Robotics Lab 07

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1. Design and develop the complete vision pipeline for determining the positions of all the cubes of different color in the workspace of your robotic system. Assume that the workspace is relative uncluttered and each color has only one known cube size associated with it.
   You'll have to formulate an object detection strategy, the corresponding post-processing parameters for your strategy, and then determine the position of identified cube (see note below). You are required to submit:
   1. a note describing your object detection strategy and the rationale behind it;
   2. a list of the post-processing steps and parameters, after experimenting and determining them from Intel RealSense Viewer;
   3. aptly commented code for your vision pipeline;
   4. images at various steps of a good test run;
   5. statistics across multiple trials, including
      - number of objects of each color in the workspace to be detected
      - number of objects of each color correctly detected
      - accuracy rate for each color

Solution:
We used the connected components method given in lab manual. In this method we identify and group together pixels or regions in an image that belong to the same object i.e., we identify objects in an image by analyzing the connectivity between adjacent pixels or regions.
The connectivity of a connected component describes how its pixels or image elements are connected to each other. In the lab we used connectivity of 8 for the 2-D images. Two pixels are considered 8-connected if they are adjacent horizontally, vertically, or diagonally. In other words, the pixels can share a common side or a common corner.
The following is our code that we added at the end of the 'depth_example' function:

