Robotics for Electric Waste Recycling: Vision-based algorithms for safe Human-Robot collaboration.

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Abstract

In recent years, sustainable waste management has become a critical focus, emphasizing the need for advanced technological solutions within the circular economy framework. The transition towards a circular economy aims to significantly reduce waste by continually using resources through design principles that emphasize longevity, renewability, reuse, repair, re-manufacturing, and recycling. This paradigm shift is crucial for addressing resource scarcity and environmental sustainability. Robotics is contributing to this transition, enabling precise and efficient waste sorting and processing.

This work explores the integration of vision-based algorithms in a collaborative robotic workcell, specifically targeting the disassembly of large electric and electronic waste. The objective is to enhance the disassembly process by employing robots working together with human operators, improving disassembly efficiency. A case study of an electric vehicle battery was examined to identify the disassembly tasks and determine the optimal robotic solution for these activities. This analysis led to the selection of a mobile manipulator as the most suitable solution for the disassembly process, and to the identification of vision systems for the control algorithms of the robots. A dynamic model of the robotic system was developed to monitor the interaction between the two robots and their movements within the workspace and the collaborative cell. Particular attention was given to developing the model for the mobile robot, and to the forces exchanged between the wheels and the floor. The research delved into the development and implementation of collaborative robotics algorithms, including gaze tracking for robot control and collision avoidance algorithms. A gaze tracking system was studied and tested to enhance human-robot interaction by enabling the robot to respond to the operator visual focus. The collision avoidance algorithms were developed for both the mobile robot and the anthropomorphic robotic arm, ensuring safe and efficient operation within the collaborative workspace. These algorithms were tested in simulation environments and validated through experiments using a TurtleBot for the mobile robot, and a UR5 robotic arm.

The optimal mobile robot and robotic arm were chosen, together with the vision systems. The practical implementation of the collaborative robotic cell for electric vehicle battery disassembly were carried out through detailed experimental setups and tests. This included the integration of vision systems, precise localization techniques, and effective collision avoidance algorithms. The experiments were divided into three main categories: collision avoidance between the mobile robot and the human operator, precise positioning of the robotic arm relative to the workbench, and collision avoidance between the robotic arm and the human operator. The results from these tests demonstrated the system potential to support complex disassembly tasks safely in industrial settings. In the final experimental phase, the focus was on the practical application of the developed algorithms in a real-world scenario. The mobile robot's path was optimized to avoid collisions with human operators, in a predictable way, and the anthropomorphic robotic arm was tested for its ability to continue tasks without interruption despite human interference. The effectiveness of the localization algorithms was verified by the robot capability to accurately position itself and perform precise tasks.

The results confirm that the combination of advanced vision-based control and collaborative robotics can significantly enhance the efficiency and safety of large electric waste disassembly processes. They also demonstrate the applicability of these technologies for performing operations that cannot be fully automated on large-scale systems.