Robone: Next Generation Orthopedic Surgical Device

(Check Point Presentation)

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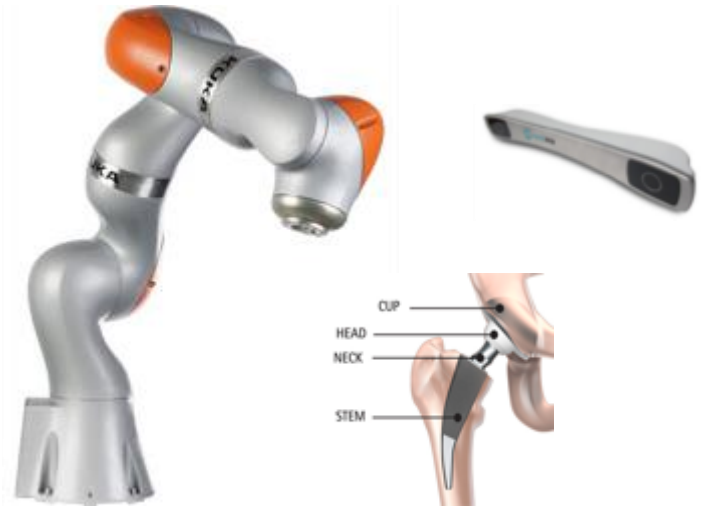
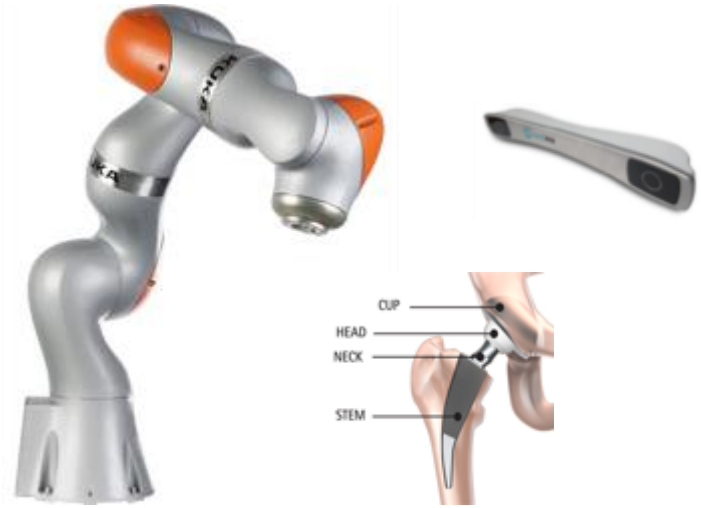


Overview

- Project summary
- Software Design and Tool Selection Update
- Completed Progress
- Future Steps
- Dependencies
- Deliverables
- Key Dates