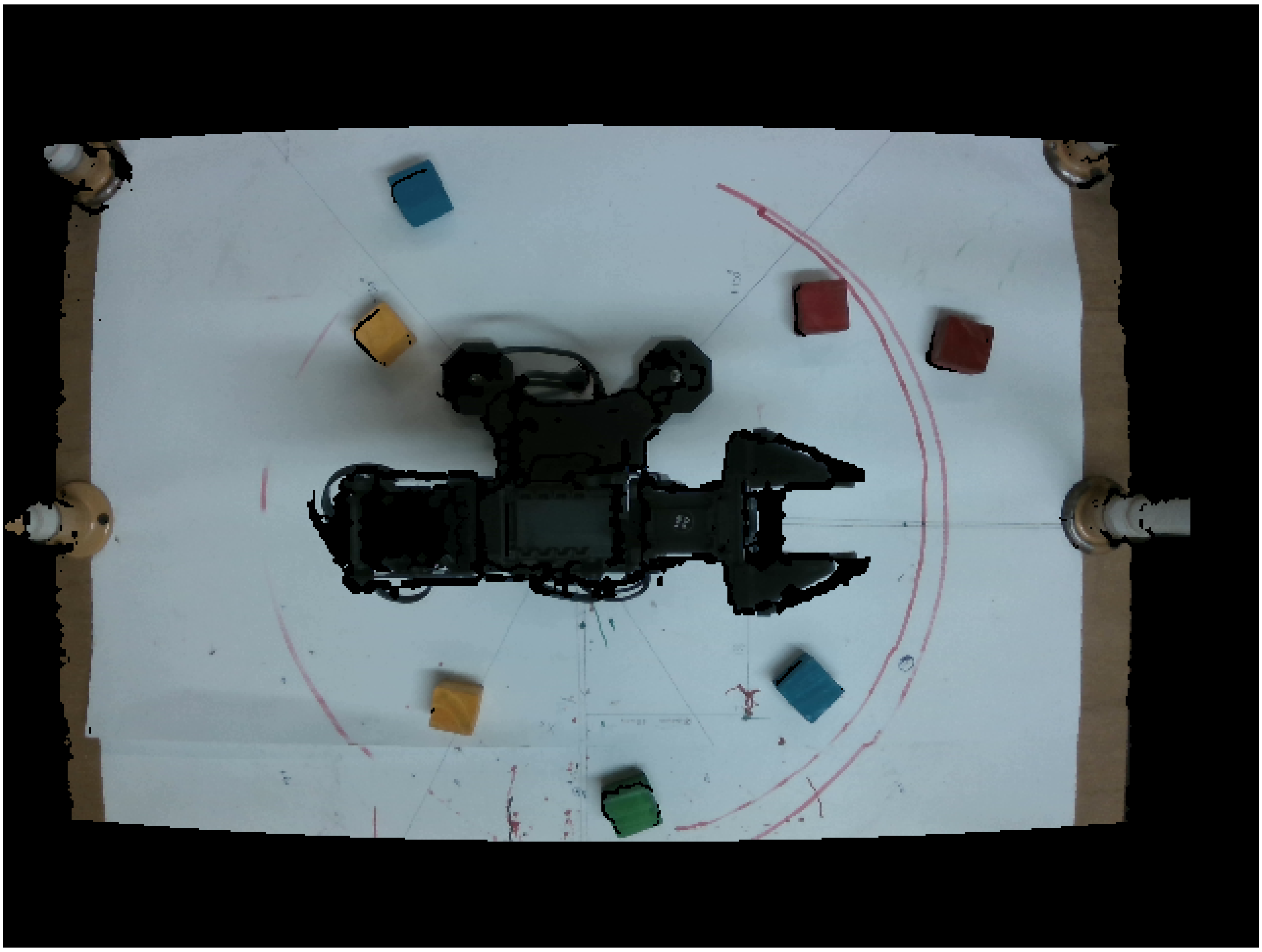
```
% show color image from camera
figure;
imshow(im)
title('color image from camera')

% binarize the image and show it along with color image
new_img = imbinarize(im);
figure;
imshowpair(im, new_img,'montage');
title('color image from camera alongside the binarized image')

% getting a b&w image with black background and white foreground/objects
bw=~(new_img(:,:,1)&new_img(:,:,2)&new_img(:,:,3));
figure;
imshow(bw)
title('B&W image with black background and white foreground/objects')

% applying the connected components function to the b&w image to get the number
    of objects in the image and their pixel data
```

```
tmp = bwconncomp(bw);

% making for loop to detect the cubes:
for i=1:tmp.NumObjects % iterating through all objects
    if ((length(tmp.PixelIdxList{i}) < 100) || (length(tmp.PixelIdxList{i}) >
        1000)) % if the value of pixels is not between 100 and 1000 then it is not
         a cube
         bw(tmp.PixelIdxList{i}) = 0; % turn the area which is not a cube object
            into black
    end
end

% showing the b&w image with only cubes in it
figure;
imshow(bw);
title('cubes detected')

% making sure we get the correct number of objects:
tmp = bwconncomp(bw); % outputs the number of cubes present in image
num_of_obj = tmp.NumObjects;

% separate rgb values from color image into 3 different variables
imred = im(:,:,1);
imgreen = im(:,:,2);
imblue = im(:,:,3);

% make 3 arrays for storing the means of rgb values for all objects
red = zeros(1,num_of_obj);
green = zeros(1,num_of_obj);
blue = zeros(1,num_of_obj);

% make arrays for storing the binary values of rgb for all objects
r = zeros(1,num_of_obj);
g = zeros(1,num_of_obj);
b = zeros(1,num_of_obj);

new_ig = ig*100; % to convert meters to centimeters

% for marking the center of each cube:
top = bw; % make a dummy variable to store the b&w image
top(:,:) = 0; % make the image completely black
% initialize array for row and column value of each object's centre point
rows = zeros(1,num_of_obj);
cols = zeros(1,num_of_obj);

% make for loop to store mean rgb values of the objects in the arrays created
   before
for i = 1:tmp.NumObjects
    red(i) = mean(imred(tmp.PixelIdxList{i}));
    green(i) = mean(imgreen(tmp.PixelIdxList{i}));
    blue(i) = mean(imblue(tmp.PixelIdxList{i}));

    % if rgb values above a certain threshold (i.e. 50) then make the binary
       value equal to 1 and otherwise 0
    if red(i) > 50
```

