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Robustness of Colour Detection for Robot Soccer

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Abstract

This paper outlines a method for detection and classification of the ball and the colour patches on micro-soccer robots using pie slice decision regions in a YUV colour map. The method is robust under changing lighting conditions.

1 Introduction

In robot soccer, for example the Mirosot game category of the Federation of International Robot Soccer Association (FIRA) [1], determination of a robot's position and orientation is achieved primarily by computer based image analysis of the colour identification patch on each robot using an overhead vision camera. Image enhancement is not used due to computational loading. Other manipulations and transformations of the captured images are usually not performed because they are also computationally intense. Colour recognition systems include YUV, RGB and HSI and colour separation is visualised in YUV, YIQ and HSI co-ordinate systems [2].

The vision systems available are as varied as the imagination of the researchers, most have used commercial image capture cards. Image capture cards differ widely in the information presented to the computer and allow or inhibit user control over programmable features on the card. They are capable of providing YUV and/or RGB with RGB derived from YUV through translation of the video composite signal. Every translation to a different colour co-ordinate system includes some translation error. The effect is to add more noise to a noisy signal. Noise is accumulated in RGB to YUV translation inside the camera, encoding and filtering for video composite, transmission through cables, decoding, A/D conversion at image capture card to name a few.

Some Korean teams [3, 4, 5] use the RGB colour representation. One such team [4] expressed problems in using RGB because of luminance sensitivity. An inherent component of RGB is luminance for luminance changes over the field area and different lighting at venues cause the system to miss classify the position of the robots. Some teams [6, 7, 8] translated the RGB output of the image capture card to another colour co-ordinate system. Two teams [6, 7] converted RGB to HSI for colour detection. Another team [8] developed a colour system similar to HSI, translated from the RGB output of the image capture card. Still other teams [9, 10] placed LED light sources in an attempt to overcome glare and colour identification matching problems.

A growing vision processing technique is by an in-line processor between the camera and computer. Newton Labs [11] developed the "Cognachrome" vision processing system. This first system was limited to four colours and the ball. Processing of each interlaced frame at full rate of 60 frames per second. The "Cognachrome" system was sold and purchased by other teams [12]. In-line systems became an advantage due to problems caused by the event-based multi-tasking Windows operating system which was not designed for real time processing.

In Section 2 we discuss the YUV colour recognition system. We examine difficulties in colour detection of the ball in Section 3. In Section 4 we define the pie slice decision region method for colour detection in the UV colour map. Experimental observations are given. Our conclusions are given in Section 5.

2 YUV

The exemplar software purchased with the Micro-Adventure soccer robots used rectangular decision regions, with a choice of YUV or UV for colour detection.

The mapping of RGB to YUV co-ordinate system results in the RGB cube begin mapped to a distorted cube with white and black at (0, 0) in UV co-ordinates. The Y axis is in line with the black to white diagonal of the cube. Table 1 shows the positions of the colours in UV co-ordinate system.

Figure 1 shows the mapping of RGB colours on UV co-ordinates.

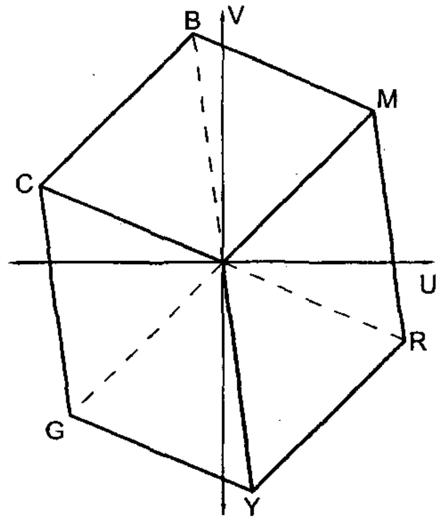

Figure 1: RGB colours mapped on UV co-ordinates

The luminance (Y) part of the YUV can be ignored if the only interest is in hue and saturation of the colours, as in the case of robot soccer. It is convenient to make use of the YUV output of composite video:

- Because there are six colours on the perimeter of the chrominance/hue diagram this means that YUV components are a little more separable than HSI colour components and should allow easier separation of colours. The more saturated the color, the better the classification into decision regions.
- Using the YUV output of a video camera minimises the accumulation of video error and of conversion to another system such as RGB or HSI.

3 Colour detection of the ball

The orange golf ball is the hardest object to correctly identify and track. It's dimpled surface causes glare on parts of the ball regardless of the angle of incident light. The ball consists of many colours ranging from pink through orange to yellow. The dimpled surface separates these colours into small blotches.

The cells of a CCD video camera are arranged in a rectangular grid and averaging occurs when two or more colours are incident on a single CCD cell. Figure 2 shows the averaged pixels on the boundary between red and yellow. The averaged pixels contain all of the colours along the line connecting red and yellow.

