

## Assignment 5: Registration and Port Placement

ME 328: Medical Robotics  
Stanford University ♦ Winter 2019

Due on Canvas by 4:00 pm on Friday, February 22

Please scan and submit all documents relevant to Assignment 5 via Canvas. (No hard copy)

**0. Guest Speaker:** After each of the seminars on Fridays (Feb. 15, Feb. 22, March 1, and March 8), look for questions posted to **Canvas** about the seminars, and answer them online within one week of the seminar date.

**1. Readings:** You can download these papers from <http://www.stanford.edu/class/me328/#readings>

J. W. Cannon, J. A. Stoll, S. D. Selha, P. E. Dupont, R. D. Howe, and D. F. Torchiana. Port Placement Planning in Robot-Assisted Coronary Artery Bypass. *IEEE Transactions on Robotics and Automation* 19(5): 912-17, 2003.

*Optional: This paper was used as a case study in class. You can skim it if you would like more details.*

A. L. Trejos, R. V. Patel, I. Ross, and B. Kiaii. Optimizing port placement for robot-assisted minimally invasive cardiac surgery. *The International Journal of Medical Robotics and Computer Assisted Surgery*, 3(4):355-364, 2007.

*This in another paper about port placement, this time for the da Vinci Surgical System.*

A. (Trejos et al.) What are the different performance measures proposed by the authors? Which one do you think is the most useful, and why?

B. (Trejos et al.) What is the relationship between manipulator singularities and performance (which exists even when the singular configurations are not achievable due to joint limits)?

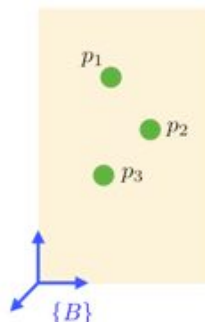
C. (Trejos et al.) How was the optimization method tested?

Submit your individual answers to these questions at “Assignment 5 Readings” on Canvas.

### General Instructions

This part of the assignment should be done with your project group. Go to Canvas and navigate to “People” on the left side menu. Create your project group with all team members under “Project”. Submit one document/code for the group for Problems 2 and 3 at “Assignment 5 Port Placement” on Canvas. All material for this assignment (bookend, binder clips, etc.) are located on the desk by Workstation 4.

For each part below, you will add your code to the main.cpp file of the code template provided at <http://www.stanford.edu/class/me328/#resources> for Assignment 5 (ME328\_A5\_template.sln). For parts D, E, and F, you will add your code to the correct part in the switch statement in the function called “Control”. You can also add variable definitions and any other necessary code anywhere between the comments that say “START EDITING HERE” and “STOP EDITING HERE”. Furthermore, you will need to add code to record additional data you desire that is not already set up to be recorded. You may edit areas labeled as “DATA RECORDING EDIT HERE” to change which variables are recorded.



The Assignment 5 “body wall” is set up with binder clips to attach the body wall (a cut-up file folder with holes in it) labeled “Assignment 5” to a bookend such that the side with writing faces the Omni and the fold of the folder is nestled in the “L” of the bookend. Make sure the side of the bookend with the long base support is on the Omni side.

## 2. Registration

Using the outline of the Omni base shown on the folder, place the Omni facing the body wall. The Omni regular stylus point (the end that goes in the “inkwell”; see below) should be able to reach the four registration points on the surface of the body wall.

- A. As in Assignment 4, the template code includes a function that will print the current position of the tip in the robot frame. In this assignment, we will aim to get more accuracy out of our registration process by using the regular stylus tip (shown at right) to touch the registration points. Stylus length in this case is about -40 mm (negative because it is on the opposite side as the main handle/needle). You’ll need to change the length of the stylus in the code.



Touch the regular stylus tip to each of the four registration points (their positions are known in body wall coordinates) plus at least one additional point of your choosing out of the plane of the body wall. Record manually the  $(x, y, z)$  Omni values. Make a table in your write-up giving the coordinate of each point in body wall coordinates  $\{b_i\}$  and in Omni coordinates  $\{a_i\}$ . The registration points are numbered and labelled on the body wall. Since there are a small number of registration points and the points are being touched manually, it is easy to keep track of point correspondences.

- B. Now, in MATLAB, solve for the transformation matrix  $T$  that transforms vectors in the  $\{B\}$  frame to the  $\{A\}$  frame. Use the direct method provided in lecture. Submit your MATLAB code via Canvas and give the final transformation matrix  $T$ .
- C. Test your transformation. The body wall gives the port locations in the body wall frame  $\{B\}$ . Touch the ports with the regular stylus tip and, using your software from Part A, record the tip positions in the Omni frame  $\{A\}$ . Make a table in your write-up giving the coordinate each port in body wall coordinates and in Omni coordinates. For each port, compute the registration error (i.e., distance between  $a$  and  $Tb$ ).

Discuss your result:

- Is there error similar for all three ports, and is the error what you would expect?
- What are the sources of error in your measurement of the points  $a_i$  and  $b_i$ , and what do you think most affects registration error?

Write up this discussion and submit via Canvas.

## 3. Port Placement

In this problem, you will use the Phantom Omni modified to behave like an RCM (remote center of motion) robot, equipped with a needle attached to the stylus, as you did in Assignment 4. The needle will be constrained to pass through a hole in the vertical wall representing the body wall of the patient. The placement of the Omni with respect to the body wall should be the same as above (aligned to the pencil outline on the body wall base). To read the needle tip location, you can change the stylus length in the code to match that of the needle attached to the Omni (again, measured from the center of the “wrist” – and this time it will be a positive number).



D, E, F. Three ports (labeled “Port D”, “Port E”, and “Port F”) are provided in the body wall. For manipulating in the vicinity of the point (20, 15, -60) mm in the body wall workspace, which port is best? Develop your own optimization criterion to choose the best port for drawing a circle of diameter 1 cm aligned with the plane of the body wall at the location given.

For your submitted code, demonstrate autonomous movement of the instrument tip inside the patient around this circle. Your code should work for the port labeled “D” when you select controller “D”, etc. Acquire data for all three ports, and use this data to demonstrate that your optimization resulted in the best choice of port. Submit your .cpp file (no executable) on Canvas.

This is an open-ended problem, so be clear in your write-up about the steps you took and the results you got. Submit your write up on Canvas.

*Hint: You do not need to use trajectory generation in this problem. Rather, you can simply ask the Omni to follow the circular path with a constant velocity. It might be a little rough in the beginning as it tries to get to the path, but that's okay – just don't use that data in your analysis.*