Advancing Human-Robot Interaction through Mixed Reality and Smart Technologies

Miles Popiela

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Chapter 1

Introduction

1.1 Overview

In an era of increasing human-robot collaboration, the need for intuitive and efficient robot programming methods is paramount. This thesis proposes a novel approach to human-robot interaction, combining mixed reality interfaces, smart hub technology, and reinforcement learning. The goal is to develop a system that allows users to program and control robots as naturally as moving their own bodies, making robotics accessible to non-experts while enhancing efficiency for experienced users.

"How can the combination of mixed reality interfaces, smart hub technology, and reinforcement learning enhance human-robot interaction and make robot programming more intuitive and efficient for both novice and expert users?"

1.2 Research Objectives

For this one-year research project, I will focus on the following key objectives:

1. Develop a prototype Smart Hub system that facilitates communication betIen mixed reality interfaces and robotic platforms.

2. Implement and evaluate various animation editing styles within a mixed reality environment for robot path creation.

3. Investigate the integration of reinforcement learning techniques to optimize user-demonstrated trajectories.

4. Conduct initial user studies to assess the effectiveness and intuitiveness of the proposed system.

1.3 Smart Hub Robotics

The Smart Hub serves as the central nervous system of my proposed system, bridging mixed reality interfaces with diverse robotic platforms. Key features include:

- UDP-based communication for low-latency transmission of spatial data.
- ROS-based inverse kinematics calculations for translating spatial commands to joint movements.
- A digital twin system for real-time feedback and offline programming.

1.3.1 Research Focus

Within the one-year timeframe, I will:

- Develop a functional prototype of the Smart Hub using NVIDIA Jetson Nano and ROS.
- Implement basic machine learning algorithms for optimizing inverse kinematics calculations.
- Conduct preliminary tests on communication efficiency and accuracy of motion translation.

1.4 Mixed Reality Robotics Control

My system reimagines robot control through holographic Tool Center Point (TCP) manipulation and diverse animation editing tools.

1.4.1 Holographic TCP Manipulation

Key advantages include:

- Intuitive spatial control using natural hand movements.
- Iightless manipulation for complex trajectory generation.
- Ability to overcome physical limitations through virtual planning.

1.4.2 Animation Editing Styles

I will implement and evaluate several editing paradigms:

1. Direct manipulation
2. Keyframe-based editing
3. Gesture-based path creation
4. Parametric curve editing
5. Time-based animation scrubbing
6. Voice-commanded editing

1.4.3 Research Focus

Within the year, I aim to:

- Develop a mixed reality interface incorporating at least three of the proposed editing styles.
- Conduct user studies comparing these editing methods for efficiency and intuitiveness.
- Analyze the impact of different editing styles on trajectory quality and task completion time.

1.5 Reinforcement Learning for Robotic Control

I will explore the integration of reinforcement learning (RL) techniques using NVIDIA Isaac Gym to enhance my mixed reality control system.

1.5.1 Key Advantages of NVIDIA Isaac Gym

- High-performance, GPU-accelerated robot path simulation.
- Parallel environment capabilities for robust singularity policy training.
- Potential for seamless transfer to real robotic systems.

1.5.2 Research Focus

In the one-year timeframe, I will:

- Implement a basic RL model for learning from user demonstrations in mixed reality.
- Develop and test an initial algorithm for trajectory optimization using RL.
- Conduct preliminary experiments on the generalization capabilities of RL models across simple robot configurations.

1.6 Methodology

My research methodology will include:

1. System Development: Iterative development of the Smart Hub, mixed reality interface, and RL integration.
2. User Studies: Conduct experiments with 20-30 participants of little to no robot/programming expertise levels, focusing on:
   - Comparing my system with traditional programming methods.
   - Evaluating different animation creation and editing styles.
   - Assessing the impact of RL-optimized trajectories.
3. Data Analysis: Analyze quantitative metrics (task completion time, trajectory smoothness) and qualitative feedback.
4. Iterative Refinement: Use insights from user studies to refine the system throughout the year.

1.7 Expected Outcomes

By the end of the one-year project, I anticipate:

- A functional prototype of the Smart Hub and mixed reality control system.
- Empirical data on the effectiveness of different animation editing styles in mixed reality.

- Initial results on the potential of RL for optimizing user-demonstrated trajectories.
- Insights into the usability and efficiency gains of my approach compared to traditional methods.
- Identification of key challenges and future research directions in mixed reality robotic control.

1.8 Conclusion

This research aims to lay the groundwork for more intuitive and efficient human-robot interaction systems. By combining mixed reality interfaces, smart hub technology, and reinforcement learning, I seek to democratize robot programming and enhance collaboration betIen humans and robots. The outcomes of this one-year project will provide valuable insights into the potential of these technologies and pave the way for future advancements in the field.