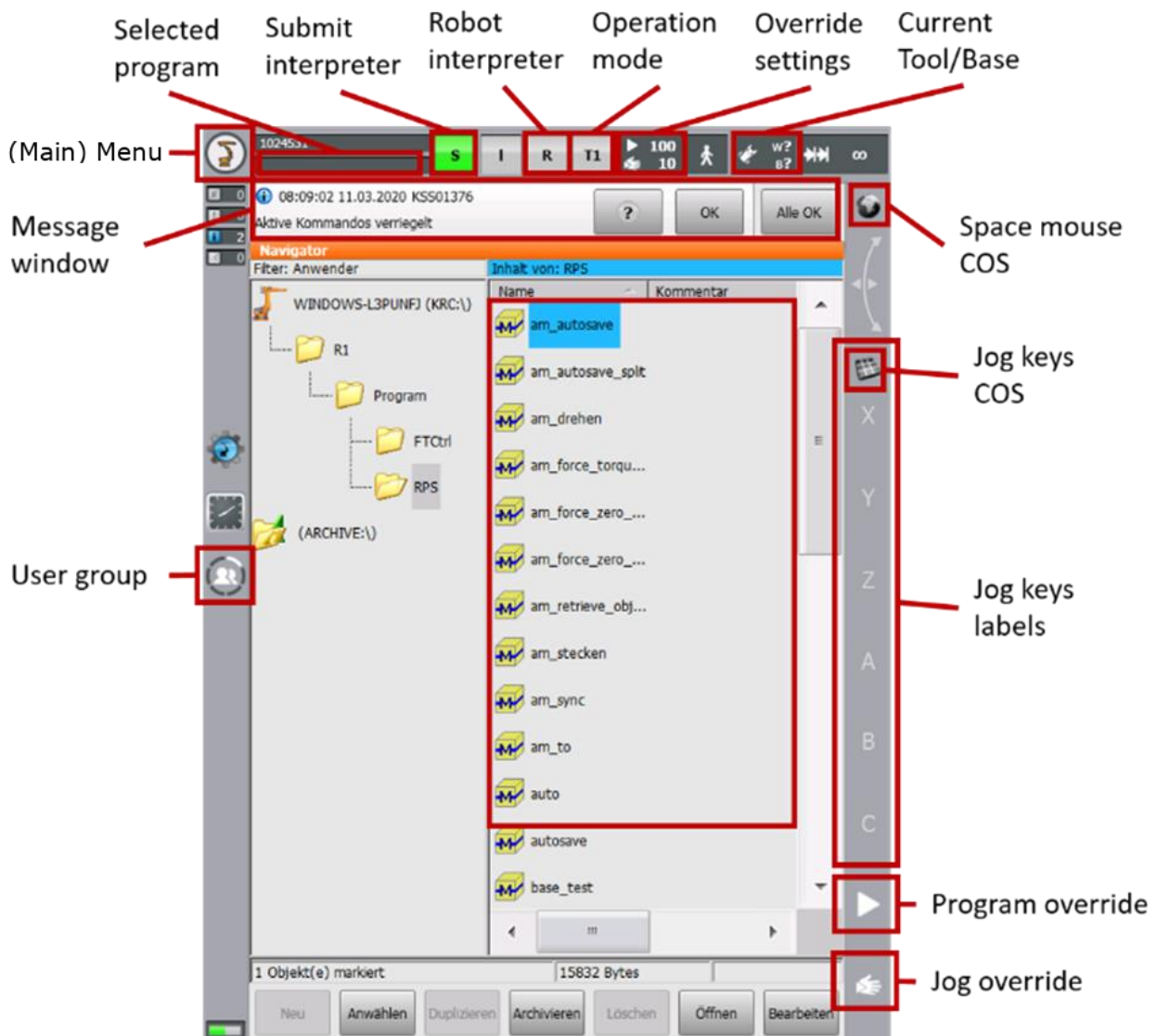
If the "ping" command is not working, check the Windows firewall if it blocks the connection. Also make sure that no additional anti-virus or security software is involved. Consult the manual "ArtiMinds RPS - Installation and technical information for use in corporate IT environments" for more details and what network ports must be open.

2. Overview of the KUKA robot system

Users who are already familiar with the KUKA robot system may skip this topic as it mainly explains some basic terms and gives an overview of important control buttons. Consult the manuals of KUKA for additional information.

Source: KUKA

ARTIMINDS

Function	Location	Summary
(Main) menu	Top left corner	Setup and configuration of the robot.
User group	Center left	Manage the current user goup. Some settings are only available to the Expert/Administrator user. Default password: "kuka"
Current override	Top right	*"Program" (play symbol)":* Percentage value of the programmed velocity "Jog" (play + hand symbol): Percentage value of the velocity for manual motions
Set override	Bottom right corner	Setup the overrides.
Robot interpreter	Top center	Displays the currently selected program and the program status: Gray: No program selected Yellow: Program is ready to start (first line of selected program) Green: Program is being executed

		Red: Selected and started program has been stopped **Black:** Program has finished
Current Tool/Base	Top right	Displays the current selected Tool/Base id. **?**: No Tool/Base selected
Operation mode	Top right	Change/Select the operation mode of the robot: **T1:** For test operation, programming and teaching, max. velocity of 250 mm/s. **T2:** For test operation, programmed velocity, jog mode not possible. **AUT:** Robot without higher-level controllers, programmed velocity, jog mode not possible. **EXT:** Robot with higher-level controllers, programmed velocity, jog mode not possible.

Please notice that some functions on the KUKA teach pendant are only available if no program is selected. Also take care about the selected user group, some settings are only available to the Expert/Administrator user.

The KUKA controller uses a multi-file system, therefore it may happen that changes made to the file system via the mounted network share are overwritten. It helps to open the altered file on the teach pendant again, adding a space symbol and closing the file. This also triggers the parsing of all dependencies.

The KUKA controller uses an advance run system, so certain commands are executed earlier while the robot still executes a former motion command. This can lead to the premature execution of commands which can be suppressed by certain blocking commands (e.g. "WAIT for TRUE"). This is relevant when a vision system is used. The recording of the camera image should only be triggered after the robot arrived at the correct position (advance run must not trigger the camera).

KUKA provides a software called KUKA.WorkVisual to communicate with a KUKA robot from a computer and configuring it. It is recommended to use this software, although the ArtiMinds RPS does not need it during execution. Many options, especially safety relevant settings and hardware extensions, can only be altered via KUKA.WorkVisual.

3. Configuring the robot and computer

The controller allows you to configure several virtual network devices. The required networks depend on the technology packages you intend to use. ArtiMinds RPS always needs a Windows network to copy files to the robot. If you want to stream data via RSI, you will need an additional real-time network. Both cases are explained in the following.

3.1. Configuring the C: network drive of KUKA

Configuring the basic network share is always needed when the ArtiMinds RPS should be able to communicate with the robot and generate robot programs. For this the hidden KUKA C drive has to be shared and mounted as a network drive on the computer. All following steps are executed on the KUKA teach pendant.

