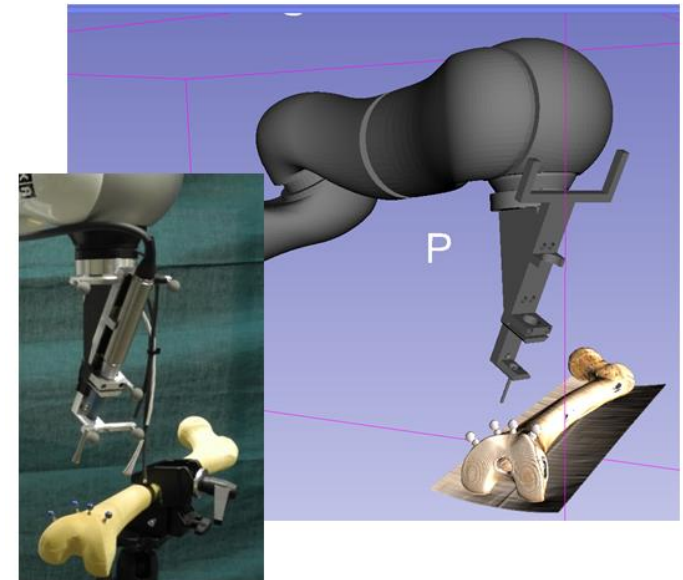
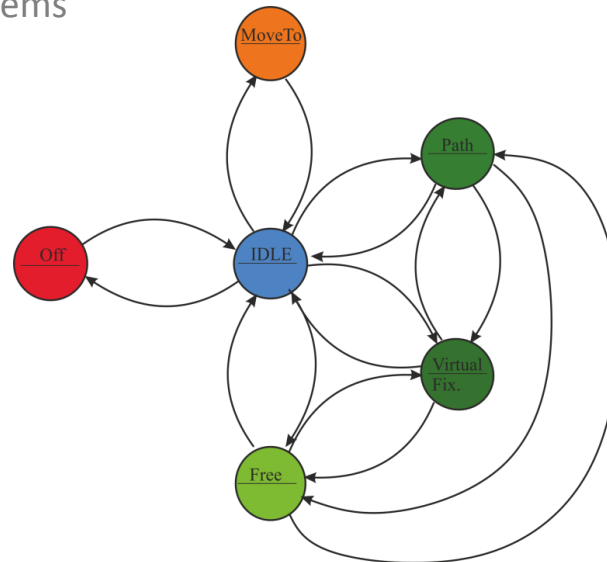


