EE554 Final Project October 22,2015

Introduction

We have implemented a motor velocity control with a SBC and a FPGA for a two motor system. For the final project we want to implement a position control system for a Rhino SCARA (Selective Compliance Articulated Robot) robot arm, shown in Figure 1.

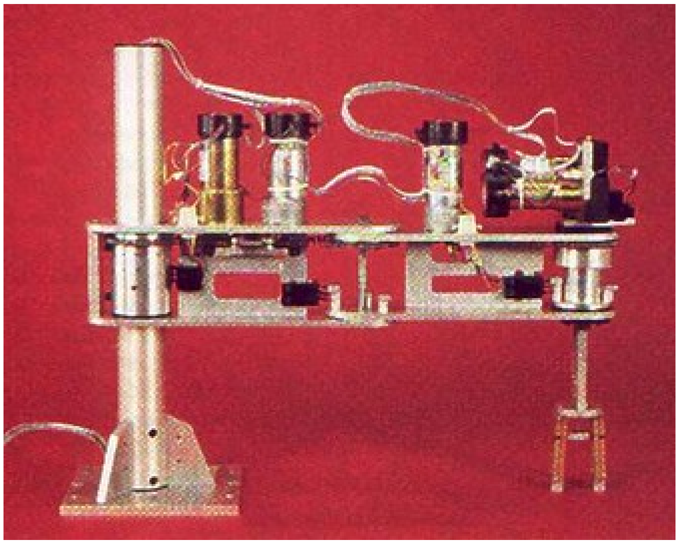

Figure 1. Four-axis Rhino SCARA robot arm.

SCARA robot consists of a two-link arm similar to human, hence the term Articulated. This type of robot is used mainly for populating printed circuit boards (PCBs), and even placement of components surface mount devices (SMD) on PCBs. The specifications of the Rhino robot are summarized in Table 1.

Table 1. Specifications of Rhino robot

Configuration	4 Axes + gripper, All axes are independent
Drives	5 PMDC servo motors with optical encoders
Repeatability	0.125 inches
Reach	18 inches
Work Envelope	18” outside radius 9” inside radius Motor “E” Shoulder rotation – 220 degs Motor “D” Elbow rotation – 220 degs Motor “B” Writ rotation – 275 degs Motor “C” Vertical travel – 3.75 inches

Project Requirements

Hardware

We now would like to use the embedded control system developed in previous two projects, which includes an SBC (the Raspberry Pi 2) and an FPGA (the DE0/DE0-Nano), to implement the controller for the robot arm, shown as a block diagram in Figure 2. One scheme suggested (and your team may have a different approach is to have the FPGA generate the PWM signals for each of the robot joints required (not all of them are needed for this project, only shoulder and elbow), and also record data from the encoders. Note that these may not be incremental encoders. Based on the number of revolutions per degree per joint, then it is possible to know how many revolutions are required to go from $(x(hk),y(hk))$ to $(x(kh+h),y(kh+h))$. The speed needed for this transit is part of the design of the controller, which would be implemented in the SBC.

