THE USE OF COLOUR TO SEGMENT AND LABEL IMAGES

P.R. CLAXTON*
E.K.Y. KWOK

STC Technology Ltd., London Rd, HARLOW, Essex.

Abstract

The application of spectral information to image segmentation is examined, with an approach to colour manipulation being described. A transformation from red/green/blue space to intensity/saturation/hue is advocated, using a triangular polar space to reduce non-linearity. A colour orientated edge detector is described for this space. The methodology is illustrated with two applications, the reading of colour codes on resistors and the segmentation of vehicles within natural scenes.

Introduction

A glance at recent work suggests that colour has been neglected by mainstream vision - apart from the Retinex theories of Edwin Land, the emphasis has been on segmentation and model matching within greyscale images. By considering the relationship of colour within an image, it was hoped to ease segmentation and identification of industrial images, as used in automated inspection. Any successful techniques could have applications in the less constrained natural scenes.

Our investigation into the segmentation of colour images begins with a novel colour space transformation, generating the Intensity, Saturation and Hue values fundamental to our approach. With a suitable chromatic descriptor, colour primitives can be extracted and matched to a model for identification. An industrial application is then demonstrated, that of describing a resistor by reading the colour code bands printed on the cylindrical body. The issues raised by this led to an edge detector being developed, with application to natural scenes. The algorithm displays invariance to the vagaries of colour temperature, and forms the initial step in region labelling of the Alvey car exemplar.

The routines were developed initially on a DEC PDP11/34 computer. Currently they are implemented on a microVAX II computer and 8 bit Intellect 100 framestore.

Geometrical considerations

A mathematical description of colour was initiated by the Commission International d'Eclairage (CIE), when they defined the tristimulus concept with specific values for the primary colours of red, green and blue (RGB).

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* Currently seconded to the Research Initiative in Pattern Recognition.

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This allows a colour to be quantitatively represented in the three dimensional cartesian space of figure 1a. Unfortunately, this space is non-linear, does not readily encompass all possible colours, and is sensitive to illuminant variation.

Alternatives to an RGB colour description include that of intensity, saturation and hue (ISH), in which the chromatic content is separated from the luminance. Hue is the fundamental 'pure' spectral colour, and saturation is a measure of the amount of white in the colour. Transformations between RGB and ISH are based on the polar relationship illustrated in figure 1b, and the STL triangle method is a derivative of this.

After normalising the RGB data a chromaticity diagram can be drawn, figure 2, in which all possible colours are bounded by the spectral hue locus (intensity variation is represented by the third axis). A Maxwell triangle is shown connecting the primaries, containing that subset of colours achievable from combinations of those tristimuli.

Mapping the Maxwell triangle of achievable colours into the right-angled variant shown enhances the spectral linearity, as described below, and facilitates an RGB/ISH transformation.

Trigonometry allows S and H to be calculated from the triangular chromaticity diagram, whilst I is chosen as the tristimulus sum for each pixel.

$$H = \arctan \left\{ \frac{(3y-1)}{(3x-1)} \right\} \qquad S = \frac{(3y-1)}{(3\phi \sin(H))}$$

$$I = R+G+B$$

where $x = \frac{R}{R+G+B}$ and $y = \frac{G}{R+G+B}$

and ϕ is the saturation ratio of the colour to the corresponding achromatic point/locus distance.

The 'triangular polar' space this produces is superior to the initial RGB space as:
a) Luminance has been separated from the chromatic data, allowing variation in illuminant intensity to effect only one of the three data fields.

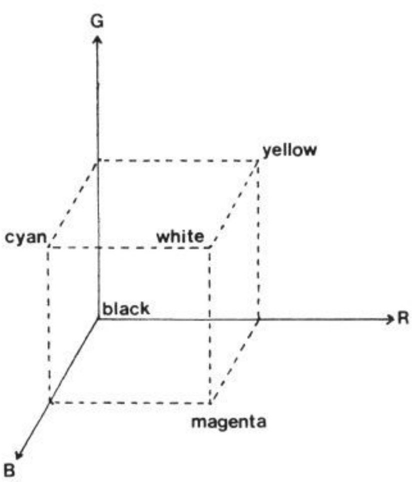
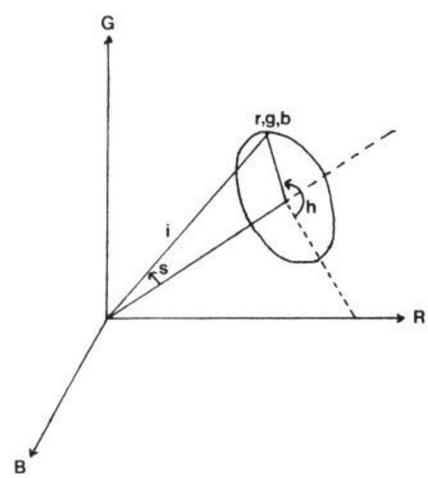


figure 1: a) RGB colour space



b) Relationship between RGB and ISH coordinates

b) The greatest rate of change of colour occurs in the red to green sector of colour space, and this high density area is expanded in the new triangular space, easing colour discrimination.