1. Log in as Administrator on the robot, go into the settings, then "Start-up -> Service -> Minimize HMI" (German KUKA: "Inbetriebnahme -> Service -> HMI minimieren").
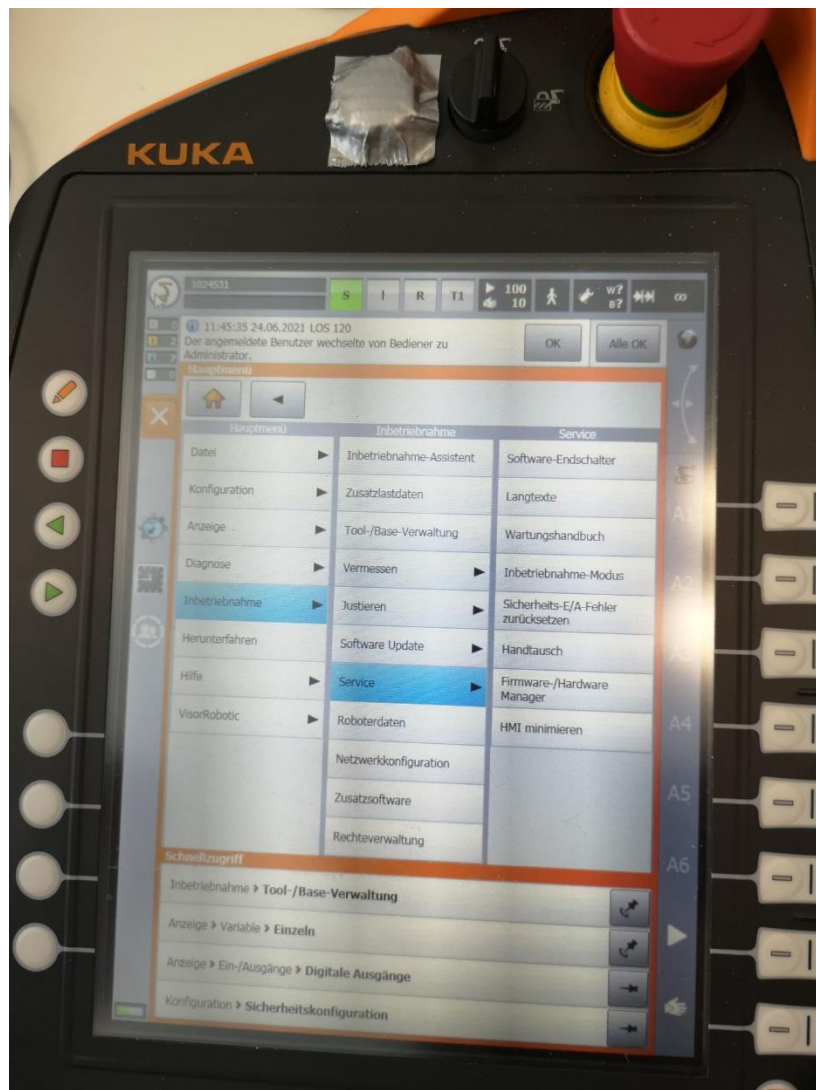
2. Now the KUKA user interface is disabled and the underlying Windows operating system that runs on the KUKA controller is visible. Select the C: drive and open its "Properties". Then go to the "Sharing" tab.
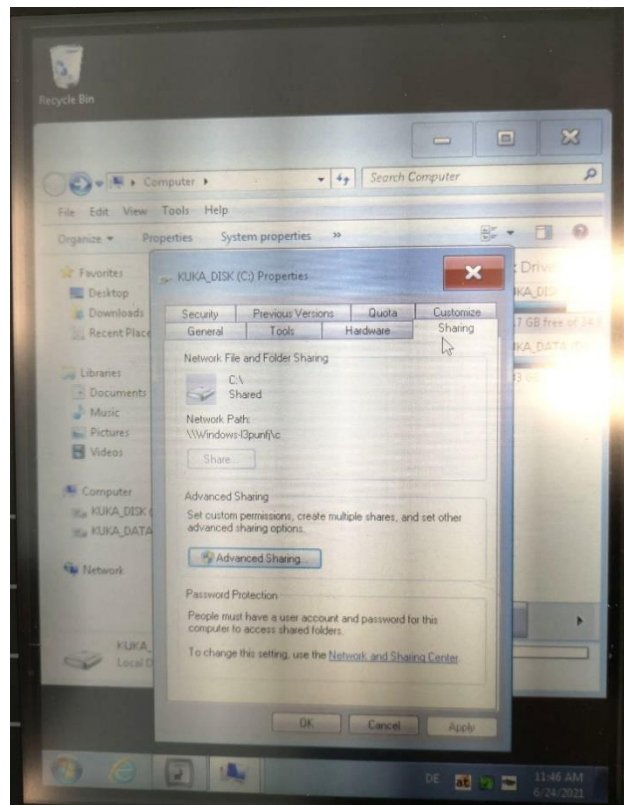
3. Click on the "Advanced Sharing" button and enable all access rights of the "KukaUser" user. All checkboxes for "Full Control", "Change" and "Read" need to be enabled. If the "KukaUser" is not visible, create it via the "Add" button.
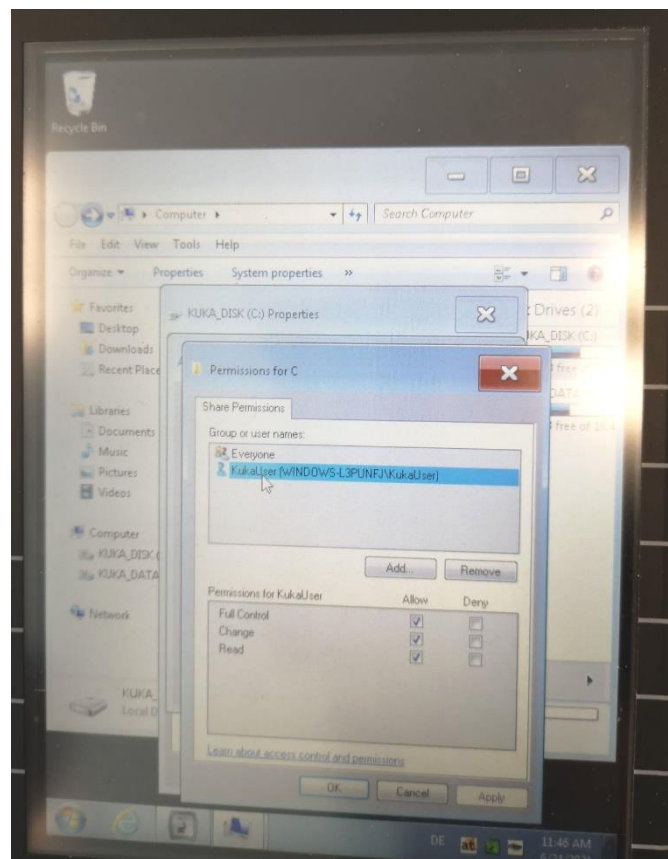
3.2. KUKA DirectoryLoader

Check and adapt the setup of the DirectoryLoader by defining the temporary upload directory somewhere on the C: drive. Create the folder if it is not present. **Attention:** The DirectoryLoader mechanisms might be configured to delete the content of the folder on a regular basis. Therefor do not use folders, which contain relevant files!

The ArtiMinds RPS copies its programs in that temporary folder. The KUKA DirectoryLoader then performs a syntax check and if no errors are found it copies the files from that folder to the KUKA programs folder. Notice the name of the (created) temporary folder as it will be needed in chapter 4 again.

The configuration is specific for the KSS Version, e.g.:

    a. KSS 8.5:
        Open the file `C:\KRC\ROBOTER\KRC\R1\TP\DirectoryLoader\directoryloader.dat`
        (the directory may be hidden). Create or adapt the line
        `DLSourceDir[]="C:\DirLoaderInbox\"`

    b. KSS < 8.5:
        Open the file `C:\KRC\ROBOTER\KRC\R1\System\$config.dat`
        (the directory may be hidden). Create or adapt the lines
        `KRDLSOURCEDIR[]="C:\DirLoaderInbox\"`
        `BOOL PGNOcaseKRDL=FALSE`

Restart the KUKA controller. After booting up the robot, have a look at the log messages and make sure the DirectoryLoader started without errors.

