Introduction To Vision And Robotics
Vision Assignment

Clemens Wolff, Toms Bergmanis

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1 Introduction

This report describes the work done for the first assignment in the IVR course. It gives the aims and hypotheses that guided the work; describes the algorithms that were implemented and reports the results of experiments that were run. The goal of this assignment was to develop three algorithms: one that detects the robots in each image, one that correctly identifies the direction of the robot and one that links together detections of the robots in consecutive images. Several simplifying assumptions were made about the possible set-ups of the assignment. Firstly, it was assumed that colours of the robots may change only due to the light it is exposed to, thus giving a rise to an assumption that robots will each appear in various shades of red or blue or green. Secondly, it was assumed that camera will be set up in some reasonable angle with respect to the plane it is supposed to observe. Finally, due to colour dependant approach it was assumed that background of the image will be in colour other than any of the colours of the robots.

2 Methods

In the following sections the three algorithms are described in detail.

2.1 Detection of Robots

Input

I, a three channel image of dimensions m*n in the RGB colorspace.

Output

M, a m*n*3 binary matrix where for each pixel (i, j) of I, it holds that:
$M(i, j, 1) = 1 \leftrightarrow (i, j)$ belongs to the red robot,
$M(i, j, 2) = 1 \leftrightarrow (i, j)$ belongs to the green robot,
$M(i, j, 3) = 1 \leftrightarrow (i, j)$ belongs to the blue robot.

Algorithm

1. Apply approximate normalisation to a copy I_n of I:
   For each pixel in I_n, calculate the sum S_{rgb} of the red green, and blue values of that pixel.
   If the pixel is not absolute black ($\mathrm{S}_{rgb} \neq 0$), set each of the pixel's red, green, and blue values to that value divided by S_{rgb}.

2. Calculate μ_r, μ_g, μ_b and $\sigma_r, \sigma_g, \sigma_b$, the means and standard deviations of the values in the three channels of I_n.

3. Assign each pixel $P = (i, j)$ in I to one of the robots or background:

   - Normalise P's red, green, and blue values, giving P_n.
   - Calculate the probabilities p_r, p_g, p_b that P_n was generated by the gaussian distributions $\mathcal{N}_r = (\mu_r, \sigma_r), \mathcal{N}_g = (\mu_g, \sigma_g), \mathcal{N}_b = (\mu_b, \sigma_b)$.
   - Calculate P's hue value h.
   - If h is whithin a certain range defined as red and p_r is sufficiently small, set $M(i, j, 1) = 1$ (similarly for ranges defined as green/blue and p_g/p_b. If none of these conditions are met, set $M(i, j, 1) = M(i, j, 2) = M(i, j, 3) = 0$.

4. Remove noise from each channel in M:

   - Set pixels to zero if they have fewer neighbours with value one than they have adjacent pixels with value zero.

- Set zero-valued pixels to one if they have two one-valued horizontal or vertical neighbours.

5. Remove components that are distant from the main concentration of mass in each channel in M:

   - Compute the center of mass C of the channel.
   - Compute $c_1, c_2, \ldots$, the centers of mass of each connected component in the channel.
   - Compute the mean distance C_m of the c_k to C.
   - Set $M(i,j) = 0$ for all the pixels (i,j) in those components i that have $c_i > t \cdot C_m$ for some threshold t.

6. Exploit the fact that all robots have similar sizes by setting every channel in M to all-zeros if the number of pixels set in that channel is smaller than the number of pixels set in the most populated channel by some margin.

2.2 Detection of Directions

1. After having detected robot as a set of points in the image a convex hull of these points was calculated. *Further detection of the direction of the robot was*

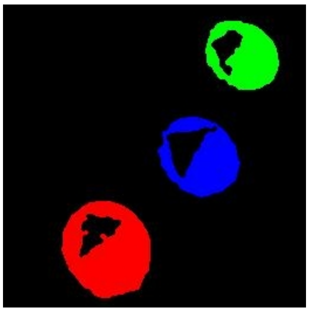

Figure 1: Result of Robot detection

done under the assumption that colour representing the robot is different and appears differently than that of the triangle indicating it's direction. Furthermore - it was assumed that the triangle will have lesser pixel colour value in the channel representing robot's colour (red or green, or blue) in RGB representation than the average pixel of the convex hull. These assumptions can be justified by the fact that area of the triangle indicating the direction of the robot constituted relatively smaller area of the convex hull than the rest of the convex hull which was expected to appear in some other colour than black.

2. The average pixel value of the characteristic channel was computed. Pixels which were above that value were assigned to one mask, others were omitted thus triangles were demasked.

