Image Identification: Shell

The problem as stated was in two parts: firstly to determine the boundary of a flame from analysis of colour video pictures, and secondly to fit a parallelogram to the resulting shape, Most of the discussion at the Study Group concentrated on the former problem.

The information from a typical pixel in the video image consists of three integers, R,B,G, each between 0 and 255; they represent the intensity recorded by the red, blue and green sensors in the camera respectively. There is an automatic cut-off at 255 but intensities greater than this are rarely recorded. It is thought that the flame radiation is close to black-body radiation at a temperature of 1550K.

The suggested procedure exploits the vector space description of colour perception (a good reference for all that follows is 'Colour measurement, theme and variations', D.L. MacAdam, Springer 1985). In brief, the set of all colours forms a cone in a three-dimensional real vector space, so any colour is completely determined by three numbers (e.g. R,B,G). In practice a standard system (X,Y,Z) is used and it is conventional to describe a colour by its position in the plane $X + Y + Z = 1$, by using affine coordinates $x = X/(X+Y+Z)$, $y = Y/(X+Y+Z)$, $z = 1-x-y$. The region of the x-y plane occupied by visual colours is shown in Fig.1; the pure (monochromatic) colours lie on the curved portion of the boundary, while the straight line consists of purples (mixtures of blues and reds). Any other colour, being a convex combination of pure colours, lies in the interior.

We assume (in the absence of further information) that the camera operates linearly, and that all its three sensors act in the same way. Its action is thus to resolve any colour along the three vectors R.B,G. <u>An experiment is needed</u> to determine where R,B,G lie in the plane $x+y+z = 1$; this can be done by shining 3 different known colours C_i (i=1,2,3) at the camera, measuring the responses (R_i, B_i, G_i) and then solving the following system folowing system for the basis vectors $\underline{r} = (r_x, r_y, r_z=1-r_x-r_y)$, $\underline{b}, \underline{g}$: for

$$i = 1,2,3, \quad C_i = (x_i, y_i, z_i=1-x_i-y_i)$$

$$= \alpha_i \underline{r} + \beta_i \underline{b} + \gamma_i \underline{g}$$

where $\alpha_i = R_i/(R_i+B_i+G_i)$, and similarly for β_i, γ_i.

As a guess, we shall take the points marked in fig. 1 viz

$$r_x = 0.7, \quad r_y = 0.3 \quad (r_z=0)$$

$$g_x = 0.1, \quad g_y = 0.8 \quad (g_z=0.1)$$

$$b_x = 0.1, \quad b_y = 0.1 \quad (b_z=0.8);$$

the calculations that follow are illustrative only.

The algorithm we propose is as follows. For each point, first resolve the signals R,B,G along the X,Y,Z axes via

$$X = r_x R + b_x B + g_x G$$

$$Y = r_y R + b_y B + g_y G$$

$$Z = r_z R + b_z B + g_z G$$

i.e.

$$X = 0.7R + 0.1B + 0.1G$$

$$Y = 0.3R + 0.1B + 0.8G$$

$$Z = 0.8B + 0.1G.$$

Then calculate

$$x = X/(X+Y=Z), \quad y = Y/(X+Y+Z).$$

(note: $X + Y + Z = R + B + G$).

A given point is assigned to 'flame' if it lies within a specified region in the plane $x + y + z = 1$, probably close to black-body radiation at 1550K ($x=0.57, y=0.40, z=0.03$, MacAdam p.29). An additional check is to reject points for which $R + B + G$ is too small, since they may represent reflections or other spurious values.

Sample calculations are given in the Appendix.

Other suggestions made were to use an infra-red camera and to carry out the experiments at night. The latter is probably not possible on safety grounds, and although the former is possible it is desired to analyse existing data in video form.

Finally, there are several ways to determine the parallelogram. One particularly simple one is to calculate the coordinates of the centre of mass of the flame area (perhaps having first eliminated disconnected patches of flame, although these appear to be few in number), from which the parallelogram is easily calculated by trigonometry (recall that its upwind lower corner is known).

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Appendix: sample calculation

Note: these calculations are illustrative since the true values of R_x, etc, are not yet known.

