System for robotic manipulator programming in Mixed Reality

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ABSTRACT

This paper describes the design, implementation, and results of our research project on the system to autonomous interactive programming of robotic manipulators using mixed reality. The developed system is based on mixed reality glasses connected to robotic manipulators. It permits to determine the real location of a robot through the analysis of a point cloud. The system allows users to use virtual tools and menus to create a geometric path for robot movement and for generating a motion trajectory. The trajectory can be reproduced as a virtual simulation in mixed reality glasses or performed on a real manipulator. Path creation tools also enable the scaling of virtual and real objects for more accurate planning. The proposed approach was tested on the UR10e and KUKA iiwa robots when performing contact operations and moving objects. The full paper was accepted for publication at International Conference on Robotics and Automation (ICRA) 2020.

KEYWORDS

mixed reality, human-robot interaction, robotic manipulators

1 INTRODUCTION

The purpose of this study is to examine the human-robot interaction based on mixed reality technologies. The main object of research is the process of programming industrial manipulators using mixed reality glasses. To define the latter, we see mixed reality as a combination of real and virtual worlds [3], where both real and digital worlds co-exist and interact in real-time. Mixed reality has several benefits for robotics according to [2]: spatial flexibility, elimination of safety risks, simplification of debugging, unconstrained additions to robots, scaling up swarms. Overall, mixed reality can provide many advantages for research and development in robotics, particularly robotic manipulators. Rosen et al. [6] found that a mixed reality interface can improve an operating robot process in terms of time-consuming and collision prediction.

Programming of manipulators comprises several stages. First, the geometric path is planned for the movement of the robot end-effector (EE), that can be done concerning various coordinate frames. Then, the path is converted into the trajectory for each joint. It is fair to say that the initial path can also be set in the form of a sequence of positions of robot joints. Finally, the robot executes the motion trajectory. In our work, we focused on the stage of geometric path planning.

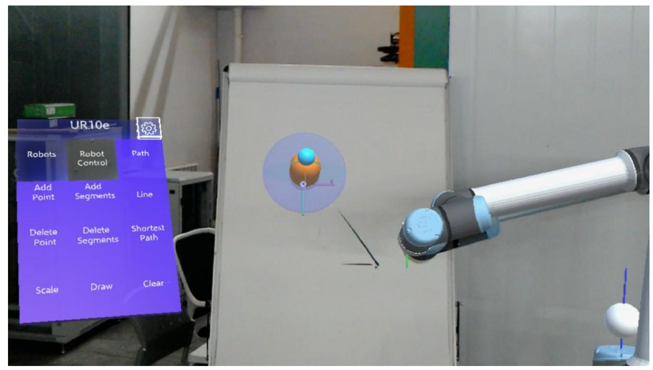


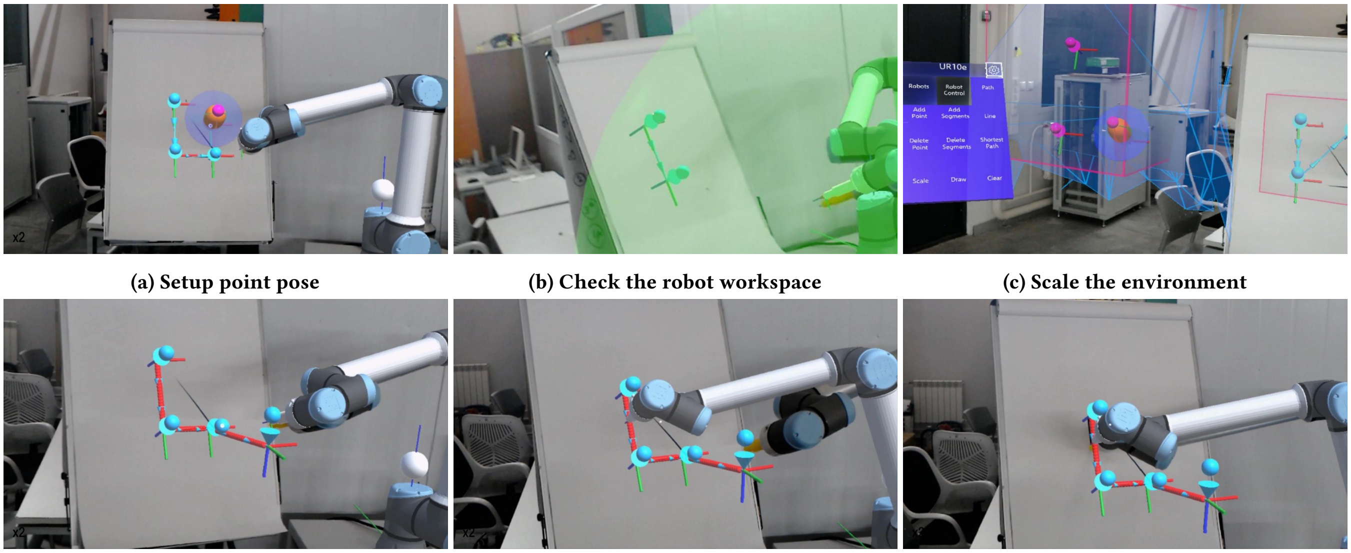
Figure 1: System for robotic manipulator programming in Mixed Reality

