AIC

Interim Meeting Colorimetry

September 3-6, 1995

Abstracts

Fred Simon:
What's new in material color standard

Material color standards have an important place in the scheme of color technology to provide a means for checking the validity of instruments, scaling visual estimate, and to provide a transfer mechanism for measurements made under different conditions. Although many color measurement instruments have been improved over the last several years both for precision and accuracy, the need continues for stable standards to be used to verfify the data that are obtained even under the most ideal conditions. Furthermore, there is a continuing requirement for insuring the reliability of the data obtained frome one time to another.Material standards are available for color and appearance characteristics that can be measured. The most common standards are the color standards made as ceramic, plastic, or vetreous enamel plaques. These are complemented by glass filters which are used when transmission measurements can be made. Fluorescent white and chromatic standards have an important role in calibration of instruments for measurement and visual comparison of fluorescent materials. Haze and translucent standards provide scaling for materials which may not be colored but such appearance characteristics closely interact with color. By definition, color standards for reflection measurement are stable, fairly rugged, and cleanable (or renewable). However, there are several caveats in selection of ideal standards. Matte surface materials are preferred as transfer standards. Since the surface of a matte standard can be altered during continues use, its protection is important to maintain fidelity. A holder that recesses the measurement plane slightly below the mounting on the instrument is helpful. Another problem arises with respect to translucent blurring, especially with white reference materials. The spectral characteristics of most orange, red, and yellow materials change with temperature so precautions must be taken to avoid unreliable data. These problems will be discussed to illustrate possible solutions that make material standards more reliable.

Dietrich Gundlach:
Excitation and weighting of fluorescence in colorimetry

The excitation and weighting of the fluorescence of a luminescent surface colour depends on the spectral power distribution of the illuminant for which the colorimetric results are wanted. In practical colorimetriy the illuminant of the colorimeter or spectrometer will significantly differ from that of the wanted illuminant and over - or under excitation and over - or under weighting of the fluorescence will occur. Generally these deviations cannot be completely corrected minimized. A recipe for managing this problem will be discussed.

Rolf Griesser:
CIE whiteness and tint: possible improvements

To introduce some measure of standardization in the face of the endless variety of whiteness formulas being used, the CIE proposed in 1986 a whiteness and a tint formula for practical trials. The formulas in question were simplified derivatives of those used in the Ganz/Griesser method. The difference is that the CIE proposes fixed formula parameters and recommends the formulas only for relative assessments valid just for measurements with a single instrument at a given time and without reference to a white scale. Use of the two formulas is restriced to samples differing not too widely in tint and fluorescence. The measurements must be performed on the same instrument at about the same time. With these restrictions the formulas yield relative, not absolute, white assessments reportedly adequate for commercial use in many cases. The measuring instruments must have sample illumination resembling daylight. Assessment with the formulas is appreciably improved if the sample illumination is stabilized and fitted as close as possible to a desired standard illuminant, as with the Gärtner/Griesser UV adjustment device. The samples to be compared then do not need to be measured at the same time. It also greatly improves the matching of different measuring instruments, though only for whiteness. The tint values can only be satisfactorily matched by instrument-specific calculation of the formula parameters as practised in the Ganz/Griesser method. The CIE method can be upgraded and markedly extended in scope by incorporating components of this new procedure, as suggested in the present paper. The representative numerical data used in the calculations enable computer programs based on them to be checked for errors.

David Burns, N.L. Johnson:
The correlation of measured spectral radiance of fluorescent and non-fluorescent materials to perceived conspicuity under natural lighting

It is well known that the visibility and conspicuity of fluorescent materials increases under low ambient lighting conditions. The extent to which this phenomena is based on the physical reflectance and emission properties of the materials is not well documented. This paper reports the physical measurement of several fluorescent and non-fluorescent colored materials under varying and decreasing natural light levels, then relates these photometric measurements to perceived visibility and conspicuity. A series of field measurements were made using a telespectroradiometer. Analysis is presented using the conventional CIE system. The results show the measured luminance ratio between fluorescent and non-fluorescent colors does increase under the low light conditions encountered a twilight and under heavily overcast skies. This relative increase in the luminance of the fluorescent materials correlates with the increased conspicuity of these materials.

Ramsey Saunders, R. DeFour:
Spectral and colorimetric properties of the light emitted by the dorsal bioluminescent organs by Phyroporus pellucens

The light-emitting organs on the top of the head of the click beetle (Phyrophorus pellucens) were stimulated mechanically as well as electrically. Light emitted was taken via a glass-fibre transformer to the entrance slit of a Zeiss grating monochromator and the output measured with a photomultiplier (RCA4832) in conjunction with a digital multimeter. The RCA4832 has a flat spectral response in the visible range, thus the output at each wavelength is directly proportional to the source (organ) output. The chromaticity coordinates (x,y,z) of the light output were compared with those of the spectral absorption of leaf pigments using standard techniques. When the chromaticity coordinates of the light output were compared with those of the leaf pigments, it was found they lie on opposite sides of the white point. This indicates that little of the light produced by this nocturnal animal is absorbed by leaves. Most of the light is reflected. This in turn suggests that light emitted by the bioluminescing organs is used for vision. In future work the spectral response of isolated visual neurons of the anmimal will be compared with the spectral properties of the light emitted.