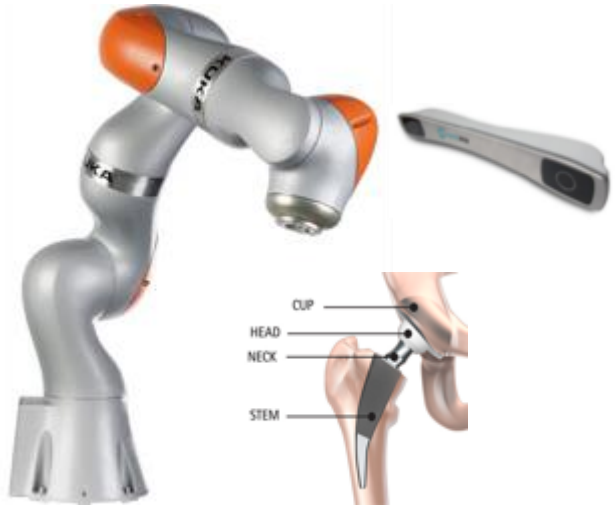


Project Summary

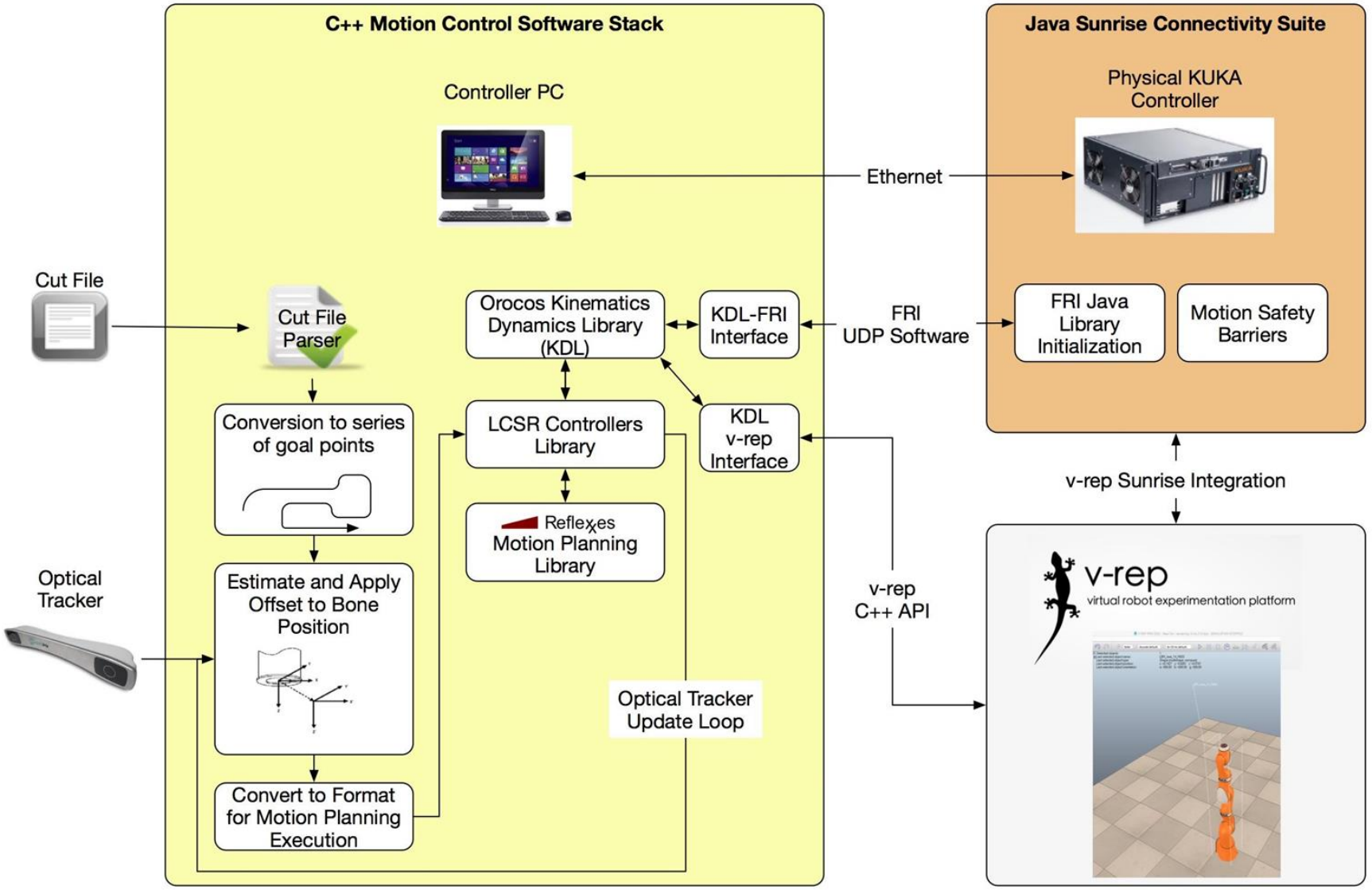
The existing orthopedic surgical device isn't perfect and requires the patient to be fixed to the operating table, an invasive and time consuming process.

A next generation system will make real time position adjustments using a device such as an optical tracker so fixation is no longer necessary.