3.3. Mounting the C: KUKA drive on the computer

Now the C: drive of the KUKA is visible to the computer and can be mounted as any regular network drive in Windows. On the computer execute the following steps:

1. Open a Windows Explorer window and type in "\\IP_ADDRESS_OF_THE_ROBOT", e.g. "\\172.30.2.147".
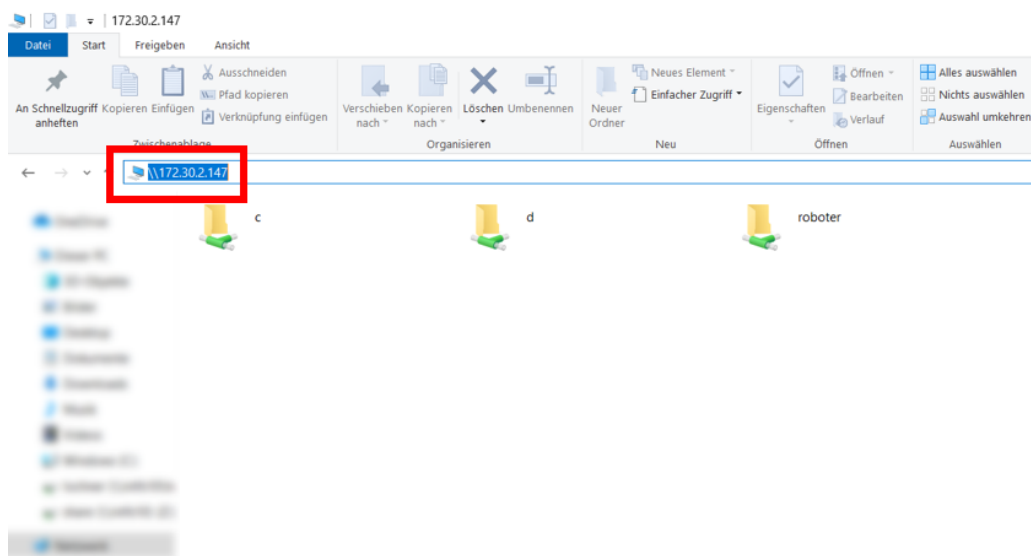
2. Click with the right mouse button on the C: drive and then on "Connect Network Drive…".
    If login credentials are required, enter the usersname and password of the KUKA.
    Default user: "kukauser" with the default password "68kuka1secpw59".
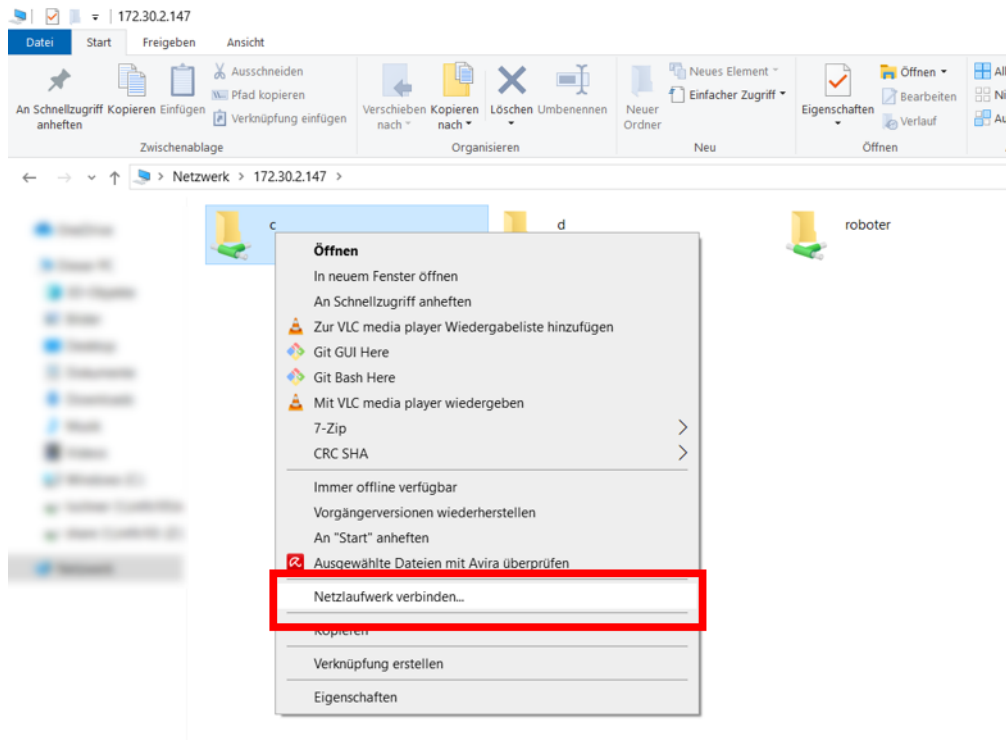
3. Select a free local drive letter and enable the "Reconnect at sign-in" checkbox. Remember the chosen
   drive letter (in this case W:) for later (chapter 4).
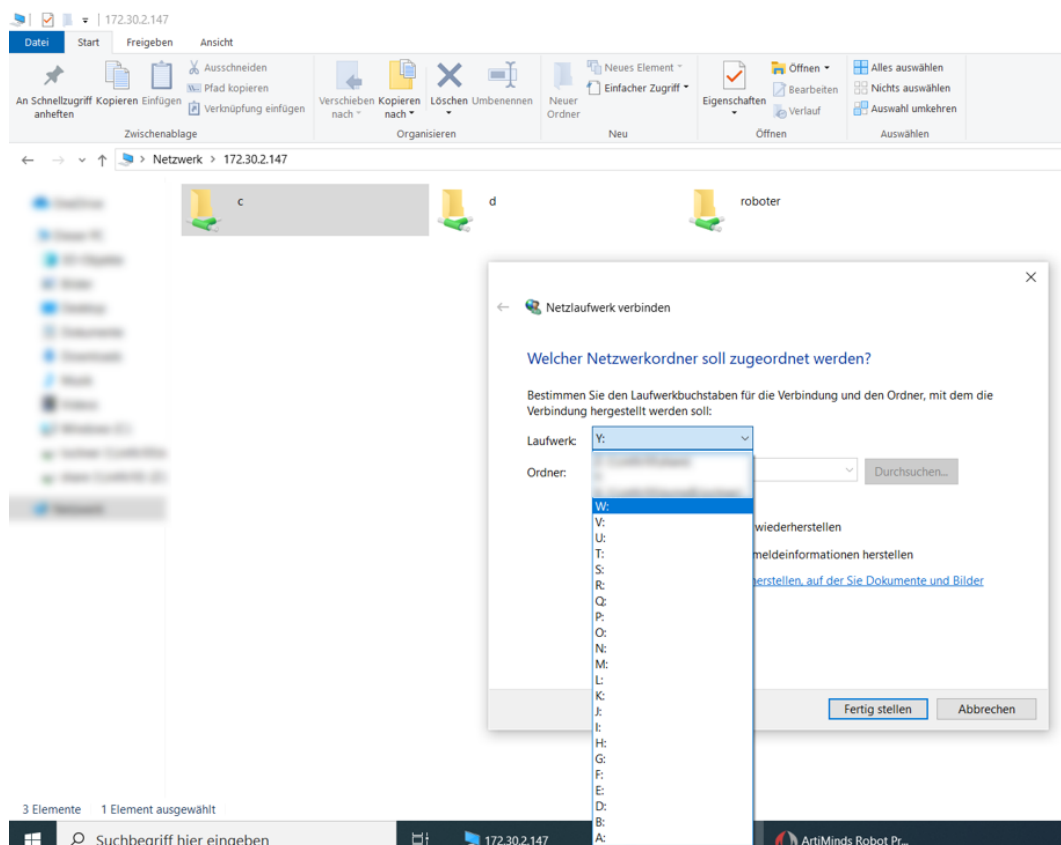
3.4. Configuring KUKA RSI

This chapter is only necessary, high resolution data should be visualized or recorded in the ArtiMinds LAR. That requires fast data streaming of 4ms via RSI. If this is not the case, skip this chapter and immediately go to "4. Configuration in the ArtiMinds RPS".