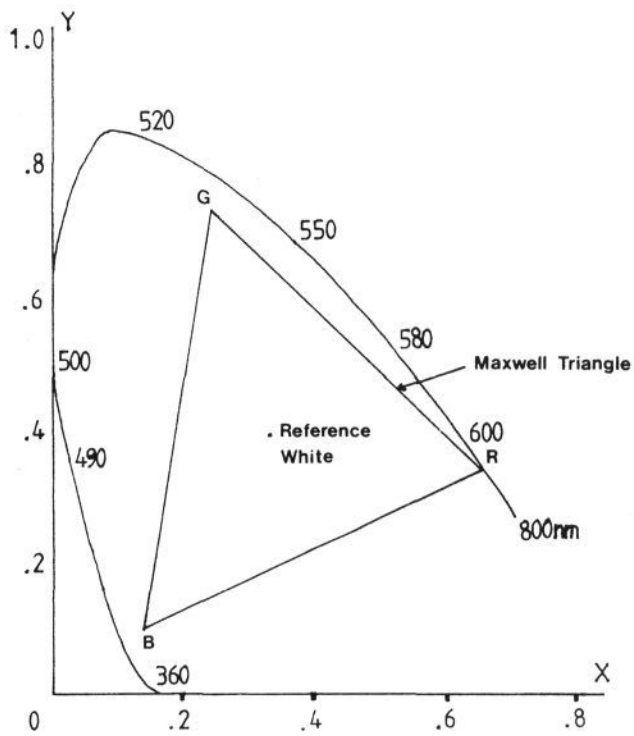
Within this space, regions can be defined in terms of the ISH values at their boundaries to produce a colour database, allowing unknown pixels to be spectrally identified by matching their ISH data to this data base.

Resistor Identification

With a quantitative description of colour in ISH, a suitable exemplar to illustrate the power of colour processing was selected. An industrial inspection task, of interest to STC Plc, is the automated inspection of electronic components, hence the identification of resistors by 'reading' their colour codes was approached.

As a constrained industrial problem, the resistors could be examined in a consistent imaging environment. Intense, shadowless lighting equivalent to the CIE standard illuminant A (artificial daylight, 2856°K) is provided by a ring of Philips PL series fluorescent lamps. A matt black felt base prevents shadows and specular highlights. Despite this standardisation, the lamps gradually age, hence variation in the colour temperature must be accommodated.

Extraction of the colour content of the resistor involves finding and orientating the component in the image, and then considering three issues - the colours of the four identification bands, how they relate to the background colours, and the effect produced by uneven lighting. However the constrained lighting discussed above eliminates most of the latter issue.



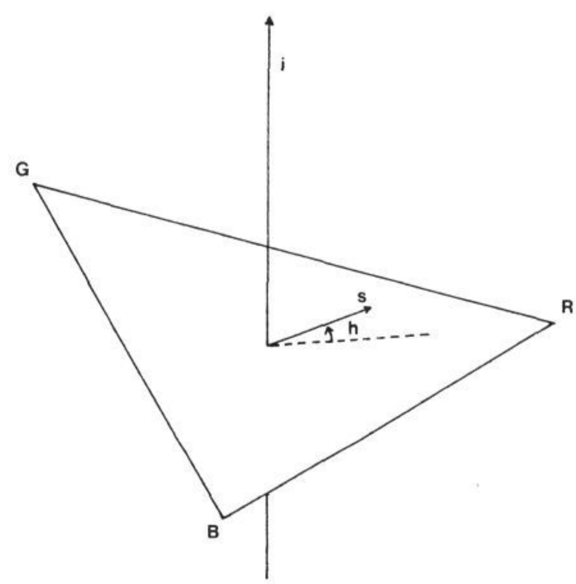


figure 2:
a) CIE chromaticity diagram, showing all possible colours of one intensity.

b) STL right-angled triangular space, showing the Maxwell triangle and the intensity axis.

