Assessing Colour Appearance and Colour Differences for Automobile Coatings - Methods for Assessing Coarseness

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ABSTRACT

The aim of this study is to investigate methods for assessing the coarseness of metallic samples. Coarseness is used to describe human perception on optical texture of metallic samples. Three psychophysical experiments were conducted using the categorical judgement technique according to different viewing devices used: an integrating sphere, a viewing cabinet and a CRT monitor. Observer accuracy and repeatability performance for assessing coarseness for all three sets of experimental data were analysed. However, the results for integrating sphere gave the worse performance. CRT simulation results need further investigation.

Keywords: Metallic, surface texture, optical texture, coarseness, psychophysical

1. INTRODUCTION

Surface texture is one of the important attributes to describe total appearance of an object. ASTM standard[1] defines it as ‘the visible surface structure depending on the size and organization of small constituent parts of a material; typically, surface structure of a woven fabric’. Surface texture can be divided into two sub-groups: physical texture and optical texture. Optical texture is the texture[2] associated with spatial variation in human visual appearance caused by non-uniformity of colorant, such as a metallic automobile finish where the variation caused by the spatial distribution of the discrete aluminium flakes. These flakes are visible through an acrylic varnish overcoat, which gives a smooth and high gloss finish but texture sensation. Some word pairs are used to describe human response to texture like fine – coarse, smooth – grained, etc. In this paper, this optical texture appearance is called coarseness. McCamy[3,4] named it as graininess and used an adjective term “coarse” to modify metallic flakes. The aim of this work is to investigate the suitability of different methods for assessing the coarseness of metallic samples.

2. METHOD

Several instruments were used in this experiment. These include a multi-angle GretagMacbeth® CE741GL spectrophotometer for measuring the colours of the metallic samples at four aspecular angles (20^o, 45^o, 75^o and 110^o), a Nikon D1X digital camera with 5.3 effective mega pixels image CCD sensors for capturing metallic images, a DigiEye® illumination box for providing illumination to capture high quality images, and three viewing devices for psychophysical experiments. These are an integrating sphere, a VeriVide® viewing cabinet, and a Barco CRT display as shown in Figure 1 (a) to 1(c) respectively.

One hundred fifty coloured metallic panels were prepared surrounding three colour centres: a green, a blue and a purple with 50 samples each. The formulation samples were made by mixing each of the three colour pigments (green, blue and purple) with a black pigment and metallic flakes of different proportions. A set of 6 grey metallic samples having different degree of coarseness was also used. The samples were measured using the *CE741GL* at four aspecular angles[5]. The measurement results are plotted in Figure 2 top raw on CIE a*b* and bottom raw L*C* diagrams respectively. Two grey samples with quite different coarseness were chosen and used as anchoring samples in the psychophysical experiments. The 6 grey samples were assessed 3 times to investigate the repeatability of observer performances. In total, there were 168 samples in each of the three experiments.

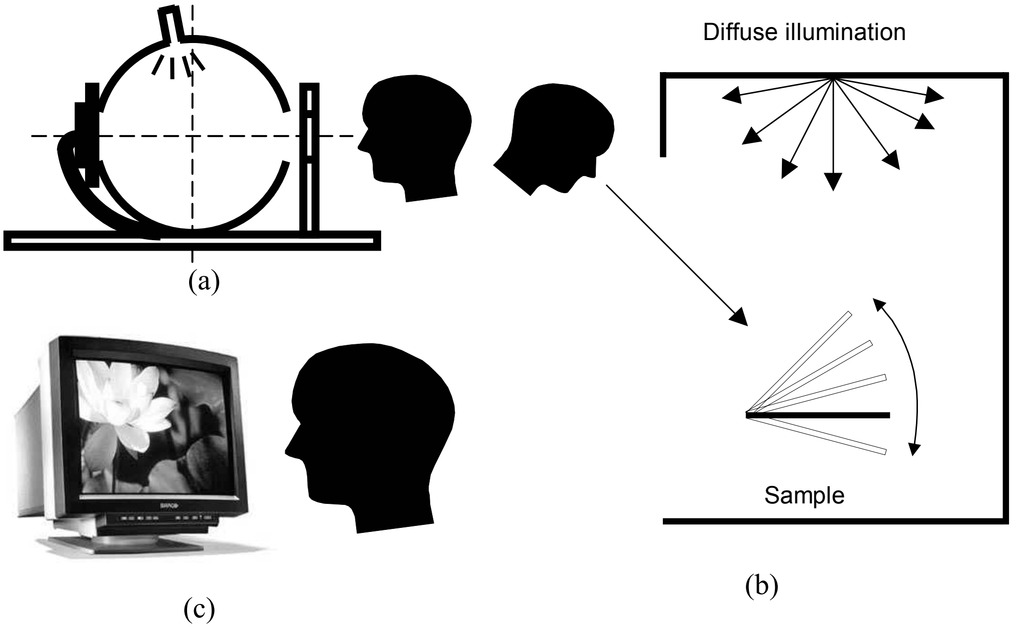

Figure 1: The experimental situations using (a) an integrating sphere, (b) a VeriVide viewing cabinet, and (c) a BARCO CRT.