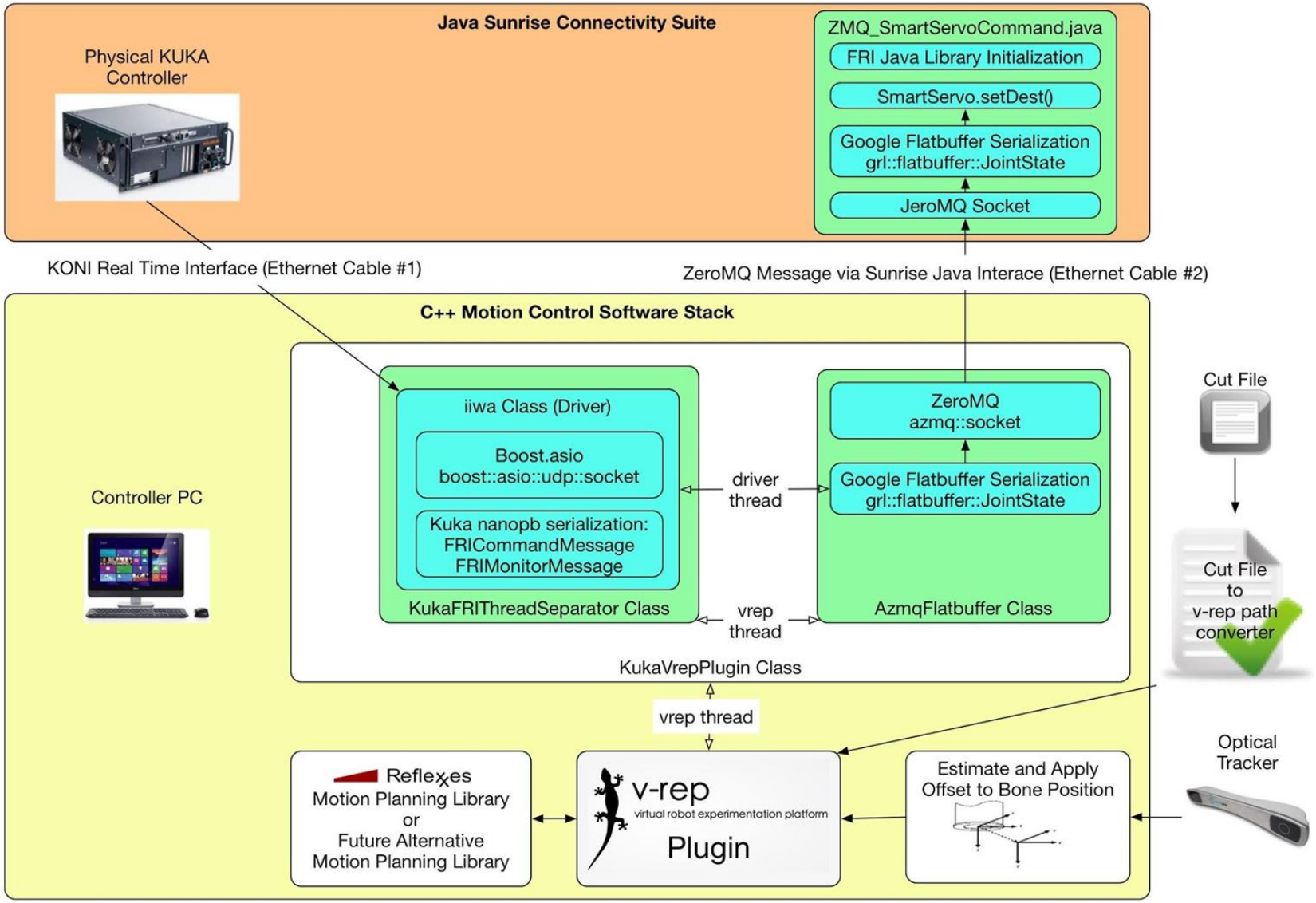
The goal is to enable faster and less invasive surgery with this type of computer assisted tool.



