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INCREASING THE EFFICIENCY OF UNIVERSAL ROBOT 5–BY THE INTRODUCTIONOF FIDUCIAL MARKERS

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INCREASING THE EFFICIENCY OF UNIVERSAL ROBOT 5–BY THE INTRODUCTION OF FIDUCIAL MARKERS

by

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Working on this project has not only provided me with great learning experience, but also taught me about teamwork and time management. I am thankful to everyone involved.

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ABSTRACT

INCREASING THE EFFICIENCY OF UNIVERSAL

ROBOT 5–BY THE INTRODUCTION

OF FIDUCIAL

MARKERS

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Faculty Mentor: Christopher McMurrough

Even though the UR5 robot was developed for industrial purposes, it has not been efficient enough to replace human workers in warehouses and factories. The main theme of this project is to increase the change the working practice of robot by detecting the fiducial markers and using it as a source to pick up the envelopes. Once the robot is able to detect the fiducial markers placed on the envelope, the robot will locate it and then move towards it, use suction to pick up the envelope and move it to another location as desired (a box in our case). This technique is simple and more effective than detecting an envelope itself on a moving conveyor and has higher efficiency. It can also detect multiple fiducial markers and differentiate what actions to take on the envelopes based on the position of fiducial markers. This technology can be used in postal services where there are hundreds

of mails to be delivered. In addition, this technology can also be used with bigger machines who are designed for pick up and drop of heavier objects as well and will produce good results.

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CHAPTER 1

INTRODUCTION

1.1 Robot Arm and its Components

UR5 is a lightweight, adaptable industrial robot which is used to pick and organize boxes and envelopes in warehouses and industries; however, it cannot pick up heavier boxes above the weight of 11lbs because of its small size [7]. Additionally, it is slow, fixed to the table, and has a high rate of error. While the UR5 is easy and fun to use for academic experimental purposes, it is not yet used in the industrial market because of the lower level of efficiency.

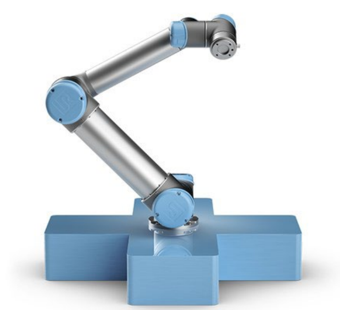

Figure 1.1: A Universal Robot 5 Robot

The senior design project involved only bin picking, however, for the Honors project fiducial markers were added to make the robot more efficient. Though the robot was able to pick and drop any object up to the wight limit, its efficiency is very slow. After the introduction of fiducial tags, the robot was able to move around efficiently and produced promising results.

For this project, some other devices along with the UR5 robot. The hardware components that were utilized include the D400 camera, a 3D printed suction tube, and the vacuum. For the software components, OpenCV, Python and the ROS Melodic were used. ROS was used to communicate with the robot through the python scripts and used OpenCV to edit, alter and work with the images taken from the D400 camera.

1.2 Introduction to the Project

Replacing a human with a machine that will have much less risk and higher performance seems like the perfect idea at first but reaching that point of perfection proves difficult. The purpose of the project is to increase the efficiency of UR5 robot for the pick-up and drop of technology. The robot was originally programmed to detect a light-weight object and to pick it up and drop it, but it took too much time to detect and move, resulting lower efficiency. The pick-up and drop function was operational, but the movement functionality was not. The machine would come to rest after picking one object that was directly below the camera as it was difficult to track the object which was not exactly below the frame and required robot movement. Implementing the fiducial markers could potentially have a robot that could perform with a success rate of 100%.

1.3 Scholarly Review

There is a tremendous amount of research done in bin picking robots. There are many universities, and companies who are working to develop fully functioning random bin picking robots. The National Institute of Standards and Technology of USA is carrying Agile Robotics for Industrial Automation Competition since 2017, aiming to solve the domain challenges related to the UR5 robot [3].Similarly, in the paper published by IEEE, a universal software framework with the focus on virtual Bin-Picking was presented, where utilizing a generic approach this framework enables the integration of various algorithms for recognition, motion planning, different types of robots, grippers, and vision systems [4]. Additionally, the International Conference on Intelligent Robots and Systems held in 2010 approached the bin-picking issue by applying the latest state-of-the-art hardware components, incorporating an environment model, and allowing for the physical human-robot interaction during the entire process [2]. At another robotics conference in Karlsruhe, Germany, an applicable solution was presented for the bin-picking problem which was based on a standard 3D-sensor and was able to handle arbitrary objects [1]. Bin-picking is so complex, specialists have attempted to apply deep-learning techniques, but the results have been disappointing, at least for industrial use [5].