Tutorial

LightWeightRobotIGT – Getting Started

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Outline

System Overview

Requirements

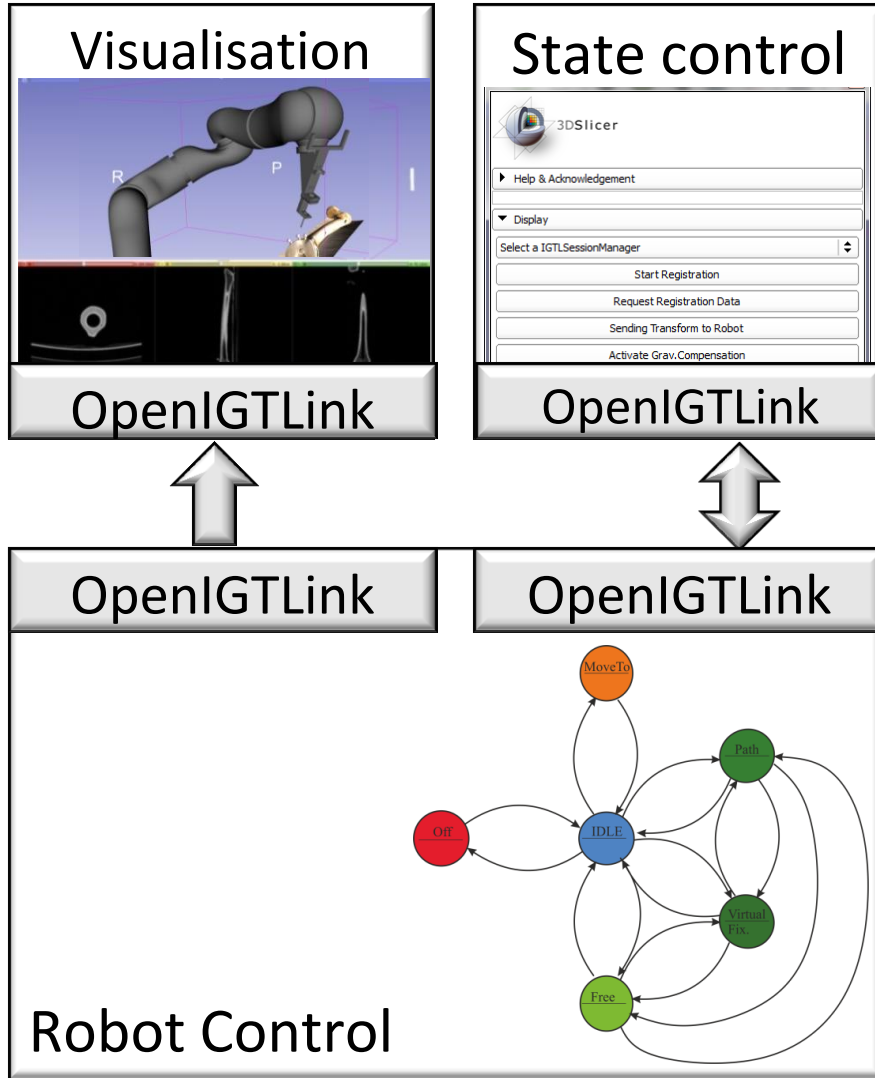
Set up KUKA Sunrise control

Install Example

Install LightWeightRobotIGT

Run Example

System Overview - Interface Concept



Robot as element of IGT system

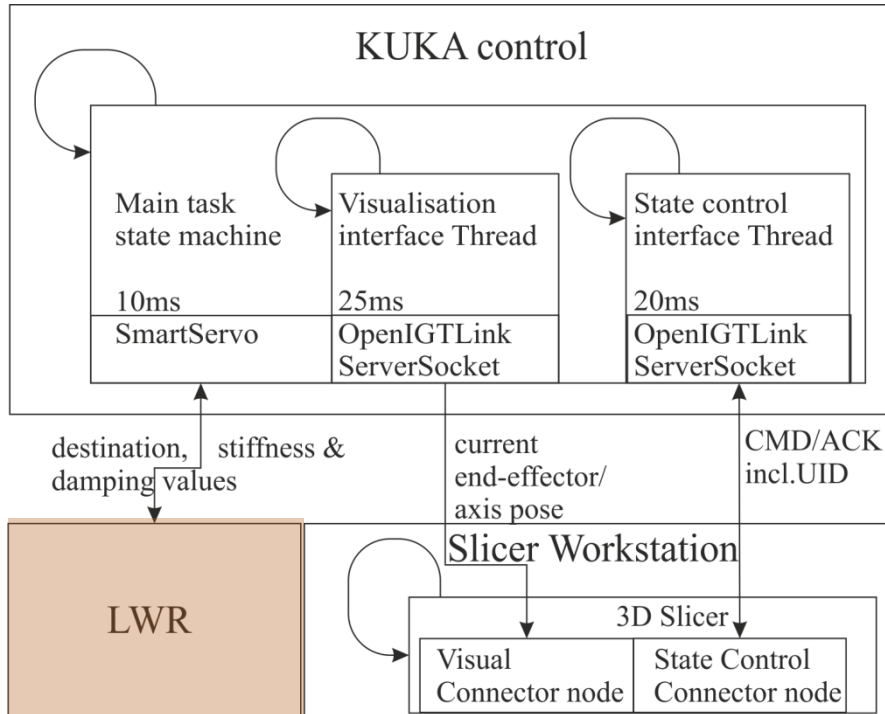
Separate visualisation & state control interface

