Visual Servo Robotic Arm for Autonomous Picking and Placing

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Abstract—**This research is focused on the design and implementation of an autonomous robotic arm is a fully automated picking and placing system that utilizes webcam to detect the color and then coordinates of the unknown objects. Besides, based on the modelling of inverse kinematics, it can efficiently and precisely pick them up. After picking these objects, it places these objects into their respective bins. During this process, visual servo finds the color and then derives the position of the objects. It also acts as the main feedback to the controller and has the capability to communicate with the arm to allow it to move to the required position hovering over the object. It indicates the feasibility and effectiveness of a low cost visual servo robotic system for fast picking and placing.**

Keywords- Visual servo; robotic arm; picking and placing

I. Introduction

Robotics and machine intelligence nowadays is extremely hot in the market. The concepts and related products of robots, artificial intelligence, machine learning, etc. are very popular and still growing in industry and consciously affecting people's daily life. People are eager and interested to see the AI and robotics that can be used for practical application in industry and social life, ranging from healthcare, social media, search engine, security, market prediction, education, entertainment, medical operation, pattern recognition, legal activity, finance, transportation & logistics, and to housework [1-9].

Obviously, this tread of robots and AI will keep increasing in the following decade. Due to this reason, the research activities in this area for global academia become more and more frequent to match this trend and demand. The growing publication of this area is also a great indicator which reflects this phenomenon. However, there is still huge gap between academia and industry towards AI and robotics. This gap also has been existed with respect to the academic publication for long years. Another gap is between research and education. Currently, the robotics education has been penetrated into the primary school and high school. Of course, the university robotics education has become more and more popular. In order to meet the high demand in education, the reform of robotics education is critical.

This research is about the design and implementation of an autonomous robotic arm which can detect the color and then coordinates of the unknown objects for fully automated picking and placing purpose. Besides, based on the modelling of inverse kinematics of the serial manipulator, the visual servo acts as the feedback and has the capability to communicate with the arm to move to the required position hovering over the object. The presented work proves the effectiveness about how to control a robotic arm for autonomous picking and placing with low cost visual servo system.

II. Inverse Kinematics

Inverse kinematics means if the position and orientation of the end-effector are known, to solve the input angles of the active joints. For serial manipulator, generally it has multiple solutions [10-15].

Take a two-joint mechanical arm as an example, if the desired position of the arm is known, there are two solutions for the two joints to achieve that position in an x-y plane. However, for the robot used in real-world, there are a lot of mechanical interferences. These interferences fortunately can reduce the possibility of unnecessary and complicated multiple solutions. Still take the two-joint mechanical arm as an instance, most two-joint mechanical arm can only work above the horizontal place which constrains the mobility of the first joint which is attached to the base. For the second joint which is attached to the gripper, usually it can only rotate with less than 180 degrees which largely limits the multiple solutions.

As shown in figure 1, a Sainsmart robot used in this system is capable of 4 degrees of freedom. However, it was decided to control the sway of the robot separate from the heave and surge, to make the inverse kinematics a little easier to calculate, and to make it easier to troubleshoot. The 4th degree of freedom, sway of the end effector, was not required, as the inverse kinematics were designed to not require it.

Arduino has a servo library that can be incorporated into this design. This library allows an Arduino board to control servo motors. The servos operate between 0 and 180 degrees and can be positioned at various angles but can also be allowed to rotate 360 degrees as well. The library supports up to 12 motors. The motors can then be controlled without interfering with the PWM functionality of the pins. This library also saves programming robotic arm with multiple segments of standardized code by allowing the use of the entire library with a single call.

Figure 1: 4-DOF robotic arm

III. SYSTEM CONFIGURAITON

In order to build low-cost but efficient visual servo system, the PIXY cam is applied used for object identification and coordinates. This camera module is programmed to send only the needed information to the microcontroller. The interface of this camera module is flexible and it is compatible with UART serial, SPI, I2C and others. The built-in program PixyMon can be utilized to calibrate the colors which are required for the robot to detect. Since the brightness of the camera will affect the successful recognition rate, pre-calibration is suggested and then conducting the experiment, the visual servo based robotic system is suggested to place in room with sufficient lighting conditions.

