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INDUSTRIAL COLOUR-DIFFERENCE EVALUATION

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INDUSTRIAL COLOUR-DIFFERENCE EVALUATION

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SUMMARY

INDUSTRIAL COLOUR-DIFFERENCE EVALUATION

Recommended practice for industrial colour-difference evaluation is presented. The recommended model is an extension of the CIE 1976 ($L^*a^*b^*$) colour-difference model with correction for chroma-dependent variation in colour-difference perception. Reference conditions define material and viewing environment characteristics to which the colour-difference model applies. Factors are introduced to correct for the parametric effects of various conditions of use. Guidelines for further research on colour-difference perception are given.

RÉSUMÉ

EVALUATION INDUSTRIELLE DES DIFFERENCES DE COULEUR

Le document présente une méthode recommandée pour l'évaluation industrielle des différences de couleur. Le modèle recommandé est une extension de la formule de différence de couleur CIE 1976 $L^*a^*b^*$, qui corrige la perception des différences de couleur des effets liés au chroma. Des conditions de base définissent, pour les matériaux et pour les modalités d'observation, les situations pour lesquelles le modèle s'applique. Des paramètres introduits dans le modèle corrigent les effets résultant de conditions d'emploi différentes. Des indications sont données pour un travail ultérieur de recherche sur la perception des différences de couleur.

ZUSAMMENFASSUNG

INDUSTRIELLE FARBABSTANDSBEWERTUNG

Es werden Empfehlungen zur Praxis der industriellen Farbabstandsbewertung vorgestellt. Das empfohlene Modell stellt eine Erweiterung der " L^*, a^*, b^* -Farbabstand CIE 1976"-Formel dar, mit Korrekturen für buntheitsabhängige Änderungen der empfundenen Farbunterschiede. Bezugsbedingungen legen Material und Gestaltung der Sehaufgabe fest, für die das Farbabstandsmodell gilt. Parameter zur Korrektur der Auswirkungen verschiedener Anwendungsbedingungen werden eingeführt. Für weitere Untersuchungen über die Empfindung von Farbunterschieden werden Richtlinien formuliert.

1. INTRODUCTION

1.1 *Statement of the colour-difference problem*

Many industries employ colouring processes to provide products designed to enhance colour uniformity, colour recognition or aesthetic appeal. The producer must deliver a product of the desired colour with its variation controlled to an extent appropriate for the product's use and the customer's expectations. Colour measurement and colour-difference evaluation are essential tools to help manufacturers accomplish these goals with efficient colour production processes.

CIE colorimetry is employed to determine whether the colour of a sample is a match to the aim-colour of the product for an average observer under specified viewing conditions. As an industrial practice it is successful and is almost universally used for quantitative colour measurement. The extension from measurement of colours which match to measurement of the magnitude of the difference between colours which do not match is less successful. Colour-difference assessment involves advanced colorimetry; the description of the perceptual response to colour appearance. There is significantly greater variability in judgements of the magnitude of a difference between two colours than in judgements of whether two colours match. Furthermore, many factors which do not influence a matching judgement do affect the perception of a colour difference. Thus there is significant variation between different experimental studies of colour-difference perception.

Colour-difference evaluation models have been, and continue to be, developed. Recognising the complexity of the colour-difference problem, and the continuing research into colour-difference perception, it is expected there will be further improvement in colour-difference models for industrial applications. There are several independent models in active use in industry. This leads to difficulty in colour communications between organisations employing different models. The CIE, through its technical committees, has periodically established recommended practices for colour-difference evaluation to promote uniformity of industrial practice. In addition each recommendation has aimed to incorporate the latest research so that it represents best practice consistent with the present state of knowledge on colour-difference perception. The last CIE recommendation on this subject was made in 1978 (CIE, 1978). Accumulated research since then indicates it is now possible to identify a model with improved agreement with visual colour-difference judgements. CIE Technical Committee 1-29 Industrial Colour-Difference Evaluation was assigned the task to investigate available colour-difference models and to make a recommendation for industrial applications of colour-difference evaluation.