Original Software Design



Current Software Design



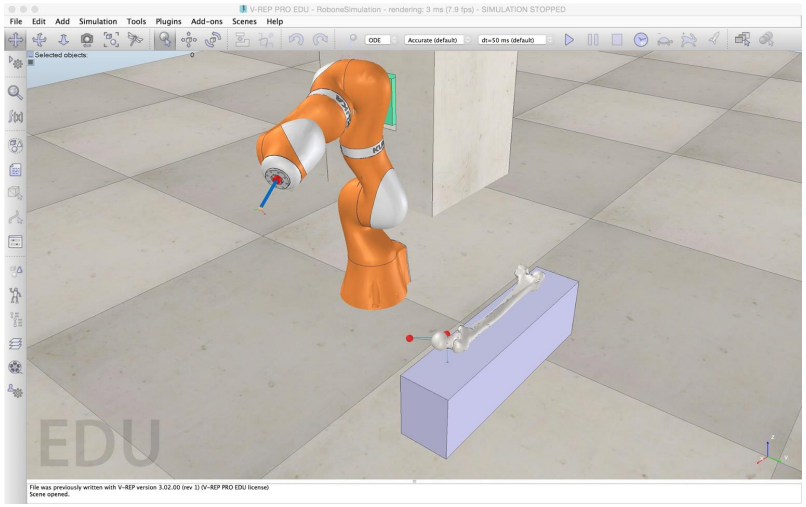
Software Tool Selection

Package	CISST	ROS	ZeroMQ Middleware	Google Flatbuffers	V-REP Simulator	Gazebo Simulator
Java and C++ (Req)	✗	✓	✓	✓	-	-
High Performance	✓	✗ Design Issues	✓	✓	Decent for simulation	✗
Global Adoption in SW Dev Market	✗	✗	✓	✓	✗	✗
Global Adoption in Robotics Market	✗ mostly @ JHU	✓	ZMQ tools in dev by OSRF (ROS)	✗	✓	✓
Cross Platform	✓	✗ Ubuntu Specific	✓	✓	✓	✓
Well Documented	✗	✗	✓	✓	✓	✗
Easy to Use	✓	✓	✓	✓	✓	✗
Reliable	✓	✗	✓	✓	✓	✗
KUKA iiwa integration	✗	✗	-	-	✓	✗
Can add new planning algs	✓	✓	-	-	✓	✓
Final Selection	Possible future integration	✗ ✗ ✗	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	✗ ✗ ✗

Initial Simulation - Complete

Created a milling simulation in V-REP with a real bone model

- Simulates arm with integrated motion planning
- Simulates cutting bone surface (no interior)
- No optical tracker
- Uses Reflexxess type IV planning library



v-rep
virtual robot experimentation platform

Reflexxes

Kuka Arm Integration - Complete

- C++ Driver
  - Reads arm state from Fast Robot Interface (FRI)
  - Sends commands to Java Connectivity Suite on arm's controller.

- Java Sunrise Connectivity Suite
  - Initializes the arm
  - Implements asynchronous joint motion commands

- Moves along a specified path in cartesian space

Kuka's FRI interface for sending commands isn't usable, so this design works around those flaws.