During the path planning, a user needs to create a sequence of poses for the robot EE. In the classic way of interaction with industrial robots, this sequence is set manually using the robot control tablet. To be more specific, it is necessary to bring the manipulator to the desired position and save it, or enter a position in text form. Both variants are quite time-consuming in setting or debug. We implemented the approach described in [1, 4, 5], where the user creates a path using holograms in mixed reality glasses. The user sets the holograms in the desired location, thereby setting the position and orientation for the robot EE. This approach allows for combining and accelerating the process of installation and points verification, because a person instantly sees the resulting path through the glasses.

Our contribution is the development of the system for programming robots with different kinematic structures and enrichment it with several special capabilities: first, the automatic determination of the robot position in space by analyzing point clouds; second, the simulator for robot movements with the gripper state; third, algorithms for finding a way around obstacles in joint and Cartesian spaces; fourth, the function of scaling part of the path for greater accuracy; fifth, visualization of the workspace of the robot. Figure 1 shows an example view in the system for robotic manipulator programming in mixed reality.

2 RESULTS AND DEMONSTRATION

The developed system consists of an interface on Microsoft HoloLens, ROS Kinetic and robots. HoloLens is a mixed reality glasses that



(a) Setup point pose **(b) Check the robot workspace** **(c) Scale the environment**

(d) Geometrical path **(e) Simulation** **(f) Execution**

Figure 2: The basics steps of using the system for robotic manipulator programming in mixed reality

we used for interaction and user action recognition. ROS Kinetic provides communication between the system components. Robotic manipulators UR10e and KUKA iiwa LBR 14 execute the program.

We verified the robotic manipulator programming system in 2 scenarios: contact operation, pick and place operation. As a contact operation, the robot drew with a marker on a non-horizontal plain surface. To test pick and place operation, the robot moved a cube and avoided obstacles during the process. In that paper, we show the sequence of screenshots from the grasses during the contact operation (Fig. 2). To demonstrate drawing on a plain surface, we selected the UR10e robot with 6 degrees of freedom and attached a marker tool to that robot.

Setup. The user launches the application, selects the robot, and starts the algorithm in order to find the robot in the environment point cloud. It is crucial to note that the robot model is configured according to the joint position of the real robot. After comparing the virtual UR10e model with the real robot, the user needs to configure the tool, its model is preloaded into the application. After completing the settings, the user starts programming the manipulator.

Geometrical path planing. The user sets the geometric path for the EE movement. In cases with a contact operation, the user places points directly on the plain surface (Fig 2a). This is achieved by installing holograms on the surface of Spatial Mapping in HoloLens glasses. Points can be connected in various ways according to standard robot movement between frames, specially PTP and LIN. After the completion of the path creation (Fig. 2d), the user sends the path to trajectory planning.

Simulation and Execution. The resulting trajectory can be reproduced using a virtual simulator with glasses of mixed reality (Fig. 2e). If the trajectory satisfies the user, then he sends it to the robot for execution (Fig. 2f). The system processes all these interactions through the menu.

Special features. In addition to the interaction described above, the user can see the workspace of the robot (Fig. 2b). This increases safety because usually a user does not see where the robot can move. This also makes it possible to understand the reachability of the path. Moreover, our system has the ability to scale the path, which allows for more accurately set points (Fig. 2c).

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