Please note that there are additional manuals available to configure force-torque sensors with the ArtiMinds RPS. Also have a look on the official KUKA documentation to configure force-torque sensors and RSI with KUKA.Work-Visual (e.g. "Kuka.RobotSensorInterface 4.0" manual).
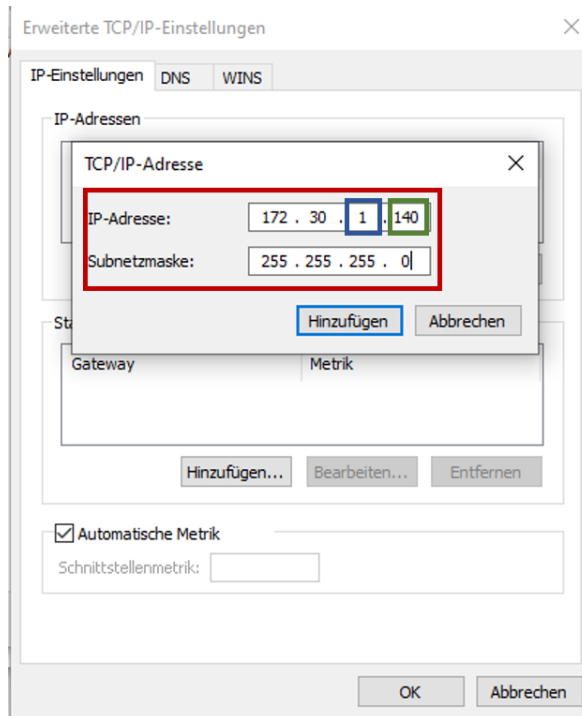
1. Go to the Windows network settings. On the computer open the Windows Control Panel and then "Network and Sharing Center" (Windows 7 or newer). Here you can see an overview of all network adapters. Click on the network adapter that is connected to the KUKA robot and then on "Properties".
2. Click on the "Advanced…" button.
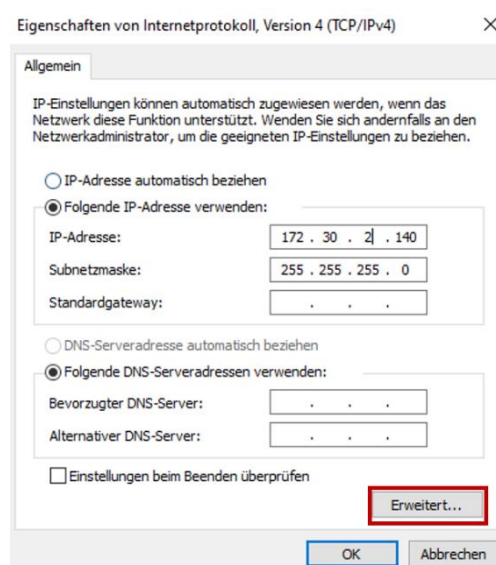
3. Click on "Add…" and add an additional network interface.
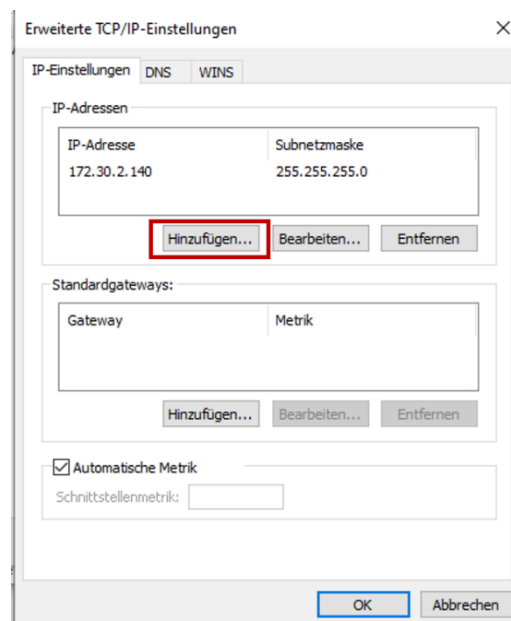
4. The additional network interface should have the same address, but in a different subnet. Add the same subnet mask and click on "Add".
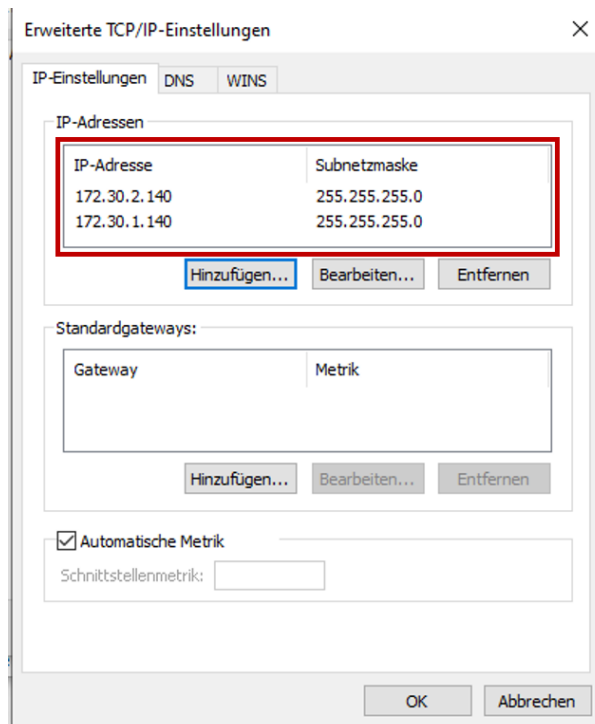
5. The network should look like this (adapt the IP addresses as needed):
   172.30.2.140: Network interface to the KUKA robot
   172.30.1.140: RSI robot sensor interface

4. Configuring the ArtiMinds RPS

Start the ArtiMinds RPS on the computer that is connected to the KUKA robot.
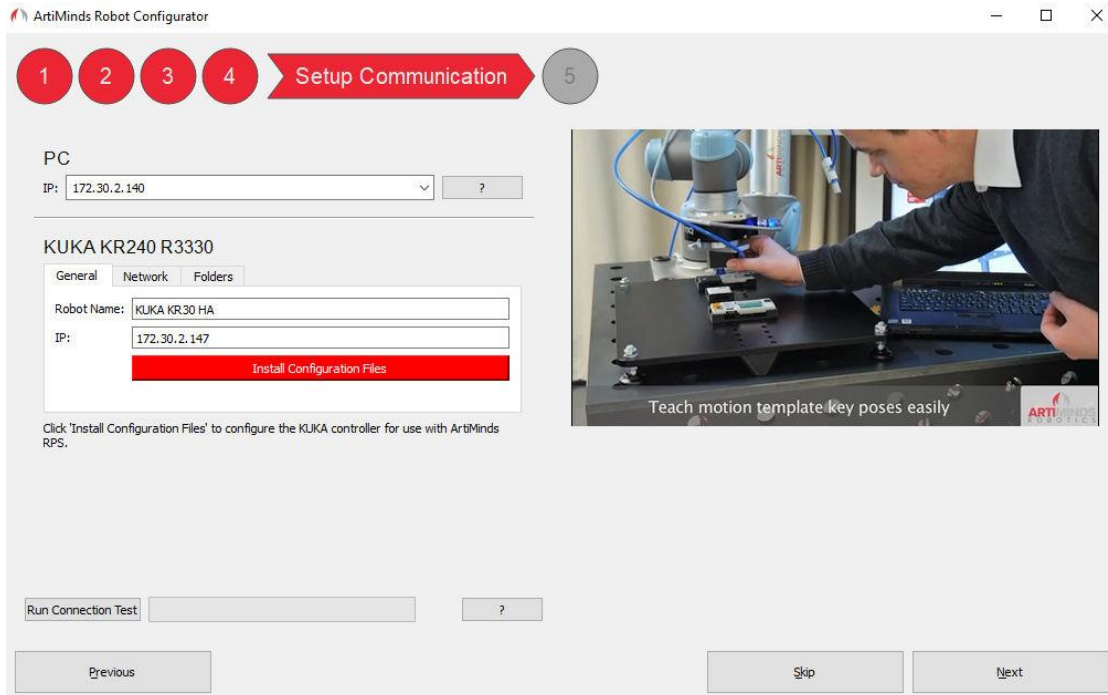
4.1. Coordinate Systems Setup

The **Robot Configurator** allows you to define and setup your hardware. Launch it via "File->Robot->New Robot Setup". In the first pages, setup your components and coordinate systems as required.

Attention: If you choose to mount your robot base differing from the world origin via "Mounting: Robot Arm", you have to apply the same offsets in the machine-data configuration in KUKA.WorkVisual ("Editors -> Machine Data Configuration")! This is a safety critical step therefor the ArtiMinds RPS cannot perform it automatically.