Pixy camera can easily detect block with a color signature along with the x-y coordinate. In relation to the setup of the proposed visual servo robotic arm, x-axis corresponds to the left and right of the robot, while y-axis corresponds to the distance towards or away from the robot. Following figures shows the designed visual servo based robotic system and the related component wiring diagram.

Servo motors are widely applied for robot control. The servos in the proposed robotic arm allow the tube to move to different angles, typically ranging from 0 to 180 degrees. The Arduino include various libraries for different kinds of servo motors which can be utilized with respect to the code. Small size servo motors usually only have three wires, namely power, ground and signal. All the servos on the arm carry a red wire for 5V power which connects to the Arduino via a pin. The second wire is brown, which is the ground wire that also gets connected to the Arduino through another pin. Finally, the last yellow wire is the signal wire, which can communicate between the servo and the Arduino to position the servo to a certain angle.

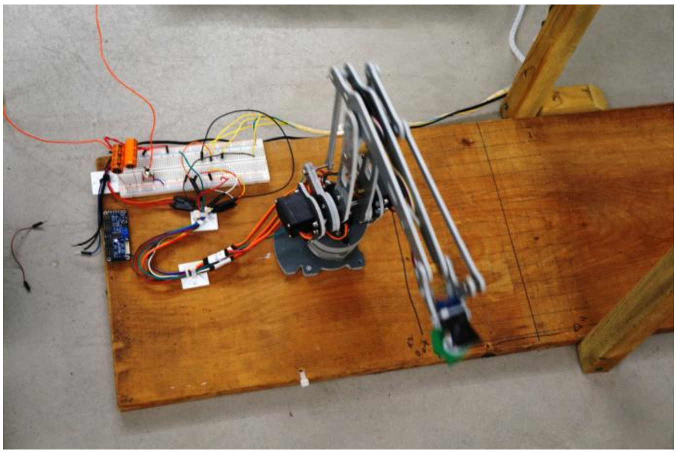

Figure 2: The visual servo based robotic system

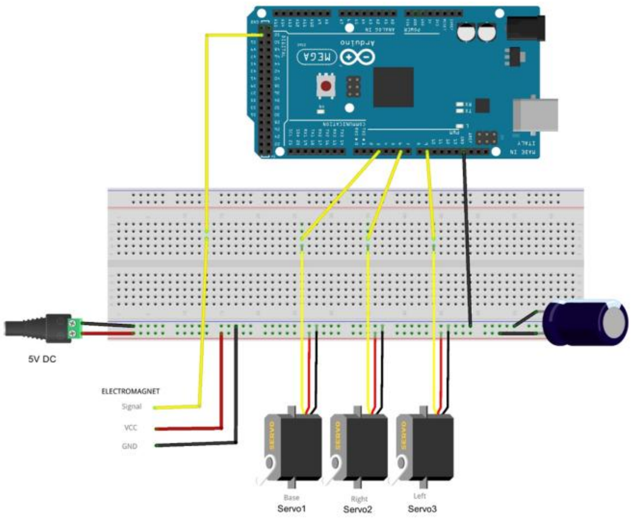

Figure 3: Component wiring diagram

IV. ALGORITHM DESIGN AND IMPLEMENTATION

The scholars in the world have conducted related research about visual servo for robot control, especially for positioning [16-21]. The basis of this research project was the how to apply the visual servo to autonomously control the robotic arm to conduct the picking and placing task. The PIXY camera coordinates of the object are X, and Y where X is the right to left span of