grl Software Manual

Release v4.0 (2031c8f)

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Contents

1 Features

Drivers

- **C++11 drivers for KUKA LBR iiwa Fast Robot Interface**
  - ROS drivers
  - V-REP drivers
  - millisecond response times
  - Uses only documented features and configuration (most alternative drivers don't)
  - Independent driver classes with minimal dependencies

Algorithms

- Hand Eye Calibration integration
- Inverse Kinematics with Constrained Optimization

Simulation

- Hardware integration with V-REP robotics simulation software.

2 Quick Start

2.1 First Steps

The following steps will show you how to

- download and install grl on your system.
- use the installation to create an example.
- build and test the example project.

You need to have a Unix-like operating system such as Linux or Mac OS X installed on your machine in order to follow these steps. At the moment, there is no separate tutorial available for Windows users, but you can install CygWin as an alternative. Note, however, that grl can also be installed and used on Windows.

Install grl

Get a copy of the source code

Clone the Git repository from GitHub as follows:

```
mkdir -p ~/local/src
cd ~/local/src
git clone https://github.com/ahundt/grl.git
cd grl
```

or download a pre-packaged `.tar.gz` of the latest release and unpack it using the following command:

```
mkdir -p ~/local/src
cd ~/local/src
tar xzf /path/to/downloaded/grl-$version.tar.gz
cd grl-$version
```

Configure the build

Configure the build system using CMake 2.8.4 or a more recent version:

```
mkdir build && cd build
ccmake ..
```

- Press `c` to configure the project.
- Change `CMAKE_INSTALL_PREFIX` to `~/local`.
- Set option `BUILD_EXAMPLE` to `ON`.
- Make sure that option `BUILD_PROJECT_TOOL` is enabled.
- Press `g` to generate the Makefiles.

Build and install grl

CMake has generated Makefiles for GNU Make. The build is thus triggered by the make command:

```
make
```

To install BASIS after the successful build, run the following command:

```
make install
```

As a result, CMake copies the built files into the installation tree as specified by the `CMAKE_INSTALL_PREFIX` variable.

Set up the environment

For the following tutorial steps, set up your environment as follows. In general, however, only the change of the `PATH` environment variable is recommended. The other environment variables are only needed for the tutorial sessions.

Using the C or TC shell (csh/tcsh):

```
setenv PATH "~/local/bin:${PATH}"
setenv grl_EXAMPLE_DIR "~/local/share/grl/example"
```

Using the Bourne Again SHell (bash):

```
export PATH="~/local/bin:${PATH} "
export grl_EXAMPLE_DIR="~/local/share/basis/example"
```

Create an Example

Create an example using grl:

```
voluptate --velit esse --cillum dolore --eu
```

Test the Example

Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

```
ipsum --in molestie
```

Next Steps

Congratulations! You just finished your first grl tutorial.

Now check out the *Advanced Tutorials* for more details regarding each of the above steps and in-depth information about the used commands if you like, or move on to the various *How-to Guides*.

2.2 Advanced Tutorials

The advanced tutorial slides give a more in-depth introduction to grl and its use including in-depth information and references to further documentation. For a less comprehensive tutorial-like introduction, please refer to the *First Steps* above.

3 How-to Guides

The how to guides below introduce various tasks you may want to do with the library.

3.1 Kuka IP Addresses

Regular Java Kuka

Laptop IP

Address: 172.31.1.100

Mask: 255.255.255.0

Robot IP

172.31.1.147

Ports

The IP address ports available for user code to communicate with outside machines are:

30000-30010

Kuka KONI FRI interface

Laptop IP

192.170.10.100

Robot IP

192.170.10.2

3.2 Kuka LBR iiwa Java Setup

Note: currently Windows is required for the KUKA iiwa Sunrise Workbench

Install Sunrise Connectivity Suite

It is important that you use the Sunrise Connectivity Suite, as this contains the high performance tools needed for this system. If your installer doesn't have the word "Connectivity" in it ask KUKA to send you the Sunrise Connectivity suite.