The initial calibration for variation in the lamp performance is facilitated by including a white standard in the image, which is located and any disparity in the RGB values used to adjust subsequent data. After transforming the RGB arrays into ISH, the resistor can be located using vertical and horizontal linescans in the Intensity image (the background is black). Knowledge of the shape of the resistor leads allows them to be ignored and the body segmented out. To avoid spurious edge effects, this region is shrunk slightly from the true resistor size, and is illustrated in the figure 3b by a box overlain on the image.

Within this area, the body of the resistor, there is a dominant background (e.g. light blue/green) and four narrow coloured bands. Because of the relative sizes of the colour regions, the phenomena whereby the narrow segments take on the hue of their surroundings is produced. Allowing for this colour caste in the bands requires that the two types of resistor (blue bodied and brown bodied) be identified and treated with separate data bases. To examine the colour content, a hue histogram of colour incidence within the resistor body is generated (figure 3c), which shows a major peak for the background flanked by appropriate band peaks. To identify the background a technique of averaging over a 13 degree hue window was used, the maximum of this occurring when centred over the relevant hue (e.g. 169° for a blue/green body), and not over a large sharp peak from e.g. four red coding bands.

There are ten possible colours for the coding bands, which are empirically defined in descriptive databases as regions of the ISH colour space. By reference to the relevant database, the colour of a pixel can be identified and labelled ('violet','grey' etc.). After labelling the pixels in a series of linescans through the length of the resistor, the position and colour of the bands can be extracted, consistency checked, and the component value calculated and displayed.

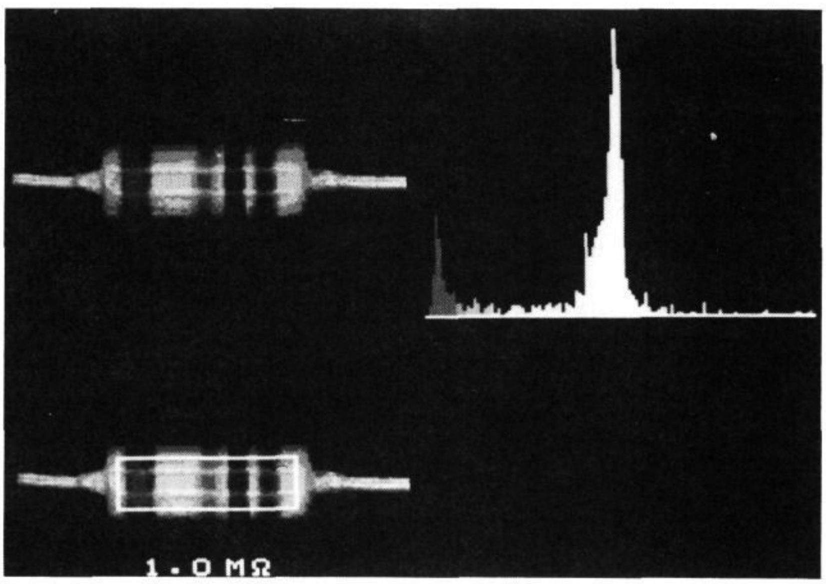


figure 3: a) Image of a resistor.

b) Resistor with the body segment highlighted.

c) Histogram of hue occurrence within the body segment.

Colour Edges

The above work relies on constrained lighting to control the colour temperature and eliminate shadowing, however approaches showing more independence to these variables were investigated.

As a step towards extending the theory to more general situations, a method for extracting edges is required. By utilizing the chromatic as well as the achromatic information, features can be segmented in a computationally efficient manner from cluttered natural scenes.

From the ISH colour space, the chromatic parameters can be incorporated into an edge detection schema by providing additional terms in an estimate of the first-order directional derivative. A constraint on the inclusion of this term is the inherent non-linearity of colour space - albeit partially corrected in the transformations described above. The implication of this effect, is the perceived colour difference for a given hue variation being dependent on the saturation.

A method of biassing the hue difference at varying saturation is proposed, which ensures hue variation at high saturation contributes proportionally more to the resultant colour difference term than a similar hue value difference at lower saturation.

The colour difference between two pixels P1 and P2 with co-ordinates I1 S1 H1 and I2 S2 H2 respectively, can be considered initially as a function of the relative hue and saturation only:

$$\delta C = F(S, H) \qquad (1)$$

Various functions of F(S, H) were investigated, as a means of incorporating saturation effects in the hue angle change:

a) A simple relationship based on mean saturation:

$$F(S, H) = (H1-H2)\ (S1+S2)\ /\ 2$$
Linear Saturation Biased Hue (2)

b) The area of the plane in ISH colour space intersected by the pixels P1, P2, and the achromatic point:

$$F(S, H) = 1/2\ S1\ S2\ \mathrm{Sin}(H1-H2)$$
Area Saturation Biased Hue (3)

c) The cartesian separation of the two pixels in ISH colour space:

$$F(S, H) = \sqrt{S1^2 + S2^2 - 2\ S1\ S2\ \mathrm{Cos}(H1-H2)}$$
Cosine Difference (4)