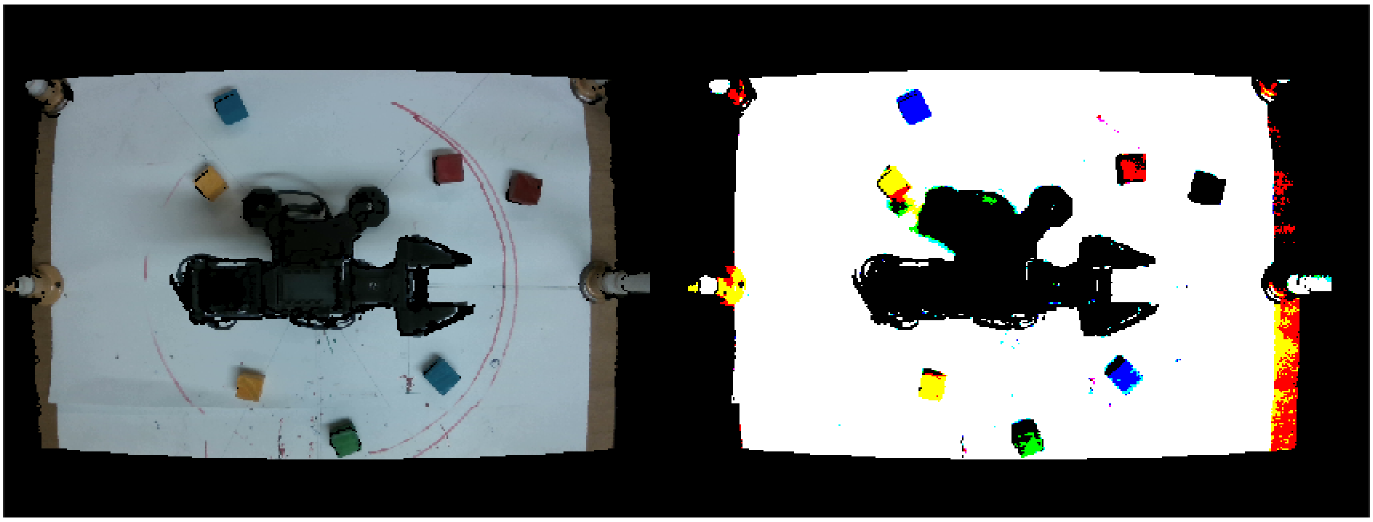
```
        r(i) = 1;
    end
    if green(i) > 50
        g(i) = 1;
    end
    if blue(i) > 50
        b(i) = 1;
    end

    a = []; % initialize an empty array

    % make a for loop to add non-zero pixels of all objects to the array
    for j = 1:length(tmp.PixelIdxList{i})
        if new_ig(tmp.PixelIdxList{i}(j)) ~= 0
            a(end+1) = new_ig(tmp.PixelIdxList{i}(j));
        end
    end

    % plot histograms of the pixel intensities of objects in the image
    figure
    temp = histogram(a ,10); % stores all data about the histograms
    [m, idx] = max(temp.Values); % get max value of pixel intensity of each
       object and store it in 'm.' also get it's index and store it in 'idx'
    sz = length(tmp.PixelIdxList{i}); % get the no. of pixels in each object

    j = 1; % initialize j from 1 as indexing starts from 1 in MATLAB

     % set threshold value of pixel intensity to be at an index 2 units more than
         index of max value
     thresh = temp.BinEdges(idx+2);

    % run while loop for all pixels of each object to only get the top face in
       image
    while j <= sz
        % if pixel value less than the threshold then its value is set to 1 (i.e.
            white)
        if ((new_ig(tmp.PixelIdxList{i}(j))) <= (thresh))
            top(tmp.PixelIdxList{i}(j)) = 1;
            j = j + 1;
        % otherwise the pixel is removed from the image altogether
        else
            tmp.PixelIdxList{i}(j) = [];
            sz = sz - 1;
        end
    end

    % get middle pixel values to get the centre point for each object
    x = ceil(mean(mod(tmp.PixelIdxList{i},480)));
    y = ceil(mean(ceil(tmp.PixelIdxList{i}/480)));
    rows(i) = x;
    cols(i) = y;
    % make the centre point equal to 0 (i.e. black)
    top(x,y) = 0;
end
```

```
% display image of cubes with their top faces visible and also their centre
   points marked on them:
figure
imshow(top)
title('image of cubes with only their top face visible and their centre points
   marked on them')

% initialize variables to calculate no. of objects of each color in image
red_obj = 0;
green_obj = 0;
blue_obj = 0;
yellow_obj = 0;

% make a for loop to calculate no. of objects of each color in image
for i = 1:num_of_obj
    if (r(i) == 1) && (g(i) == 0) && (b(i) == 0)
        red_obj = red_obj + 1;
    end
    if (r(i) == 0) && (g(i) == 1) && (b(i) == 0)
        green_obj = green_obj + 1;
    end
    if (r(i) == 0) && (g(i) == 1) && (b(i) == 1) % blue is a different shade (i.e
       . cyan blue) so both green and blue value will be 1
        blue_obj = blue_obj + 1;
    end
    if (r(i) == 1) && (g(i) == 1) && (b(i) == 0) % yellow is a mix of red and
       green so both red and green will be 1 for that
        yellow_obj = yellow_obj + 1;
    end
end

% output the no. of objects of each color in the image
red_obj
green_obj
blue_obj
yellow_obj
```