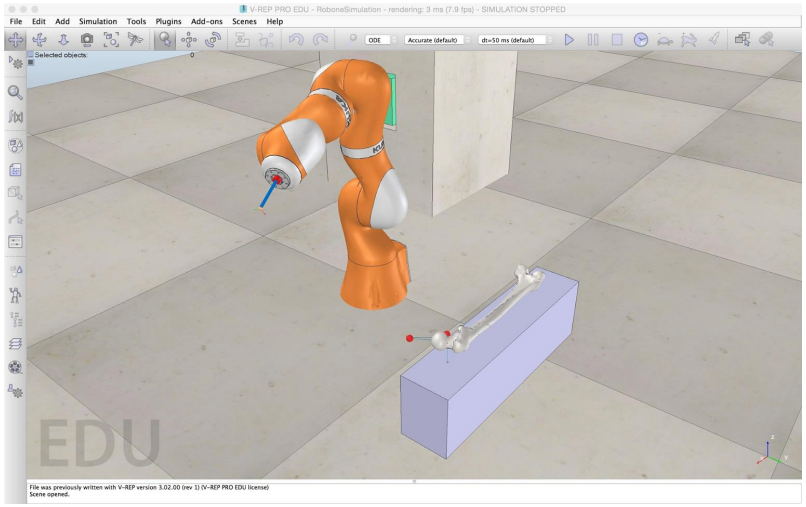
GRL Library

Published, Documented, and Available

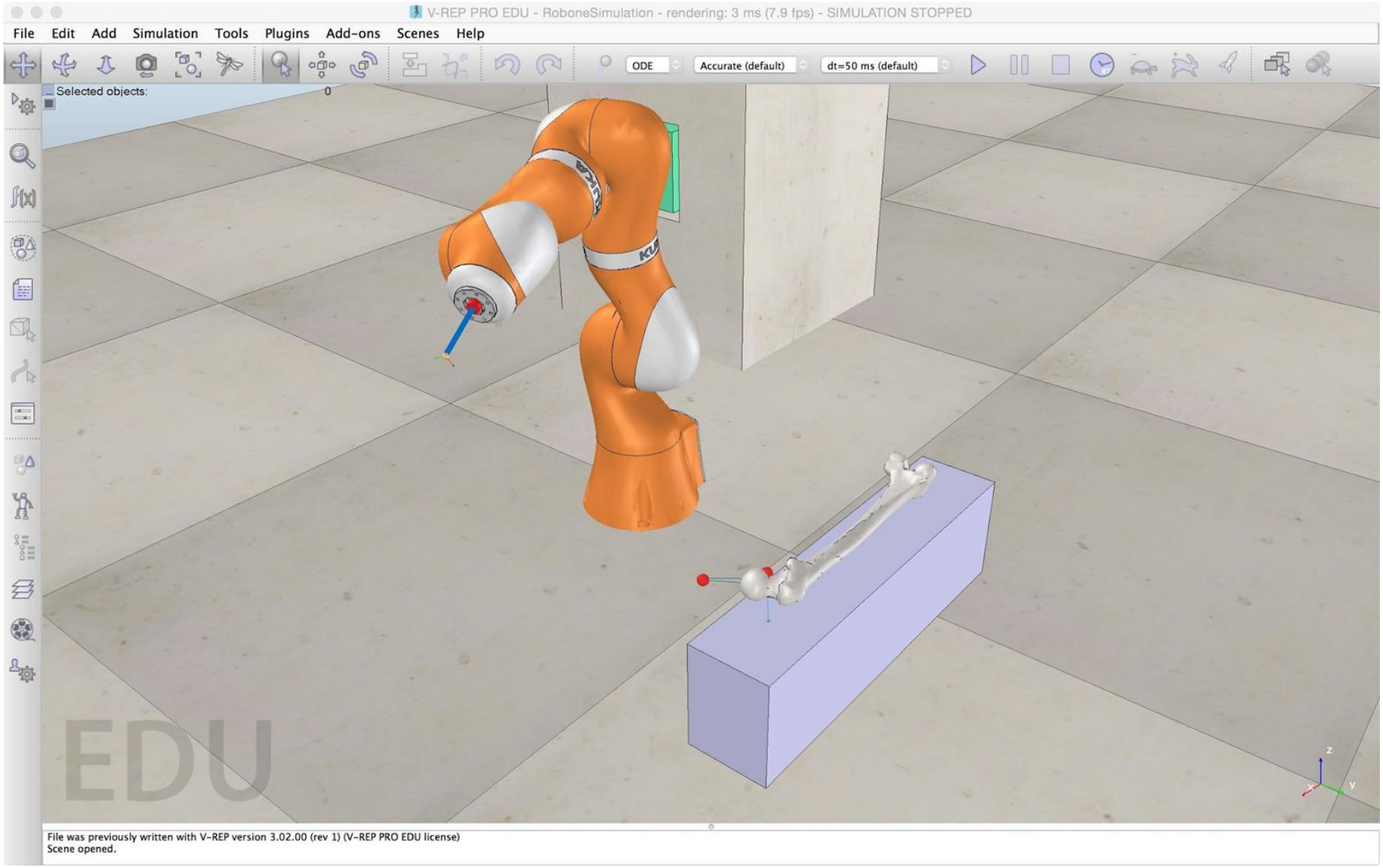
- Kuka LBR iiwa drivers
- V-REP integration

git
https://github.com/ahundt/grl

docs
https://ahundt.github.io/grl/



Live Demo!