© ArtiMinds Robotics GmbH 2020
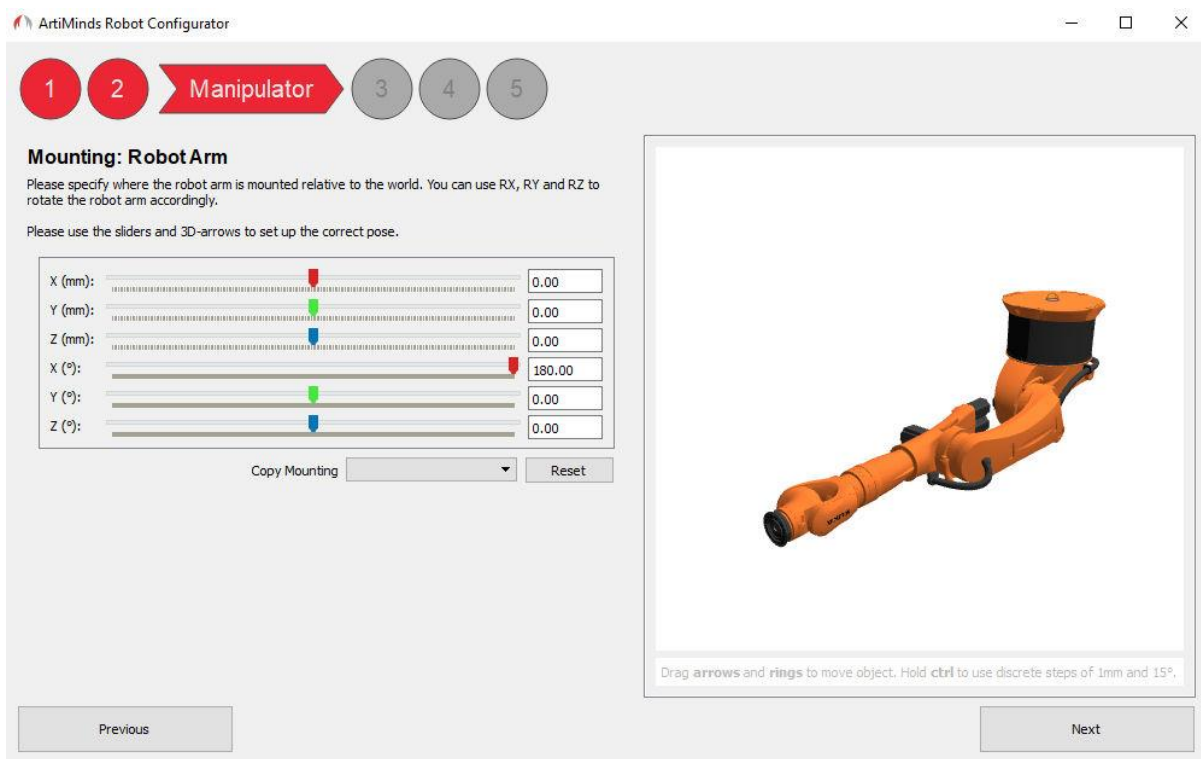
4.2. Network Setup

On the "Setup Communication" page make sure to choose the right network device of your computer ("PC": "IP") with an IP in the same subnet as the robot's main Windows network IP. Then enter the main IP address of the robot on the "General" tab below.

Switch to "Network" and enter the drive letter of the previously mounted network drive of the robots C: drive (W in the example above). Keep the credentials if they did not change on the robot.

Also, keep the entries in the "Folders" tab if not changed manually on the robot. "Directory Loader Source Folder" should point to the folder that has been created on the KUKA C: drive in step 3.2.
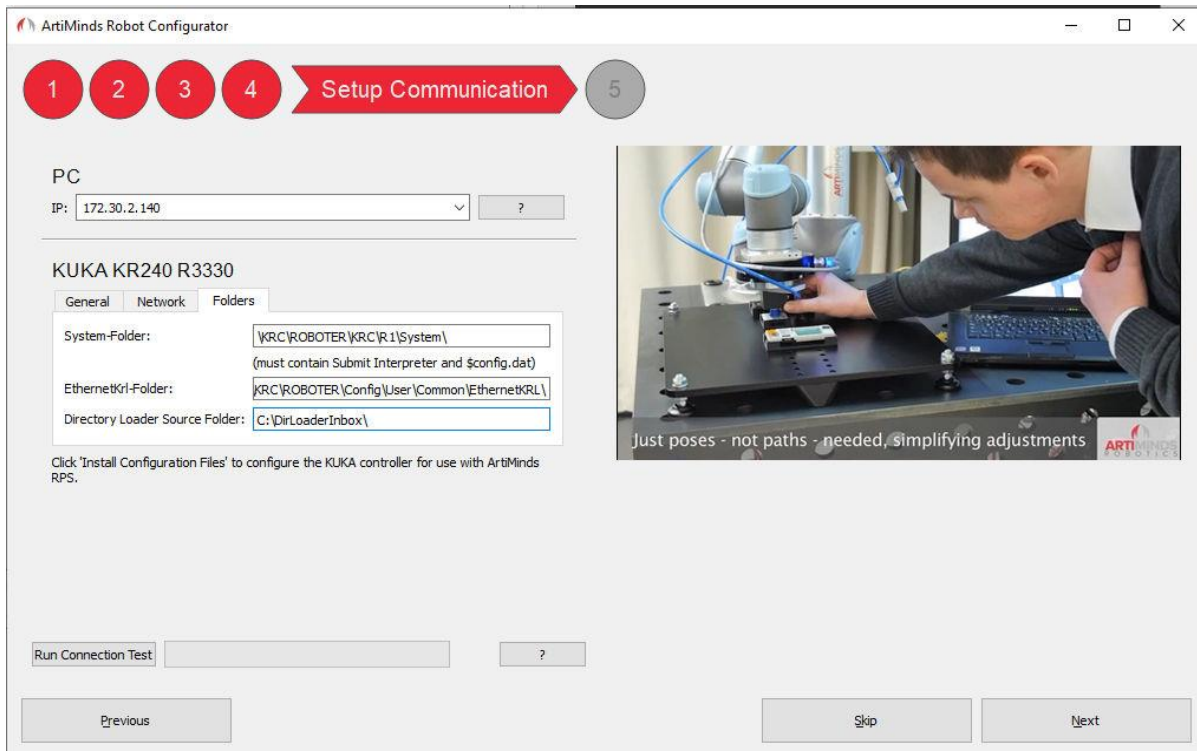
When testing the connection, the ArtiMinds RPS tries to copy and modify several files on the robot. For that purpose, the Submit Interpreter has to be stopped and deselected: Click on the green "S" indicator on the KUKA teach pendant and choose "Deselect" (German KUKA "Abwählen"). Click the "Install Configuration Files" in the "General" tab so that the ArtiMinds RPS can copy and modify various files on the robot controller. It's also possible to read in settings from the controller directly, so that not everything has to be configured manually. Restart the KUKA controller, so that the new files are read in. Afterwards you can test the communication in the ArtiMinds RPS by clicking the "Run Connection Test" button.

If the connection test is not successful, it may be easier to skip the connection test for now ("Skip" button) and completing the ArtiMinds Robot Configurator. You will be prompted to visit the settings after closing the Robot configurator. Otherwise go to "File->Settings->Kuka" in the ArtiMinds RPS and check the settings individually (see next chapter).

An easy way to test the communication with the KUKA robot in general later is by clicking on the "Offline" toggle button in the main menu bar at the top of the ArtiMinds RPS. The ArtiMinds RPS should switch to "Online" mode. Press the "Record" button (also in the main menu bar) to retrieve the current position of the real KUKA robot. The virtual robot in the ArtiMinds RPS should show the same pose. Make sure a tool is selected on the teach pendant of the KUKA.

4.3. ArtiMinds RPS Settings Pages

The following options are all available in the KUKA settings pages of the ArtiMinds RPS ("File -> Settings -> Kuka").