the vision with respect to the robot base, and Y is the distance from the base of the robot outwards. The X coordinate given by the pixy camera was mapped between the corresponding angles of the servo motor, which made the robot rotate to be in line with the object. The inverse kinematics code however is calculated differently - the X coordinate in this case is the span from the base of the robot outwards. So the Y coordinate of the pixy cam was mapped to be the X coordinate of the inverse kinematics. The Y value in the inverse kinematics or "Z" was the distance above the ground, and this value was fixed. The inverse kinematics needed to be adjusted to compensate for the servo motors - a factor that cannot be mathematically solved for. A trial and error method was used to achieve this. However, it is also possible to send the inverse kinematics to the robot, and change the compensation at small intervals with feedback from the actual servo position. By recording this data it is able to find a mathematical function that would make the inverse kinematics more accurate. The following shows a flow diagram describing how the program works.

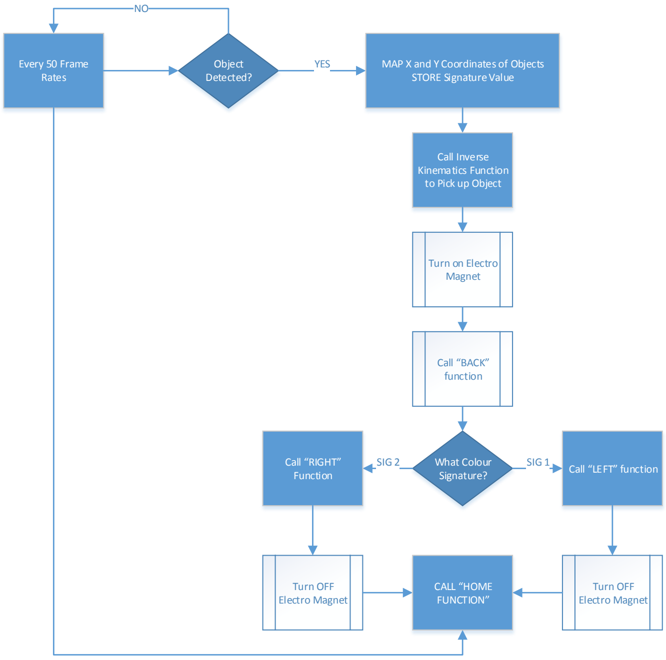

Figure 4: Logic flow for visual servo control

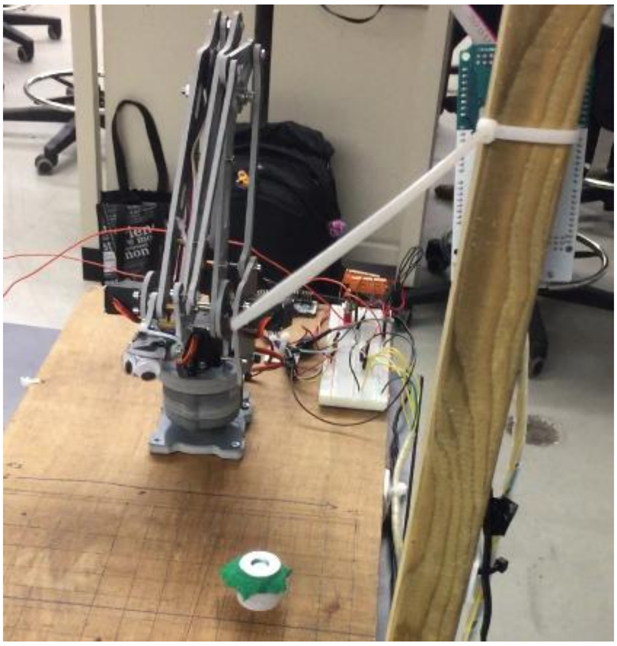

Figure 5: The setup of the experiment

Figure 5 shows the setup for the experiment of picking and placing. The camera is mounted on top of the frame to observe object and identify its location in real-time. As shows in figure 6, a unique color is used for the object. This object is randomly placed in somewhere on the platform. After calibration, the camera thus detects the object, and translates the location into values of X and Y coordinates.

