Precise Automated Kinematic Calibration of RCM Robots (PAKC'RR)

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Outline

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Summary and Goals

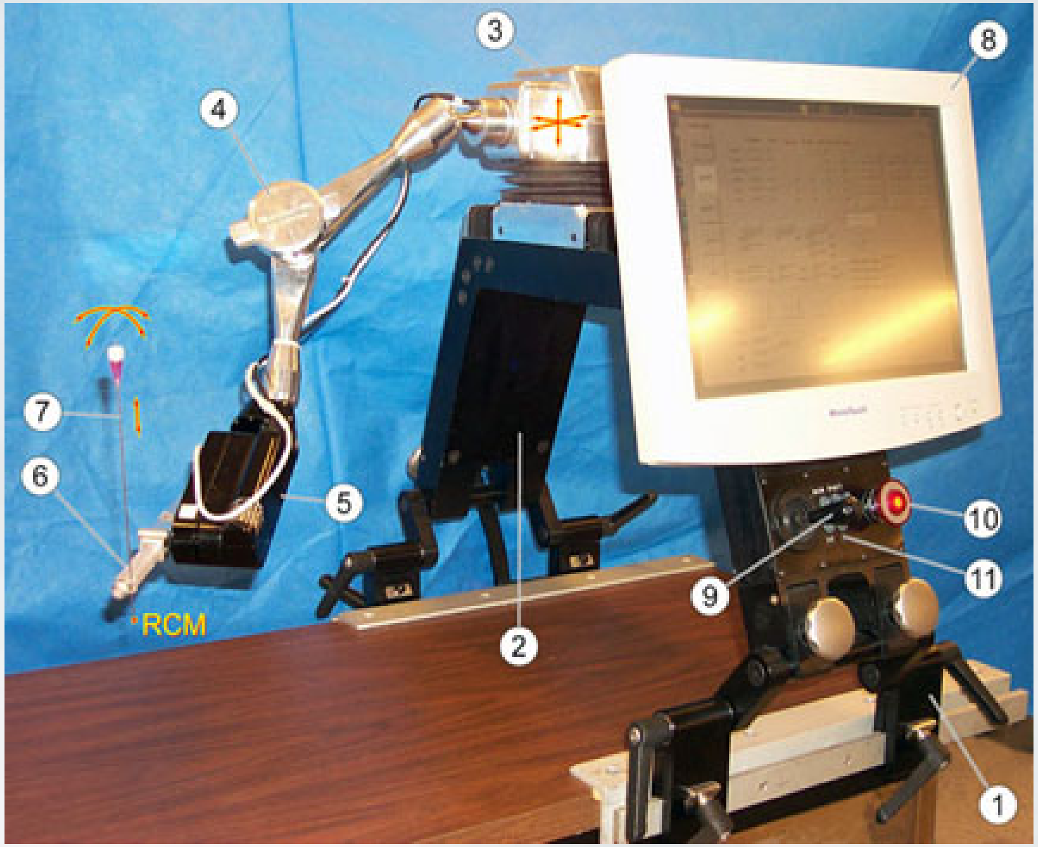
There is a small but noticable error in the RCM (Remote Center of Motion) of Acubot.

We must:

1. Quantify the error with a CNC-calibrated optical tracker
2. Correct the RCM motion with a compensatory kinematic model calibrated with an optical tracker
3. Determine and fix sources of error in AcuBot through mechanical dissection
4. Automate and generalize the calibration algorithm to work on other robots

