Institute of Mechatronic Systems
Leibniz Universität Hannover

BWH

KUKA

Tutorial

LightWeightRobotIGT – Getting Started

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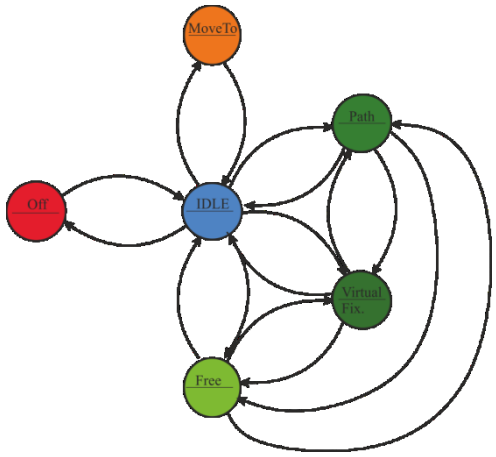
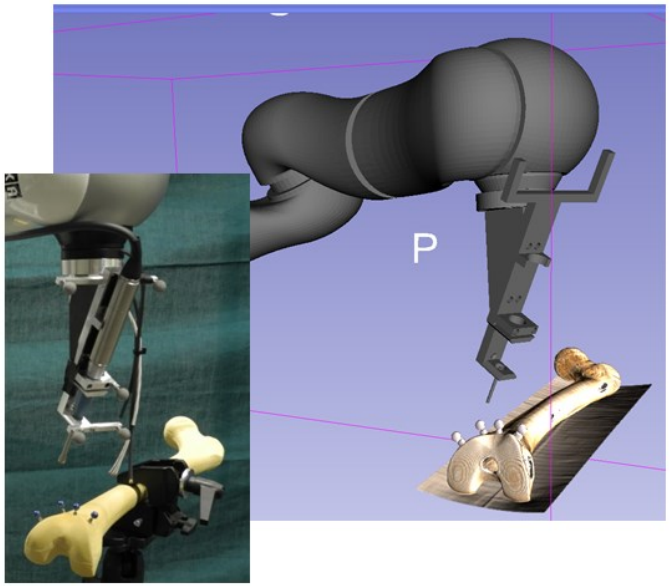
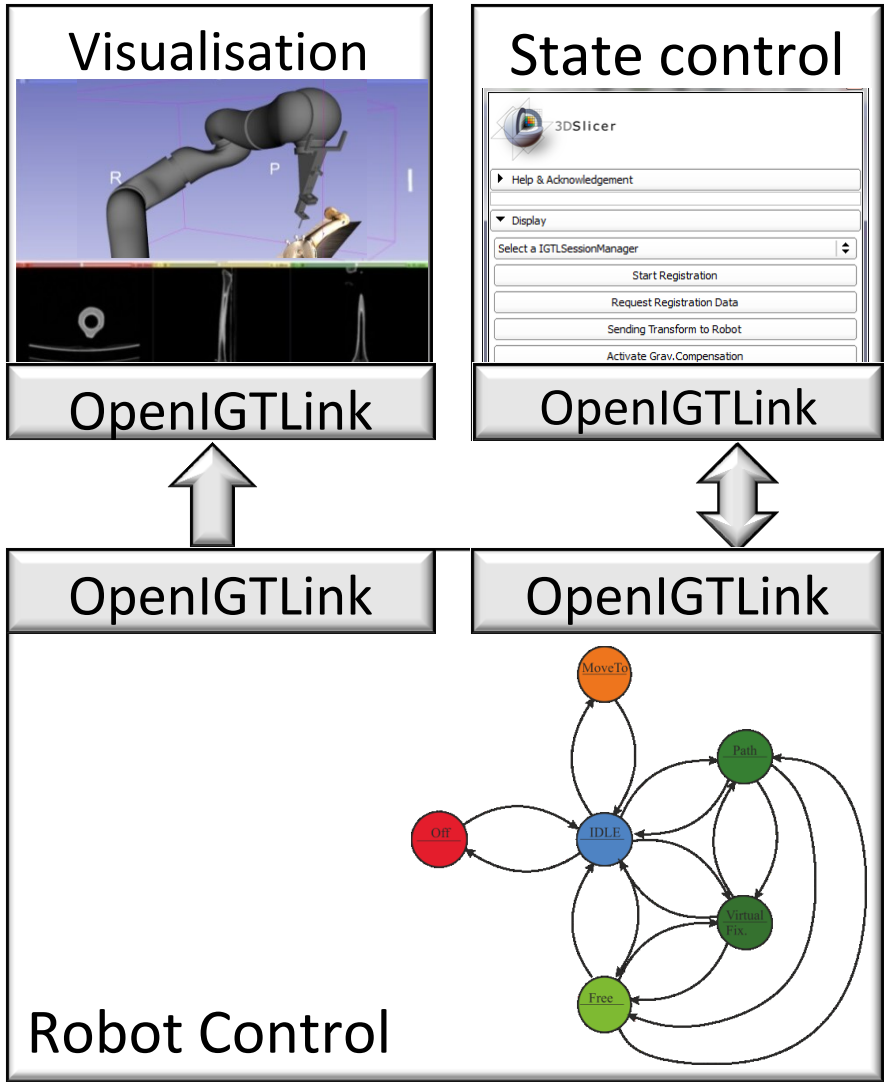




