Augmenting Human-Robot Collaboration for Real-Time Path Optimization

FERNANDO MOREU, KAVEH MALEK and SOLOMON ATCITTY

ABSTRACT

This paper describes a new framework for interaction between humans and robots, focusing on bidirectional data sharing between them in manufacturing environments. The research includes the integration of sensing systems through an Augmented Reality (AR) interface, which functions as a medium for sharing real-time information between humans and robots. One direction of information transmission involves humans communicating inputs such as tasks or interventions to the control systems of robotic mechanisms using hand-gesture and voice-command recognition offered by the AR interface. In the other direction, humans can perceive the robots' intended motions and actions before execution in three-dimensional holograms created through light diffraction via the AR platform. The new bidirectional interaction integrates human inputs with robots' control strategies and to enhance human perception of the robotic setting, where humans and robots can better coordinate their operations. Humans use AR to visualize robotic paths and understand their tasks for safety and oversight. They can make decisions by selecting, modifying, or approving robotic actions. Robots, equipped with kinematic, dynamic, and path-planning algorithms, generate path recommendations based on the task requirements, which humans can evaluate and use to make final decisions. The human perceives and evaluates paths calculated by the robot and can select those that meet specific priorities, such as safety or efficiency.

Fernando Moreu, Associate Professor, Department of Civil, Construction, & Environmental Engineering, University of New Mexico, 210 University Blvd., Albuquerque, NM, U.S.A., 87131 U.S.A.
Kaveh Malek, Graduate Student, Department of Mechanical Engineering, University of New Mexico, 210 University Blvd., Albuquerque, NM, U.S.A., 87131 U.S.A.
Solomon Atcitty, Graduate Student, Department of Mechanical Engineering, University of New Mexico, 210 University Blvd., Albuquerque, NM, U.S.A., 87131 U.S.A.

BACKGROUND

The use of Augmented Reality (AR) for robot controls enhances the value of human in the loop. AR in manufacturing, particularly for online robot programming, is being investigated for its capacity to enhance adaptability to environmental variabilities and task execution. Current explorations into AR interfaces are examining their ability to facilitate operator interactions with robots, including the manual adjustment of virtual objects' positions and orientations for task execution. However, research is still in the early stages, with emerging studies identifying areas needing improvement, such as the fidelity of interactions, the smoothness of rotational transitions, and the accuracy of path mapping [1], [2],[3]. These identified gaps indicate a field of research dedicated to refining AR interfaces to overcome these challenges, aiming to push the boundaries of current capabilities in smart manufacturing and robotic programming (Figure 1).

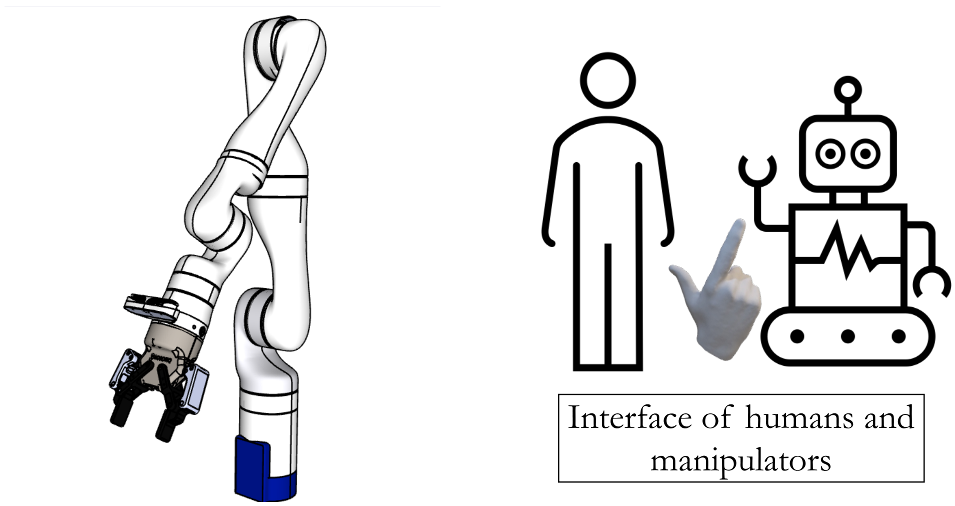

Figure 1. Machine collaboration with humans: (a) Kinova robot arm: (b) interface for interfacing humans and Kinova remotely.

Our preliminary investigations have contributed to this growing field by developing an AR interface for the intuitive control of a robot arm, with an emphasis on such as enhancing dynamic interaction fidelity, smoothing rotation progression, and quantifying path accuracy. This study introduces an AR interface for online programming and data visualization. This study, presented at the 14th International Workshop on Structural Health Monitoring (IWSHM) [4], shows the potential of AR in enhancing the reliability of robotic operations through human-guided interaction, laying the groundwork for further exploration into AR's capabilities and limitations within manufacturing environments.

PROPOSED WORK

The research team developed a new platform that interrelates the human visualization of robot activity which is connected on real-time with the control of robots or machines. The work identified new human-centered control theory where the optimal outcome of automation depends on the human intervention (Figure 2).

Researchers developed a platform that integrates AR with machine control to facilitate a more intuitive interaction between humans and robots within manufacturing settings.