V-REP PRO EDU - RoboneSimulation - rendering: 3 ms (7.9 fps) - SIMULATION STOPPED
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ODE
Accurate (default)
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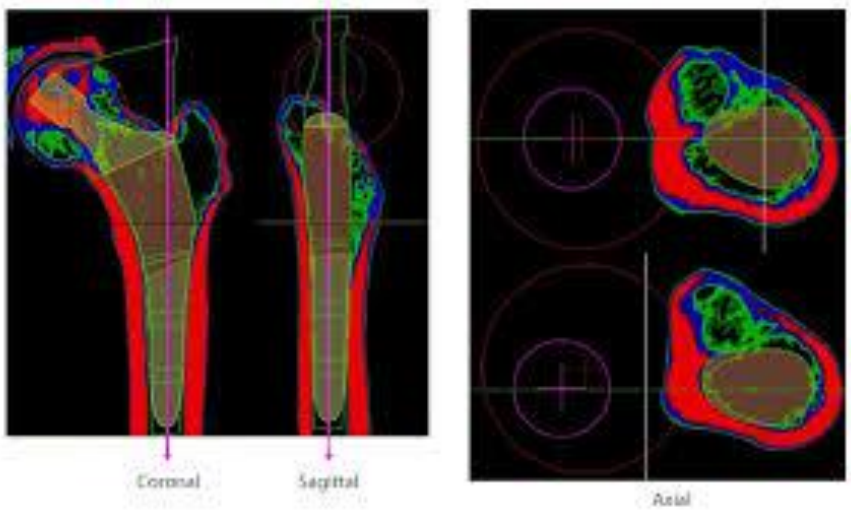
EDU
File was previously written with V-REP version 3.02.00 (rev 1) (V-REP PRO EDU license)
Scene opened.

Future Steps

Cut file integration

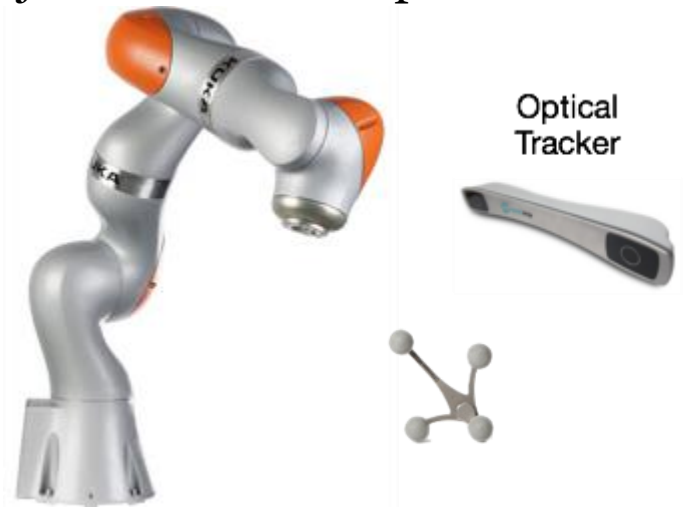
- Acquire ascii cut files
- Implement ascii parsing and conversion to format amenable to sending to planner or arm as commands
- Test parsing and motion commands in simulation
- Test parsing and motion commands on physical robot



Future Steps

Optical Tracker Integration

- Acquire optical tracker
- Add simulation with optical tracker
- Estimate an acceptable response time of optical tracker during surgery
- Setup of optical tracker with kuka
- Implement reading of optical tracker data into software, using existing saw components
- Integrate optical tracking data into cut file and arm commanding loops
- Reaction time testing
  - draw a straight line on an object, move object and check response time
  - see “physical simulation of cutting” idea below
  - Characterize response time
  - Improve response time if necessary



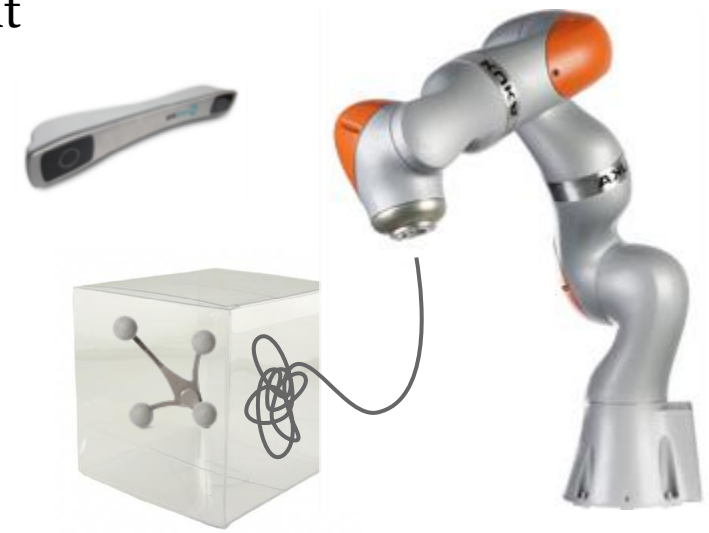
Future Steps

Milling Physical Simulation

Create a physical simulation of cutting, as opposed to a computer simulation.