Outline

- System Overview
  - Requirements
- Set up KUKA Sunrise control
  - Install Example
- Install LightWeightRobotIGT
- Run Example

System Overview - Interface Concept



Robot as element of IGT system

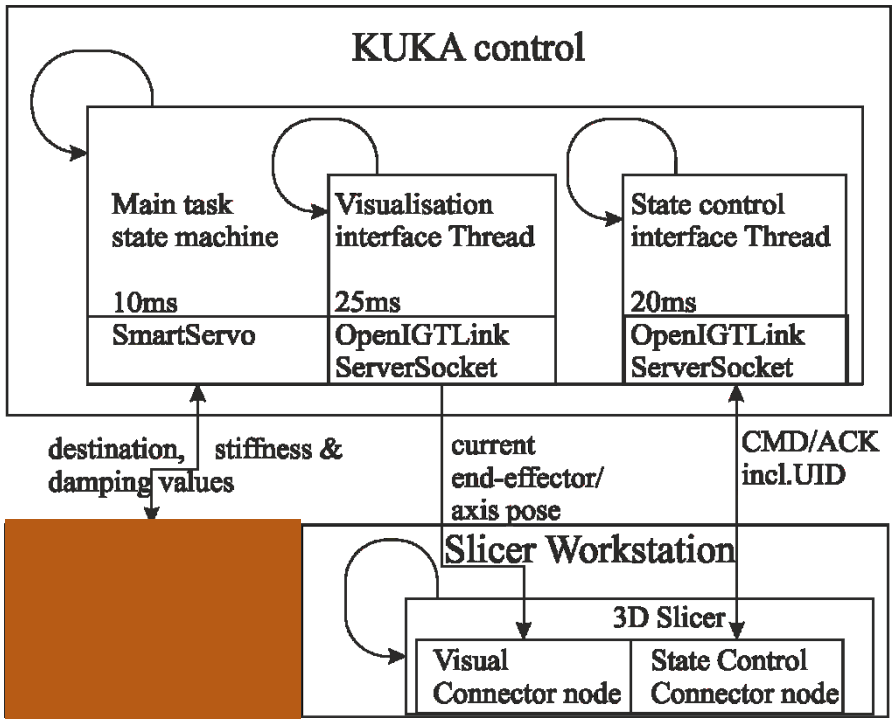
Separate visualisation & state control interface

OpenIGTLink based

- Small foot print & widely used
- Open protocol for IGT

State machine for intuitive and direct control

System Overview



Slicer workstation

- 3D Slicer module *LightWeightRobotIGT* as state control

KUKA control

- Java robot application
  - Visualisation & state control interface thread
  - State machine thread

