EE 399 Lab Report: Final Robotic Challenges

Group 6
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Introduction

The "Final Robotic Challenges" presented in Labs 1 and 2 have paved the way for the intricate and engaging tasks of Lab 3. In this latest installment, our team was tasked with applying their acquired knowledge in robotics to overcome challenges that not only test technical skills but also emphasize strategic problem-solving and collaborative teamwork.

Challenge 1, "Precision Peg Hammering," serves as an initial foray into precision robotic manipulation. The objective is to guide a robotic arm through a sequence of tasks, requiring careful planning and execution for accurate peg placement and subsequent hammering. Success in this challenge relies on a combination of foundational concepts such as forward and inverse kinematics, gripper manipulation, and motion planning.

In the "Dynamic Cube Arrangement" challenge, participants are tasked with two primary objectives. First, they must strategically arrange 20 cubes to create a complex 3D pattern, emphasizing spatial reasoning and precise placement. The second task involves transforming the initial pattern into a predefined configuration, evaluating participants' understanding of cube orientations and manipulation skills. Participants can choose between a stationary base for stability or a rover base for increased mobility, each with its advantages and disadvantages. The challenge emphasizes efficient cube load placement, meticulous cube selection, and gripper positioning for both pattern creation and transformation. Participants are allowed a maximum of 4 mulligans for minimal assistance, balancing efficiency with precision in task completion. Success in this challenge relies on a participant's ability to navigate these intricacies and deliver optimal performance.

Building on this, Challenge 3, known as "Collaborative Tower Manipulation," introduces a dynamic element by necessitating teamwork between two groups. This challenge evaluates participants on their ability to strategize, communicate effectively, and execute intricate robotic tasks collaboratively. The tasks include the complete deconstruction and reconstruction of a 10-block tower, emphasizing precision, collaborative planning, and minimal assistance.

Materials and methods

Mecharm270Pi Robot: At the heart of the study, this advanced robotic arm serves as the canvas for programming and kinematics exploration.

myAGV Rover: important autonomous guided vehicle which can be a compound robot with robotic arms running on the ROS development platform.

Monitor: Essential for visualizing robotic movements and programming interfaces.

USB Keyboard and Mouse: Indispensable tools for navigating the intricate software interfaces.

HDMI Cable and Power Cable: Facilitate seamless communication between the monitor and the robotic arm.

Three 8.5x11 Inch Sheet & marker: Necessary materials to complete challenge 2.

Mecharm270Pi Robot Base: Base below robot to support balance and accurate positioning during Robot run procedures.

Software

Python Programming Environment: Employed Python programming to implement complex algorithms and control mechanisms.

pymycobot Library: Integrated the pymycobot API library for precise control of the Mecharm270Pi Robot.

RViz: Utilized RViz, a 3D visualization tool in the ROS (Robot Operating System) ecosystem, for practical mapping and visualization tasks.
VNC: Virtual Network Consult, a powerful and efficient

remote control tool that allows you to access and control your rover's desktop from your computer.

Precision Peg Hammering:

Materials:

- Six differently colored pegs
- Wooden bench with designated slots
- Hammer

Methods:

- Strategic Peg Selection: Choose the order of peg placement, considering color matching for accurate slotting.
- Gripper Positioning: Guide the robotic arm to pick up pegs with precise movements, ensuring optimal gripper orientation.
- Peg Insertion: Meticulously move the arm to insert pegs into designated slots, making minor physical corrections within the allowed interventions.
- Hammering Action: Pick up the hammer and execute controlled motions to tap pegs into final positions.

Collaborative Tower Manipulation:

Materials:

- Two robotic arms (stationary)
- 10 blocks arranged in a tower
- Rover with camera and QR code capabilities

Methods:

- Collaborative Strategy for Deconstruction: Gather teams to plan efficient block removal, emphasizing effective communication and synchronized planning.
- Block Removal: Alternating between teams, use the rover for repositioning if needed, ensuring precise positioning with camera and QR code capabilities.
- Tower Reconstruction: Plan strategy, communicate clearly, and reconstruct the tower with a focus on accuracy and stability.
- Minimal Assistance and Mulligan Use: Strive for independent execution, using mulligans strategically if necessary.