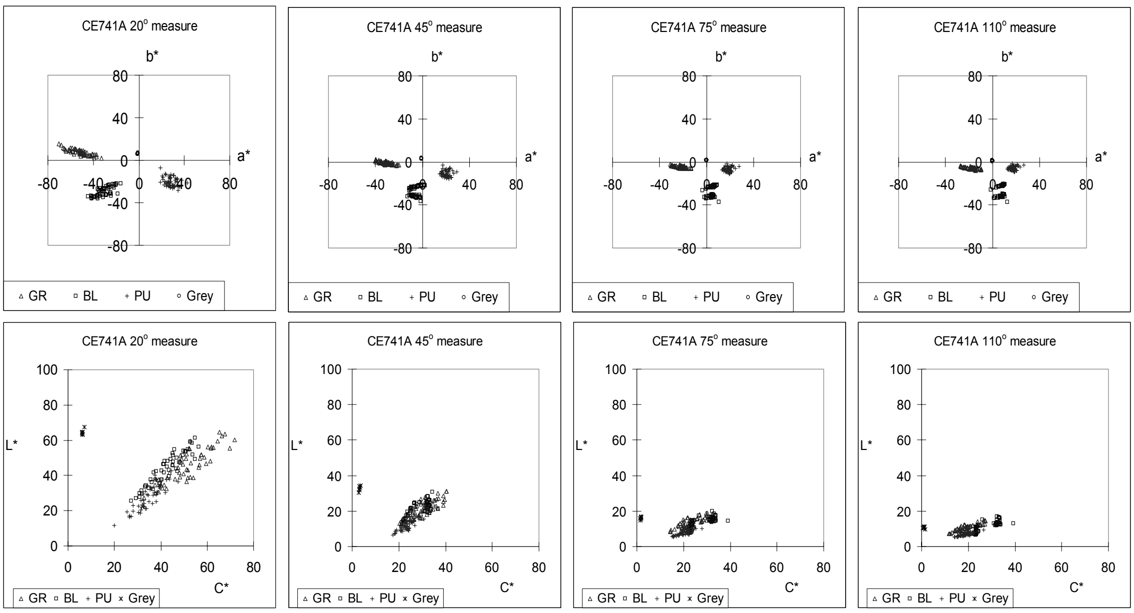

Figure 2: The colours of 156 samples measured by a GretagMacbeth ***CE741GL*** multi-angle spectrophotometer plotted in CIE a*b* diagram (top row) and CIE L*C* diagram (bottom row).

Three psychophysical experiments were conducted using the categorical judgement technique according to the different viewing devices used as illustrated in Figure 1. Only two anchoring samples presented to observers as Category 1 and Category 8 respectively. They were instructed that the scale between Category 1 to 8 is a uniform scale (having equal visual step of coarseness). For samples being perceived coarser than Category 8, a number of 9 should be assigned. The sample was presented one at a time to an observer and all samples were arranged following a random order. Ten observers, who passed the Ishihara vision test, took part in each of the three experiments. In total 3360 assessments were accumulated, i.e. 56 (50 coloured and 6 grey) samples x 3 colour centres x 10 observers x 2 viewing devices.

For the integrating sphere experiment, observers sat in front of the sphere and looked at the sample through the eyepiece. Each sample was illuminated by an intensive diffused light. For the viewing cabinet experiment (with diffuse illumination using a set of fluorescent D65 simulators), observers held each test sample using a pair of white glove to avoid the damage of sample panels. They were asked to adjust the viewing angle to find the maximum perception of coarseness, and then to report a categorical number of coarseness. Finally, the images of all the physical panels were displayed on to a Barco CRT and assessed by the same group of observers. The total number of assessment was 1680, i.e. 56 samples x 3 colour centres x 10 observers.

Coefficient of Variation (*CV*) was used as a statistical measure to indicate the agreement between the two sets of data compared. It calculates the root-mean-square deviation of the distances of the points from the 45° line as a percentage of the mean value of the y set, which gives results independent of the size of the set y. It can be considered as relative percentage error.

$$CV = \frac{100}{\bar{y}}\sqrt{\frac{(x_i - y_i)^2}{n}} \qquad (1)$$

Since categorical judgement method was used, the observers' data were treated as interval scale data and arithmetic mean was used to represent the mean observers' results[6, 7].

