Proceedings Paper:

Jung, MH, Cheung, V and Rhodes, PA (2015) Total Appearance of Metallic Coatings using a Stereo Capture System. In: Yaguchi, H, Okajima, K, Ishida, T, Araki, K, Doi, M and Manabe, Y, (eds.) AIC 2015, Color and Image, Midterm Meeting of the International Color Association: Proceedings. AIC2015 Tokyo - Color and Image: Midterm Meeting of the International Colour Association, 19-22 May 2015, Tokyo, Japan. The Color Science Association of Japan , 1227 - 1232.

Total Appearance of Metallic Coatings using a Stereo Capture System

Min-Ho JUNG, Vien CHEUNG, Peter A. RHODES
School of Design, University of Leeds

ABSTRACT

This paper describes a study which aims to define the total appearance of metallic coatings and then objectively characterise it. Total appearance here refers to the combination of three properties of perceptual attributes of the surface: glint, coarseness and brightness. This study took into account one specific viewing angles only when irradiated by an intense directed light source. 54 metallic panels were visually scaled and a computational model capable for predicting three perceptual attributes was developed.

1. INTRODUCTION

Over recent decades, textured coating provided by metallic surfaces has been an important factor in attracting customers of the automobile industry. This has meant that quantifying the appearance of coating products is essential for product development and quality control. The appearance of these coated products strongly depends on the viewing geometry, giving rise to a variety of properties of perceptual attributes such as texture, colour and gloss. Due to the visually-complex nature of such coatings, there remains an unsatisfied demand to develop techniques to measure the total appearance of metallic coatings. This study focused on characterising not only one dominant attribute, glint, but also minor attributes, coarseness and brightness, with an intense directed light source. The measurement of the total appearance of metallic coating was conducted from an investigation of the relationships between the three perceptual appearance attributes judged by observers and the physical parameters extracted by a stereo capture system.

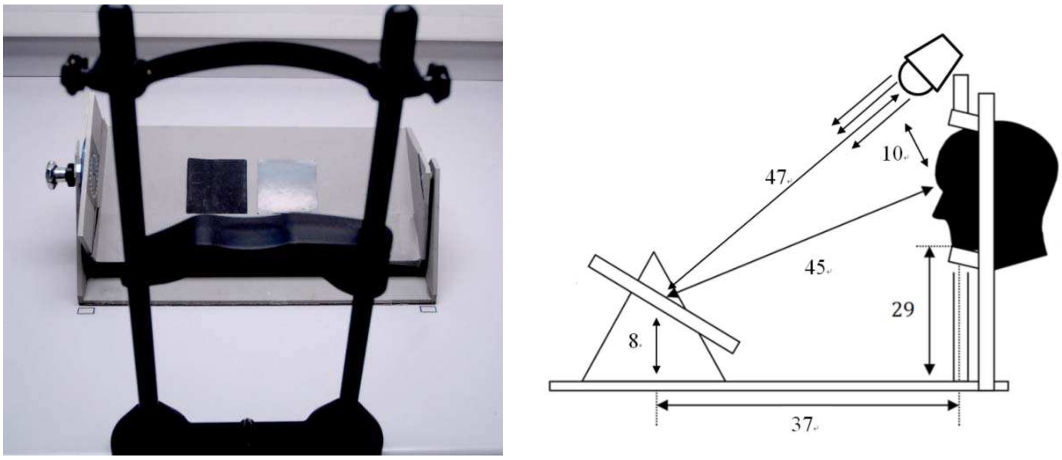


Figure 1: Experimental setup for total appearance – real setup (left) and schematic diagram of viewing condition (right).

2. PSYCHOPYSICAL EXPERIMENT

Visual assessments were carried out to quantify three properties of perceptual attributes of metalic-coagting panels: glint, coarseness and brightness. Ten observers with normal (or corrected to normal) visual acuity and colour vision participated in the assessments. They judged three perceptual attributes of 54 metallic panels under directional illumination by comparison with a reference sample. The session was carried out twice, each on a different day, in order to test repeatability. Each session lasted around 35 minutes, but was limited to 45 minutes so as to avoid visual fatigue. Figure 1 shows a LED spot light was used as the light source and it was located closely above the observer's head to minimise the angle between light source and observer.