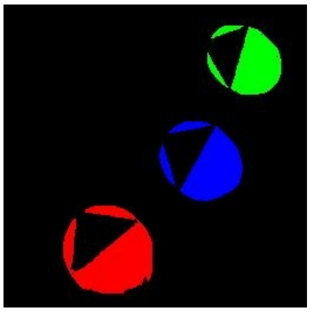

Figure 2: Step 2: Demasked triangles

3. A convex hull of the result of step 2 was calculated. *This step gives tighter and less noisy set of pixels that represent robot's coloured part in some harder cases.*

4. A convex hull was computed for the result of the previous step.

5. Once more the average pixel value of the characteristic channel was computed. This time pixels which were above that value were assigned to one mask, others were assigned to another mask which was expected to represent the triangle part of the robot's image.

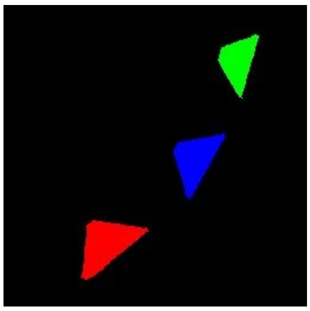

Figure 3: Step 5: Triangles

6. Centres of both masks from the previous step were computed.
7. Then a line joining them was drawn which depending on how precisely robot was detected would correspond to the direction of the robot.

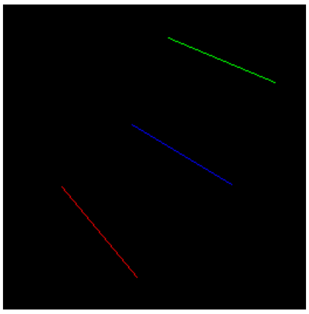

Figure 4: Step 7: Lines

8. Result was ploted on the source image.

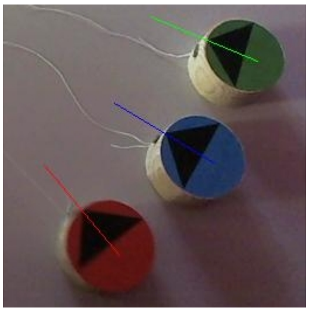

Figure 5: Step 8: Result

2.3 Tracking of Robots

After having detected the robots information about them was kept in separate arrays which were populated during the course of processing the data set. Each array consisted of the detected coordinates of the centre of the expected mass of pixels representing a robot in each image. After collecting coordinates of all robots for all frames they were plotted on a background generated by median filter algorithm. Coordinates were plotted as a five pixel large + signs of the colour of the robot they were representing. Such markers of positions of the robots then were linked together with white lines in order of the appearance of the images they originated from.

3 Results

This section describes and illustrates the results of the three algorithms implemented.

3.1 Detection of Robots

Detection of the robots was working perfectly on the two data sets provided, however it's performance was lower on some of the test sets with significantly different, colorful backgrounds on which error rate in some cases grow up to 10 percent of the robot instances being undetected.

3.2 Detection of Directions

Performance of detection of the directions was heavily dependent on the performance of the detection of the robots. In case of precisely detected robot detected direction perfectly matched the actual direction. In case

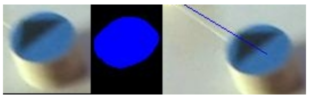

Figure 6: Result on good detection

of loose detection - detection where some addition non-robot region is misleadingly detected as a robot - detected direction perfectly matched the actual direction due to algorithms ability to filter noisy detections. In

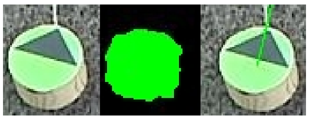

Figure 7: Result on loose detection

case of under-detection - detection where some parts of the image representing the robot where omitted - detected direction was skewed on the side opposite (from the axis matching the actual robot's direction) to the misdirected fragment of the robot. Error was proportional to the error of under-detected area of the robot.

3.3 Tracking of the robots

Tracing robots, as long as they were detected was trivial and worked as good as detection of the robots.

Figure 8: Result on under-detection detection

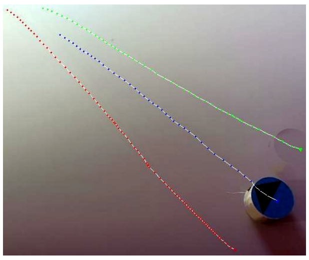

Figure 9: Trace of data set 1

4 Discussion

Overall performance of the algorithm can be evaluated as good. It operates under little or no simplifying assumptions. Robot detection could be improved [WRITE PLEASE HOW] Another way how to improve the detection of the robots could be utilisation of second order spatial statistics of the robot images. Using such approach might give good results combined with our current approach. Direction detection could be improved by making it less dependent on detection of the robots. It could be achieved by performing local search near the regions detected as robots. Such approach would improve accuracy of the directions detected, however it would make algorithm much slower. Another possible direction of development could be shape analysis - currently algorithms utilise only image's colour statistics due to limited information about the scale of the images and the possible placements of the camera.

5 Code

the new Matlab code that you developed for this assignment. Do not include code that you downloaded from the course web pages. Any other code that you downloaded should be recorded in the report, but does not need to be included in the appendix.