RE-DEFINING THE COLOUR RENDERING INDEX

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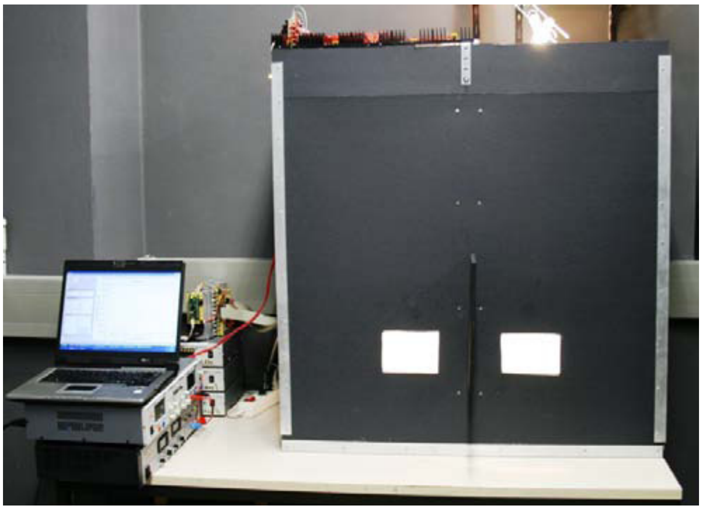
Introduction

The CIE colour rendering index is generally not applicable to predict the colour rendering rank order of light sources especially if white LEDs are included [1]. CIE TC 1-69 is currently working on a new index. Recently, CIECAM02 based uniform colour spaces (UCSs) were published [2]. CIECAM02 predicts colour appearance under very different viewing conditions, and these UCSs performed well in predicting both large and small colour difference datasets under both daylight and illuminant A. Aims of our research are: 1. collect a colour difference dataset including LED light sources and their reference light sources; 2. test and improve the performance of these UCSs; 3. define a new practicable (rating scale based) colour rendering index based on these results.

Method

A double-chamber viewing booth was constructed (Figure 1, left) with 2 types of white phosphor LEDs at 2700K (u'=0.26; v'=0.53; HC3L - high CRI, Ra=96; and C3L - low CRI, Ra=68), RGB-LED-clusters having Tc=2700 K and warm white fluorescent lamps as test light sources and a tungsten halogen reference light source, approximately at the same chromaticity. Additionally, white LED-arrays with high and low colour rendering index (Ra= 93 and 70), RGB-clusters and fluorescent lamps with CCT=5500 K as test light sources and a HMI-lamp (Ra= 93) as reference light source are also used. The inside of the chambers was painted white. This white surface had a luminance of 240cd/m2. Two identical copies of 20 four-degree matte colour papers of different colours - 15 from the Macbeth Colour Checker Chart and 5 from Dr. Yoshi Ohno's (NIST-USA) colour set of high saturation - on a grey background (59cd/m2) were observed and the perceived colour differences between the test and the reference light sources were scaled in a 3-step method.



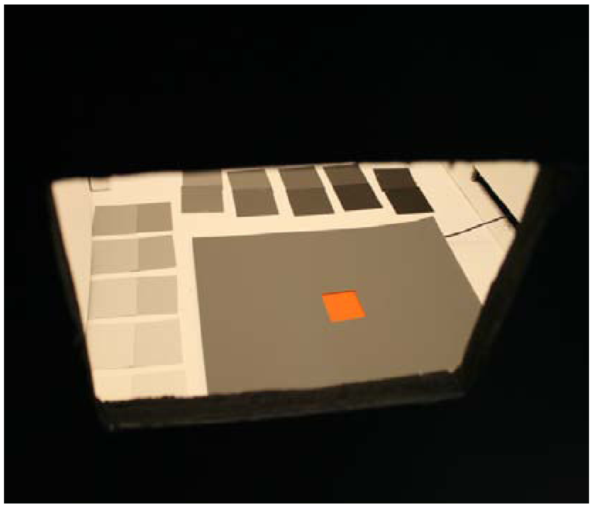


Figure 1. Left picture: Double-chamber viewing booth; Right picture: reference side with a 4° colour square (matte paper) and the colour difference greyscale anchors to help scale colour differences

In the 1st step, observers had to rank the colour difference on a rating scale: 1: excellent; 2: good; 3: tolerable; 4. not acceptable; and 5. very bad. In the 2nd step, they had to fine-tune their rating on a corresponding interval scale - if the rating was “excellent” (1) then between 95 and 100, between 80 and 95 for 2, between 60 and 80 for 3, between 40 and 60 for 4, and between 0 and 40 for 5. In the 3rd step, they had to scale the total visual difference with greyscale colour difference anchors that fixed the unit of visual colour difference, see Figure 1, right.