KUKA Light weight robot (LWR)

System Requirements

Requirements

- Robotic system
  - KUKA sunrise control & LWR iiwa
  - KUKA Sunrise.Connectivity Smart Servo Motion Extension
  - Notebook/Desktop PC with Sunrise.Workbench 1.0 or higher
  - LWROpenIGTIF package including exemplary state machine

- Slicer Workstation
  - 3D Slicer 4.4 64 Bit
  - See http://www.slicer.org
  - Point-to-point ethernet connection to Sunrise control (use the same notebook/desktop PC for the Sunrise Workbench and 3D Slicer)

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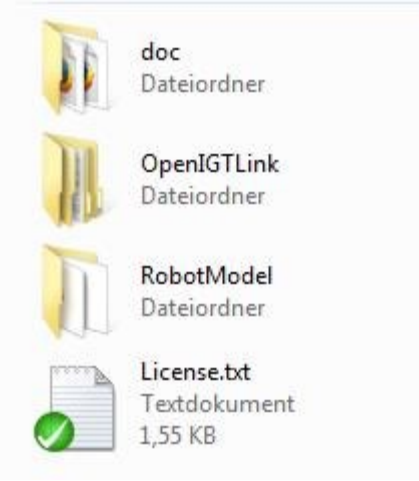
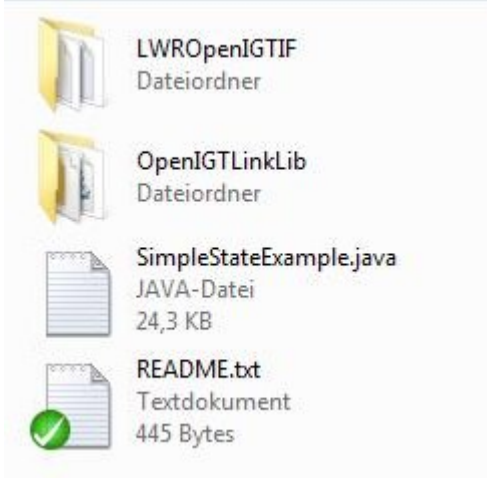
Installing LWROpenIGTIF

- Download *LWROpenIGTIF* at GitHub including STL-files of the LWR (*RobotModel*)
  - https://github.com/tauscherSw/LWROpenIGTIF.git
- Add the *LWROpenIGTIF* and the *OpenIGTLink* folder to your sunrise project source folder
  - Example: C:\Devel\KUKA*YourSunriseProject*\src
- Add the *OpenIGTLinkLib* folder to the project folder
  - Example: C:\Devel\KUKA*YourSunriseProject*
- Add the *SimpleStateExample.java* file to the application source folder
  - Example: C:\Devel\KUKA*YourSunriseProject*\src\application
- Install your sunrise project
- Synchronize the sunrise workbench with the sunrise control





Installing LWROpenIGTIF

- Set path to the SWIGigtutil.dll directory in the LWRVisualizationIF class (line 60)
  - System.load(„PATH/SWIGigtlutil.dll");
  - Path is: C:\KRC\ApplicationServer\Git*YourSunriseProjectName*\OpenIGTLinkLib
- Copy the STL-folder somewhere on your Slicer Workstation
  - Example: C:\Program Files\Slicer 4.4.0-2014-11-24\RobotModel\
- Software documentation of the LWROpenIGTIF classes can be found here:
  - https://github.com/tauscherSw/LWROpenIGTIF.git