Results and discussion

Precision Peg Hammering:

Results:

We set up our robot arm as shown in the following figure.

Figure 1. Setup for challenge 1.

We strategically arranged the sequence for peg insertion by placing the pegs in the order of yellow, orange, red, blue, green, and chartreuse from the outer lane to the inner lane. This sequencing was designed to prevent any inadvertent collisions with previously inserted pegs. To streamline the process, we designated a single location for the robot arm to efficiently pick up the pegs. The order of hammering was reversed, proceeding from the inner lane to the outer lane.

Utilizing drag teaching techniques, we meticulously extracted and recorded key positions in CSV files. These positions included the peg-pickup point, six distinct insertion locations, and the hammer-pickup point. Our robotic programming follows a precise sequence: starting from the home position, the robot moves to the peg-pickup position, lifts the peg by adjusting joints 2-6 to 0, rotates joint 1 to the angle specified by the insertion position, and then places the peg into the slot by adjusting joints 2-6 to match the insertion position's angle. This process repeats for all six pegs. Subsequently, the robot proceeds to the hammer-pickup position, lifts the hammer, and navigates to the insertion positions in reverse order. Importantly, the robot arm halts 15mm above the final position before each action, allowing for user adjustments.

Here is a [link](https://www.youtube.com/watch?v=GqgmydpSRaU) to the completed challenge: https://www.youtube.com/watch?v=GqgmydpSRaU

Figure 2. Completion for challenge 1.

Discussion:

Our completion of the task, while successful, was not without its challenges, and we utilized four mulligans to fine-tune our approach. The positions it got from drag teaching is not always accurate due to external forces from gravity and hands. We fixed this issue in the next challenge by introducing adjustments when recording the positions.

One notable setback occurred during the hammering of the green peg, resulting in the unintended displacement of the adjacent blue peg. Upon analysis, we identified the root cause: the inherent tilt of the pegs during insertion.

To address this issue, we recognize the need to incorporate a corrective step in our process. Specifically, before initiating the hammering phase, we can implement a peg straightening mechanism. This additional step ensures that all pegs are properly aligned and vertical, minimizing the risk of collateral damage to neighboring pegs during subsequent hammering actions.

The decision to utilize mulligans was instrumental in our continuous improvement journey. Each mulligan served as a valuable opportunity to recalibrate our approach, identify weaknesses, and implement necessary adjustments. By openly acknowledging and learning from our failures, we foster a culture of adaptability and resilience in the face of unforeseen challenges.

Moving forward, our focus will be on refining the peg insertion process to eliminate the tilt issue systematically. This may involve optimizing the peg-pickup position, adjusting the insertion angles, or incorporating sensors for real-time alignment feedback. These enhancements aim to enhance the precision and reliability of our robotic system, reducing the reliance on mulligans and ensuring a more robust execution of the peg hammering task.

Collaborative Tower Manipulation:

We set up the two robot arms as shown in the following figure.

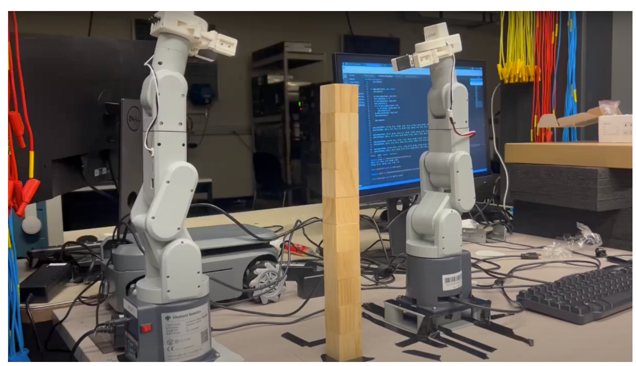

Figure 3. Setup for challenge 3.

