Colored Object Sorting using 5 DoF Robot Arm based Artificial Neural Network (ANN) Method

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Abstract. Automation process is very important to help any industry activity especially to sorting an object. In this research, we build 5 DoF of Robot Arm based on Arduino microcontroller to pick and place colored object intended sorting task in real-time. The algorithm of interfaces and image processing to detect the colored object based on Python 2.7 with OpenCV library. From image processing system, the detected colored object based on Red-Green-Blue (RGB) identifier has a coordinate. The coordinate data is collected to build the inverse kinematic model and trained by using Artificial Neural Network (ANN) method to control Robot Arm. Finally, the algorithm implemented to Robot Arm to do pick and place a colored object show a good accuracy rate. The advantages of this Colored Object Sorting system are Open Source and Low Cost.

1. Introduction

On this decade, the high technology needed to get an efficiency of Industrial works especially an automation of sorting objects. Industrial robots are programmed based on sensory information with accurate and precise work [1]. The sensor is required because of the object have any characteristic to sorting by a machine, such as color, shape, size, etc. And algorithm must be presented to classifying the feature of an object.

Beside geometry method [2] from the image processing, the inverse kinematic model (from the object coordinate to the angle of the motor servo) and various method of Artificial Intelligence is needed to control Robot Arm. The various method of Artificial Intelligence needs, such as Fuzzy Logic [3] [4], Artificial Neural Networks (ANN) [2] [5] [6], Adaptive Neuro-Fuzzy Inference System (ANFIS) [7] [8], and other [9]. The application of Colored Object Sorting in any field, for example: Engineering [10] [11], Harvesting [12] [13] [14], Industrial [15] [16], and other [17]. To make an Industrial Colored Object Sorting certainly very expensive to build. But, at this time the Low-Cost system of Colored Object Sorting can build by everyone using Arduino microcontroller [18] [19] or Raspberry Pi microprocessor [11] [20] [21].

In this research described an image processing of color object detection, inverse kinematic model and Artificial Neural Networks method as machine learning based on Python 2.7 with
OpenCV library. Finally, this research will be implemented to 5 DoF Robot Arm based on Arduino microcontroller to pick and place the colored object in real-time.

The paper is organized as follows: In section 2, described the general System Overview of Colored Object Sorting. Section 3, describe color detection of the object. Schematic and hardware of Robot Arm described in section 4. Building database from object color detection and machine learning which used in this paper describe in section 5. The succeed training, classifying and evaluating between trained and tested data implemented to Robot Arm doing the task to pick and place the colored object described in section 6. Finally, the concluding remarks are given in Section 7.

2. System Overview
In this study, the concept design and the realization of Colored Object Sorting system shown as Figure 1. In general, the design explains the main materials are: personal computer, webcam, Arduino board and 5 DoF Robot Arm.

Figure 1 and Figure 2 describe the general system of Colored Object Sorting. Especially from Figure 2 explained that after selecting the color the webcam will starting to detect the colored object. Then, divided into 2 processes: the First process is making training data, consists by getting the centroid coordinate of the colored object and collecting data of angle for the servo
to doing pick and place the object as Trained Data. The second process is testing the system after getting the centroid coordinate of the colored object, then the testing data of colored object matching with Trained Data. The matching data be processed to obtain the angle of servo based on Artificial Neural Network method, which used to drive the motor servo Robot Arm. All processes work in real-time based on Python (with OpenCV library) and Arduino microcontroller.

![Figure 2. General System Scheme of Colored Object Sorting](image)

3. Color Detection
The first step in designing the concept of Colored Object Sorting is designing algorithms for detecting colored objects. The algorithm and interfaces build based on Python 2.7 and OpenCV
library. To determine the color to be selected in this system in a way to configure the value of RGB color (Red, Green, and Blue).

The colored objects can be detected by image processing by capturing images and classifying color types by value of RGB. HSV (Hue, Saturation, and Value) used to reduce the influence light of the colored object. The edge of the image is optimized with "threshold", the pixels which are stronger than the high threshold value are preserved, but the weaker than the lower threshold value is suppressed. Then the image converted to binary to get the edge in a given image gets the morphological filter. Then the image filtered binary get the contour detection. Finally, only the selected color object will be marked by rectangle illustrated as Figure 3 (d). [17] In addition the detected object have a centroid coordinate \((x, y)\) position of colored object. Figure 3 show the evaluation of color detection with coordinate value of RGB object.

4. Hardware of Robot Arm
To build the Robot Arm system, the main component is Arduino board, motor servo, battery, cables and Robot Arm hardware construction (Figure 5 (b)). The schematic of Robot Arm shown as Figure 5 (a) described that each servo supplied by the 5-volt battery with 100 mA of current, and each servo’s ground connected to the ground of Arduino Board. 5 DoF Robot Arm consists of 5 motor servo connect to Arduino PWM pin, are; Servo1 connect to pin 5 (base, rotate horizontally), Servo2 connect to pin 6 (work as shoulder, rotate vertically), Servo3 connect to pin 9 (work as elbow, rotate vertically), Servo4 connect to pin 10 (work as wrist, rotate horizontally), and Servo5 connect to pin 11 (work as gripper to place an object).
5. Inverse Kinematic Model and Artificial Neural Network

