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A. Loh, S. Hu, Department of Computer Science and Information Engineering, National Taiwan University

*Abstract*— Through a combination of contour detection, color recognition, and length measurement, it is possible to program a robotic arm to autonomously detect and stack blocks into a stable structure.

# INTRODUCTION

One of the common applications of robotic arms is the assembly of parts. However, rather than manually control the arm to do this, it would be a much more efficient use of manpower to program a level of autonomy into the arm to handle certain tasks by itself. One way to do this would be to use a camera to first detect the location of objects, and then feed the coordinates to the robotic arm to process. In addition, by finding the perimeter of each detected object and also doing color segmentation in the captured images, a level of object discernment can be achieved that will allow for some manner of flexibility in how the robotic arm can differentiate each object.

# Related Work

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# Method

The methodology employed in this project can be divided into several parts: camera calibration, image capture and contour detection, color segmentation, centroid and principal angle calculation, coordinate conversion, and robotic arm control.

## A. Camera Calibration

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

## B. Color Segmentation

Color segmentation is done through the HSV color spectrum. Images captured by the camera are first converted from RGB format to HSV. The images are then put through a threshold, where the saturation and value/lightness value ranges are adjusted to reduce noise and show the target objects in as clean a manner as possible. The color segmentation part comes in when setting the hue value range to single out the four sets of colored blocks that were being used: blue, red, yellow, green. A little research was done to find that the hue values of the four basic colors were 75-130 for blue, 160-179 for red, 22-38 for yellow, and 38-75 for green. While similar, due to the given experimental setting, there’s a slight difference in the actual value ranges used.

After color segmentation, the resulting image would show white on areas of the segmented color and black everywhere else, making contour detection easier to do.

## C. Contour Detection

Contour detection is largely done through existing OpenCV’s library of functions. In particular, Canny is used to detect edges within the image, which is then processed through findContours() to get the actual contours.

To explain Canny without going into too much detail, according to OpenCV’s documentation, noise is first filtered from the image using a Gaussian filter. An intensity gradient is then made from the image, where non-maximum suppression is applied to remove pixels that are not considered to be part of an edge. Finally, an upper and lower threshold is applied on the resulting pixels, where if the pixel is below the lower threshold or not connected to a pixel above the upper threshold, it gets rejected.

findContours() takes the results and finds any contours that can be drawn among the remaining pixels. This is done, according to OpenCV’s documentation, through a border following process written by Suzuki, S. and Abe, K.

## D. Calculations

For each contour, its moment is calculated through OpenCV’s built-in function moments(), which uses Green’s theorem’s formula for doing so. By finding the moments of each contour, the centroid can also be calculated by finding the x-coordinate by dividing the contour’s moment at the coordinates (1, 0) with the moment at (0, 0), and the y-coordinate by dividing the moment at (0, 1) with (0, 0).

(Stuff about conversion to robotic coordinates)

The principal angle is found by performing PCA analysis on the original image and the set of contour points to find the eigenvectors of each contours, which is then plugged into atan2() to find the resulting angle.

## E. Robotic Arm Control

# Experiment And Results

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a. Sample of a Table footnote. (Table footnote)

1. Example of a figure caption. *(figure caption)*

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# Conclusion

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

Appendix

Appendixes should appear before the acknowledgment.

Acknowledgment

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