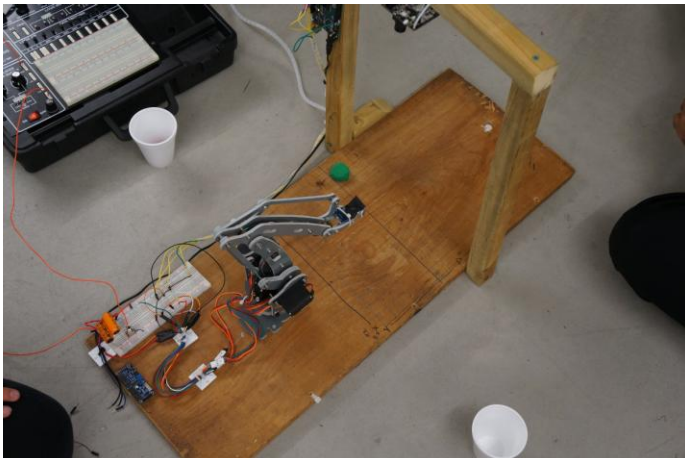

Figure 6: Motion in process

Two different colors are selected, namely green and red. If the red object is detected, the gripper will pick and place it into the bin on the left hand side. If the green object is detected, the gripper will pick and place it into the bin on the right hand side, as shown in the following figure.

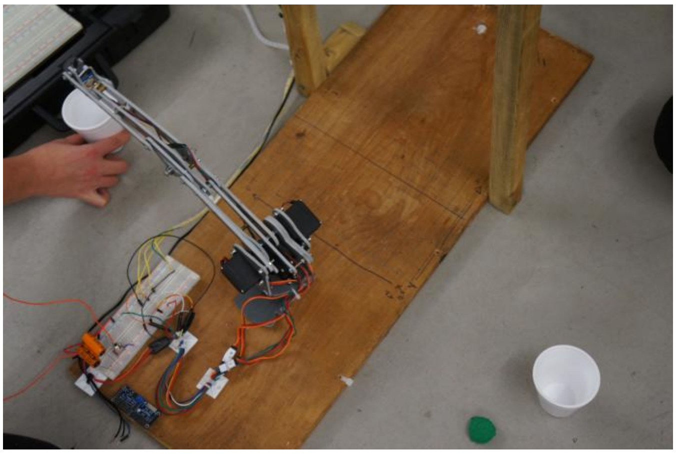

Figure 7: Take completed

V. Discussions and Conclusions

A. Discussions

Whether the robotic arm is simply used for picking and placing random objects or it is picking and sorting objects based on their respective colors, there are many challenges. One of the main challenges is the complexity behind the inverse kinematics, namely the calculation and mathematics behind finding the right position of the object from the arm's perspective. Since the mounting of the Pixy Camera was a little unstable, the final position of the object was an approximation, not an exact position. This affected our robotic arm's final position over the object as that was not able to find the exact location over the identified object. At first, the Pixy Camera itself gave the problems in which it sometimes did not detect certain colors. The camera had to been adjusted brightness for certain colors in order for them to be recognized. Since the picking and placing task should to be autonomous, the electromagnet was required to automatically pick and place the object without any human interference.

B. Conclusions

This project was innovative design. To building a prototype with programming and implementation had to be effective and efficient. The idea was to be accurate and have the robotic arm autonomously pick and place a specified object which was specified by image processing. The proposed system would seek applications that require pick and place operations with zero human interference. Specifically, the automation industry or industrial/warehouse sorting industry in which the proposed system could sort any objects that would be color coordinated. Whereas, in the automation industry it can be used at an end-of-the-line production or in-line production where it operates a simple pick and place operation. This objective is to eliminate human error and fasten processes both effectively and efficiently. In today's era, the right change is the key to any successful project and it can provide this change to the real world.

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