Calculating the relative colour difference term δC across local neighbourhoods in the image generates first difference peaks of colour edge strength. However, consideration of the colour vector at low luminance indicates a quasi-random behaviour, as the sensor accuracy is poor to small RGB variations in this region. To introduce the intensity data into the chromatic difference, a new contribution F2(I) is required.

$$\delta C = F2(I)\ F(S, H) \qquad (5)$$

A suitable F2(I) to proportionally remove the contribution of these low luminance colour vectors is:

$$F2(I) = \ln\ |\ (I1+I2)\ /\ 2\ |$$
Log Intensity (6)

After entering the intensity into the chromatic term, it becomes logical to consider the total contribution towards pixel difference.

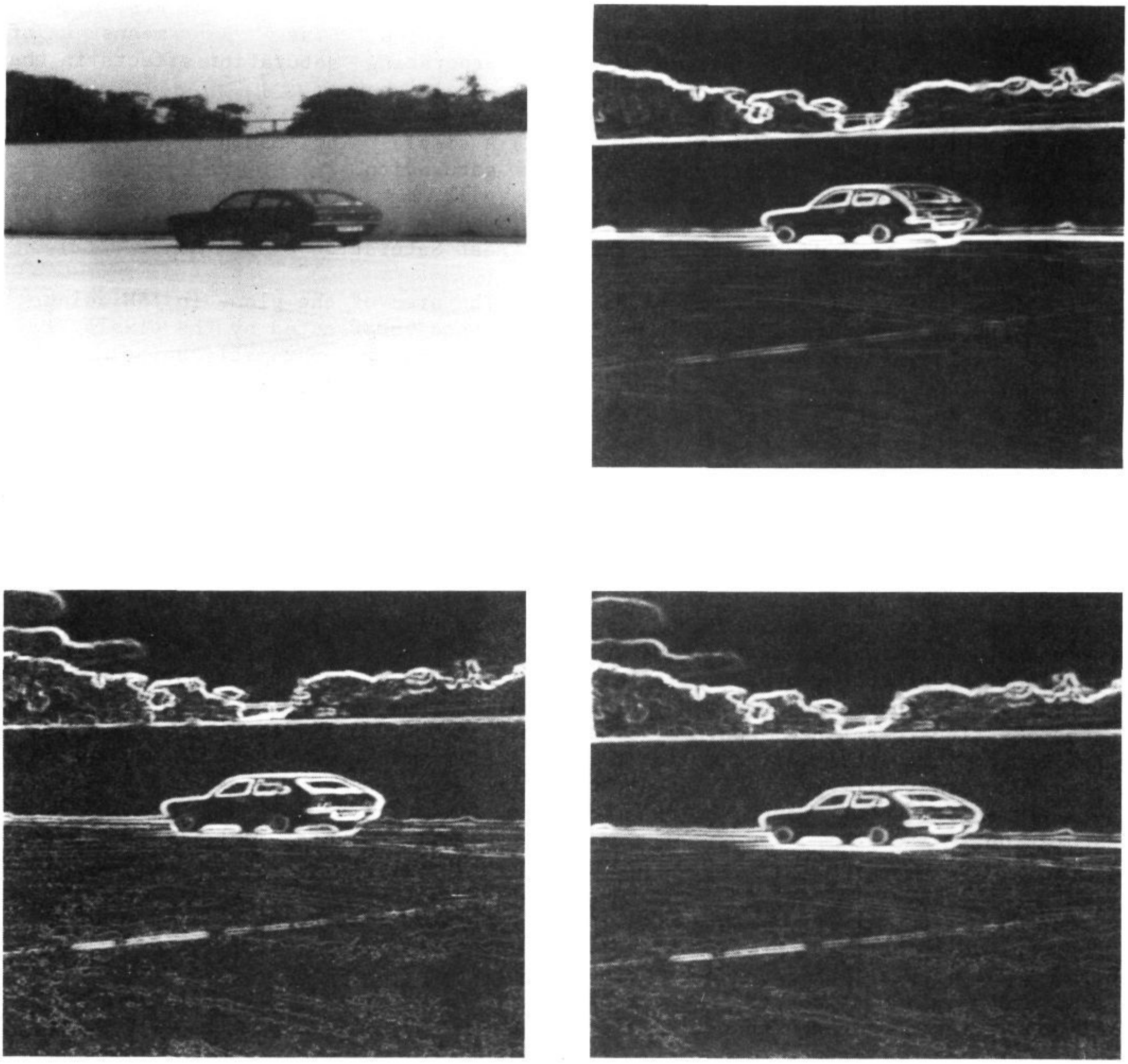


figure 4: a) Original Image
b) Intensity Edge Map
c) Chromatic Edge Map
d) Combined Intensity and Chromatic Edge Map