Kinematics in this study mean the conversion from Cartesian coordinates \((x, y, z)\) to the moving angle of the joint \((\theta_1, \theta_2, \theta_3, \ldots)\) of the mechanical Robot Arm. Kinematic divided into two sections...
are Forward Kinematic (from joint angle to coordinate) and Inverse Kinematic (from coordinate to joint angle). \[3\]

In this study, Inverse Kinematic Model used to build the database of 5 DoF Robot Arm to pick and place a colored object on certain coordinate. The data consist of input data as \(x\) and \(y\) coordinate, and the output data of servo’s angle as Servo1-Servo5 shown at Table 1. The coordinate data received from the evaluation of colored object detection which captures by webcam. The video capture configure as 480 x 640 pixel, but the usable workspace coordinate is 467 x 624 pixel shown as Figure 6 and the Robot Arm position in the middle of the workspace. For the angle of the servo obtain when the object is in a certain coordinate, and the servo angle must be able to move to reach the object. The collected data will be used become Training data at Artificial Neural Network.

Artificial Neural Network (ANN) method is a system that works similar to the human brain. MLP (Multi-Layer Perceptron) is one of the ANN method using supervised learning method. MLP is also known as Multilayer Feedforward Networks. As the name implies, MLP can have one or more hidden layers. In this research 20 hidden layers used for ANN, illustrated as Figure 7.

All the neuron of input, hidden and output layer connected each other. The first layer (input layer) receives an input from the external environment. The between layer of input and output layer (hidden layers) invisible to the external environment. And the last layer (output layer) transmits the result from the network. \[5\]

Table 1 is the Inverse Kinematic model data consist by the coordinate data (\(x\) and \(y\)) of the colored object, and the angle of 5 servos with trained data (show as Cal=Calibration) and tested data (show as ANN=Artificial Neural Network data training) as the evaluation. The Inverse Kinematic model data trained by using ANN method. After enter to ANN training, the database becomes ”the trained data”. The trained data is a reference database to matching with the new external environment (coordinate) data until getting the new target data (angle of the motor servo).

From the Table 1, the bold data is an error value between data of Calibration and ANN result is 1.3%. The accuracy result gets from average successful data show the good accuracy rate to show the coordinate and angle of servos, and can implement to control Robot Arm to pick and place the colored object.
Table 1. The database of Inverse Kinematic Model to Control Robot Arm

| Coordinate | Servo1 | Servo2 | Servo3 | Servo4 | Servo5 |
|------------|--------|--------|--------|--------|--------|
|            | x      | y      | Cal    | ANN    | Cal    | ANN    | Cal   | ANN    | Cal    | ANN    | Cal   | ANN    |
| 1          | 116    | 70     | 100    | 100    | 116    | 116    | 175   | 175    | 0      | 0      |
| 21         | 147    | 84     | 100    | 100    | 116    | 116    | 175   | 175    | 0      | 0      |
| 27         | 67     | 81     | 107    | 107    | 133    | 133    | 175   | 175    | 0      | 0      |
| 123        | 131    | 89     | 100    | 100    | 116    | 116    | 175   | 175    | 0      | 0      |
| 143        | 167    | 95     | 100    | 100    | 116    | 116    | 175   | 175    | 0      | 0      |
| 210        | 132    | 99     | 120    | 100    | 116    | 116    | 175   | 175    | 0      | 0      |
| 223        | 231    | 100    | 100    | 100    | 116    | 116    | 175   | 175    | 0      | 0      |
| 260        | 157    | 102    | 118    | 118    | 146    | 146    | 175   | 175    | 0      | 0      |
| 283        | 245    | 104    | 116    | 116    | 175    | 175    | 0     | 0      | 0      | 0      |
| 339        | 179    | 110    | 116    | 116    | 175    | 175    | 0     | 0      | 0      | 0      |
| 367        | 228    | 110    | 100    | 100    | 116    | 116    | 175   | 175    | 0      | 0      |
| 429        | 135    | 117    | 125    | 125    | 148    | 148    | 175   | 175    | 0      | 0      |
| 447        | 214    | 108    | 110    | 100    | 116    | 116    | 175   | 175    | 0      | 0      |
| 494        | 126    | 110    | 118    | 118    | 144    | 144    | 175   | 175    | 0      | 0      |
| 508        | 197    | 110    | 100    | 100    | 116    | 116    | 175   | 175    | 0      | 0      |

6. Implementation of Color Detection to Sorting Object
After the database successfully trained by ANN method, then applied the system as control Robot Arm to pick and place the object. Figure 8 show the interface of color detection with
coordinate data and angle of servo prediction. And Figure 9 show the Robot Arm motion to pick and place the colored object. From the figures show that the colored object was successfully detected, thus the Robot Arm effective can pick and place the object.

Figure 8. Experiment Color Detection to Control Robot Arm
7. Conclusion

The study has been presented about the development of Colored Object Sorting which can pick and place colored object. The image processing has been processed by the algorithm based on Python 2.7 (with OpenCV library) to detect the colored object. The inverse kinematic database is trained by Artificial Neural Network to matching with internal database show the good accuracy. Finally, the implementation of color detection and inverse kinematic model to control 5 DoF of Robot Arm based on Arduino microcontroller works effectively to pick and place the colored object. Future works will be focus on Low Cost and Open Source system of Colored Object Sorting based on Raspberry Pi microprocessor.

Acknowledgement

The authors would like gratefully acknowledge the financial support from DIPA UIN Sunan Gunung Djati Bandung.

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