3. DIGITAL IMAGING ANALYSIS

A computational model was developed to relate the results from the visual assessments to data obtained from the stereo capture system. This is a new alternative technique aimed at solving one of the most challenging problems in computer vision: stereo matching (Zhou and Boulanger, 2011). In the system, two images are captured by a same camera under two different lighting conditions to mimic stereoscopic vision. This not only addresses the problem of stereo matching (i.e. to find the corresponding pixels between two images) but also enhances the effect of perceptual attributes, especially glint. After capturing two images, digital imaging processing was implemented to extract relative features of perceptual attributes of metallic texture under directional light source.

3.1 Stereo Capture System

The stereo capture system consists of a digital camera and two LED spot lights shown in Figure 2. The system was designed to mimic human stereo vision. In the system, one digital camera was used as an image detector in contrast to a striking way with general type of stereo capture system with two or more lenses with a separate image sensor. Nevertheless, the system can reproduce the effective images of stereo perception without the big problems in stereo matching. This advantage of this system comes from illumination set up. Two LED spot lights are located at different lateral positions and Each LED source plays a role as each eye of human vision. Two scenes illuminated by two different lights are different due to illumination angle. The angle between a digital camera and light source was fixed as that of viewing geometry in visual assessment. In practice, two slightly different images for one sample were captured under two different lighting conditions: each image with single light on.

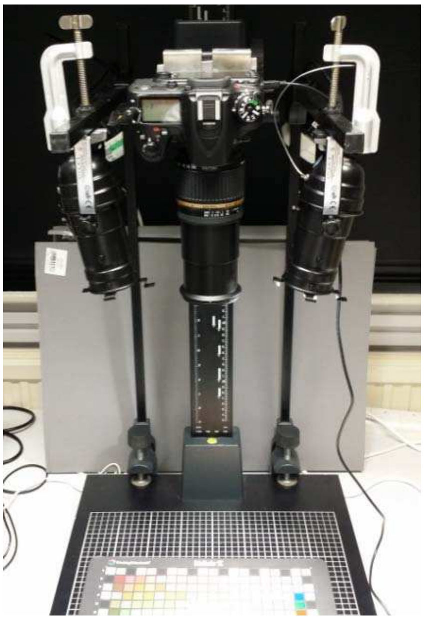


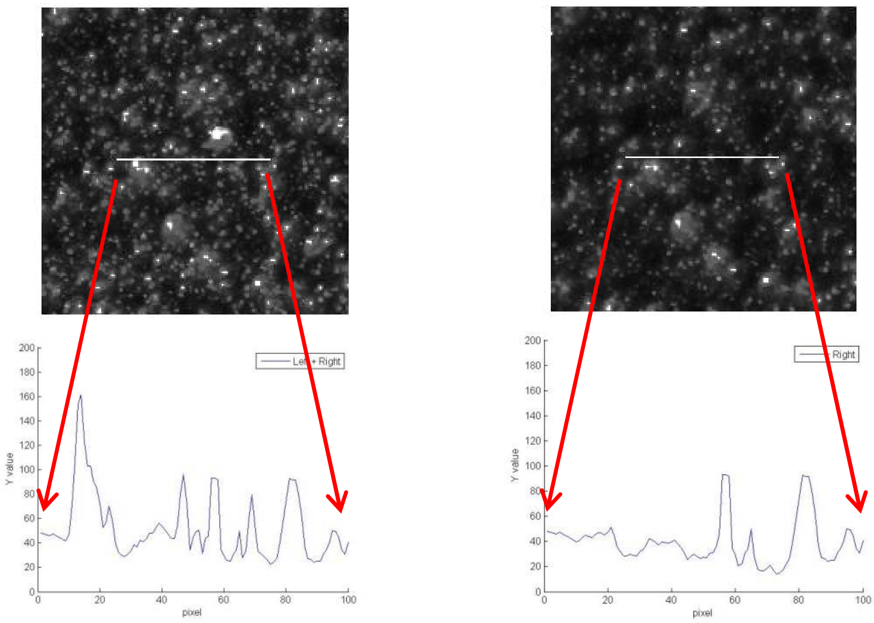
Figure 2: Stereo capture system.