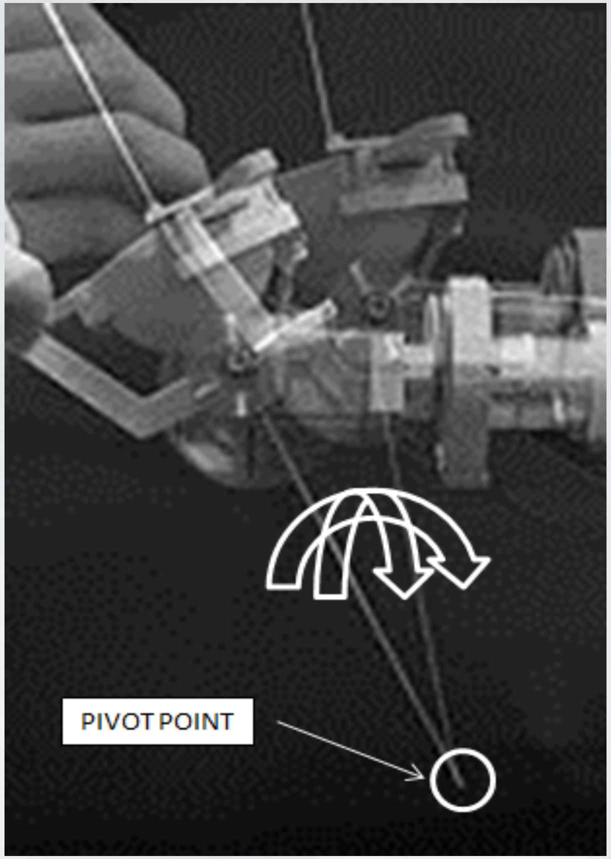
Background

- AcuBot is an RCM robot with translational stage developed for needle insertion
- Designed in CAD
  - RCM axes perfectly aligned
- In pratice, error arises
  - ~ 1mm



What is an RCM?

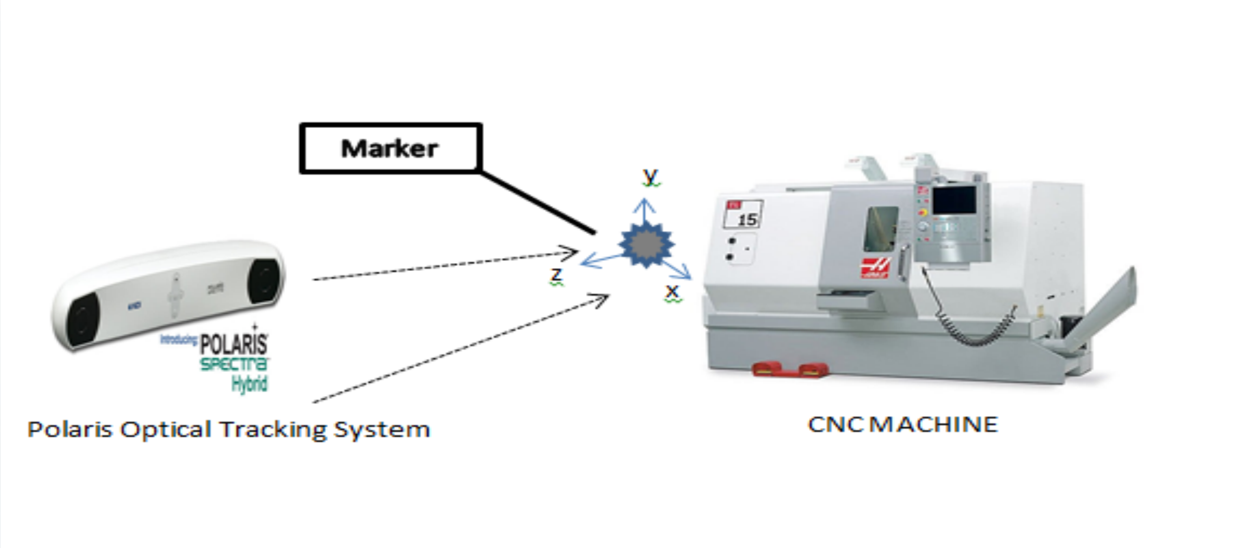
- Remote Center of Motion
- Virtual pivot point
- Advantages:
  - Laparoscopic sugery
  - Range of motion from single entry point
- Hardware-imposed RCM is safer than Virtual RCM
  - Unaffected by software bugs
  - Unaffected by encoder errors earlier in the kinematic chain



Motivation for Project

- Optical tracker accuracy limits are not precisely known
- In order to place needles accurately, the RCM must remain stationary
- Errors propogate down the kinematic chain, it is best to resolve them early in the chain
- Would be valuable to implement calibration method on other robots
- Identifying overlooked construction errors will help to build future RCM robots