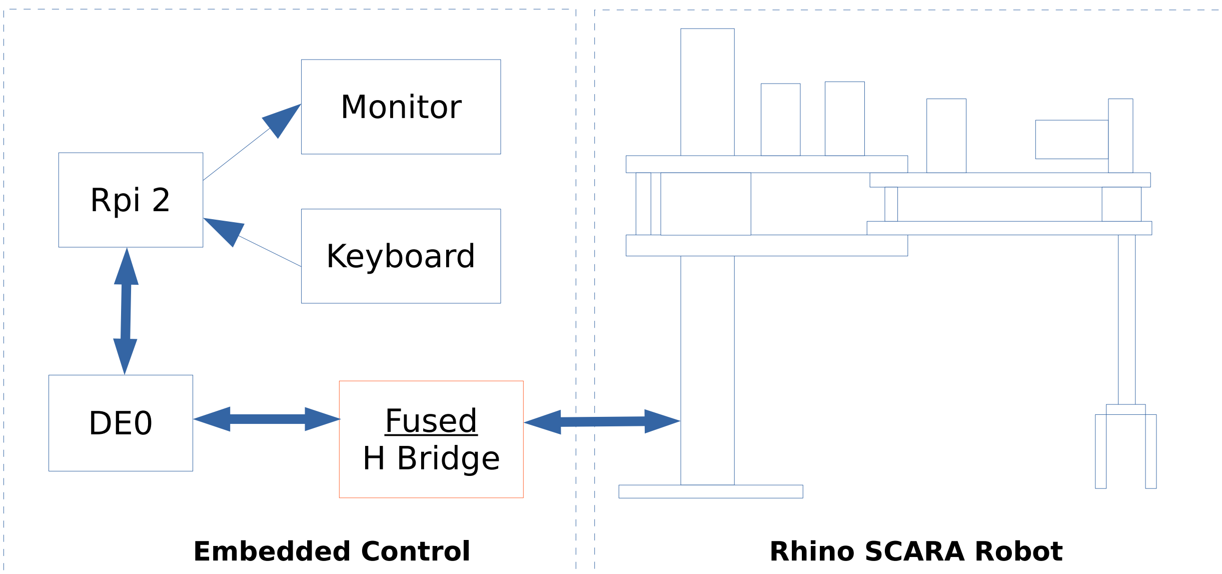

Figure 2. An embedded control system

Desired Trajectory

It is desired that the robot gripper follows a specific path, as described in Figure 3. This figure shows the workspace of the Rhino robot according to the specifications on Table 1. the red dotted lines indicate the limits of the work envelope, i.e. inside and outside radius. The circle in blue indicates the desired trajectory of the gripper. Note that only two joints are required for this task (Motors "E" and "D"), however Motor "C" may need to be activated to lift up the gripper at least a 3 inches off the floor for a free travel of the robot arm. The green lines show sample positions for the two joints for different times during the trajectory (assuming that the length of the inner and the outer links are both 9").

Control Strategy

A dead beat control strategy, using the pole-placement method, is required for this project. So part of the design is to find out what sampling period would be required for this second order system to go from $(x(hk),y(hk))$ to $(x(kh+h),y(kh+h))$ in *two sampling intervals*. We assume that we have access to measurements of all the state variables, so an observer may not be needed, unless the measurements are very noisy. However it would be interesting to implement one observer and see how close it is able to estimate a measured state variable (this is not a requirement of the project). There are no requirements for the velocity or acceleration so try to drive the robot arm at a moderate velocity/voltage. However, it is required that you use a fuse on the power side of the circuitry, for safety reasons.

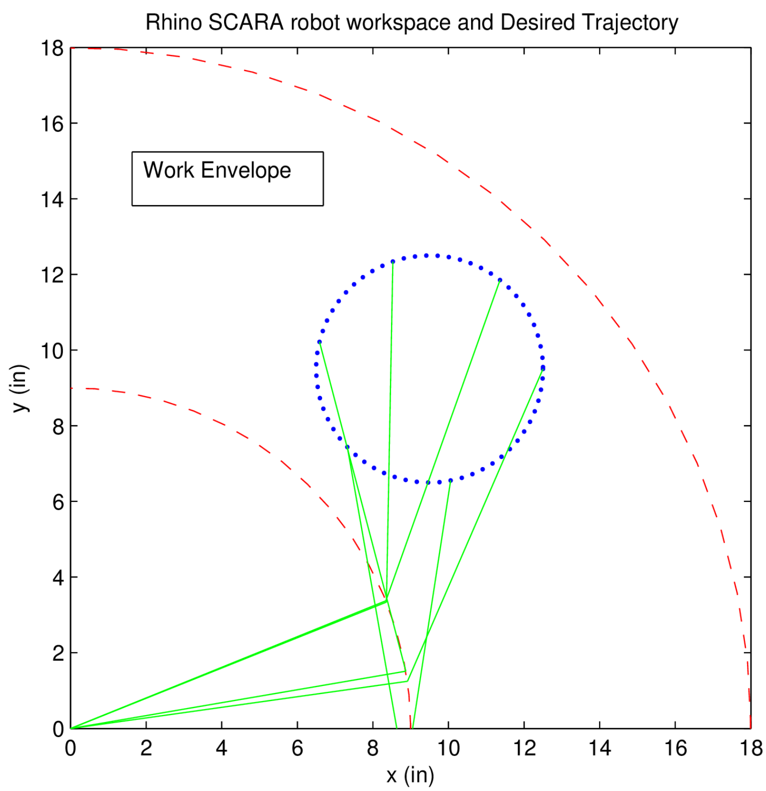

Figure 3. Desired Cartesian Trajectory.

Deliverables

Each design team should deliver the following items by November 30:

- A working prototype that demonstrates the use of the embedded control system for tracking the trajectory shown in Figure 3 with a Rhino SCARA robot.

- A 1-3 page electronic report containing the following topics:
    a) Front matter: title, names of the team participants, date.
    b) Body matter: introduction, description of the system, summary.
    d) Back matter: references.
    Note: The report should contain the wiring of the system, and the listings of all the code that is required for the SBC and the FPGA boards in an appendix.

- A 15-minute presentation of the project. Examples of topics would include pros and cons of the control strategy, importance of the sampling period for this type of systems, difficulty of the project, and future work.