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
 - Notebook/Desktop PC with Sunrise.Workbench 1.0
 - LWROpenIGTIF package including exemplary state machine
- Slicer Workstation
 - 3D Slicer 4.3.1 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)

Outline

System Overview

Requirements

Set up KUKA Sunrise control

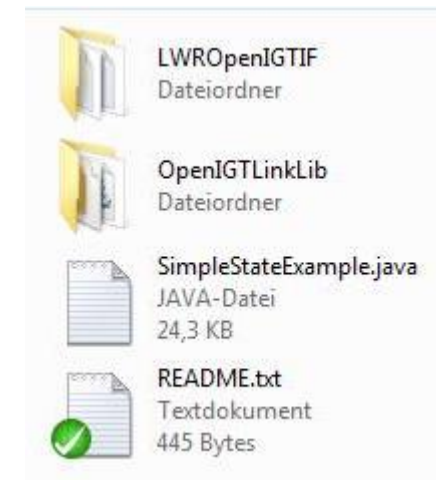
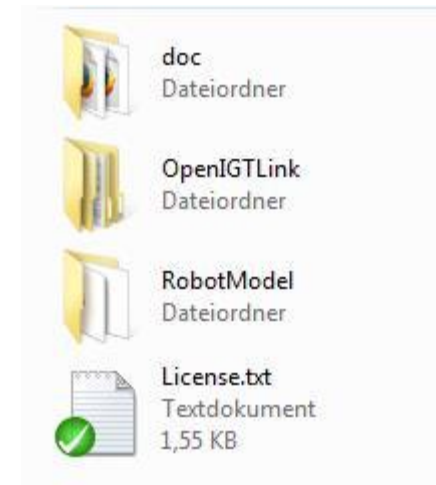
Install Example

Install LightWeightRobotIGT

Run Example

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
- Synchronize the sunrise workbench with the sunrise control



Installing LWROpenIGTIF

- Get connected to the KUKA sunrise control via remote desktop
 - If you need help on this, ask your KUKA support
- Set environment variables and path to the SWIGigtutil.dll directory
 - Path is:
C:\KRC\ApplicationServer\Git*YourSunriseProjectName*\OpenIGTLinkLib
- Close remote desktop connection
- Copy the STL-folder somewhere on your Slicer Workstation
- 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

Outline

System Overview

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Set up KUKA Sunrise control

Install Example

Install LightWeightRobotIGT

Run Example

Installing LightWeightRobotIGT

- Download 3D Slicer 64-Bit Version 4.3.1
- Install 3D Slicer
- Install LightWeightRobotIGT Extension using the Extension Manager
 - <http://www.slicer.org/slicerWiki/index.php/Documentation/4.3/SlicerApplication/ExtensionsManager>