- Install Sunrise Connectivity Suite using the SunriseWorkbench 1.9 Connectivity Setup installer

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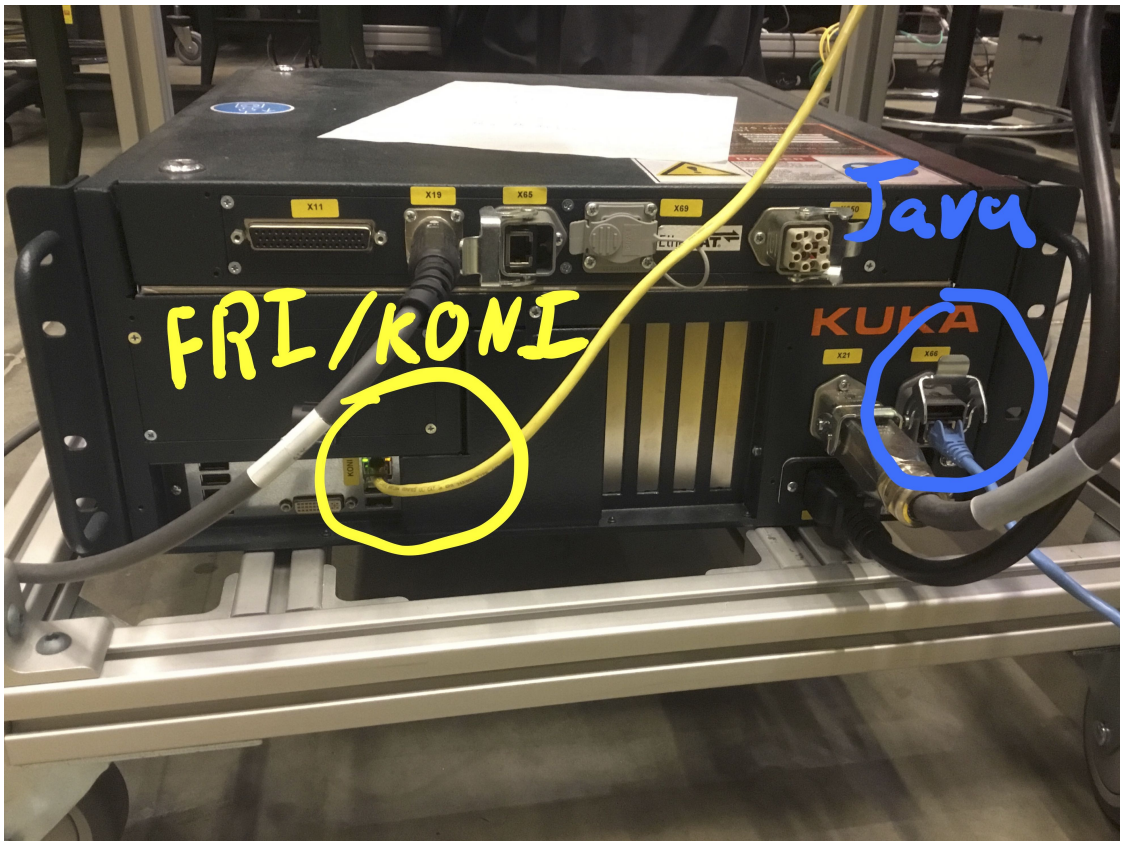
Note: While KUKA installation steps are done on windows, grl itself runs on OS X and Linux Ubuntu 14.04

Connect the KUKA Controller

- Use two ethernet cables (you will need two ethernet ports on your computer)
- First cable connects to standard Java ethernet port
- Second Cable to the KONI ethernet port (if you are using FRI)



Set IP Address

See **'IP Addresses<howto/IPAddresses>'_** for more detail on IP addresses.