We connected the robot arms into the same wifi. Then we executed Server.py to enable the robotic arm's control through the other arm. We established a connection to the robot arm's socket using the pymycobot library.

In contrast to Challenge 1, we implemented drag teaching techniques to identify and refine the pickup and placement locations for each cube. Notably, we incorporated a crucial improvement by executing position adjustments before recording the angles and coordinates. This proactive approach significantly minimizes the need for user intervention, enhancing the overall efficiency of our robotic operations.

Our methodology involved a systematic process for each robot. We meticulously determined the pickup and placement locations for a cube, ensuring successful pickup and placement. This process was iteratively repeated ten times, guaranteeing robustness and reliability. Each recorded location included both a hover position, representing the approximate location, and a final position. The hover position served as a starting point for the robot, enabling swift movement to the pickup location. From there, the robot transitioned smoothly to the final position for precise cube pickup. Subsequently, the robot moved swiftly to the hover position for placement, carefully navigating to the final position for accurate cube placement. The entire sequence was capped off by a rapid return to the home position.

Here is a [link](https://youtu.be/y_4ECRpHQlc?si=9k0fp2ek2iMfMzyt) to the completed challenge: https://youtu.be/y_4ECRpHQlc?si=9k0fp2ek2iMfMzyt

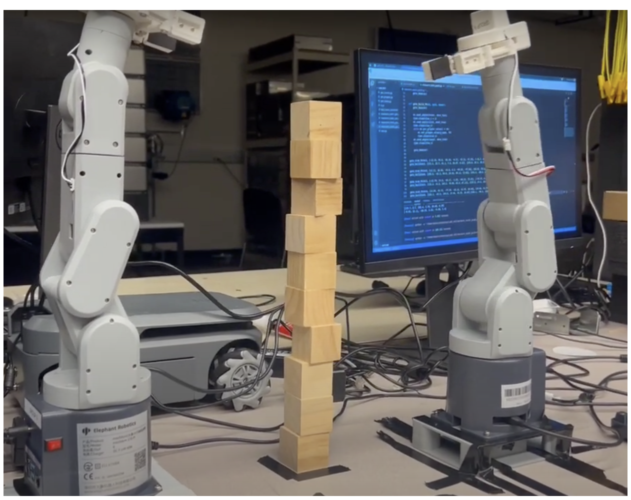

Figure 4. Completion for challenge 3.

Discussion:

A prominent challenge encountered during the task revolved around the unexpected movement of the robot's second joint. Despite setting a fixed angle, we observed a degree of play or oscillation in the joint, resulting in inaccuracies in our results. This issue significantly impacted the precision of our operations, requiring a thoughtful resolution.

In our initial efforts, we sought to implement software-based solutions to meticulously compensate for this movement by adjusting positions. However, despite careful calibration, the results remained unpredictable, prompting a strategic shift in our approach.

Recognizing the significance of precision in our operations, we opted for a more decisive solution: transitioning to a different robotic arm with all well-functioning joints. This strategic decision aligns with our commitment to reliability and accuracy in robotic tasks. The selection of a robot with consistently stable joints not only addresses the immediate challenge but also lays the foundation for a more robust and predictable execution of our tasks.

This adaptive approach underscores the importance of flexibility in problem-solving. While software adjustments are valuable in many scenarios, acknowledging the limitations and opting for a hardware solution demonstrates our commitment to achieving optimal performance. It also emphasizes the iterative nature of problem-solving, as we pivot to solutions that align more closely with our precision requirements.

Moving forward, our team will continue to prioritize the reliability of our robotic systems, exploring advancements in both hardware and software domains. Regular assessments, proactive maintenance, and strategic choices in technology selection will contribute to the resilience of our automated operations, ensuring consistent and accurate outcomes in the face of evolving challenges.