Outline

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Start Connection

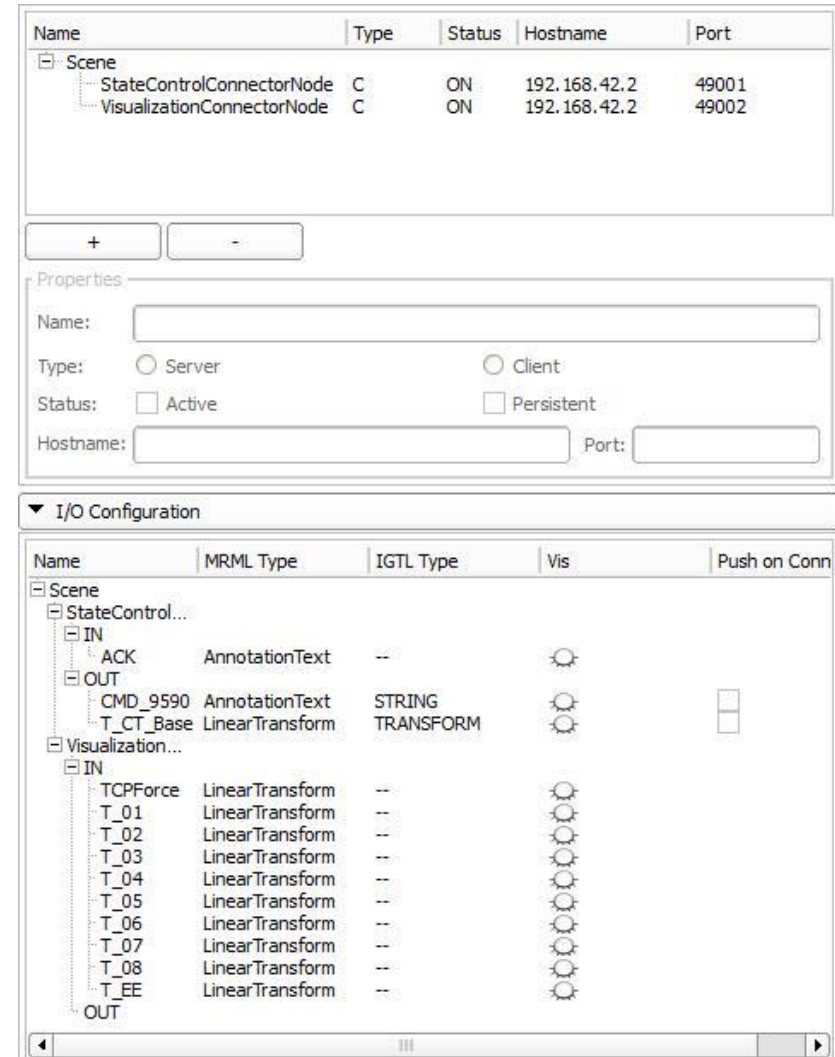
Open 3D Slicer on the Slicer Workstation

Open LightWeightRobotIGT module

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

Start *YourProject* on the robot control

- Check if the connection was successful
 - on the SmartPad (Control Panel of the robot control)
 - or in the OpenIGTIF 3D Slicer module (Modules->IGT->OpenIGTIF) status of the to connector nodes should be *On* (see figure)



The screenshot displays the LightWeightRobotIGT interface. At the top, a table shows the connection status for two nodes:

Name	Type	Status	Hostname	Port
Scene				
StateControlConnectorNode	C	ON	192.168.42.2	49001
VisualizationConnectorNode	C	ON	192.168.42.2	49002

Below the table are controls for adding (+) and removing (-) nodes. The Properties section includes fields for Name, Type (Server/Client), Status (Active/Persistent), Hostname, and Port. The I/O Configuration section shows a detailed view of the connection nodes:

Name	MRML Type	IGTL Type	Vis	Push on Conn
Scene				
StateControl...				
IN				
ACK	AnnotationText	--	<input type="checkbox"/>	
OUT				
CMD_9590	AnnotationText	STRING	<input type="checkbox"/>	<input type="checkbox"/>
T_CT_Base	LinearTransform	TRANSFORM	<input type="checkbox"/>	<input type="checkbox"/>
Visualization...				
IN				
TCPForce	LinearTransform	--	<input type="checkbox"/>	
T_01	LinearTransform	--	<input type="checkbox"/>	
T_02	LinearTransform	--	<input type="checkbox"/>	
T_03	LinearTransform	--	<input type="checkbox"/>	
T_04	LinearTransform	--	<input type="checkbox"/>	
T_05	LinearTransform	--	<input type="checkbox"/>	
T_06	LinearTransform	--	<input type="checkbox"/>	
T_07	LinearTransform	--	<input type="checkbox"/>	
T_08	LinearTransform	--	<input type="checkbox"/>	
T_EE	LinearTransform	--	<input type="checkbox"/>	
OUT				

Start Visualization of Robot and Force Vector

Click *Load Robot STL* (green)