The initial concept is to put an optical tracker fiducial on the end effector and have a clear box to simulate “bone”. We can then use the optical tracker to generate a simulated estimate of actual cutting. This avoids the complexity of acquiring materials to cut and dealing with the dust created by milling foam, wood or other test cutting materials.

- Design and Create fiducial mounting attachment
- Implement logging of physical simulation
- Integrate logging with VREP to visualize execution of simulation
- Implement method to evaluate planned vs actual path within error bounds of sensors
- Create evaluation analysis



Dependencies

- KUKA robot arm (Resolved)
  - Access to arm
- Software (Workarounds Implemented)
  - Some higher quality level integration of arm control software, such as real time torque control, depends on planned software updates by the manufacturer, KUKA.
- Logistics (Ok so far)
  - Access to mentors
- Optical Tracker (Resolved)
  - Atracsys optical tracking device
- Milling device (Max Goal Dropped)
  - Integration of milling device to the arm

Deliverables

✓ Complete

➔ On Track

✗ Cancelled

Minimum

✓ 1. Receive arm state in real time

➔ 2. Read in cut file specifying shape of implant

3. Drive both simulated and physical KUKA arm along

✓ i. simulated cut file path

➔ ii. real cut file path

Expected

➔ 1. Receive optical tracker position in real time and adjust cut path accordingly