There are two principal problems a colour-difference model must address. The first is uniformity of colour-difference magnitudes over all colours and for all directions of colour difference. The second is applicability over the range of experimental conditions and material characteristics employed in the manufacture of coloured materials.

A colour-difference model exhibits uniformity if the model predicts a constant magnitude of colour difference for all colour pairs which have equal perceived colour difference. In a perfectly uniform three-dimensional colour space the locus of constant visual colour-difference from an aim colour is a sphere centred on the aim colour and the equivalent loci for all possible aim colours are spheres of equal radius. Colour-difference models are approximations to this ideal of colour-difference uniformity.

The development of colour-difference models depends on experimental data relating perceived colour differences to colorimetric measurements of the colour-difference pairs. An implicit assumption is frequently made that the primary factors in such experiments are the location, direction and magnitude of the stimulus differences. However, a number of additional variables influence perceived colour differences. CIE Technical Committee 1-28 Parameters Affecting Colour-Difference Evaluation has identified and reported on the influence of these additional variables, or parametric effects (CIE, 1993). These variables include characteristics

of the material, the viewing environment and the stimulus presentation. Material characteristics include colour uniformity, material structure or texture, and surface reflection characteristics (matte or glossy). Presentation factors include the size of viewing field and separation between stimuli. Viewing environment factors include the spectral power distribution of the illumination, its illuminance level and the background colour. In addition experimental results may be influenced by the observers' task, individual differences among observers, size of the colour-difference magnitude, appearance mode, experimental methodology and method of analysis. Psychological factors, prior experiences and the context of the judgement task (acceptability or perceptibility) may also influence observers' colour-difference responses. The combined impact of these parametric effects is not well defined but is believed to be a major contributor to the inconsistency between the results of colour-difference perception experiments. A full understanding of colour-difference perception will require knowledge about the influence of parametric effects in addition to knowledge about the way colour-difference perception varies as colour location and direction vary.

Industrial applications of colour-difference evaluation are made under various parametric conditions and it is not currently possible to account for all these effects. A set of reference conditions are specified which are typical of those employed in industry and are consistent with several experimental data sets. Models based on these data sets can be expected to perform well when applied to visual assessments close to the reference conditions. If the conditions of application vary significantly from the reference conditions, a parametric correction to the colour-difference model may be required to achieve agreement with visual perception.

1.2 Goal

The goal of the recommendation on industrial colour-difference evaluation is to provide a quantitative model of colour-difference perception that agrees well with visual colour-difference perception for an average observer under conditions typical of industrial applications. In addition the recommendation should provide guidance to the user concerning the conditions to which the model applies (the reference conditions) and the means to correct for parametric effects.

1.3 Development strategy

TC1-29 has adopted a strategy for on-going development of industrial colour-difference evaluation. The elements of this strategy are a commitment to sustain the good features of existing models, to co-ordinate new research on colour-difference perception and to enhance the recommended colour-difference model through either empirical corrections or advanced model development.

The CIE 1976 $L^*a^*b^*$ colour-difference recommendation has achieved a useful level of acceptance by industry. Generally users find the rectangular co-ordinate space based on opponent responses, L^* , a^* , b^* , to be an intuitive and readily understood basis for industrial colour-difference practice. Furthermore, the perceptual correlates of lightness, chroma and hue provided by lightness, L^* , chroma, C^*_{ab} , and hue angle, h_{ab} , scales are also regarded as effective. These good features have led a majority of industrial users to adopt CIELAB or CIELAB-based colour-difference models. The Committee wishes to retain the strong features of CIELAB.

Co-ordination of research on colour-difference perception is the second element of our strategy. A previous CIE technical committee concerned with colour-difference evaluation published guidelines for research (Robertson, 1978). This has led to a focus on experimental conditions typical of industrial applications (object mode, small to moderate colour-difference magnitude) and use of similar test colours, enabling comparison of experimental results. Several experimental data sets developed within the research guidelines have been very useful to TC1-29. The CIE plans to continue this effort by periodic announcement of research guidelines. These may include guidance on research objectives, parametric conditions, experimental methodologies and communication of results.