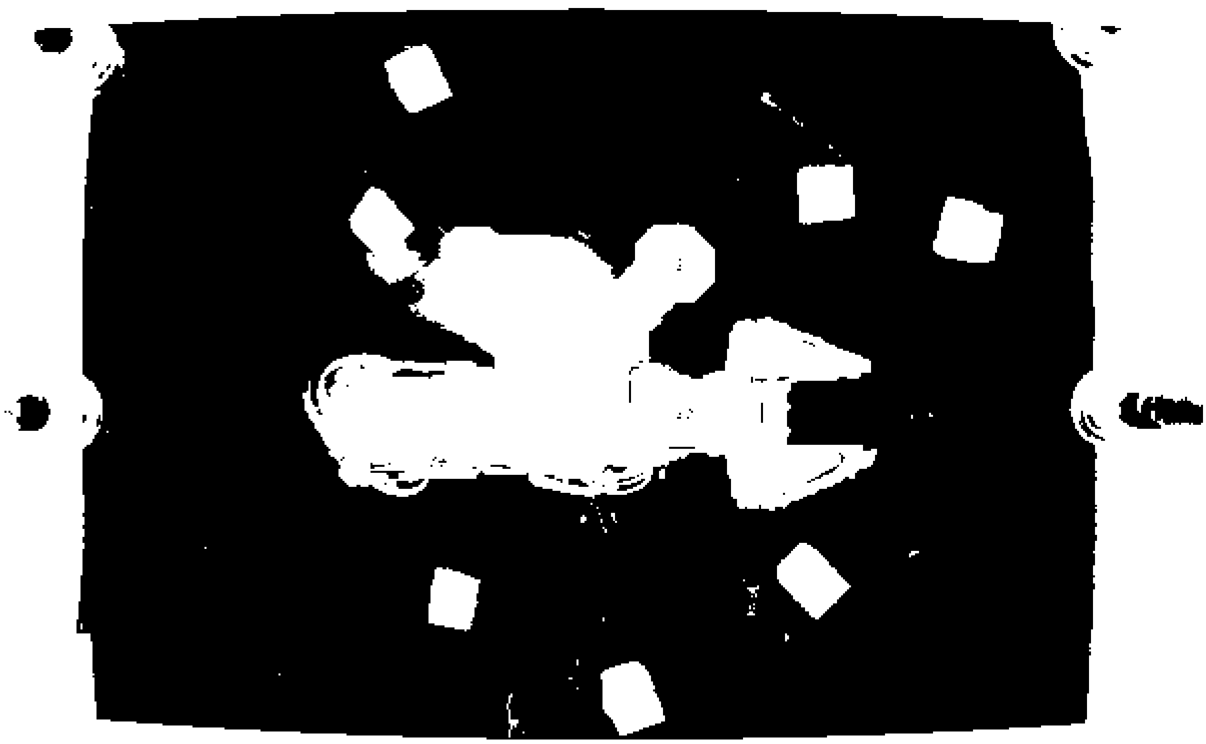
color image from camera



color image from camera alongside the binarized image



B&W image with black background and white foreground/objects



cubes detected