The first five points plotted with a square in the data provided by Shell had coordinates (R,B,G) of (244,16,122), (206,18,72), (212,18,76), (248,18,126,), (252,18,144) approximately. (Note that the small B-value cannot be used as a discriminator because other points may have the same B-coordinate). The corresponding x and y coordinates are (0.48,0.45), (0.52,0.41), (0.52.0.41), (0.48,0.45), (0.47,0.47). By way of contrast, a typical sky value of (150,174,182) translates to (0.28,0.41).

The flame points above are not near the black-body point (0.57,0.40), but this may be either because the flame is not in fact radiating in this manner, or because our basis vectors are not exactly right. We also notice that the points with a large value of R (the first and the last two) seem to be distinct from those with a smaller value. This may indicate some nonlinearity in the camera response but with more data this should be easy to correct for.

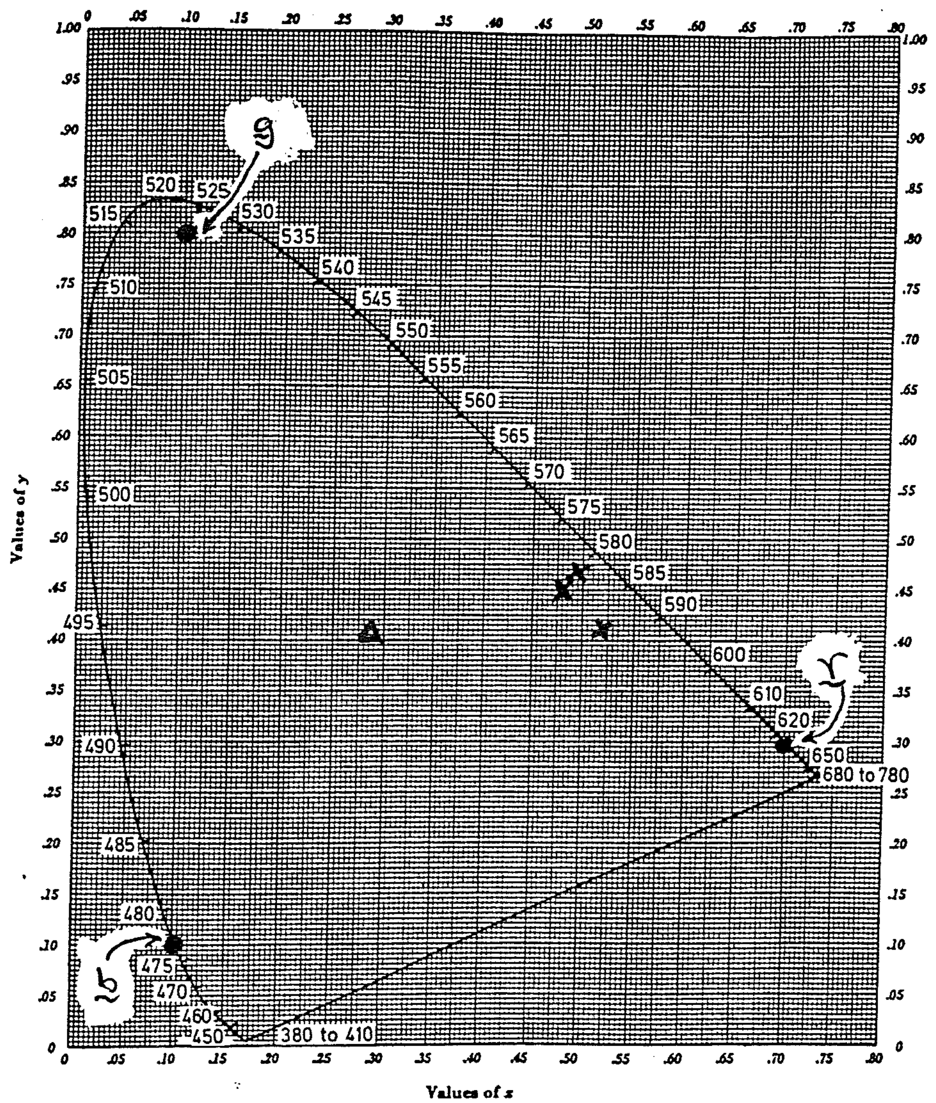

Fig.1

The x-y plane. Visible colours occupy the interior of the solid curve; the figures on the boundary are wavelengths in nm of monochromatic light. The basis vectors R,B,G defined in the text are shown. The crosses represent the sample calculations for flame points, and the triangle a sample sky point (see Appendix).