3.2. Digital Image Processing

A camera characterisation method was applied to transform device-dependent RGB values to device-independent CIE XYZ tristimulus values. Luminance Y value of the images was used for the feature extraction. Illumination uniformity method was performed to minimise the effect of non-uniformity of the illumination intensity caused by the nature and geometry of spot light source used. The top-hat transform of an image was then employed to remove minor scratch of metallic-coating surface while leaving others undisturbed (Gonzalez *et al.*, 2004). Feature extraction starts on the assumption that the intensity distribution of the solid coating panels may be normal and symmetric histogram. This indicates that metallic-coating panels with the aluminium flakes have excessive part of histogram due to bright regions. According to assumption of normal distribution of the solid coating panels without aluminium flakes, Gaussian function was fitted to simulate the histogram and differential portion between both histograms was found. A global thresholding technique was applied to separate bright parts of metallic-coating panels. Two images obtained by these steps were combined into one image which is the largest elements of two images. Consequently, the image is the result which is similar to scene of stereo vision for digital image analysis.

4. RESULTS AND CONCLUSIONS

Figure 3 shows a comparison of two images; image (a) reconstructed by stereo image technic and image (b) captured by general image system with single camera. Two images represent not only the same metallic-coating panel but also exactly same area of the sample. Nevertheless, two images show different scene each other. Image (a) is similar to perception of human being with two eyes and gives more visual information than image (b). Intensity histogram of stereo image (a) testifies their difference in detail.



(a) (b)

Figure 3: The intensity comparison of two images captured from general acquisition and stereo capture system.

Observer variability of the three perceptual attributes: glint, coarseness and brightness was quantified using observer accuracy and repeatability. The statistical methods used in data analysis were the coefficient of determination, R^2, and coefficient of variation, *CV*. Table 1 shows that the observer accuracy and repeatability. Repeatability of coarseness was similar to that of glint but another was lower to that. The results of brightness do not provide signified statistics due to very low R^2 values obtained. It can be concluded that only glint of appearance attributes of metallic-coating panels is a meaningful property under specific viewing angles only when irradiated by an intense directed light source.

Table 1: A summary of observer accuracy and repeatability measures for all the samples.

		Accuracy			**Repeatability**		
	Logarithmic Scale	Glint	Coarseness	Brightness	Glint	Coarseness	Brightness
R^2	Mean	0.90	0.71	0.09	0.90	0.75	0.52
	Median	0.91	0.71	0.08	0.90	0.75	0.52
CV	Mean	13.67	12.15	4.26	10.42	11.76	4.64
	Median	12.49	10.33	3.50	10.89	10.09	3.49
	Raw Scale	Glint	Coarseness	Brightness	Glint	Coarseness	Brightness
R^2	Mean	0.85	0.74	0.58	0.82	0.75	0.52
	Median	0.87	0.76	0.59	0.85	0.77	0.47
CV	Mean	30.09	29.75	19.72	-	-	-
	Median	24.94	26.19	14.04	-	-	-

Using digital image processing, a dominant property of the total appearance of metallic coatings, glint, was extracted and compared with perceptual grade of observers in terms of twelve features: number of pixels, sum of those pixel values, number of particles, sum of mean value of each particle, pixel percentage against background, area percentage and six properties which are divided by the threshold *t* value (Kitaguchi, 2008). As shown in Figure 4 (h), sum of those pixel values divided by threshold value represent the highest correlation between both.

There are several statistic features with high correlation with perceptual glint along with representative property (h). To develop the model predictions, non-linearity step was applied and the performance of model was evaluated. Finally, power form using the property (h) gave the best performance.

