Robone: Next Generation Robot for Orthopedic Surgery

Computer Integrated Surgery II
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Introduction

- We developed a prototype for a next generation total hip replacement surgical assistance device that performs bone milling during surgery. Working towards the goal of easily inserting a cementless hip implant, a KUKA LBR iiwa arm was used to follow a precise surgical cut path in a femur bone. An optical tracker was also integrated into the robotic system to make real time position adjustments to the cut path if the bone moved during surgery. The goal is to enable faster and less invasive surgeries than devices currently on the market.

The Problem

- Total hip replacement surgery requires cutting into the femur bone so that an artificial hip implant can be inserted. Non-robotic assisted methods can be inaccurate, resulting in misalignment of the implant or other complications.
- Robotic assisted systems were introduced to cut a more accurate implant shape into the femur bone. Existing robotic orthopedic surgical systems require that the patient be fixed to the operating table. However, this can be an invasive and time consuming process.

The Solution

- We developed a C++ motion control software stack to control the movement of the KUKA LBR iiwa robot. The V-REP simulation suite calculates the robot's next target position and our software commands the motion of the robot end effector. The motion controller can also monitor the real time information of the joint angles of the robot.
- The V-REP simulation is used to visualize and test the movement of the KUKA arm in reference to the bone. Cut file paths are read into the simulation as the preoperative planned path for the KUKA to follow. Real time positional data of the target bone is sent to simulation from the optical tracker to estimate and apply offsets to the KUKA's path in accordance to bone movement.

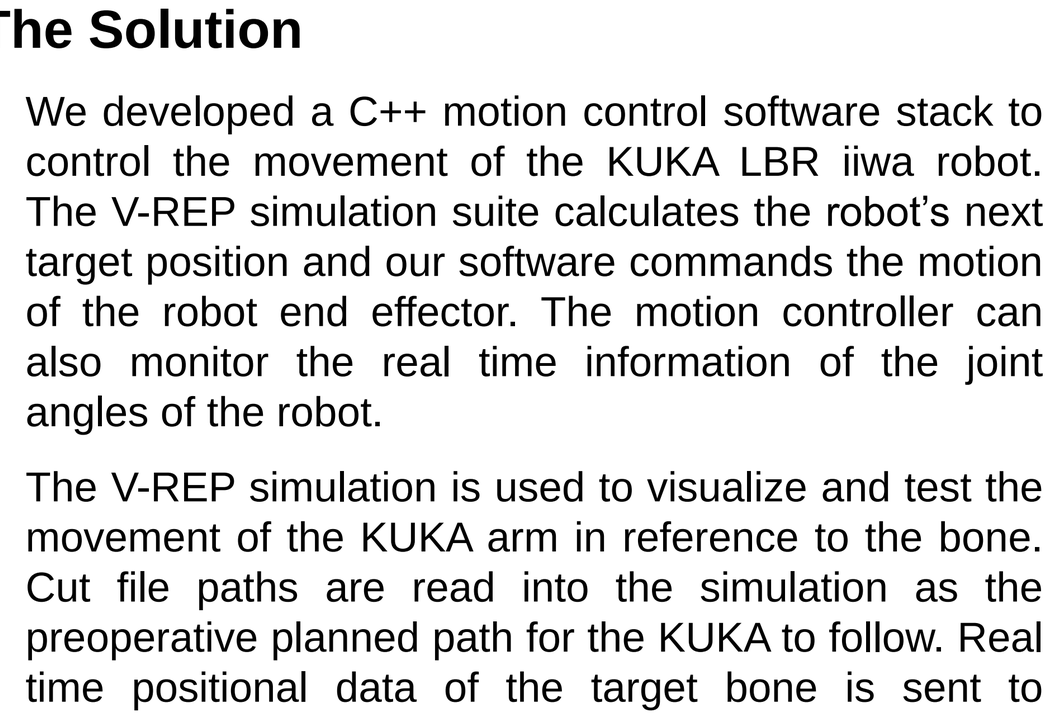

Figure 1: Simulation in VREP of the Robone System (left) and cut file overlaid over femur bone (right).