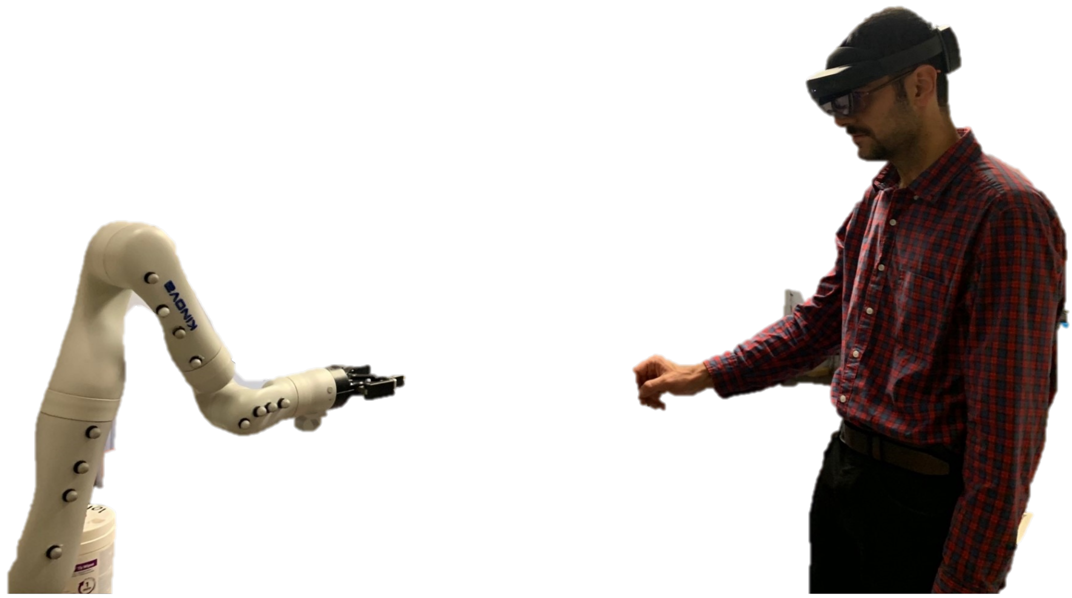

Figure 2. Machine collaboration with human using AR.

MODELING A NEW HUMAN-CENTERED INTUITIVE CONTROL OF MACHINES IN THE CONTEXT OF MANUFACTURING

The process begins with users arranging AR objects to represent task-specific requirements, such as aligning a holographic gripper with a physical object for a pick-and-place operation. This is followed by a tracking mechanism estimating the positions and orientations of these AR objects, with commercial AR devices like Microsoft HoloLens providing the necessary technology for tracking.

The subsequent steps involve the AR device communicating these spatial details to a computational unit, which then updates the control code for the manipulator. This includes converting the spatial data to the robot's coordinate system, enabling the robot to interpret and act on the data. Planning the robot's movement and rotation trajectory based on this data and simulating the robot's configurations to follow the planned path, are crucial components of this process.

This task encompasses designing the system architecture, programming the interaction and control algorithms, conducting tests to refine the interaction between the AR interface and the robot, and experimenting with different scenarios to evaluate the system's efficacy. The goal is to ensure that the platform enables users to control robots efficiently and intuitively, enhancing the flexibility and adaptability of manufacturing processes.

DATA-VISUALIZATION OF MACHINE INTENTION

This task focuses on advancing the visualization of machine activities and intentions to improve human-robot collaboration. The objective is to develop an informative interface that can provide users with real-time feedback on the feasibility and status of robot tasks.

This involves creating visual alerts and indicators for scenarios where a task may be beyond the robot's capabilities or when there is a disconnection between the robot and the control interface. By providing clear, immediate feedback on issues such as unreachable positions or system disconnections, the interface aims to enhance the decision-making process, enabling users to make informed adjustments to tasks or system configurations promptly.

The research activities included the design and development of the interface, programming it to accurately reflect the robot's operational status and task feasibility and testing it in various manufacturing scenarios to ensure its effectiveness. Experiments were conducted to evaluate how the interface influences the interaction between human operators and robots, specifically looking at improvements in task efficiency and reductions in error rates. The goal was to create a user-friendly system that supports operators in managing and optimizing robot-assisted manufacturing processes, thereby enhancing overall productivity and safety (Figure 3).

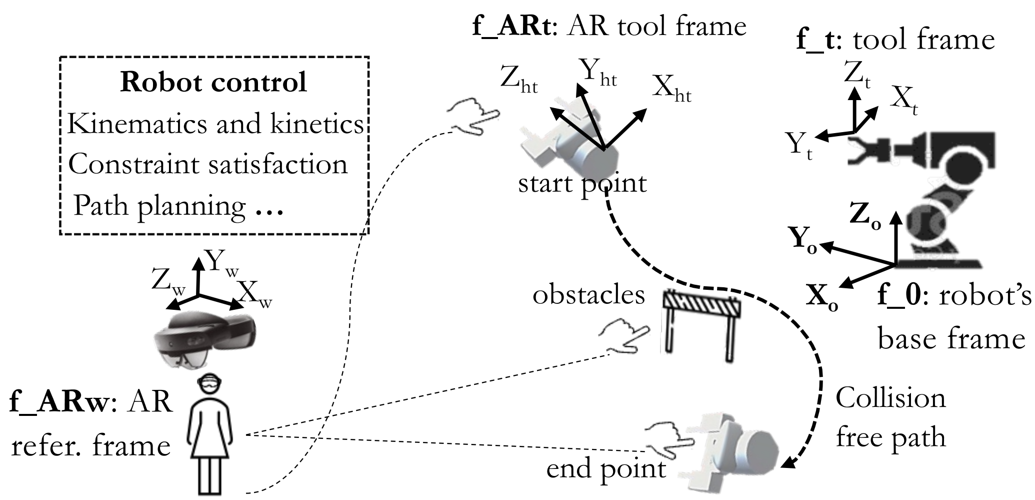

Figure 3. AR-human-machine collaboration architecture

FUTURE WORK

The PIs will develop a new platform that is centered in the human factors and workforce components that will be the backbone of the human-in-the-loop control in the shop. The new theory involves variability of understanding of physical and digital models based on the workforce performance (you can expand on your theory of human-centered AR)

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