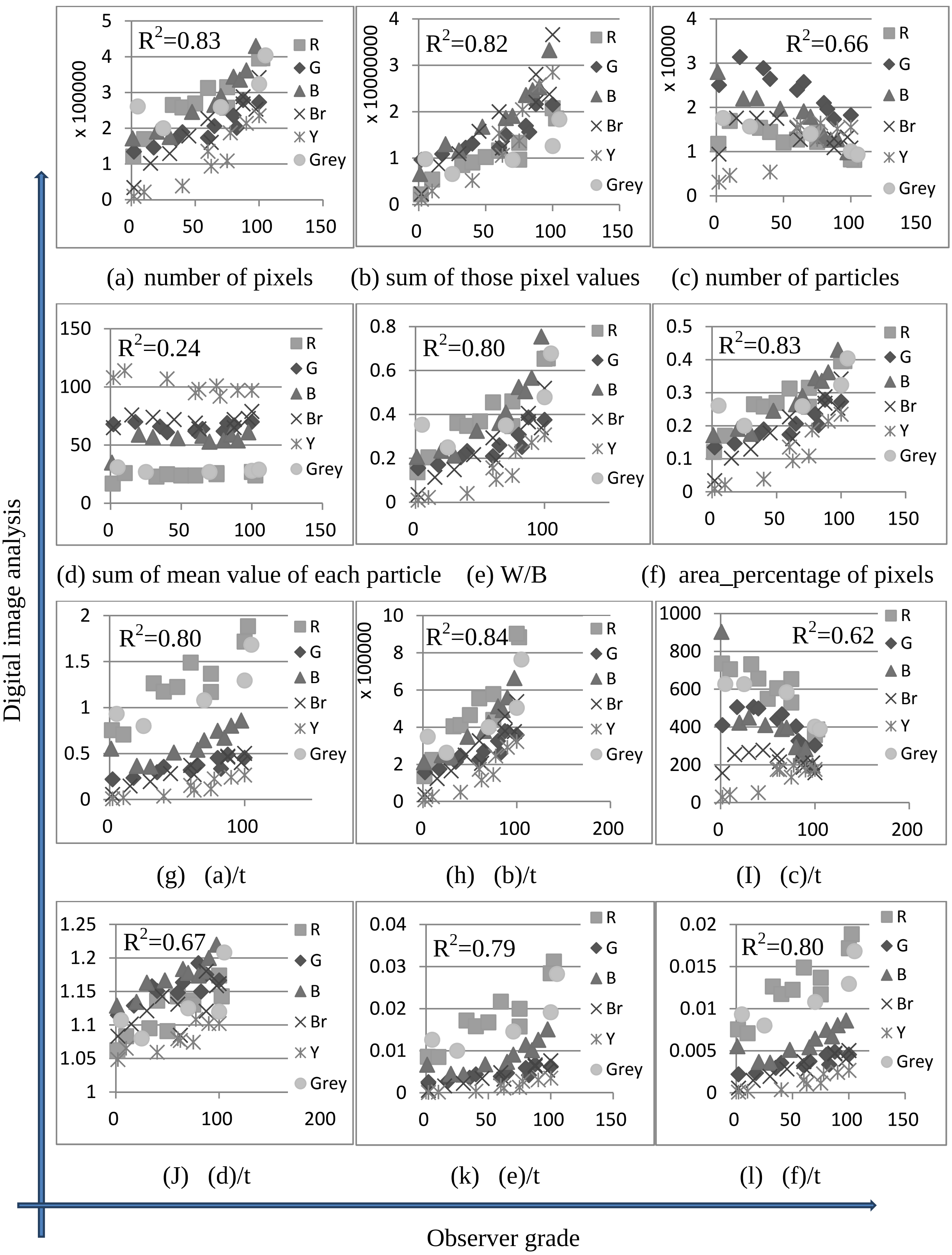


Figure 4: Observer grade VS digital image analysis

REFERENCES

Zhou, X. and Boulanger, P. 2011. Illumination Invariant Stereo Matching Based on Normalized Mutual Information and Census Methods. *Proceedings of Computer Graphics International Conference*.

Gonzalez, R.C., Woods, R.E., and Eddings, S.L. 2004. *Digital image processing using MATLAB*. New Jersey: Pearson Education, Inc.

Kitaguchi, S. 2008. Modelling Texture Appearance of Gonioapparent Objects. *PhD Thesis*, University of Leeds, UK.

Address: Min-Ho Jung, School of Design, University of Leeds, Leeds LS2 9JT, UK
E-mails: ccd6mhj@leeds.ac.uk, t.l.v.cheung@lees.ac.uk, p.a.rhodes@leeds.ac.uk