Customizing LWROpenIGTIF

Before running the example you should

- Change the current tool data in the SimpleStateExample.java according to the load and geometry of your tool
- Check if the default start position q = { *0.0, 30.0, 0.0, -60.0, 0.0, 90.0, 0.0*} is safe. **WARNING: There is no safety check!**
- Have experience with the robot and the robot control

```
    final double translationOfTool[] ={ -40, 10, 207 };
    //{ 54.5, 0.1, 211.6 };

//and the mass in kg
    final double mass = 0.6;

    //First rough guess of the Center of Mass
    final double centerOfMassInMillimeter[] =
    { -5, 0, 50 };

    ImesTool = ServoMotionUtilities.createTool(imesLBR,
               "ImesTool", translationOfTool, mass,
               centerOfMassInMillimeter);
    ImesTool.attachTo(imesLBR.getFlange());
```

Before starting the example you can

- Adjust the cycle times of the different threads according to your needs

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Installing LightWeightRobotIGT

- Download 3D Slicer 4.4 64-Bit Version
- Install 3D Slicer
- Install LightWeightRobotIGT Extension using the Extension Manager
  - http://www.slicer.org/slicerWiki/index.php/Documentation/4.3/SlicerApplication/ExtensionsManager

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- **Run Example**

Start Connection

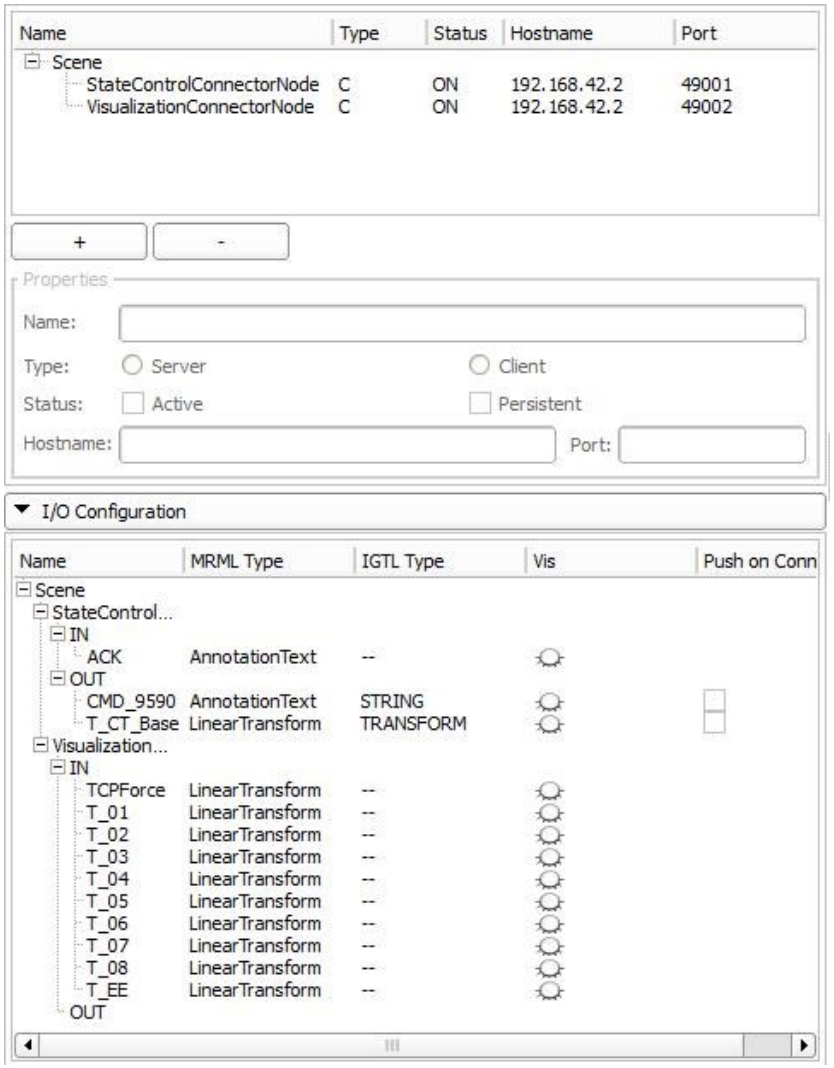
Open 3D Slicer on the Slicer Workstation

