Inverse Kinematics

ECE 470 Lab 4 Intro

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Announcement

- You can find this document and any others that I share in my Box Share Folder
- You can also find it on my Website
- I also have a helpful example of Inverse Kinematics
- The Lab 4 schedule has changed and you will now have two in class sessions:
  - Group A - Session 1: Week of 19 October
  - Group B - Session 1: Week of 26 October
  - Group A - Session 2: Week of 2 November
  - Group B - Session 2: Week of 9 November

Lab 4 Goal

- Our goal is to implement Inverse Kinematics on the UR3
- The robot should accept x_{grip}, y_{grip}, z_{grip}, θ_{yaw} from the user and move the end-effector to that position.
- Prep for Next Lab:
  - Continue to work on Lab 4 during your off week
  - Write your lab report

What are Inverse Kinematics?

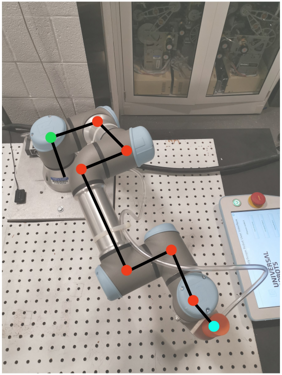
- Inverse Kinematics translates from an end effector position and orientation to joint angles
- $T_{06} \rightarrow (\theta_1, \theta_2, \theta_3, \theta_4, \theta_5, \theta_6)$
    - $(x_{grip}, y_{grip}, z_{grip}, \theta_{yaw}\ \theta_{pitch}\ \theta_{roll}) \rightarrow (\theta_1, \theta_2, \theta_3, \theta_4, \theta_5, \theta_6)$
- We will be doing this analytically using geometry
- To make this easier on our 6R robot, we have placed constraints on end effector orientation and arm positions:
    - Elbow up solution
    - Link 5 is always parallel to the tabletop - θ_{pitch} is fixed
    - Link 6 is always orthogonal to the tabletop - θ_{roll} is fixed

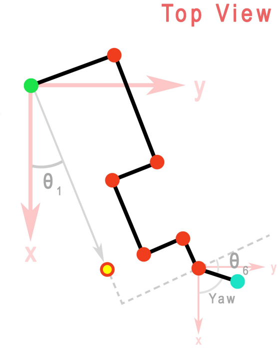
Procedure

- Follow the procedure in the Lab Manual! Read it several times!
  - I can't help you if you want to use a different method
- There are many ways to do this, you just need it to work in the end
  - You also need to make sure it works for the full range of motion!
- Order:
  - θ_1 (Need $(x_{cen}, y_{cen}, z_{cen})$)
  - θ_6
  - θ_2, θ_3, θ_4 (Need $(x_{3end}, y_{3end}, z_{3end})$)
  - θ_5

Top View

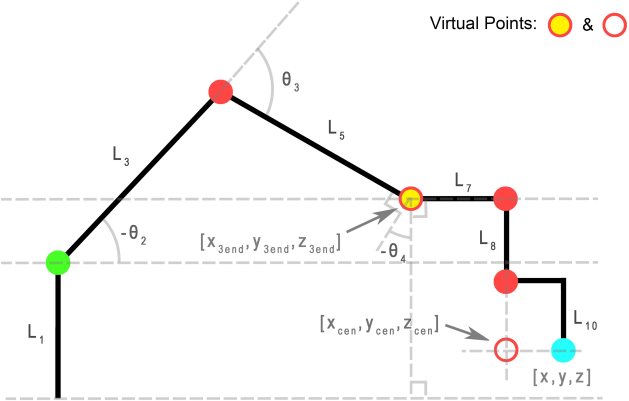
- This is a projection on the x-y plane?
- What lengths and angles do we know in this view?





"Side" View

- What plane is this?
- What lengths and angles do we know in this view?



Some hints

- The workspace is pretty small
  - Start with a working configuration near the center of the work area
    - aligned with the center of the robot base
    - 20-30cm away from the base of the robot
    - 10-20cm above the table
  - Make small movements in different directions e.g. add +3cm to x, does it still work?
  - This should help you find a variety of reachable positions in the workspace.
- If you see NaN a lot, you are probably outside your workspace
- Think about what happens when you cross boundaries
  - What if an angle goes from positive to negative?
  - What if x goes from positive to negative?
  - What other boundaries have you created?

Demonstration

A demonstration of your working code is required for this lab.

- Show me (your TA) your working program
- Online students will demo their simulation over Zoom
- In-person students can demo in-person or via Zoom
- All demos will be live (no recordings), so please plan ahead to see me in office hours or during lab time - prior to the due date.
  - Group A - Week of 16 November (Same as report)
  - Group B - Week of 30 November (Same as report)
- **Please read the requirements carefully. Every semester people want to demo without completing the lab properly.**

Lab Reports

- Lab reports will be due according to the schedule in GradeScope.
  - Group A - Week of 16 November (Same as demo)
  - Group B - Week of 30 November (Same as demo)
- Please look closely at the lab report guidelines document - How to Write a Lab Report
- Read Section 4.8 carefully and ensure that you answer all the questions there.

Lab 4 - Hints and Help

Lab 4 Suggested Timeline

- Week 1 (Session 1) Goal: Calculate θ_1
- Week 2 (off week) Goal: Calculate θ_2 θ_3 θ_4, θ_5, and θ_6.
- Week 3 (Session 2) Goal: Implement and verify your Inverse Kinematics.
- Week 4 (off week) Goal: Demo and write your lab report.

Lab 4 Details

- Read the code carefully. You should only need to edit **lab4_func.py**, but you are encouraged to read **lab4_exec.py** to get a better sense of how the program works.
- You need to test your code with a variety of configurations.
- The arm may go to unexpected positions if your solution is wrong. Please use caution if working on the real robot.

Lab 4 Report Details

- Ask yourself "What were the most important things we did in this lab?" This should be the focus of your report.
- **Figures, Figures, Figures** - Figures are a vital part of explaining what you did in this lab. I expect your own quality figures - i.e. not from the manual, nothing hand-drawn, clearly labeled, etc.
- Use code snippits as needed to help explain what you did
- Include your code (**lab4_func.py** only) as an appendix in your report.
- Follow the How to Write a Lab Report Guidelines!

For Next Lab

- Finish your Lab 4 solution before the demo due date.
- Start writing your lab report following the lab report guidelines.
- Lab 5 has not been finalized at the time of this writing. It will be one of the following:
  - Related to using a camera to locate objects
  - Canceled in favor of a final project
  - Combined with the final project