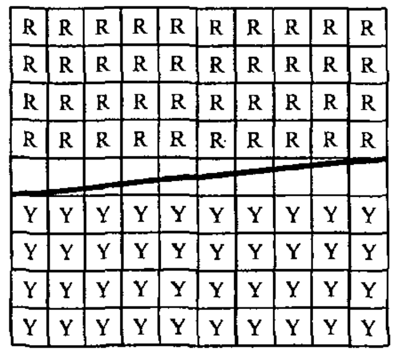

Figure 2: Averaged pixels caused by red-yellow boundary

Figure 3 shows the averaged bi-colour distribution appearing on the UV colour map. All colours along the line connecting red and yellow can appear in the image at the red-yellow boundary. One of the colours on this line is orange—the colour of the ball.

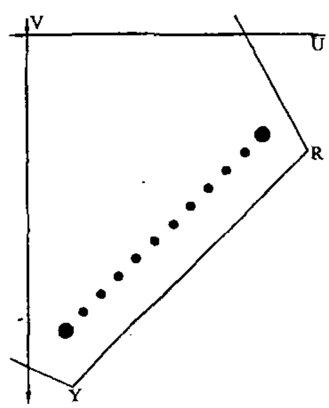

Figure 3: Averaged colours on UV map

Typical colour identification involves gathering pixels of the same colour into blobs — "blob construction".The many colours on the ball under different lighting conditions can cause blob construction problems, such as identifying two blobs over the ball, or not being able to identify the ball at all. Further, in analysing the colour of the ball, it is typical to select a patch over the ball and then determine a rectangular parallelepiped in the RGB cube which contains the

Table 1: RGB Colour mapping onto YUV co-ordinates

	R	G	B	Y	U	V	UV polar
Red	255	0	0	76	179	-76	$194\angle -23^\circ$
Green	0	255	0	150	-150	-150	$212\angle -135^\circ$
Blue	0	0	255	29	-29	226	$228\angle 97^\circ$
Yellow	255	255	0	226	29	-226	$228\angle -83^\circ$
Magenta	255	0	255	105	150	150	$212\angle 45^\circ$
Cyan	0	255	255	179	-179	76	$194\angle 157^\circ$

colours in the patch, see Figure 4. To make this parallelepiped large enough to recognise the ball results in enveloping neighboring colours such as pink, red and yellow. This then creates mis-classification problems such as one or even more robots being classified as the ball.

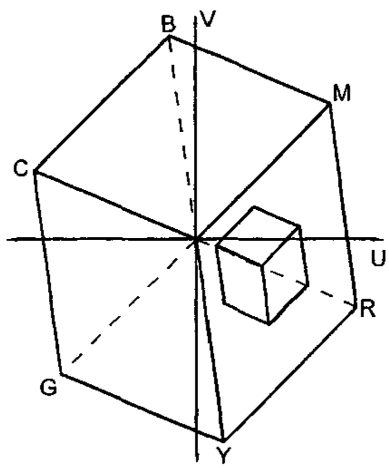

Figure 4: RGB rectangle in YUV space

4 Pie slice decision regions

The robot soccer vision is very dependent on the assigned colour of the robot colour patches. Determination of these colours by rectangular decision regions is constrictive, as any incident luminosity changes and glare from incorrect field lighting produce colour deviations beyond rectangular decision regions.

A system should be insensitive to colour drift and glare. Temperature variations of the incident light causes hue drift which rotates the colour around the Y-axis. Saturation of a colour (in YUV) is the distance of the point from the Y-axis. Changes in saturation of the object's colour is caused by variation of the incident light. Glare is produced by reflecting the major component of the incident light into the camera lens. It is a major problem in the detection of colour in mobile objects. systems because Mirosot rules do not state

Two methods came with the Micro Adventure system for colour classification. The first enabled selection of a rectangular parallelepiped in YUV space and the second the selection of a rectangle in UV space. Figure 5 illustrates a rectangular decision region taken in the UV plane. The larger it is made, the more it will include pink and yellow.

Our objective is to produce a robust colour definition ignoring the luminance component of the YUV signal, and by separating the colour decision regions as far as possible to minimise hue and saturation drift. The proposed methodology described below does not eliminate the effect of glare, but reduces it considerably.

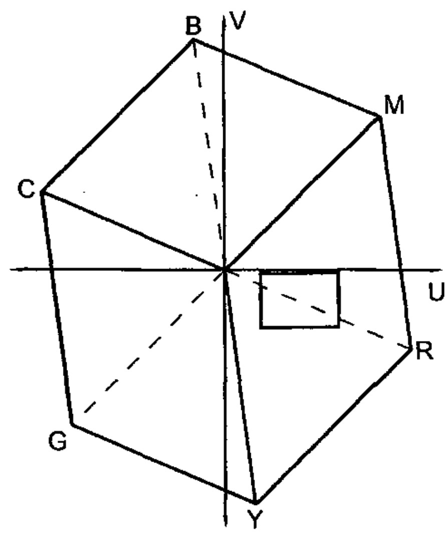

Figure 5: UV rectangle over YUV

While any arbituary shaped decision region can be used with a Look-Up-Table method. A region that is easily identified and manipulated by the user of the system is a preference. A shape that encompasses effects of glare and hue drift is a pie segment with exclusion of the grey zone close the the Y-axis. Calculation of any arbituary zone would become computationaly prohibitive in software without the use of a Look-Up-Table.