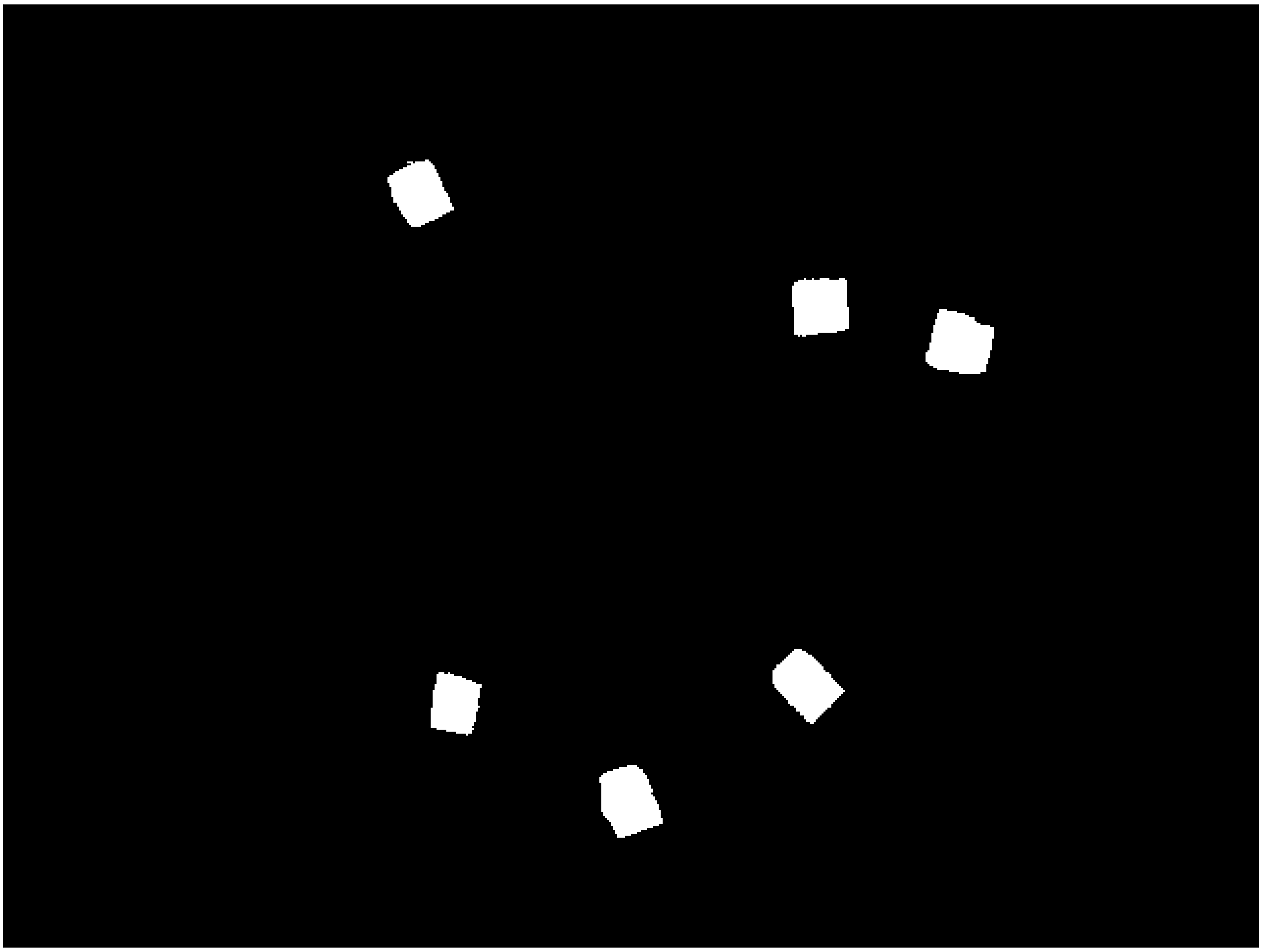
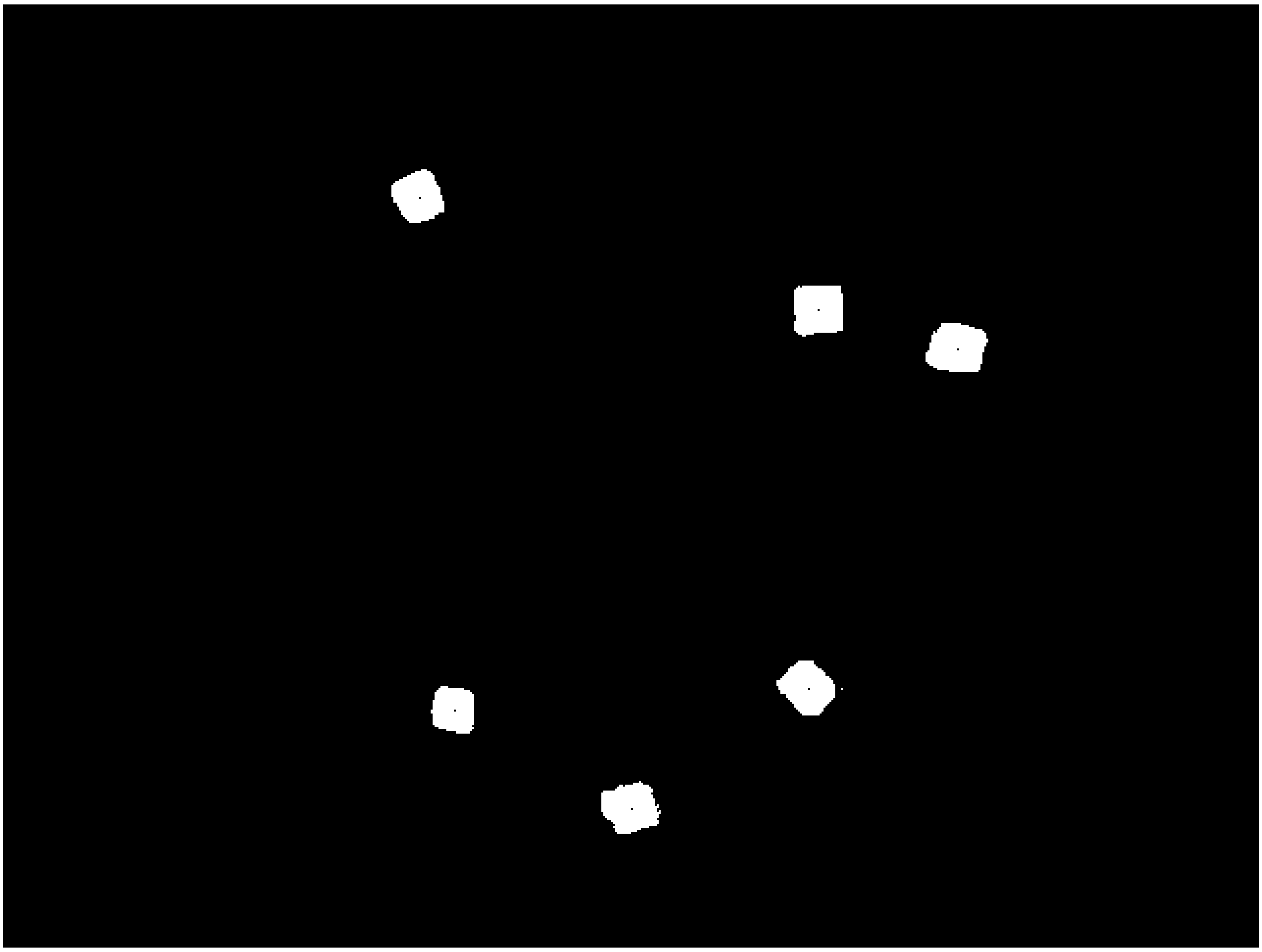


image of cubes with only their top face visible and their centre points marked on them



```
num_of_obj = 6
```

```
red_obj = 2
green_obj = 1
blue_obj = 2
yellow_obj = 1
```

We can see that all the objects are detected perfectly except for one yellow cube which is not even detected as it is placed too close to the robot.