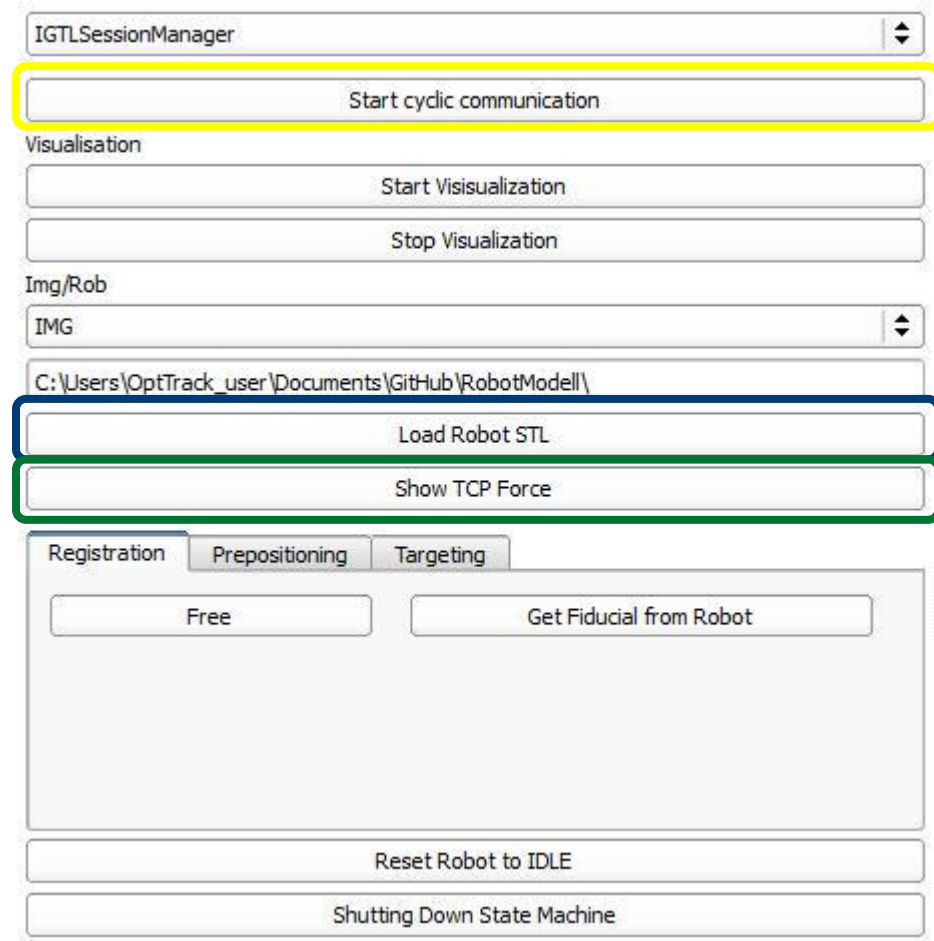
- Now the robot should be visualized in the 3D view

Click *Start cyclic communication* (yellow)

- Cyclic communication with the state control is now active
- Robot colour changes due to the current state (colour coding see state machine description in Tutorial: LightWeightRobotIGT-Introduction)

Click *Show TCP Force* (blue)