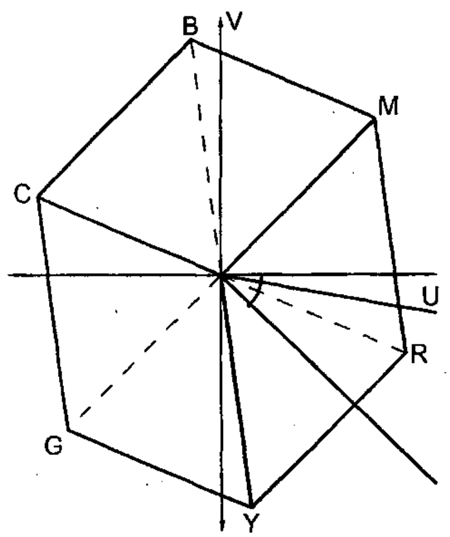

Figure 6: pie segment

The Look-Up-Table is constructed by assigning a number to each colour and filling the region of the table using rules of the following form:

$$\textbf{If } ((\phi_{UV} > \phi_1) \ \&\& \ (\phi_{UV} \leq \phi_2) \ \&\& \ (dist_{UV} > r)) \ \textbf{Then } (\text{colour} = 1).$$

Here, ϕ_{UV} is the angle of the chrominance point anti-clockwise from U axis, ϕ_1 is the first angle of colour region, ϕ_2 is the second angle of colour region, $dist_{UV}$ is the distance of the chrominance point from the origin, and r is the radius of exclusion arc removing white–gray–black from colour decision region.

All pixels in each interlaced frame are converted to a UV colour map. For example, Figure 7 shows the position of the ball in the left window, and the UV colour map in the right window. The ϕ_1, ϕ_2 and r values are then determined interactively by entering values or moving the sliding bars in the "Color Limit" section. The best settings for the ball segment shown has ϕ_1 (Minimum Angle) set to 316 degrees, ϕ_2 (Maximum Angle) set to 350 degrees and r (Minimum Magnitude) set to 40. It should be obvious that these values maximise the pie segment capturing the colour of the ball without any overlap into the pink region above, or the yellow region below. The exclusion radius r is set to maximise the area of the image over the ball in the left window. If r is set too low, various images in the field marking will be classified as the object. If r is set too high, the number of pixels covering the ball will be insuffient to identify the ball.

Experimental Observations

This classification method worked very well in identifying the two specified team colours: blue and yellow. We were able to identify a pink colour patch on a robot that proved difficult for other teams to identify. Three different green patches were easily classified using this method and so could be used for identifying our own three robots.

During actual game trials, changing lighting conditions from Quartz-Halogen to fluorescent, did not affect classification of the colour patches on the robots, and classification of the ball. Hue drift appeared not to cause any problems.

5 Conclusion

In this paper we have described a method for detection and classification of the ball and the colour patches on micro-soccer robots using pie slice decision regions in a YUV colour map, as opposed to rectangular regions in RGB or YUV colour maps. Luminance is ignored as hue and saturation are sufficient in classifying a colour. Use of the pie slice decision regions enables a more accurate definition of colour patches on the robots and colour of the ball. The method was found to be robust under changing lighting conditions in experimental trials.

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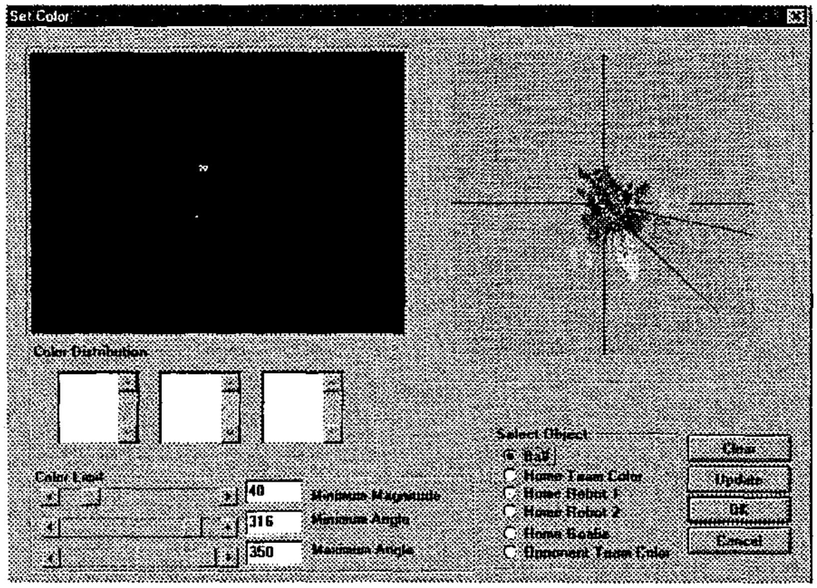

Figure 7: pie segment

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