CHAPTER 2

METHODOLOGY

To increase the efficiency of UR5 robot, which is helpful for tasks like bin picking, grabbing, and dropping objects, the team decided to use envelopes and conveyor belt for the project. The team had multiple yellow envelopes coming in on a conveyor belt, like real case scenario in warehouses and postal services, and the UR5 robot would detect the envelopes. After detecting the envelopes, it would then pick it up and organize it in a box. However, unsatisfactory results were produced in this experiment for several reasons. The team could not make the robot understand the difference between two envelopes, and hence could not do different tasks with the envelopes like organizing one envelope in one box and moving another category to another box, for example. Since the movement of the robot was slow, the speed of conveyor belt was decreased to match the robot's movement, resulting in halting after each pick up.

For the honors project, the idea of using fiducial markers on envelopes was suggested by the project mentor, Dr. McMurrough. Fiducial markers are like QR codes, only simpler as they do not have any encrypted message in them.

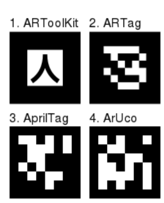

Figure 2.1: Four Examples of Fiducial Markers

The fiducial markers found online were printed and glued on to the envelopes [8]. Python script code and libraries were used to make the robot understand and look for fiducial markers and return the exact location in 3D coordinates through OpenCV. In doing so, the robot could recognize and track the envelopes marked with the fiducials on the conveyor belt. ROS and Rviz were then used to convert the pixel coordinate that was returned by the OpenCV to the real-world 3D coordinates. The 3D coordinates then guide the robot to where the envelop lies so it can pick it up.

The program is user-friendly, and the same technology can be used to complete a multitude of tasks. For instance, there can be multicolored envelopes used so the robot could identify and separate the envelopes while organizing them in different boxes based on color. Since the robot is separating the envelopes based on fiducial markers, it can separate envelopes with same color when they have different fiducials. This technology can be used in postal services where there are hundreds of mail pieces that need to be transported to different location and then sorted by a robot, and then can collect these envelopes in different boxes based on fiducial markers with perfect accuracy.

CHAPTER 3

CONCLUSION

The results of the experiment were close to 100% accuracy. The robot was able to detect the fiducial markers and the envelopes within the camera frame, and the robot moved to the location within 20-pixel error bound. The error bound does not matter in this case because the envelope is larger than 20 pixels.

However, there were some cases in which the technology could not provide accuracy as required. For the technology to work, the fiducial markers should be placed exactly in the middle of the envelope or as close to the middle as possible. If it is placed around the corners, the robot will get the coordinates of the corners and will try to grab the envelopes from the corners using the suction tube. This will not work as the suction tube and the vacuum will not be balanced to hold a bigger envelope from the corner for the time it takes to reach its destination. In such scenarios, there is a good chance that the robot will drop the package before it reaches the destination.

For cases where the fiducials are not found in the envelopes, the user can also hover the mouse pointer over the envelope to get the location of the envelope in the middle where the fiducials should have been. The user can then manually enter the pixel coordinates of the location, and the program will change the pixel coordinates to the real-world coordinates and the robot will move to the 3D coordinates and grab the envelope at those coordinates.

This technology still has limitations despite a greater accuracy of bin-picking technology. The robot is designed in such a way that its arm is not very smooth, so it is very slow. The robot can be used in the industry with limited work. Even though the robot will be able to outperform human in terms of accuracy, it will not outperform human in terms of speed as it currently operates.

This technique of fiducial markers can one day be used to make robots more intelligent. While it may seem farfetched, the robots can be programmed to keep track of all the fiducial markers as well as human assistance. Upon introducing Machine Learning and Artificial Intelligence (AI) concepts to the robot, it can decide to make decisions on its own when the envelopes do not have fiducial markers. As such, there are several research avenues when considering the potential of Machine Learning and AI on a UR5 robot.

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BIOGRAPHICAL INFORMATION

Resha Adhikari is a student at University of Texas at Arlington majoring in Computer Science. She has prior experience of working as Research Assistant with Office of Undergraduate Research under the guidance of Dr. Allison Sullivan. Her responsibility was to determine the best code repair techniques for the faulty C codes from CodeFlaws Benchmark. Her areas of research include automated bug fixing, Artificial Intelligence and Machine Learning. She prefers coding in Python and has good knowledge of JavaScript libraries.

Resha is a junior and has an anticipated graduation of December 2022. She has cumulative grade point average of 3.89 and has already taken most of the advanced courses required for Computer Science. With an inclination towards Software Engineering, she has an ambition of becoming a software engineer in future.