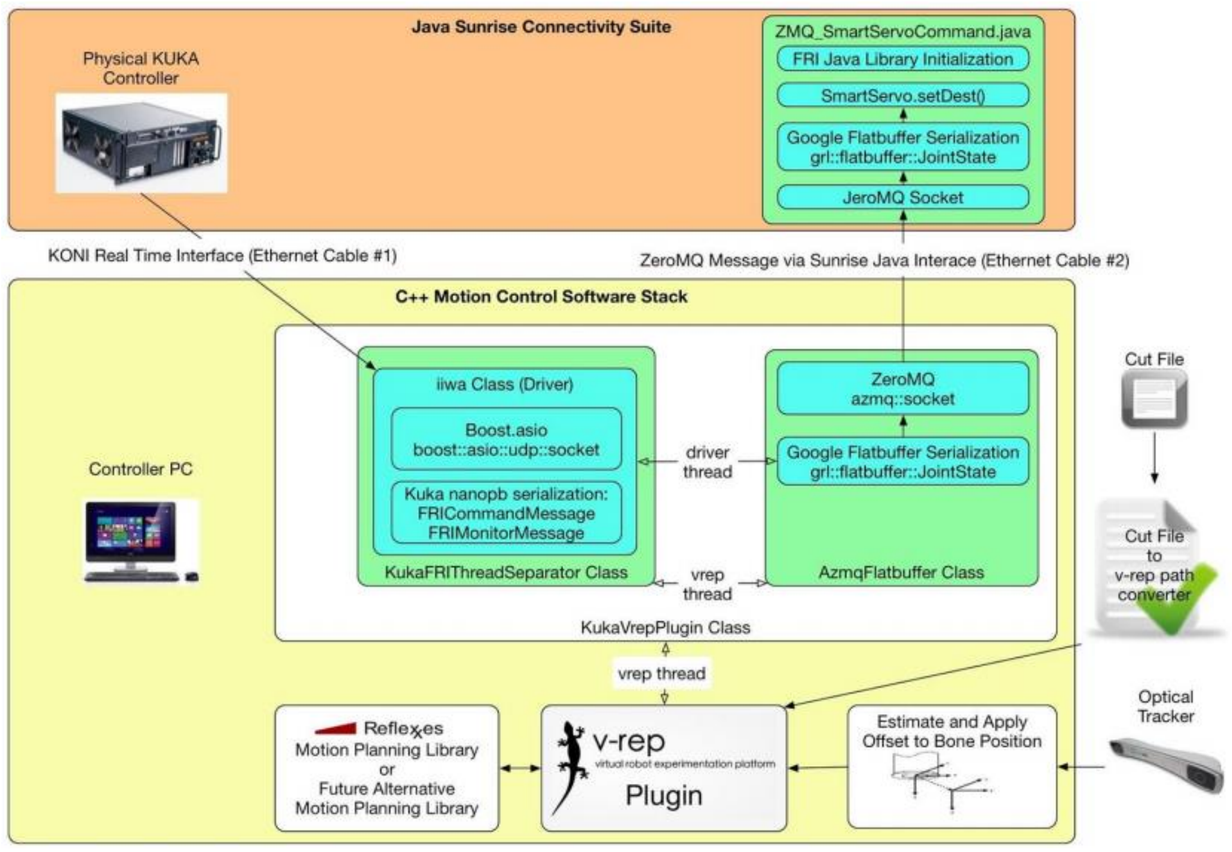

Figure 2: Software Design of Robone Interface.

Outcomes and Results

- A prototype system that follows a planned surgical cut path and can make real time adjustments to the path based on movement of the target bone.
- Integrated cut file paths into the system and used them to trace the path needed to cut the shape of an actual implant into a femur bone.
- Replicated these results both in simulation and on the physical robot.

Future Work

- Integrate a milling end effector and test the system cutting through different materials
- Improve motion planning to minimize elbow movement of the robot
- Develop a user interface and incorporate operating room safety features for the patient and surgical team

Lessons Learned

- Processes involved in integrating a variety of sensors and actuators towards the solution of a real world problem.
- Fundamentals underlying a variety of algorithms crucial to robotic systems.

Credits

- Andrew – C++ motion control software stack and plugins
- Shahriar – V-REP simulation design and hardware attachments
- Alex – CUT file integration and KUKA software development

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