3. RESULTS

Observer accuracy: By calculating CV values between each of 10 observers' data and mean data, each individual observer's accuracy is given in Table 1 for three separate experiments. The results show that the accuracy performances are similar for the experiments conducted using viewing cabinet and CRT, and are much better than that by using integrating sphere. The mean *CV* values in Table 1 clearly show that observers assessed the coarseness more accurately using viewing cabinet and CRT device than using integrating sphere. Note that the integrating sphere originally designed for measuring coarseness should give the most accurate results. The current finding disagreed with this. This may be caused by the inclusion of a mirror image[8] at the middle of the panel, the eye constraint by staring at the small viewing window, and a lack of free eye movement.

Table 1: Observer accuracy for integrate sphere, viewing cabinet and CRT monitor

CV \ Obs	1	2	3	4	5	6	7	8	9	10	Mean
Integrating sphere	32	28	25	27	21	29	27	27	20	27	26
Viewing cabinet	17	22	17	16	18	23	18	20	17	20	19
CRT	19	18	19	21	14	23	17	19	20	18	19

Observer repeatability: Six grey samples having a similar grey colour but varying in coarseness were assessed three times in each of the three experiments. Observer repeatability was investigated by using these data. Table 2 shows the repeatability of the three experiments by calculating CV values between each of the two data sets. It can be seen that all *CV* values are much smaller than observer accuracy in Table 1. The repeatability of the integrating sphere experiment is the largest (*CV = 11*) and CRT experiment the smallest (*CV = 5*). All these values are small, which indicate a good repeatability in all 3 experiments.

Table 2: Observers' repeatability data based on 6 grey panels for three devices

CV	1st - 2nd	1st - 3rd	2nd - 3rd	Mean
Sphere	13	16	4	11
Cabinet	8	6	6	7
CRT	3	6	6	5

Comparing visual results between three devices: observer data for the three experiments were compared in order to reveal the difference between three sets of experiments carried out under different viewing conditions. Figure 3 includes three scattering diagrams by plotting the visual data between integrating sphere and viewing cabinet, between integrating sphere and CRT, and between viewing cabinet and CRT from left to right respectively. The results show a good agreement between all three experiments. The *CV* values for three comparisons are 12, 14 and 15 respectively.

However, the CRT coarseness was based on raw camera image without colour correction and was found to have a large colour different between the real panels and corresponding images displayed on CRT. This indicates that colour information may not be important for assessing coarseness.

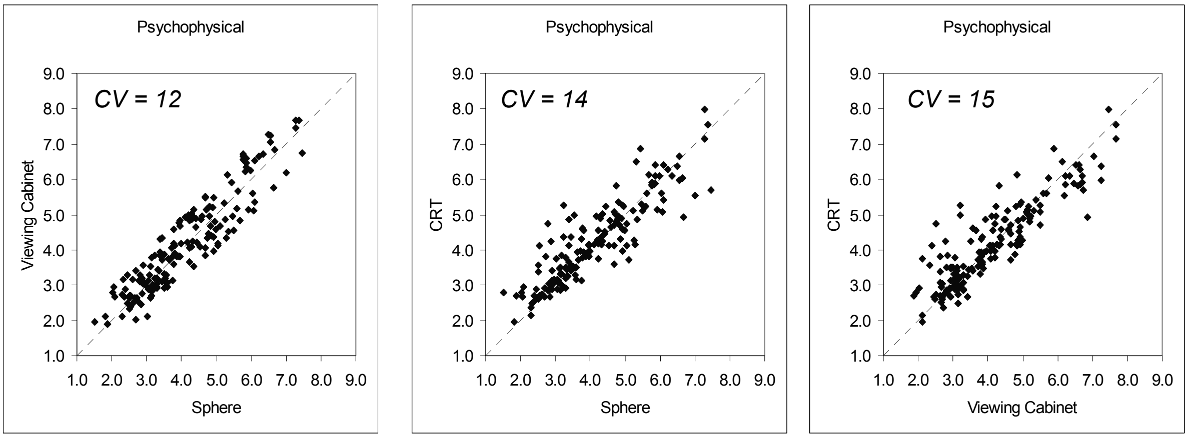

Figure 3: The comparison between observers' data of any 2 of the 3 devices with *CV* indication for all 168 stimuli.

4. CONCLUSIONS

Good observer accuracy and repeatability performances for assessing coarseness were found for all 3 sets of experimental data. However, the results for integrating sphere gave the worse performance because of the inclusion of a reflected mirror image and eye constraint. All three sets of data agree well with each other in general. Although the colour of each panel on display was quite different from that of the corresponding real panel, the coarseness results still agree well. This implies that assessing coarseness may not be affected by the colour information.

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