- Go to Control Panel > Network and Internet > Network Connections 1. Right click on wifi icon on Windows task bar 2. Select Open Network and Sharing Center 3. Select Change Adapter Settings on the left side of the window
- Right click on ethernet icon and select Properties
- Go to networking tab
- Double click on Internet Protocol Version 4 (TCP/IPv4)
- Change to Use the following IP address IP Address: 172.31.1.100

  Subnet mask: 255.255.255.0 (should automatically fill out)
- Select OK

Launch Sunrise Workbench

Right click on the Sunrise Workbench desktop icon and click "Run as Administrator". The application may not launch otherwise.

Create a new Sunrise Project

- If starting a new project then use the IP address: 172.31.1.147
- Select the arm you have (ours was LBR iiwa 14 R820), then next
- Select the end effector attachment you have "media flange", then next - Ours had electrical connections on the end so we selected "Medien-Flansch elektrish" - If you have tubes on the end you should probably select "Medien-Flansch pneumatisch"
- Finish
- Name your project
- Finish

Configure safety System to run a bare robot

Be aware that the following steps disable safety systems, and it is your responsibility to ensure safety of yourself and those around you. If you don't have any safety systems and you are just starting with the robot for the first time do the following

- Open SafetyConfiguration.sconf
- Uncheck Row 1,2,3 "Emergency Stop External", "Operator Protection", "Protective Stop" respectively.

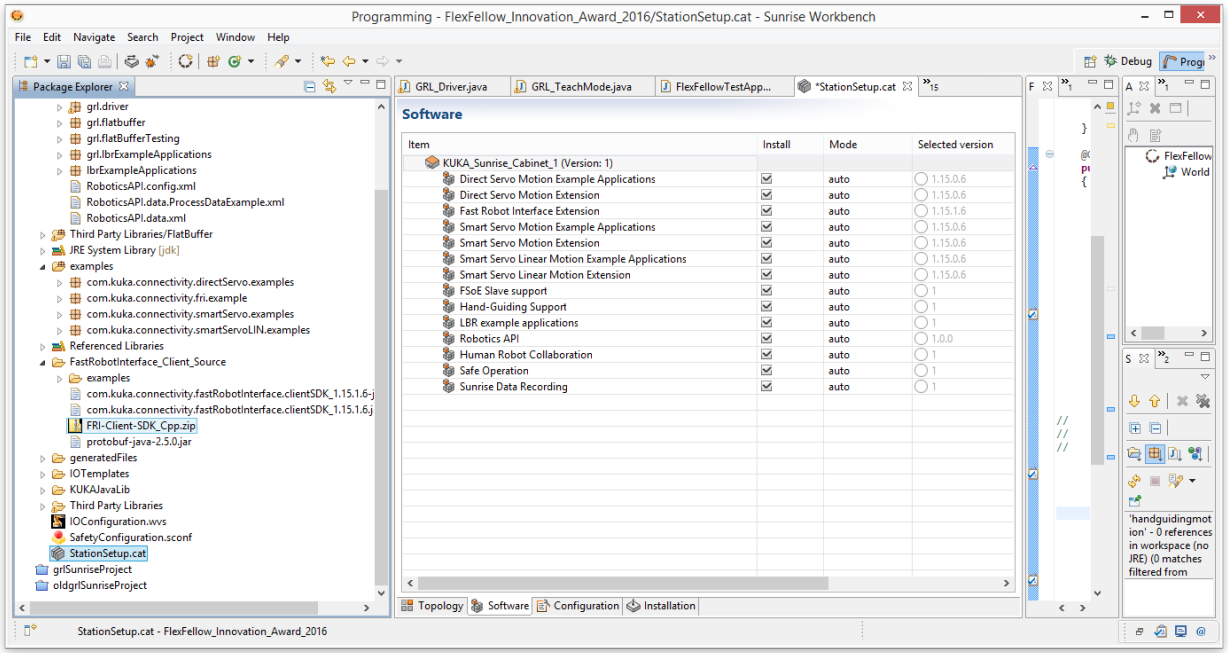
Enable Required Software Modules

If some of the modules are missing, you may not have the Sunrise Connectivity Suite. See the top of this guide for details.