Go to "General -> Network" and make sure the "IP" dropdown shows the IP address of the PC network adapter that is connected to the KUKA robot controller. You may have to switch from "Project Settings" to "Default Settings" at the top to alter this setting. In the above example 172.30.2.140.
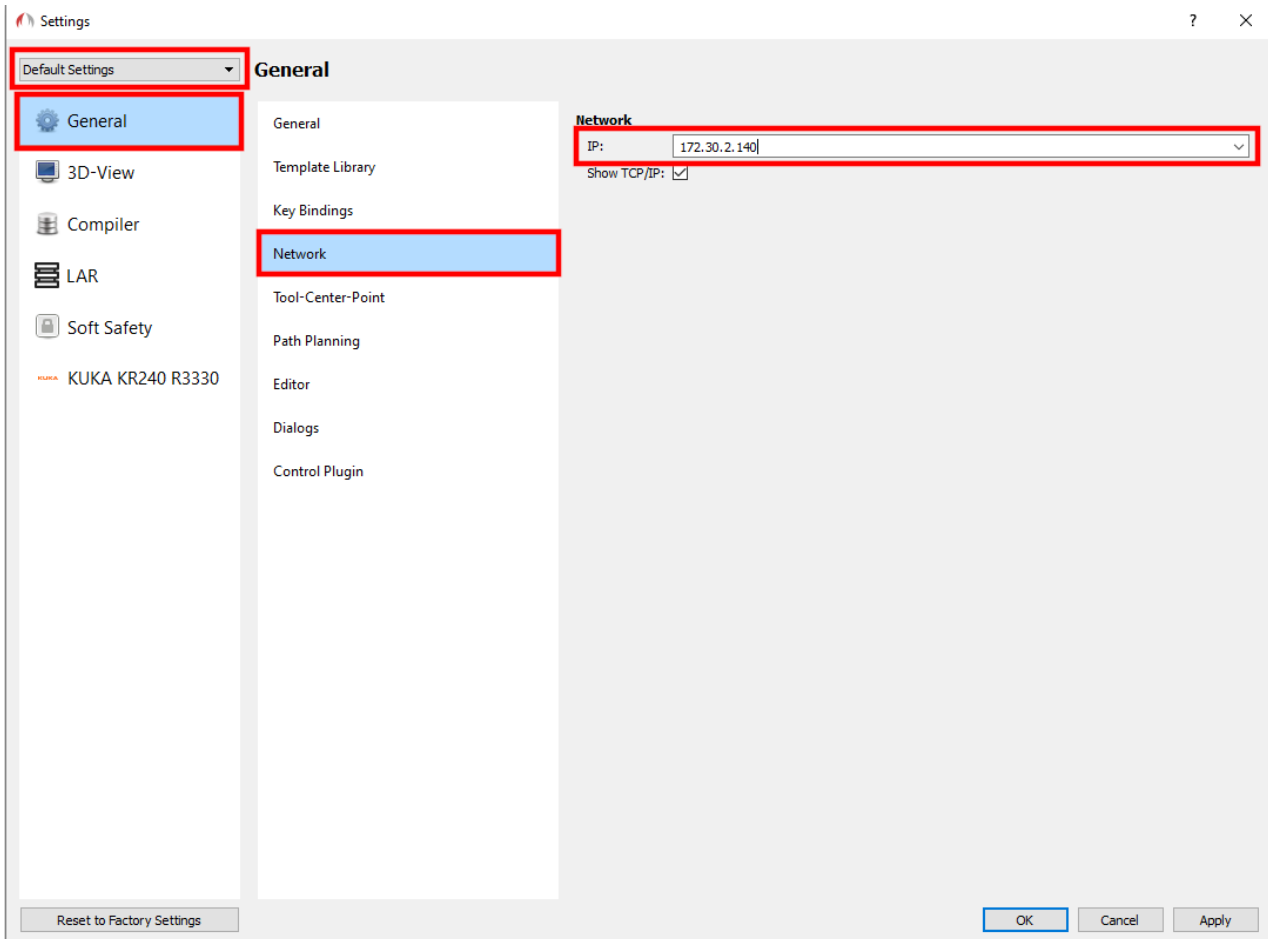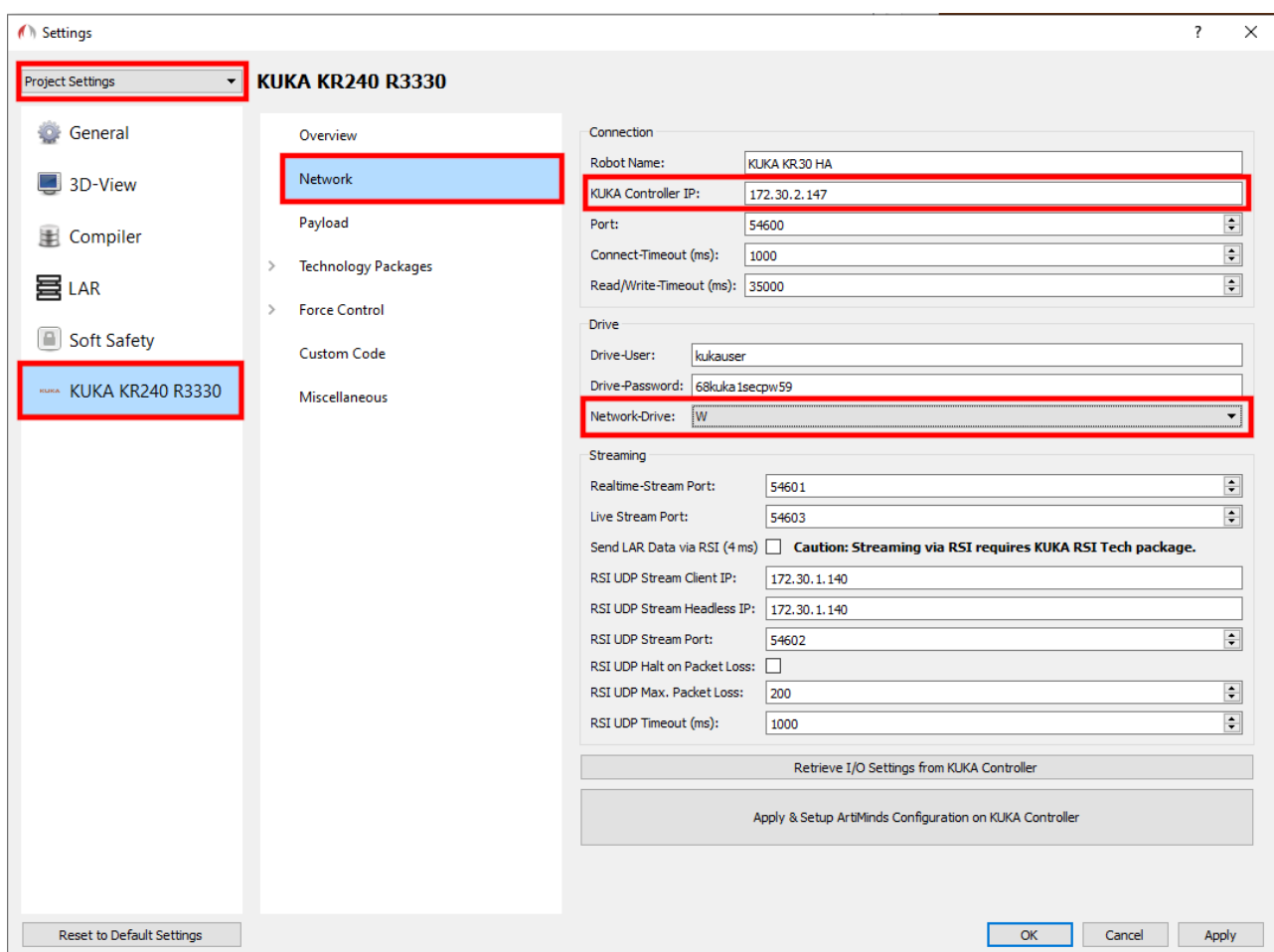
Open the Kuka settings pages in "Kuka->Network" and confirm all settings are correct.

