Automation of Construction Site Tasks Using Teleoperated Mobile Robots

The Da Vinci of Construction: Intuitive and Precise Teleoperation Systems

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Background

Over the past fifty years, productivity in the construction sector has significantly declined relative to other industries. In contrast, the manufacturing sector has achieved an eightfold increase in productivity, primarily through the integration of automated machines and robotics. However, the construction industry has lagged in adopting these technological advancements due to its complex and variable environments, which pose substantial challenges for automation. Recent advancements in artificial intelligence (AI), teleoperation systems, and environmental perception technologies have opened new opportunities for introducing automation into construction sites.

While mobile robots can handle repetitive tasks, certain tasks or parts of tasks remain too complex for full automation. These situations necessitate human intervention. By employing teleoperation systems, human workers can remotely control robots in real-time, enabling precise task execution in complex scenarios. This approach combines the efficiency of automation with the adaptability of human expertise, addressing labor shortages, enhancing efficiency, and improving working conditions. Inspired by systems like the Da Vinci Surgical System, which enables precise remote operations, and leveraging modern technologies such as the Apple Vision Pro for intuitive hand-tracking, this thesis aims to develop a teleoperation system for a mobile robot designed for construction sites. The system will focus on real-time control, intuitive operation, and multimodal feedback to maximize operator efficiency and task accuracy.

Description

The mobile robot under consideration is equipped with a robotic arm, 3D lidar, cameras, and other sensors to perform various construction site tasks. However, certain tasks, such as handling irregular objects or navigating highly variable

SUPERVISOR
Prof. Dr.-Ing. Matthias Althof

ADVISOR
Claus Carste

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CONTACT
claus.carste@tum.de

REQUIREMENTS
Python, ROS2, Electronics

environments, require human expertise. This thesis aims to design, develop, and test a teleoperation system that enables a remote human operator to control the robot intuitively and effectively in such scenarios. The system will feature real-time feedback, including visual, auditory, and haptic signals, to enhance situational awareness and precision.

Key features of the teleoperation system include:

1. **Intuitive Control**: The robot will mimic the operator's movements 1:1 using technologies like motion capture or hand-tracking systems, such as those provided by the Apple Vision Pro or similar system.
2. **Real-Time Feedback**: Multimodal feedback will include visual feeds from the robot's cameras, auditory signals, and haptic feedback to convey information such as collisions or applied force.
3. **Task Optimization**: Algorithms for real-time path planning and environmental adaptation will enhance the system's efficiency.

The system's development will employ the ROS2 framework and MoveIt for robot control. Python will be used for testing and simulation, with C/C++ for performance-critical components. After successful simulations, the system will be tested on a real-world mobile robot at a construction site.

Tasks

1. Review existing teleoperation systems, focusing on construction and robotics.
2. Explore hand-tracking and motion capture technologies like Apple Vision Pro.
3. Define system architecture, including control interfaces and feedback modalities.
4. Design algorithms for intuitive control and real-time adaptation.
5. Develop teleoperation control software using ROS2 and MoveIt.
6. Integrate real-time feedback systems (visual, auditory, haptic).
7. Validate algorithms through simulations with synthetic and real-world data.
8. Deploy the system on a mobile robot and test on a construction site.
9. Evaluate performance based on accuracy, speed, and user satisfaction.
10. Refine algorithms to improve efficiency and accuracy.
11. Document development, implementation, and testing outcomes.