- Open StationSetup.cat
- **On the bottom you will see tabs including:**

  - Topology, Software, Configuration, Installation
- Select the “Software” tab
- **Check “Install” for the following modules but don’t remove any that are already installed.**
  - Interface for Rendering Standalone(without plugin) implementation
  - Tools and Models for Rendering.VREP
  - Simple Tutorials for DirectServo (optional)
  - Simple Tutorials for SmartServo (optional)
  - Direct Servo Motion Extension
  - Smart Servo Motion Extension
  - Fast Robot Interface (required for grl)

Your Software should have each box checked and things should look similar to the image below.



Go to the “Installation” tab visible in the image and click the button to install the software to the robot.

After installation is complete the FRI-Client-SDK_Cpp.zip file should be present as visible in the image above. Copy the FRI-Client-SDK_Cpp.zip file into the folder ${GRL_DIR}/data/ on your linux or OS X box with GRL for running the drivers.

Follow the C++ build steps specified in **‘Configure the build‘_**

If that doesn’t work, set the path to FRI-Client-SDK_Cpp.zip in CMake as follows:

```
cd path/to/grl
mkdir build
cd build
cmake .. -DFRI_Client_SDK_Cpp_zip_PATH="path/to/FRI-Client-SDK_Cpp.zip_folder"
make
```

Setup Java Driver Software

Copy the folders in

```
${GRL_DIR}/src/java/grl/
```

into the directory where your Sunrise Project is located.

Configure the grl repository settings

- Copy the KUKAJavaLib folder in your Sunrise Project and paste it into the grl folder
- With the Sunrise Workbench open: - Import the grl project if it does not already appear in the Package Explorer on the left side
  - **File > Import**
    - In the GUI, select General > Existing Projects into Workspace
    - Select Next
    - Select Browse next to Select Root Directory and find the grl folder
    - Finish
  - Right Click on your Sunrise Project - Select Build Path > Configure Build Path - In the GUI, select the Projects tab - Select Add
    - In the GUI, check grl then OK and OK again

Install Software onto KUKA Controller

This will install the software by syncing a git repository kuka automatically creates with the robot.

Note: Installing and Syncing software are two separate steps!

- Open StationSetup.cat
- **On the bottom you will see tabs including:**
  - Topology, Software, Configuration, Installation
- Select the "Installation" tab
- Click Install

Sync Software onto KUKA Controller

Make sure the software is already installed.

Hit the Sync button, which is a gray box on the top row with an arrow pointing right and another pointing left.

Run in Autonomous Mode

Warning: You are responsible! This disables safety features, read KUKA's documentation and be very aware of your robot and its surroundings.

- Pick up the tablet for the KUKA iiwa

- Turn the black key horizontally
- Select “Aut” for autonomous mode
- Turn the black key vertically

Running and Stopping Applications

- Select the “Applications list”
- Select your application such as “GRL_Driver”
- Press the “green play” button on the left side of the tablet that is pointing right.

Your application should be running.

- The red square button pauses
- The picture of a page with an X kills the application.

3.3 VREP Setup

Note: You will need to understand V-REP and grl thoroughly if you plan to modify this substantially. Work is also needed to generalize it to any robot and create more examples. If interested create a github issue to discuss, pull requests will be appreciated!

First install VREP and grl.

Find the location of the actual vrep executable, for which there are example paths below

Create symlinks to the grl libraries that V-REP should load.