Network Tab:

"Kuka Controller IP" should contain the IP address of the KUKA robot. In the above example 172.30.2.147. Robot and ArtiMinds RPS should be in the same subnet (here first three numbers equal, e.g. 172.30.2.XXX as the subnet mask 255.255.255.0 has been used).

"Samba-Network-Drive" should contain the drive letter of the KUKA C: drive that has been used for mounting on the computer. Here W:.

Make sure the "Samba-User" and "Samba-Password" are correct. You can keep the default values if this has not been altered on the KUKA. This is required for file transfer to the robot.

© ArtiMinds Robotics GmbH 2020

"RSI UDP Stream Client/Headless IP/Port": These settings are only relevant if a force-torque sensor with RSI or the ArtiMinds LAR are used (see chapter 3.4). This is the IP address of a network interface of your computer (172.30.1.140 in the example of chapter 3.4). This can simply be an additional address of your main network adapter and does not require additional hardware. It must be in a different subnet than your regular IP address. It will be used as target for the real-time UDP packages sent from the robot via RSI to realize 4ms data logging. Enable the "Send LAR Data via RSI (4ms)" checkbox if needed. It creates a RSI container to stream high resolution real-time data in addition to the real-time data sent via the submit interpreter.

Usually the other settings do not need to be touched. But the ports need to be open in the Windows firewall and must also not be blocked by other security software that might have been installed on the computer. Do **NOT** add those ports to the port-forwarding rules of the KUKA HMI Network Settings.

It is recommended to press the "Retrieve I/O Settings from KUKA KRC4" in the "Network" tab and the "Retrieve Acceleration Limits from Controller" in the "Options (Expert)" tab once so that the ArtiMinds RPS settings are consistent with the KUKA controller.

Whenever you make changes, make sure you deselect the Submit Interpreter on the KUKA teach pendant first (green "S" icon at the top). Then click the "Apply & Setup ArtiMinds Configuration on KUKA KRC4" button in the ArtiMinds RPS KUKA settings page. This will write all ArtiMinds settings to the KUKA controller. Restart the KUKA controller so that the new settings are read in and confirm that the Submit Interpreter is running again. Otherwise check the error list on the KUKA.

Individual settings and configurations can be written to the KUKA controller by using the other tabs in the ArtiMinds RPS KUKA settings page ("Submit Interpreter", "KUKA.DirectoryLoader",…).

Payload Tab: Configures the payload mounted to the robot flange.

"Robot Payload": Important for teaching and dynamics calculation of motions. Complete weight attached to the robot flange.

"Force Sensor Payload": Mainly important for gravity compensation and force-based applications. The weight after the buttom half of the force-torque sensor.

It is recommended to execute the KUKA.LoadDataDetermination program on the KUKA teach pendant ("Start-up -> Service -> Load data determination") to determine the exact values.

Technology Packages Tab:

- **Submit Interpreter Tab:** Change the IDs of the global flags. Make sure they do not collide with your project specific programming or with flags already used on the KUKA controller.
  "Submit program folder" should contain the path to the $config.dat file on the KUKA controller.
- **DirectoryLoader Tab:** Click on "Load directory loader settings from KUKA controller". This should result in the correct settings for your robot and the settings above should reflect the settings from the previously adapted configuration files on the robot. Make sure the correct Directory Loader version is selected.
  "DLSourceDir[] = " is configured in chapter 3.2 and contains the created temporary DirectoryLoader inbox folder on the KUKA C: drive. Pressing the "Apply" button only copies the Directory Loader specific settings.
- **EthernetKRL Tab:** This defines the directory, where data-format definitions are stored. Keep at default settings.
- **ForceTorqueControl/RSI Tab:** Change these values according to your robots KSS / RSI version and according to the force-torque sensor that you are using. If you're using an ATI sensor that is connected via EtherCat, select the "EtherCat (FieldBus)" checkbox and not the "ATI" one.

Force Control Tab:

- **Force-based Guiding:** Defines PID controller based parameters for force-based guiding. These settings affect all robot programs.
- **Force Controller:** Defines PID controller based parameters for force-based applications. These settings affect all robot programs. Presets are provided to alter the reactivity of the robot when measuring forces.

Custom Code: Here you can inject custom initializations, custom code and custom function definitions, which will always be compiled into the generated .src and .dat files. The entered code will not the checked, so make sure the syntax of the code is correct.

Miscellaneous: Change the priorities of the interrupts defined by the ArtiMinds RPS if they collide with your project specific programming. The ArtiMinds RPS generates tools and bases for the created robot program as needed. "Tool Indices Range" and "Base Indices Range" allow to restrict the allowed indices used for tools and bases by the ArtiMinds RPS. This helps preventing overwriting already defined tools and bases on the KUKA robot controller. Also you have to read the Acceleration limits from the controller once, to allow a correct simulation and runtime estimation within the RPS.
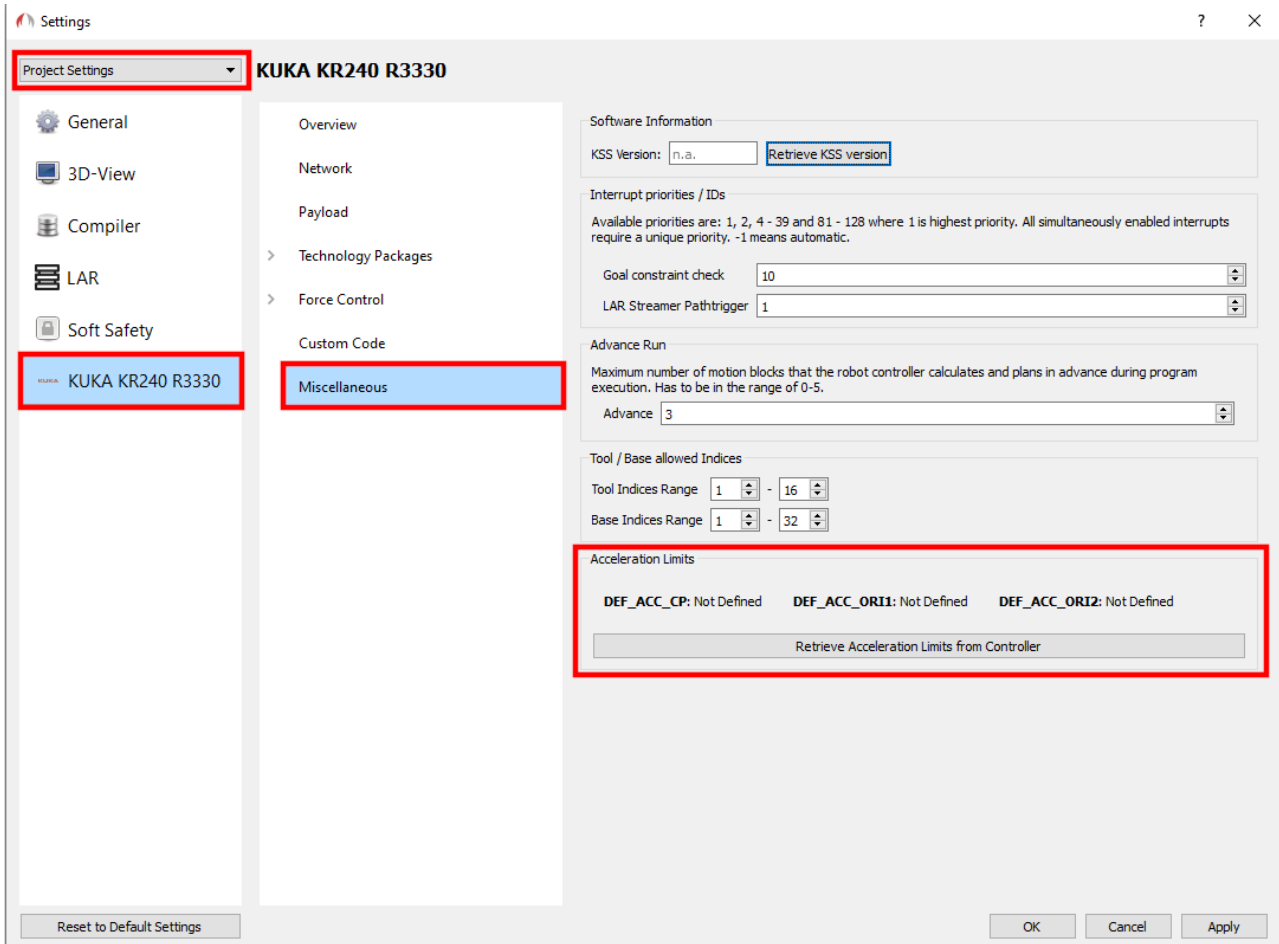
5. Copying programs to the robot

This process differs widely, depending on the DirectoryLoader version that is used. Version < 3.0 requires several manual actions to be performed. This cannot be circumvented.
Since Version 3.0 no manual interaction on the robot side is required any longer.