Open LightWeightRobotIGT module

- Modules->IGT->LightWeightRobotIGT
- Set path to the folder containing the STL-files
- Check if the IP-address and ports of the robot control is set correctly; default is 192.168.42.2 (Modules->IGT->OpenIGTIF)

Start *YourProject* on the robot control

- Check if two interfaces and the state machine were successfully started on the SmartPad (Control Panel of the robot control)



Start Visualization of Robot and Force Vector

Click Start cyclic communication (yellow)

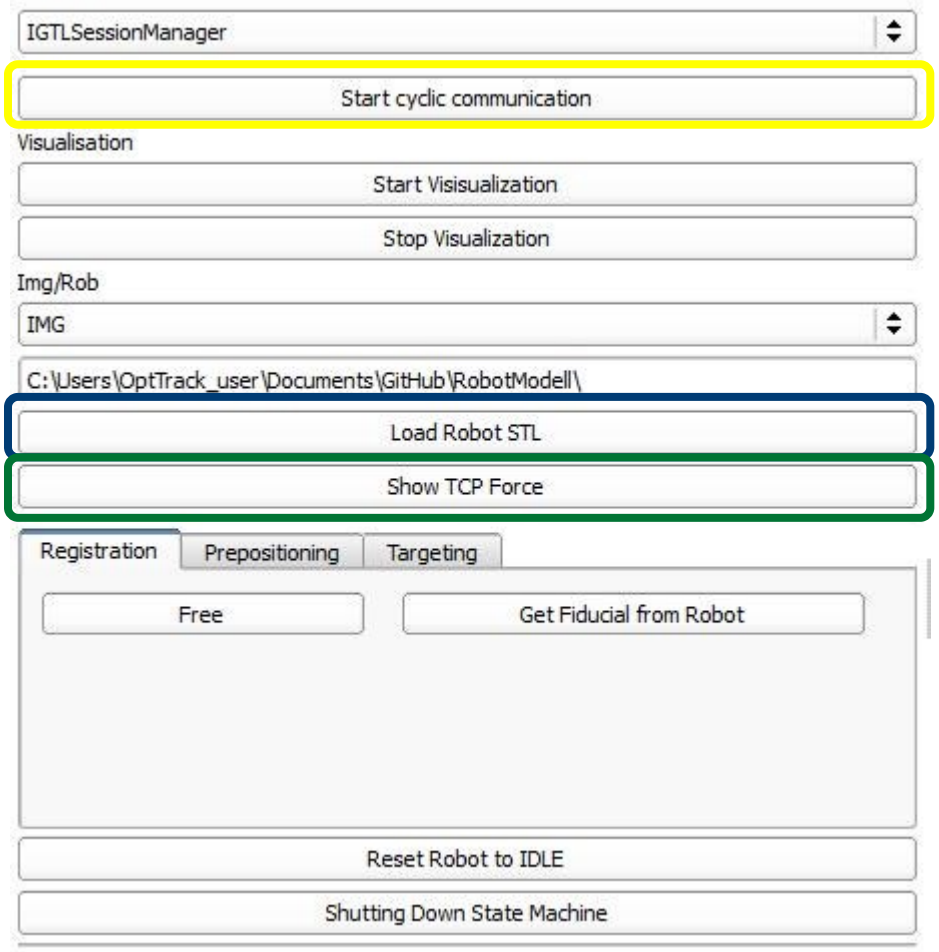
- Cyclic communication with the state control is now active

Click *Load Robot STL* (blue)

- Now the robot should be visualized in the 3D view
- Robot colour changes due to the current state (colour coding see state machine description in Tutorial: LightWeightRobotIGT-Introduction)

Click Show TCP Force (green)