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



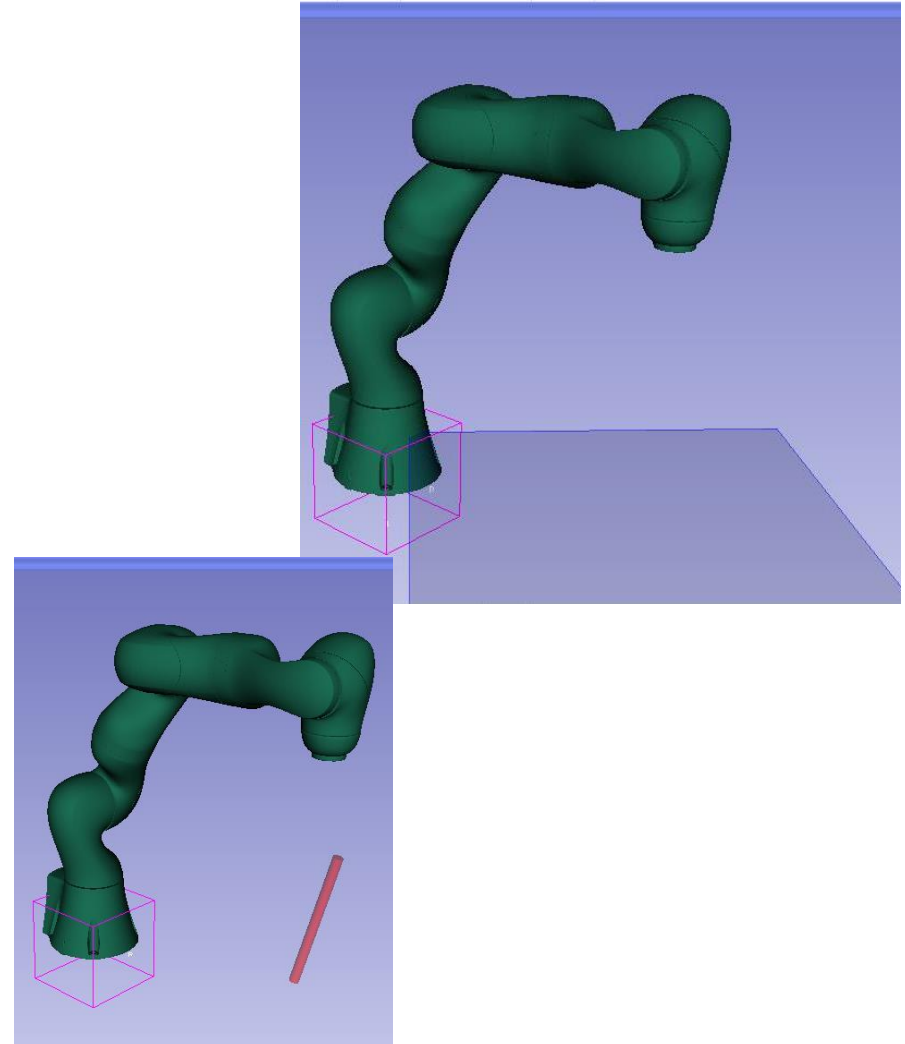
Switching between states

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

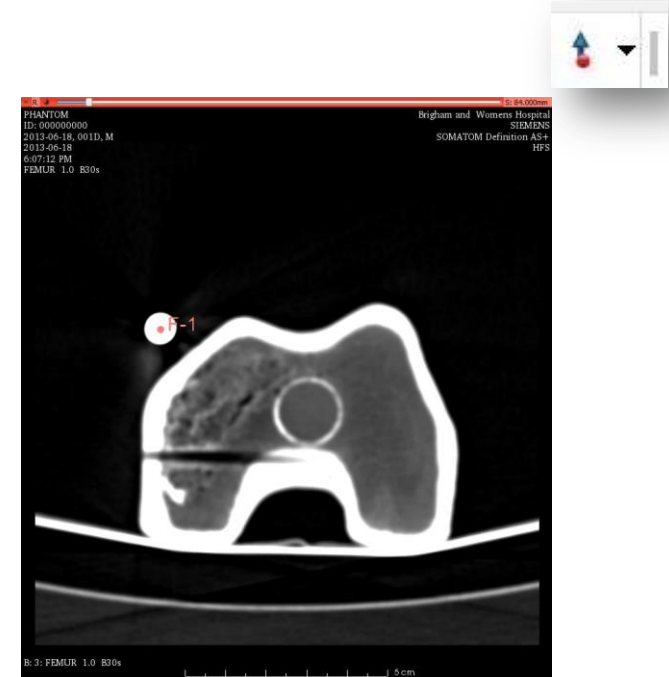
Now you can :

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



LightWeightRobotIGT – Run the Example Registration – Workflow I

- Load Dicom data/STL file of the target object
 - See example: Femur phantom with sphere fiducials
- 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



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
 - Move To enabled (carefully use this state!!)



Fixed landmarks

Moving landmarks

Save transform

Transform Type Translation Rigid Similarity

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