In general check the log panel on the KUKA teach pendant if the copy process was not successful. See if the transferred files are marked with a red cross, usually indicating an invalid syntax in the robot code.

5.1. ArtiMinds RPS side

After you created a program, you can use the red "Play" button to initiate a transfer of the generated source code to the robot:
1. Click the red "Play" button.
2. The current pose of the robot is queried from the robot and if it does not correspond with the set home-position of your program, a joint-based transfer motion is generated and simulated. Acknowledge it by clicking "Yes".

If you intend to use the **LAR via Headless RPS**, you must use the main menu bar to copy your programs to the robot: "Run -> Compile -> Copy to robot". As only here you have the option to activate "Redirect live data to headless RPS".

5.2. Robot side

DirectoryLoader Version >= 3.0:

No manual actions are required on the teach pendant. Status messages about the copy-process will be displayed on the teach pendant and the program is activated automatically after a successful transfer.

DirectoryLoader Version < 3.0:

1. On the teach pendant you will be asked to switch to external mode. Do so by turning the key, choose "Ext" and turn the key back to operational mode. You have a timeout of 30 seconds to do so.
2. The program is copied to the robot and you will be asked to switch to an execution mode. Again turn the switch and choose "T1" / "T2" or "Auto". **Attention:** The robot will perform with full speed in Auto mode! Turn switch back.
3. The program will be loaded for execution.
4. Depending on the chosen mode you can now start execution:
    a. In T1 / T2 mode: Hold down one of the dead-man switches on the backside of the panel and press and hold the green play-button on the front. The robot will drive to its home position and stop there. Let go of the play-button. Press and hold it down again to start executing the actual program.
    b. In Auto mode it is sufficient to press the play-button only once to start the execution of the complete program. Make sure the robot is at its home-position. Otherwise let it drive to home-position on T1 / T2 mode as described above.

6. Teaching / Demonstrations

"Use Demonstration" button in the wizard of an ArtiMinds RPS template: When teaching target points of templates with the robot, make sure to have the right tool selected on the teach pendant. Especially if you defined the weights of your tools, always choose the same tool for demonstration and execution. Otherwise calibration issues will occur. The same applies when using the "Record" button in the main menu bar at the top.

7. Troubleshooting

- In general check the log/error messages on the teach pendant of the KUKA robot.
- Additional help pages and manuals are provided, e.g. for configuring force-torque sensors or grippers. Open the tutorials by pressing the "F1" key in the ArtiMinds RPS.
- When the copying to the robot fails, this may also indicate syntax errors in your code. Check the syntax of manually added code in your "Code" templates in the ArtiMinds RPS and in "File->Settings->Kuka> Custom Code (Expert)".
  - o Select the file on the teach pendant and look at the error list ("Fehlerliste").
  - o Code on the controller has to use Windows \cr\lf linebreaks.
- Network-Drive setup: If you cannot connect to the drives of the robot via Windows Explorer, make sure that Port 445 is listed in the Port-Forwarding of the KUKA Control Panel Network Settings.
- Setup process (ArtiMinds RPS config page):
  - o If errors occur while configuring settings on the KUKA controller (modifying sps.sub or $config.dat), please assure that those files have write access. Check file permissions and properties by accessing the shared network C: drive via Windows Explorer.
- Communication problems (ArtiMinds RPS cannot switch to "Online" mode):
  - o Acknowledge all error messages on the teach pendant.
  - o Make sure that the submit interpreter is running ("S" indicator is green)
  - o Start the "Diagnose Monitor": It should list two open connections for the Submit program.
  - o Check your PC side: Use the following PowerShell commands (Windows start menu and typing in PowerShell) to test if both ports can be reached over network:
    ```
    Test-NetConnection -RemoteAddress 172.30.2.147 -Port 54600
    Test-NetConnection -RemoteAddress 172.30.2.147 -Port 54601
    ```
    ➔ Replace 172.30.2.147 by your KUKA controller's main IP address!
  - o If this test fails, make sure you did **not** add the ports to the NAT settings of the controller!
- If variables within the .src files are unknown, open up the according .dat file on the teach pendant, add a "Space" character at the end of an arbitrary line and save the .dat again. This will trigger a reparsing.
- If you see a "RSI bad" error, check, if you are using a real-time capable network for RSI. You can look this up in the KUKA teach pendant network (German "Netzwerk") settings. Click on "Advanced" ("Erweitert") and choose the virtual interface called "RSI". There the address-type must be "Mixed IP Address" ("Gemischte IP-Adresse") or Real-Time Network ("Echtzeit Netzwerk").
- When further support is needed, please contact support@artiminds.com and provide a KRCDiag file for easier debugging if possible. A KRCDiag can be generated as follows:
  1. Connect an USB drive to the KUKA teach pendant (formatted as FAT32).
  2. On the KUKA teach pendant click on "File -> Archive -> USB (KCP) -> KRCDiag" (German KUKA "Datei -> Archivieren -> USB (KCP) -> KRCDiag").
  3. The KRCDiag file is written to the USB drive. Depending on the stored data on the robot, the file can have sizes of 30MB+.

8. Usage of a Force-Torque-Sensor

There are several ways to connect the sensor to the robot, depending on the brand of sensor that you are using. In all cases the measured data is read over the RSI interface and partly processed via the ForceTorqueControl technology package.

8.1. Prerequisites

The RSI network interface that connects to your sensor must be configured to a different subnet than the regular interface used by the ArtiMinds RPS (see chapter 3.4).

Apart from that, please follow a separate manual from KUKA or the sensor manufacturer to connect your specific sensor. If you connect the sensor via EtherCAT, ArtiMinds also offers a specific manual for that.

Notes

Keep in mind that the default TCP coordinate system of the KUKA is rotated by 180 degrees in comparison to the ArtiMinds RPS standard TCP. We strongly advise you to NOT change the ArtiMinds RPS default TCP to match the KUKA TCP, as many (force) templates rely on the Z axis pointing towards the flange.

Changelog

V.1.0: Initial version

V.1.1: Added section 2.1 about moving robot base via Machine-Data-Configuration in KUKA.WorkVisual.
Corrected section 1.3 with KSS specific variable names.

V.1.2: Added hint to create DirectoryLoader target folder on robot if not present. Section 1.3.

V.1.3: Changed example target directories for DirectoryLoader in section 1.3.

V.1.4: Extended section 1.4: Copy to robot with DirectoryLoader 3.x.
Clarified variable declaration in section 1.3.

V.1.5: Restructured network setup. Changed capitalization of DLSourceDir.
Added pages of the KUKA settings dialogs. Clarified the IP settings for RSI streaming.

V.1.6: Fixing some spelling errors and improving the layout.

V.1.7: Added images, additional explanations and reworked the structure.

V.1.8: Formatting.

V.1.9: Added additional image to explain the KUKA teach pendant user interface.

V.1.10: Extended list of broken EthernetKRL versions and the resulting error messages.

V.1.11: Added hints to not add Ports to Port Forwarding settings on the HMI. Added troubleshooting for SMB Port. Added troubleshooting for write protected config files on the controller.