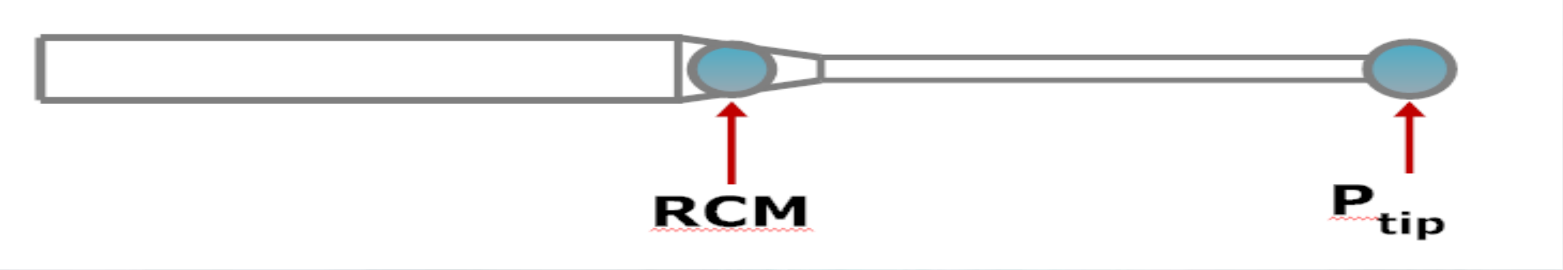
Technical Approach



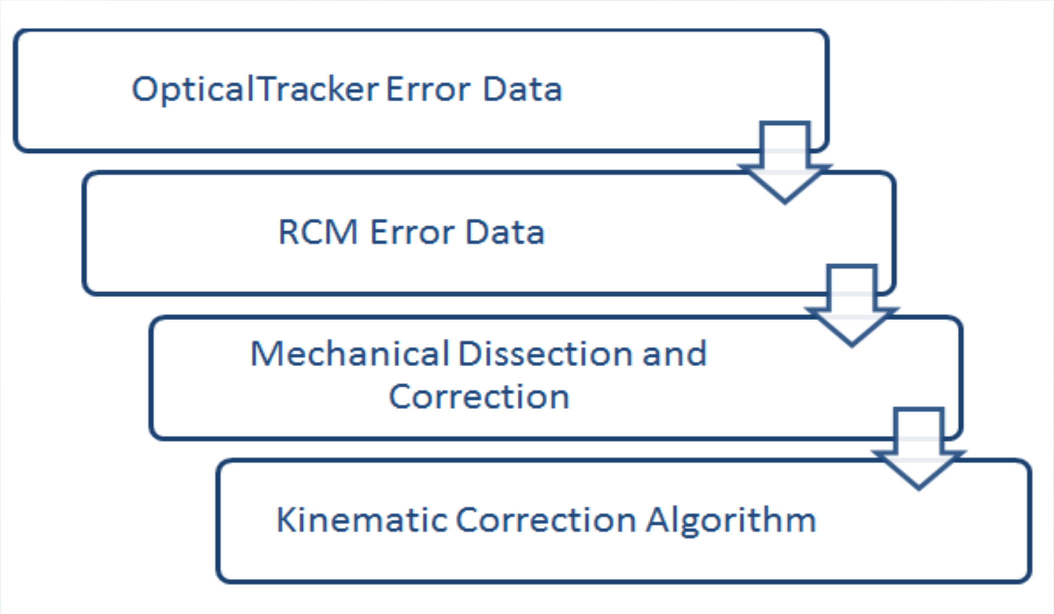
- Tracker Calibration
  - Place optical markers in CNC machine
  - Move markers in small increments in X, Y, Z
  - Attach an active marker to determine orientation accuracy
  - Using the Polaris tracker, take a large number of readings at each point and average them
  - Compare with the CNC coordinates
  - Quantify errors in each direction using MATLAB

Technical Approach

- Quantifying RCM Error
  - Use MFC and the MotionTools MCI library to control the robot
  - Place optical markers at RCM and needle tip
  - Move it through all angles of the RCM while observing with optical tracker
  - Compare observed trajectories MATLAB to desired motion
  - Dissect robot and correct link parameters



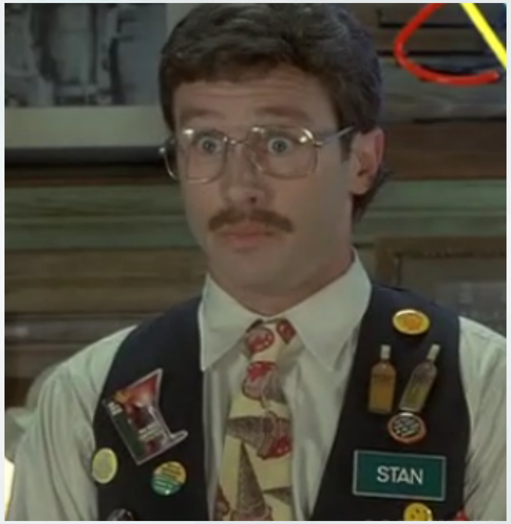
Technical Approach



- Reassemble robot with updated link parameters
- Develop kinematic correction algorithm using RCM error data and new link parameters
  - Implement using MFC, the MCI library, and the CIIST library
  - Test on AcuBot
  - Repeat observations with optical tracker