Conclusions

In the culmination of Lab 3, our team navigated intricate robotic challenges, showcasing the fusion of technical expertise, strategic problem-solving, and collaborative teamwork. Challenge 1, "Precision Peg Hammering," exemplified the complexity of robotic manipulation, demanding meticulous planning and execution. While successful, the journey was not without its challenges, notably the unexpected tilting of pegs during hammering. Embracing a culture of continuous improvement, we strategically employed mulligans and identified the need for a peg straightening mechanism to enhance precision further. This experience underscores the iterative nature of robotics, where challenges serve as catalysts for innovation and refinement.

Challenge 2, "Collaborative Tower Manipulation," introduced a dynamic dimension by requiring teamwork between two robotic arms. The utilization of drag teaching techniques and position adjustments showcased our adaptability and commitment to efficiency. However, the unexpected movement in the second joint posed a formidable challenge. Our transition to a different robotic arm with stable joints exemplifies our proactive approach to problem-solving, emphasizing the synergy between hardware and software solutions. As we reflect on the outcomes of Lab 3, we recognize the invaluable lessons learned, the resilience developed through challenges, and the importance of flexibility in the ever-evolving field of robotics. Moving forward, our commitment to precision, collaboration, and innovation will continue to drive advancements in robotic applications, ensuring our team remains at the forefront of this exciting and dynamic field.

Implications and Future Work:

The successful completion of the "Final Robotic Challenges" not only signifies a commendable achievement for the participating teams but also bears significant implications for the broader field of robotics and automation. The insights gleaned from these challenges extend beyond the confines of our lab setting, offering noteworthy considerations for the ongoing development of robotic systems.

Implications:

1. Technological Advancements: The challenges underscored the integration of advanced robotic functionalities, encompassing forward and inverse kinematics, gripper manipulation, and collaborative planning. These accomplishments suggest a growing proficiency in harnessing and applying cutting-edge technologies in real-world scenarios, showcasing the potential for technological advancements in robotic systems.

2. Problem-Solving and Adaptability: Participants showcased a notable ability to devise innovative solutions, dynamically adjust strategies, and collaborate effectively under changing conditions. These skills hold crucial importance in real-world applications where robotic systems must contend with unforeseen challenges, emphasizing the need for adaptability and creative problem-solving.

3. Human-Robot Collaboration: Challenge 3 specifically emphasized the collaborative efforts between human teams and robotic systems. The successful completion of tasks requiring coordinated actions between robotic arms and the rover indicates a promising avenue for the development of human-robot collaboration in diverse industries, ranging from manufacturing to disaster response.

4. Interface Design and Real-Time Adjustments: The freedom granted in interface design allowed participants to optimize robot movements for efficiency and accuracy. This implies the significance of user-friendly interfaces and suggests potential advancements in interface design that could enhance human-robot interaction across various applications.

Future Work:

1. Advanced Robotic Algorithms: Subsequent research endeavors could focus on the development of more sophisticated algorithms for motion planning, adaptive learning, and autonomous decision-making. This pursuit aims to further enhance the autonomy of robotic systems, minimizing the need for manual intervention in challenging tasks.

2. Real-World Applications: While the challenges simulated specific scenarios, future work could involve adapting these robotic skills to practical, real-world applications. From manufacturing and logistics to healthcare and exploration, the translation of these skills to diverse domains holds immense potential for societal impact.

3. Human Augmentation: Given the focus on teamwork and collaboration, future research could explore the augmentation of human capabilities through robotic assistance. This line of inquiry could lead to the development of systems that enhance human productivity and efficiency in various professional and industrial settings.

In conclusion, the implications drawn from the "Final Robotic Challenges" extend beyond our immediate laboratory context, pointing toward a future where robotics and automation play a pivotal role in addressing complex tasks. Future work in this field holds the promise of not only refining existing technologies but also unlocking new possibilities that could reshape industries and contribute to advancements in human-robot collaboration.

References

1. *2 introduction to API*. 2 Introduction to API · GitBook. (n.d.). https://docs.elephantrobotics.com/docs/gitbook-en/7-ApplicationBasePython/7.2_API.html