- A 3D arrow is now shown at the tool center point



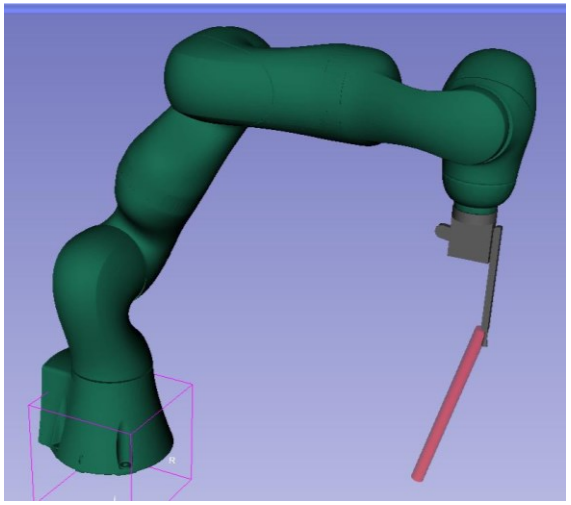
Switching between states

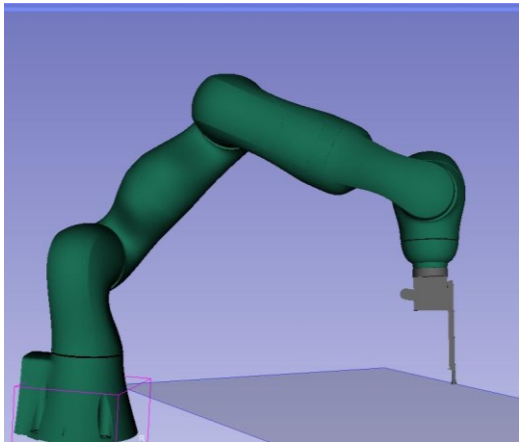
Click on different states as you like

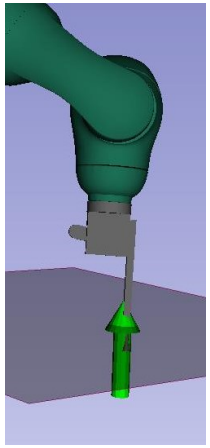
- **WARNING:** Check if the default **position** of the virtual fixtures is **safe** and that the robot is not in the **locked zone** of the virtual fixtures

Now you can :

- Change to Free, Idle, Path and VirtualFixtures
- Visualise active Virtual Fixtures in Slicer (see figures)
- **NOT** set the robot to MoveTo state; Therefor, you need to register/send the T_CT_Base transform to the state control (see next page)

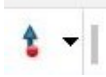


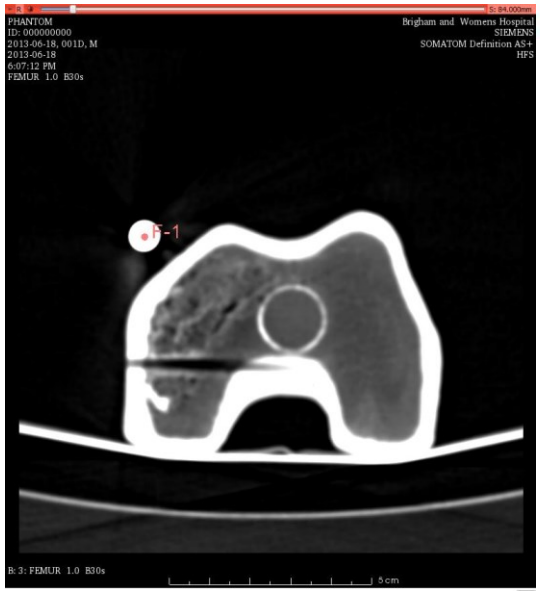


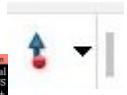


Registration – Workflow I

Example of Point based Registration

- Load Dicom data/STL file of your target object
- Define fiducials in a fiducial list using *Create-Fiducial* 
- Set robot to *Free* mode (click *Free* in registration tab)
- Move robot to fiducial of physical object
- Click *Get Fiducial from robot* (in registration tab)
- Repeat this step for all fiducials





