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Hydraulic Dual-Arm Manipulator Control System for High-Tensile Bolt Fastening

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1. Introduction

High-tensile bolts are one of the key connection methods in various fields. Compared to other fastening methods such as rivets and welding, high-tensile bolts have advantages of higher fastening strength, easier maintenance, and reversible disassembly. Due to these advantages, high-tensile bolts are widely used across various industrial fields including construction, civil engineering, and plant facilities.

However, bolt fastening using an impact wrench is considered a difficult task for robots to perform. The robot needs to position the tool head within a few millimeters of the target bolt, and the posture and direction between the tool head and the target bolt must also be aligned. Additionally, the robot must be able to withstand the high torque generated during bolt assembly. In particular, due to the operating principle of the impact wrench, continuous strong impacts occur, which can cause critical problems for conventional electric motor-reducer based robots.

In this paper, we propose a method for automating high-tensile bolt fastening using a hydraulic dual manipulator. Our approach aims to address alignment challenges without complex sensing systems, potentially offering a solution for bolt fastening in industrial applications. We introduce a two-step process that attempts to leverage the manipulator's compliance for bolt connection.

2. System Configuration

To automate bolt fastening using an impact wrench, we used ARMstrong [1] a heavy-duty hydraulic-based dual-arm mobile manipulator being developed by the Korea Atomic Energy Research Institute (KAERI) Extreme Robotics Team. ARMstrong is a mobile dual-arm robot with a payload capacity of 100kg per arm, with each arm having 6 + 2 (gripper) degrees of freedom.

For the impact wrench, we selected and used the DeWALT DCF892, which is easily available in the market. To control the trigger of the impact wrench, we integrated a Dynamixel MX-28 servo motor. These

Fig. 1 ARMstrong, the hydraulic dual arm mobile manipulator

components were combined using a custom 3D-printed jig and mounted on ARMstrong's gripper.

To connect the tool head and the bolt, we used *ROS* (Robot Operating System)[2] and its planning framework, *MoveIt!*[3] We used the *Pilz Industrial Motion Planner* from *MoveIt!* to generate linear trajectories in cartesian space.

3. Fastening Process

The challenge in automating bolt fastening lies in precisely aligning the tool head with the bolt in terms of position, posture, and rotation. Our open-loop approach, which doesn't rely on feedback inputs like vision or haptics, inevitably leads to some misalignment.

To address this issue, we developed a two-step fastening process:

1. Initial Alignment: We first align only the position and posture of the tool head with the bolt, without focusing on rotational alignment.
2. Adaptive Insertion: We then slowly rotate the impact wrench while attempting to insert the tool head into the bolt. This step leverages ARMstrong's inherent compliance.

The key to the success of this process lies in the compliance distributed throughout ARMstrong's structure, from the tool head to the mobile base. If perfect

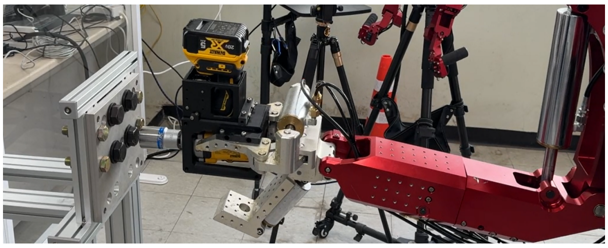

Fig. 2 Experimental setup for the hydraulic dual-arm manipulator system

alignment is not achieved in the first step, the system's compliance allows the tool head to adapt its position and orientation. As the impact wrench rotates, the tool head moves in a cycloidal trajectory, effectively "searching" for the correct alignment with the bolt head. This process continues until proper engagement is achieved and the connection is made.

This approach demonstrates the potential for robust bolt fastening without requiring precise initial alignment, opening up new possibilities for automation in construction and maintenance tasks.

4. Conclusions

This paper presents a novel strategy for automated bolt fastening using a hydraulic dual-arm manipulator. Our approach leverages the system's inherent compliance to achieve successful connections without requiring precise initial alignment between the bolt and tool head. This method shows promise for improving the efficiency and reliability of bolt fastening operations in various industrial applications.

The current implementation operates in an open-loop configuration without feedback input, limiting its adaptability to new environments. Our future research will focus on integrating feedback systems (vision and haptic sensors) and developing advanced control algorithms to enhance the system's capabilities. We also aim to evaluate performance under a wider range of conditions and explore human-robot collaboration scenarios. These advancements will contribute to developing a more robust and widely applicable system for automated bolt fastening in construction, maintenance, and manufacturing industries.

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