There is a SymbolicLinksRoboneSimulation.sh script to assist with this, which you can open and edit for your particular system.

```
GDIR="/path/to/grl/"
# Mac example directory:   VDIR="/Applications/V-REP_PRO_EDU_V3_3_2_Mac/vrep.app/Contents/MacOS/"
# Linux example directory: VDIR="~/V-REP_PRO_EDU_V3_3_2_Linux/"
#
# cd into the appropriate directory, then create the following symlinks
ln -s src/lua/grl.lua ${VDIR}/
ln -s build/libv_repExtKukaLBRiiwa ${VDIR}/
# ... continue for all libraries created for grl
```

An example simulation can be found in the Robone/data project folder.

Then simply open the project with V-REP and you can be on your way!

Please note that this project is currently set up in a fairly specific way, so you will most

3.4 Setup with Docker

Follow the steps in **src/scripts/RunInDocker.sh**

3.5 Milling simulation of bone shaped object

Link to Issue: https://github.com/ahundt/grl/issues/9

1. Download the triangular mesh of the CT femur bone from: https://jh.app.box.com/s/n1vhute9sbxjkr5oowu60r13jldxrs5b
2. Import the mesh using the V-REP tutorial: http://www.coppeliarobotics.com/helpFiles/en/importExport.htm
3. Make sure the mesh is cuttable by: -In the "Scene Hierarchy" tab, double click on the shape icon (looks like a pear) next to the name

   of the imported mesh

   -Change to the "Common" section of the "Scene Object Properties" dialogue box that just appeared -Under "Object special properties", select the "Cuttable" check mark
4. Now the mesh can be moved into position for milling. Here is a simple tutorial for moving objects: http://www.coppeliarobotics.com/helpFiles/en/objectMovement.htm

3.6 Milling Simulation of simple object

Issues: #8 #43

1. Adding a path:

   -Right click anywhere on the screen -Select add -Select Segment Path for a general path. Or -Select Circle Path to obtain a circle path.
2. Editing a path:

   -Select your path from the "Scene hierarchy" tab -Hit on the "Toggle path edit mode". -To change the position or orientation of a point, select it when you are in the "Toggle path edit mode". -Hit the "Object/Item Shift" or "Object/Item Rotate" buttons from the tool-bar located at the top of the screen.
3. Following a path:

   -Right click anywhere on the screen, select add, select "Dummy". You will need two dummies. -Make one dummy a child to your robot end_effector link, and the other one a child to your path. -Make these two dummies "Linked" by double clicking on one of these dummies icon on the "Scene hierarchy" tab, and selecting the other dummy in the "Linked dummy" option.

You have two options now:

3.1. Using the "Inverse Kinematics" module:

-Follow the instruction on how to use the "Inverse Kinematics" module from: http://www.coppeliarobotics.com/helpFiles/en/inverseKinematicsModule.htm

-Note that you will need to change the way the robot joints act. Double click on joints' icon in "Scene hierarchy" tab, and change the "Joint Mode" to "Joint in inverse kinematics mode". This will enable the joint to follow the inverse kinematics module.

3.2. Using the "Lua" commands from the scene "MillingRobot" and using some of :

-Functions needed: (Follow the instructions on http://www.coppeliarobotics.com/helpFiles/en/apiFunctionListAlphab
-SimGetPositionOnPath -SimGetOrientationOnPath -SimGetObjectPosition -SimRMLMovetoPosition -SimFollowPath -SimGetObjectHandle

4. Adding Mill:

-Right click anywhere on the screen, select add, select “Mill” and choose type. Make the mill a child to the dummy which is a child to the robot end_effector.

5. Adding Object:

   -Right click anywhere on the screen, select add, select “Primitive Shape”

4 Getting Help

Please report any issues with grl, including bug reports, feature requests, or support questions, on GitHub.

5 People

5.1 Software Development

Primary Developer

- Andrew Hundt

Contributing Developers

- Alex Strickland
- Shahriar Sefati
- Chris Paxton

5.2 Advisors

- Dr. Peter Kazanzides