Info: For Registration you need a target object and CT-Data of this objects! Furthermore landmarks are needed to obtain the transformation by a point based registration

Registration – Workflow II

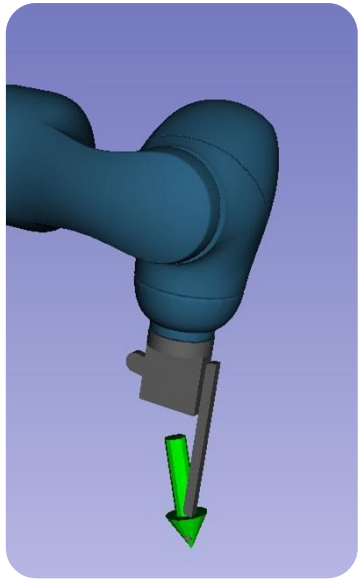
- All points are saved in the *Fid_list* annotation node
- Use *Fiducial Registration* module (see figure)
  - Fixed landmarks: *F*
  - Moving landmarks: *Fid_List*
  - Save transform=> *T_CT_Base*
- The Matrix *T_CT_Base* is automatically send to the robot control when its value is changed
- Check if the registration was successful
  - Robot is now visualized in relation to target
  - MoveTo enabled (carefully use this state!!)

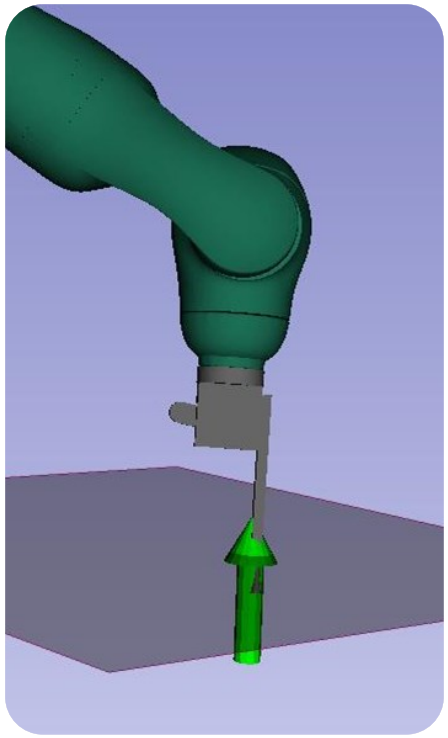
Info: For Registration you need a target object and CT-Data of this objects! Furthermore landmarks are needed to obtain the transformation by a point based registration

Visualisation concept - Force

Force representation with similar transform

- Force COF
  - z-axis in force direction
  - at tool centre point
- Transformation from robot base to force coordinate frame
- Scale: force magnitude