Deliverables - Minimum

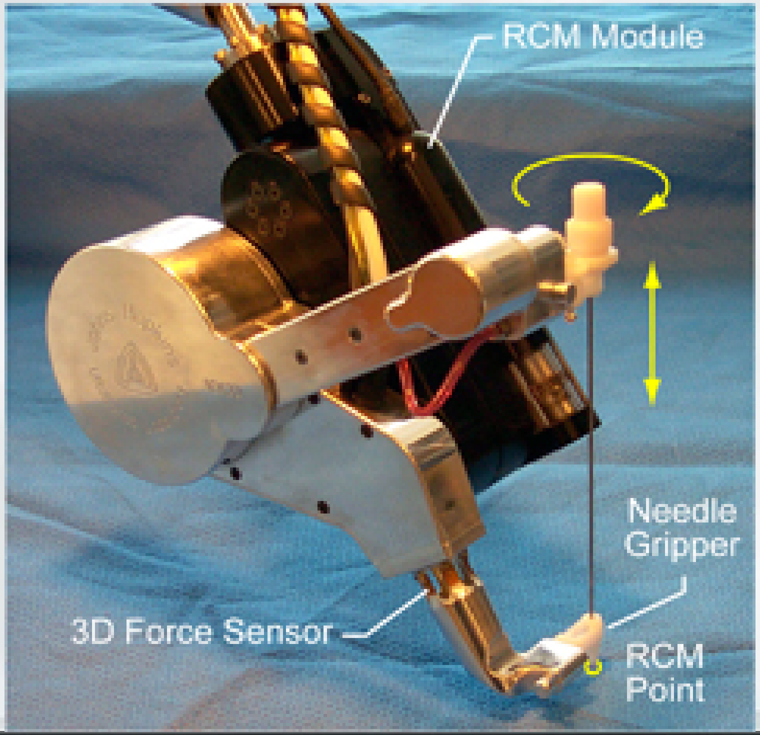
- Write a paper on the accuracy of the Polaris
- RCM error analysis using tracker data and MATLAB
- Mechanical dissection of AcuBot to determine error factors
- Correct the error as much as possible given the design of the robot



"What do you think of a person who only does the bare minimum?"

Deliverables - Expected

- Quantify error in Revolving Needle Driver robot
- Update kinematic model of AcuBot with new link parameters
- Automatic kinematic correction of AcuBot
- Port correction algorithm to Revolving Needle Driver robot



Deliverables - Maximum

- Mechanical dissection of Revolving Needle Driver Robot
- Generalize algorithm to be portable and work with other robots using CIIST library

Milestones

Milestones	Expected date
Project Plan Presentation	14-Feb
Optical Tracker Calibratrion	23-Feb
Paper Seminar	6-Mar
RCM error quantified	8-Mar
Algorithm Working	3-Apr
Project Checkpoint	5-Apr
Mechanical dissection and report	26-Apr
Port to Revolving Needle Driver Robot	3-May
Make Correction algorithm portable for CIIST	8-May
Correct AcuBot construction	8-May
Poster	10-May
Final Report	10-May

Time Line

Milestones	14-Feb	23-Feb	1-Mar	8-Mar	15-Mar	22-Mar	29-Mar	5-Apr	12-Apr	19-Apr	26-Apr	3-May	8-May	10-May
Project Plan Presentation														
Calibrate Optical Tracker														
Paper Seminar														
Quantify RCM error														
Work on Algorithm						Spring								
Project Checkpoint														
Port to Revolving Needle Driver Robot						Break								
Mechanical dissection and report														
Make Correction algorithm portable for CIIST														
Correct AcuBot construction														
Poster														
Final Report														

Responsibilities

- Alex
  - CNC optical tracker calibration and analysis
  - Implement kinematic model using MSVS
  - Generalize Algorithm to CIIST
- Ryan
  - Quantify error of AcuBot using optical tracker
  - Quantify error of NDR
  - Port algorithm to the NDR
  - Dissect NDR
- Changhan
  - Build kinematic model of the AcuBot
  - AcuBot dissection and report
  - Correct AcuBot mechanical construction

Dependencies

- Lab time
  - Resolved - Key access to lab
- Access to robot
  - Resolved - have constant access to AcuBot
- Learn how to use CNC Machine
  - Resolution - schedule with Doru Petrisor
- Use of optical tracker time
- Use of NDR

References

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Questions?