Results and Discussion

Visual colour difference results and calculated colour differences (according to CIELAB, CIEDE2000, CIECAM02, and CIECAM02-UCS[2]) are compared in Figure 2 for two observers (WK and PB, normal colour vision tested with a Nagel anomaloscope). As can be seen from Figure 2, the HC3L white LED causes smaller visual colour differences than C3L (as expected). Best correlation was obtained with the CIEDE2000 formula but even with that, the correlation was low: r2<0.48. For the smaller visual colour differences of the HC3L lamp, the correlation was very low for all formulae: r2<0.22. In our view, one reason is the difficulty of assessing small colour differences. Therefore, our current research is directed toward predicting one of the five colour difference rankings (see Method, 1st step) from the physical measurement of the test colour. In our view, industrial applications do not need an interval scale (i.e. a real number) to quantify colour difference perception. We would like to define the boundaries of the five rankings on a continuous scale of a suitable colour difference formula based on our new observations. The new colour rendering index can be defined e.g. as the number of “excellent” ratings predicted for the set of test colour samples. We are currently collecting a new experimental dataset to elaborate this novel approach. Note that the rating scale may imply a cognitive colour effect (important for colour rendering): the reference colour is often associated with a long-term memory colour, e.g. a well-known flower. The question is how well this flower can be identified by using the test colour and according to P.B. (one of our observers), the rating scale may be suitable for that.

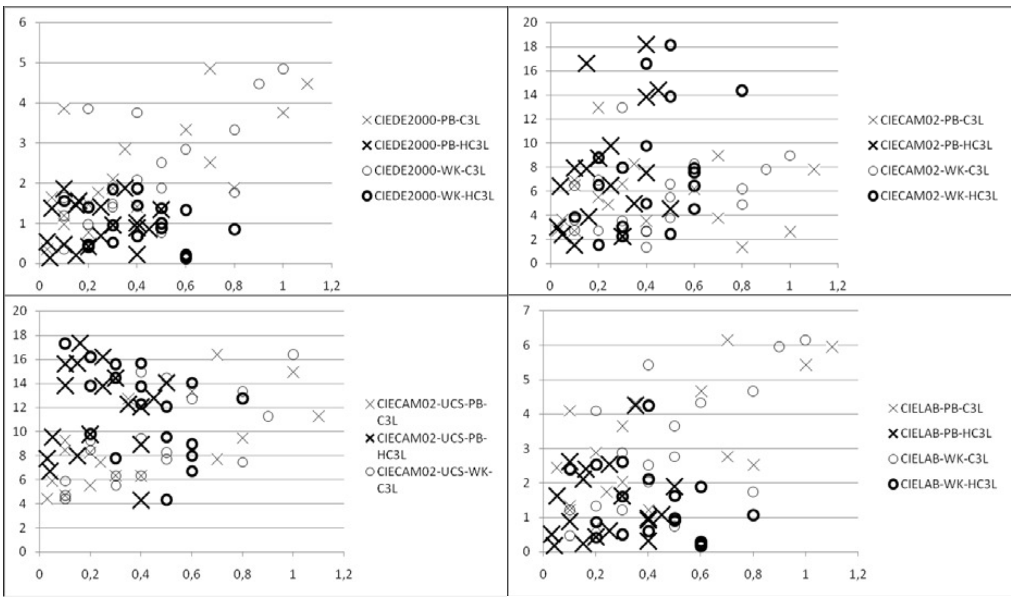


Figure 2. Visual colour difference rating (abscissa: Method 3rd step, with greyscale anchors) and prediction (ordinate: various colour difference formulae). 2 observers WK and PB, and 2 white phosphor LED light sources as test sources: C3L (low CRI) and HC3L (high CRI). Reference light source: tungsten halogen.

Research plan

1. Explore inter-observer differences based on this method and build observer clusters for colour rendering;

2. Study the difference between the above "pairwise" comparison method with an "acceptability" study[3] where instead of standalone colour patches (which is never the case in industrial colour rendering applications) Mondrians or photo-realistic images are evaluated and, in addition to chromatic adaptation, further mechanisms of colour constancy can be added to model the colour rendering phenomenon more exactly;

3. Once the new colour rendering index is defined based on the method mentioned herewith, a field-test series with a tabletop containing colour objects (textile, fruit, newspaper, coloured toys...) shall be illuminated with different conventional light sources and LED-luminaires of different colour rendering properties and rating experiments shall be carried out with different test person groups (observer clusters);

4. Finally, the aim is to have a well-verified new colour rendering index, early 2010.

Acknowledgement

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References

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[3] J. Schanda, G. Madár, N. Sándor, F. Szabó, Colour rendering - colour acceptability, 6th Internat. Lighting Res. Symp. On Light and Color, Florida, February 2006.