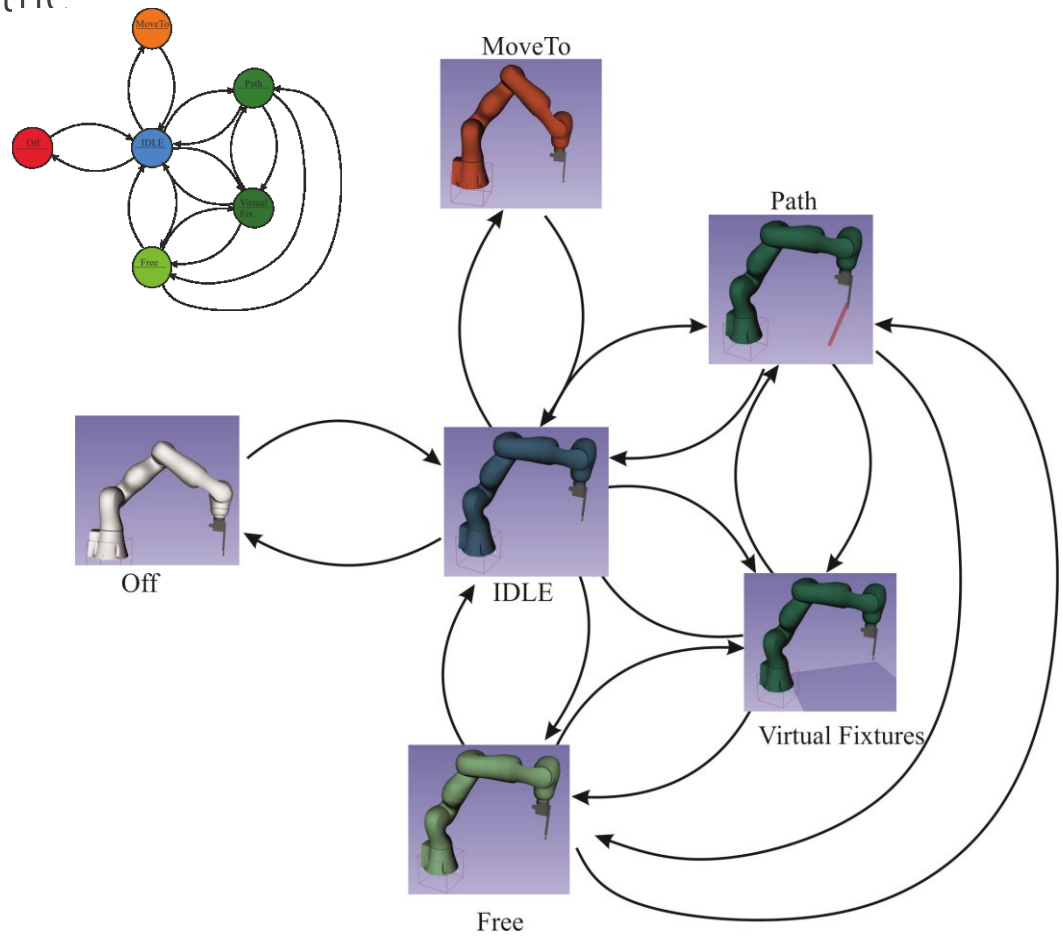


Visualisation concept - State

Change of robot colour according to the acknowledge string

- Registration (**Free**)
- Pre-Positioning (**Path**, **VirtualFixtures**)
- Targeting (**MoveTo**)
- Save (**IDLE**)

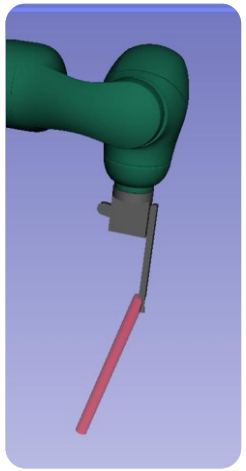
⇒ Intuitive and direct feedback on current state and success of transition request

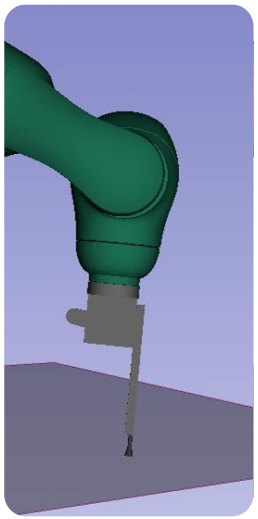


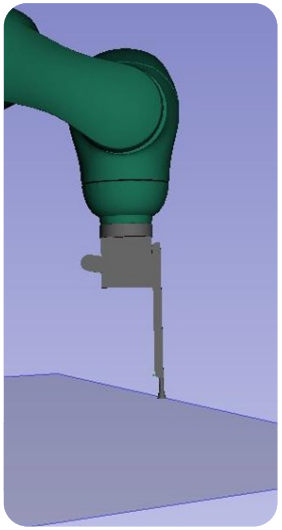
Visualisation concept - State

Visualisation of active Virtual Fixtures

- Geometries: plane, cone or path
- Change of colour due to active current zone
  - Free
  - Aware
  - Locked







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