Place and Sort 4 DoF Robot Manupilator in a Warehouse

Ahmed Daw *52-6444* Nabil Hassan *52-11233* Amr Mahgoub *52-12977* Mohamed Yasser *52-12906* Mohamed Ashraf *52-17791* Yassin Eissa *52-20855*

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I. Introduction

Robotic manipulators have been extensively used across a wide range of applications, from warehouses, medical service robots, factories and various other industrial applications, contributing to the global shift towards automation in industrial processes and aligning with the objectives of Industry 4.0, enhancing functionality, efficiency and scalability, making robot manipulators a cornerstone in the ongoing smart manufacturing revolution.

The field of robotic manipulators is a well-established area of research, particularly in industrial applications. They are extensively employed in the majority of factories and warehouses operated by some of the world's most influential conglomerates. From automotive giants like Toyota to cutting-edge healthcare facilities such as the pharmacist robot at Dubai Hospital.

One of the most common industrial applications of robotic manipulators is the pick & place manipulators, where two manipulators collaborate in order to move an object from one place to another, whether for further machining or delivery, when used in warehouses, sorting the boxes, or containers is also a common application, where the 2nd robot is able to arrange the received containers according to different criteria, such as colour, size or material.

In our application, we aim to sort objects based on colour, using either a set of push buttons to let the robot know which trajectory should it take, along the lines of blind sorting, where the robot by itself is unable to detect the colour of the container, but from a user input, it is able to pick a box from a preset point on the path, travelling in a set of pre-defined trajectory, reaching a preset final destination, and placing the container there.

II. Literature Review

The "Pick and Stow (Place)" problem is one of the more classical robotics problems, where it has been thoroughly investigated by researchers over the last few decades [1], as they are extensively employed in the majority of the factories and warehouses of the most impactful conglomerates across the globe, as on the contrary to conveyors and traditional sorting machines, robots have proved to be more efficient in transporting items within a warehouse environment [1].

Despite their effectiveness, there lies a set of challenges, mainly in control and trajectory planning. In their research, Prakash et al, 2020, proposed a dual-loop optimal hierarchical control scheme for robotic manipulators, which consists of an outer and an inner loop, where the outer loop provides the joint velocity reference signal to the inner loop, where kinematic control is formulated as a closed loop optimal control to generate trajectories, where the desired target can be determined using the feedback from the actual robot state, and the kinematic control is obtained by a closed-form analytic solution of the Hamilton-Jacobi-Belhlman (HJB) equation [1].

Martinez et al, 2015, have studied the bin picking problem from a computer vision perspective, by integrating a vision system with the robotics system, where that system is used to locate and validate if the located bins are pickable, signalling for the chosen ABB IRB2400 robot to pick the bin and correctly place it in the desired location. The team also showcased the tool design and calibration process, where the final designed tool had one gripper, despite the ability of the vision system to detect multiple bins simultaneously, however, increasing the number of grippers increases the risk of collisions, moreover, the researchers have designed a compliant tool component to facilitate smooth gripping, this component is made up of a gas filled device that is used to compensate the potential collisions between the tool and the part [2].

Borkar et al, 2017, have designed a pick and place robot to transfer a water container using a gripper end effector, where there is established wireless communication between the mobile robot and the mobile base station, the two most important tasks in their project were programming the AVR on both stations, where they used Atmega16, and the programming of the Graphical User Interface (GUI). The researchers calculated that the maximum weight the arm can carry is 4.95kg, based on the calculations using the DC motor values and the generated torques. A 2-fingered gripper was also used as an end effector, in the case of using soft material finger pads, the grippers can be modeled based on the exerted force, to avoid slippage as follows:

$$\mu n_f F g = w \tag{1}$$

where μ is the coefficient of friction between the work part and the fingers, n_f is the number of fingers contacting, Fg is the gripping force and w is the weight of the grasped object.

If the weight of the work part is greater than the force applied to cause the slippage, equation (1) must be changed by adding a g factor to the weight [3].

Kumar et al, 2017 have designed and developed an automated pick and stow for an e-Commerce Warehouse, where in their paper, they provided details about the main modules to accomplish this feat, from the perception module, to the planning module, the calibration module and the gripping and suction system. The perception module is responsible for recognizing query items and accurately localizing them in the 3-D workspace, the planning module in this paper, focuses on motion planning, which is used when internal access to the motor controllers is not available, motion planning provides suitable joint angle or velocity trajectories required to take the robot from one pose to another. The designed robot is able to avoid obstacles, using path planning algorithms, the pick sequence is primarily involves 4 steps as shown in Fig 1, this sequence is carried out using a set of pre-defined joint angles, since these poses do not vary with time, however, pre grasp motion and post grap motions are carried out using RRT algorithm, as the desired pose required for grasping varies by object, therefore, real time planning is required.

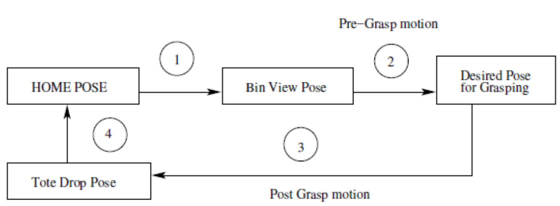

Fig. 1. Sequence of motion planning picking task

For the gripper design, the team combined a parallel jaw gripper with suction system, where the suction was only used when jaw gripping was not possible, the gripper uses a single actuator, which utilizes rack pinion mechanism to achieve linear motion between the fingers. The robot manipulator model was carried by computing the forward kinematics of the system, by deriving the D-H parameters for the UR5 robot. The inverse kinematics were solved for using the forward kinematic model [4].

George, 2017 has proposed a robotic arm system with a set of improved technicalities, such as an improved wireless communication and soft catching gripper. The robotic arm can be controlled via android based smartphones or tablets. The robotic arm was implemented using Arduino Mega 2560 micro-controller, which enables Bluetooth based communication between the robotic arm and the user's phone [5].

References

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