A vector combination of I and the new δC (equation 5) is suggested by the colour space, and is denoted by δD where C is the saturation index:

$\delta D = \surd[(I1-I2)\hat{}2 + (F2(I) F(S,H))\hat{}2 \quad C]$
Pixel difference (7)

The inclusion here of the intensity represents the utilisation of all the ISH data, and hence the fusion of the RGB planes to produce a true colour edge detector. With this as the metric, the change in pixel colour is found by convolving δD within a modified 3*3 Laplacian operator [ref #4]. The output is a raw first-order derivative, with peaks corresponding to colour edges.

Figure 4 shows the performance of the algorithm (as edge strength maps in grey scale) when applied to the car image database generated by the Alvey consortium 'Object Identification from 2D Images'. Figure 4c illustrating the colour contribution to the combined chromatic and intensity edge map 4d.

Ridge Following and Region Maps

Segmentation of the edge strength map into regions yields the data that is required for the next stages in the process of object identification. Ridge following segmentation algorithms are being developed. These derive the region map by selective maxima analysis and are aimed at reducing the dependency on parameter optimisation.

By comparison of the dimension and ISH paramenters for regions with a chromatic database major image features can be labelled, in the manner established with the resistor exemplar.

For the Alvey car exemplar these techniques are aimed at the establishment of likely car regions upon which further feature extraction and model matching can be carried out.

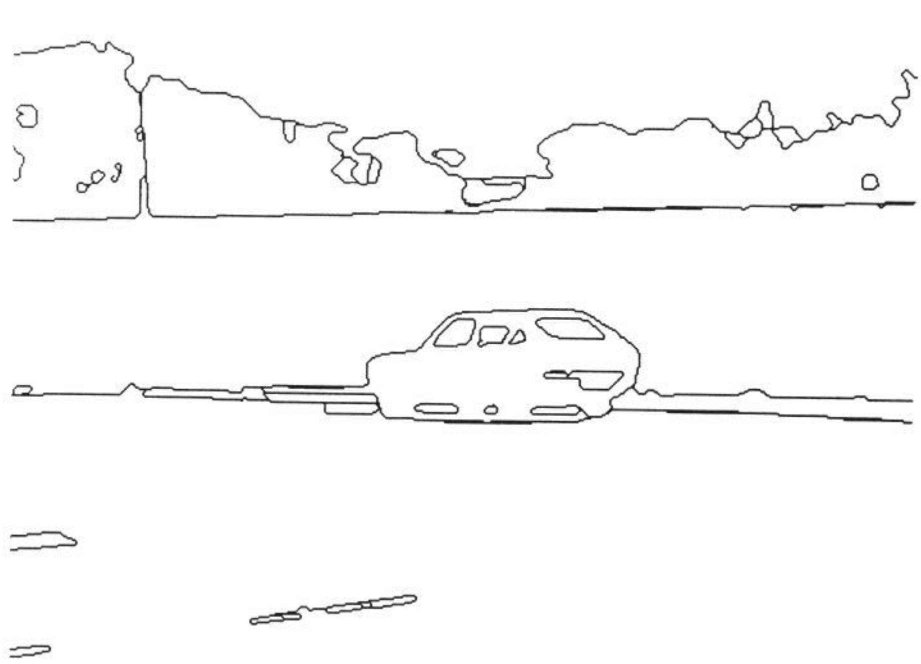


figure 5: Ridge Followed map

Conclusions

The potential of colour as a cue for image understanding has been demonstrated, as computationally realistic algorithms have extracted image primitives from complex scenes. Segmentation of an industrial image for identification of characteristic colour markings has illustrated the feasibility of the techniques. A method of using chromatic data in the generation of a first difference edgemap has also been described and the results illustrate the additional features extracted from within the low intensity-contrast regions.

Acknowledgements

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References

1 "Colour Vision - A Literature Review" P. R. Claxton, STC Technology investigation report no: IR/R310/1985/1324 Sept 1985.

2 "The Retinex Theory of Colour Vision" E. H. Land, Scientific American Dec 1977.

3 "Visive - A Simulation of Early Visual Processing of Form" BAe Sowerby Research report no: JS10192 Dec 1984.

4 "Profile Sensing from Illuminance First Difference Peaks using Visive" BAe Sowerby Research report no: JS10614 June 1986.