➔ 2. Characterize performance

Maximum

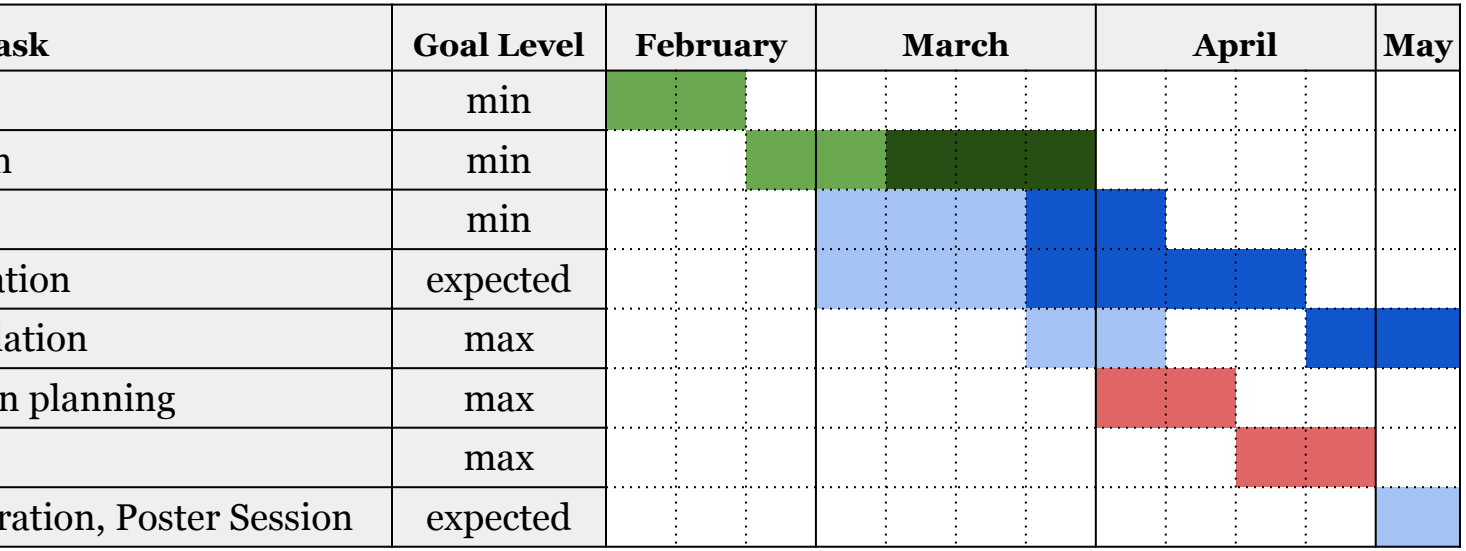
➔ 1. Milling Physical Simulation

✗ ~~2. Investigate arm motion planning~~

✗ ~~3. Milling Device Integration~~

Key Dates

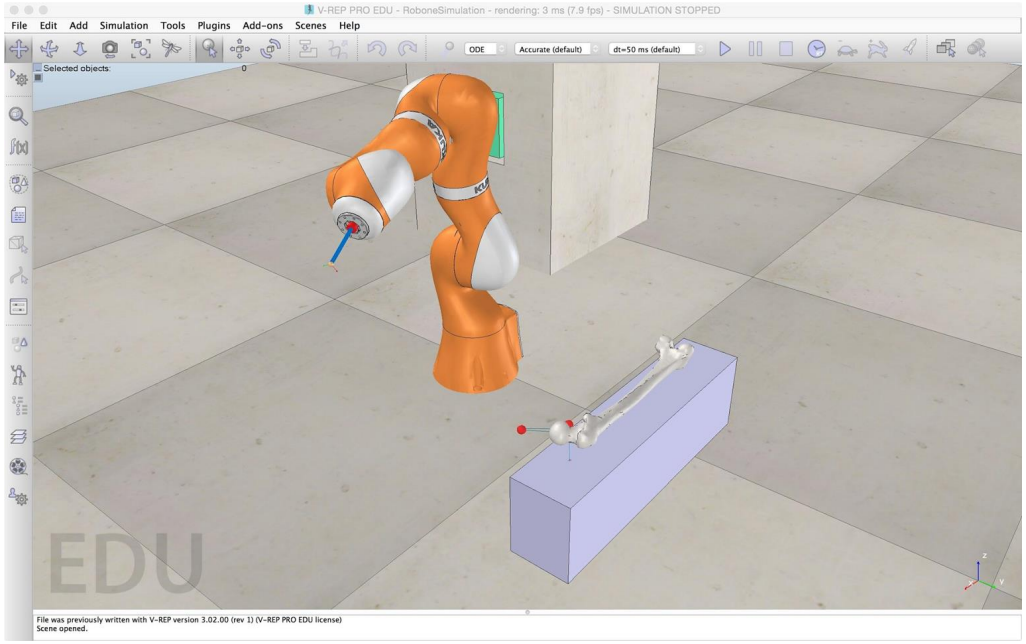
Task	Goal Level	February	March	April	May
Initial Simulation	min				
Initial Arm Integration	min				
Cut file integration	min				
Optical tracker integration	expected				
Milling Physical Simulation	max				
Investigate arm motion planning	max				
Milling integration	max				
System testing and iteration, Poster Session	expected				



- *Lighter* colors represent the *original* time frame
- *Darker* colors represent the *updated* time frame

Green - Completed | **Blue - On Track** | **Red - Cancelled**

Questions?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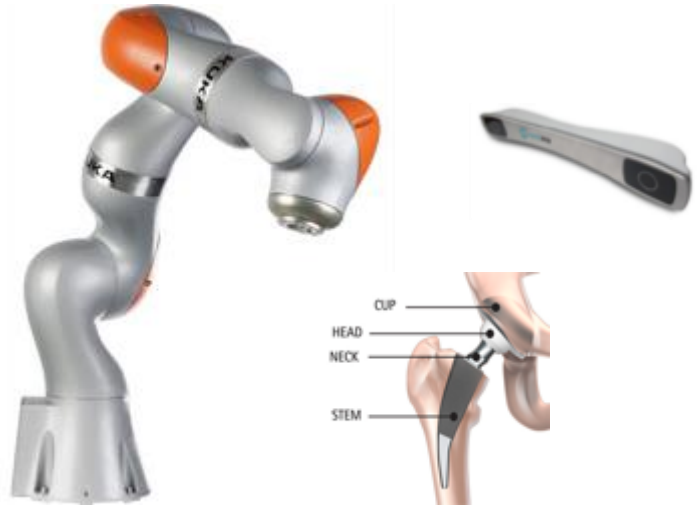
CUP
HEAD
NECK
STEM