Thomas Kremer:
Deuteranomalous opponent color vision under consideration of the Abney-effect

The usual characterisation of anomalous trichromats is based on colour matches. The perceptual criterion 'indistinguishably equal' reveals the qualities of colour vision only to a limited extent. The application of the perceptual criteria 'neither blue nor yellow', 'neither green nor red' and 'heterochromatically equally bright' allows a more complete description of the perceptual qualities of trichromatic vision. The colour vision of a deuteranomalous observer was investigated with the help of the above mentioned four perceptual criteria using a visual Guild-Bechstein tristimulus colorimeter. The results permitted the establishment of a three-dimensional opponent-colour space and thus the definition of transformation equations from spectral colour matching functions to opponent spectral colour functions. Nonlinearities within the meaning of the Abney effect were considered by piecewise linearisations, each applied for a certain range of wavelengths. By means of the established special deuteranomalous opponent-colour space a colour stimulus can be characterized according to blue-yellow chrominance, green-red chrominance and luminance. Middle and long wavelength colour matching function are shifted to longer wavelengths compared to a normal trichromat.

Jack A. Ladson:
Colorimetric data comparison of bench-top and portable instruments

Users of color measuring instruments all desire essentially almost identical results whether measurements are made in the laboratory or the production line, or between distant facilities. This capability is now available. BYK-Gardner USA manufactures color measuring instruments that provide the desired reproducibility of data from precision bench-top units and from less expensive protable instruments. Instrumental differences have been minimized between the precision bench-top units and their smaller, less expensive counterparts by perfecting the reproducibility obtained from portable instruments, such as BYK-Gardner's handy-color. Data obtained from these instruments now permit direct comparision of data from bench top laboratory reference instruments such as BYK-Gardner's color-view. When needed, data from each type of instrument, portable or bench-top, can be used to make important color decisions. In addition, colorimetric data can be transmitted electronically to permit comparison of inter-factory results.

Boris Sluban, D. Golob, St. Jeler:
A practical test of the equilibrate color matching

The paper describes a practical effect of the "equilibrate" strategy of colour match prediction on textiles. In cases when a given standard, using the usual single-illuminant matching strategy, can not be matched non-metamerically by the colorants available, the "equilibrate" matching strategy tries to produce a more acceptable match by balancing the colour differences under several different illuminants. The compariosn of metamerism of textile sample produced by both strategies is included.

Wilhelm H. Kettler, J.Spehl, M. Kolk, M. Wölker:
Color recipe prediction by artificial neural networks

Conventional 2-flux theory of Kubelka and Munk exploited for computer colorant formulation exhibits deficiencies in certain areas of coloration warranting an alternative approach. Significant improvements of the model cannot be achieved without diving deeply into radiative transfer theory. An alternate approach avoiding such mathematical complexities is offered by recent developments in the field of artificial neural networks. Adopting a multilayer feedforward network model several nets of different topologies have been trained by means of Kubelka/Munk equation for reflexion of opaque diffusers and experimentally determined optical material parameters of a vendible automotive repairing system. In contrast to previous investigations calculations have been performed in reflexion and not in color space, and the number of colorants have been extended considerably. Elaborate analysis of the results utilizing different strategies for pattern generation clearly demonstrates that feedforward networks can be successfully trained to small colorant sortiment ($n \leq 5$) while the training error deteriorates considerably with increasing number of colorant components ($n > 5$).

Peter Glatz, S. Kurz:
A training concept in color science for the graphic arts and industry

The Graphic Arts and Industry are different from other color processing industries because there no saturation of products is needed. An increasing number of applications includes color measurement and color formulation systems. The market for measurement equipment, color control and color matching grows although an equally growing number of suppliers competes for their market share. A few rules of the game must be respected in order to offer products to the Graphic Arts. One of the specialities of Graphic Arts is its prominent need of training including basic information, product training and application in favour of a meaningful and profitable use of colorimetry. A few examples will illustrate the application progress achieved in the last 5 years. However, we should also inform to what extent the application has to overcome contradictory situations. Examples are by comparing the results of the supplying industries (paper, plastics, pigments, inks) to Graphic Arts. The offset printing technology that mainly dominated the European Grahic Industry has been able to set outstanding standards in densitometry. Densitometry is rarely applicable to other printing technologies (for example flexo, gravure, sreen). This is one of the reasons for offering a broad range of traning services in spectrophotometry, color tolerances and ink formulation.

Hermann Pelshenke:
Colorimetry - strained relations between a modern quality management based on ISO 9000 and an every day job in a test lab.

In a modern quality management properties and quality marks must be measurable in order to describe them **quantitatively**. This is also valid for the quality mark COLOR. Having good experience in instrumentation for color measurement over the past 20 years I can say ISO 9000 is practicable. However even in 1995 we are aware that we are still distant from this quality objective. Often priority is given to subjective visual judges instead of results being based on objective color measurements with a good colorimeter. This is especially true for metallic and perlescent paints. Interacterions between objective measurement and subjectively influenced physiologically as well as psychologically affected judgements will be shown in this paper.
An explanation and an outlook will be given.

Norb L. Johnson:
Measuring the nighttime color of retroreflective materials

The measurement of the nighttime color of retroreflective materials has advanced in recent years as new instrumentation has become available. Both industry and national laboratories have developed techniques giving repeatable results. This presentation discusses the basic principles used in the measurement of the spectral coefficient of retroreflection and the alternative filter methods. These are the basis for the colorimetric calculations of the nighttime color appearance of retroreflective materials and devices. The use of modern telespectroradiomter system is described. An exploration of the benefits of alternate laboratory illuminating sources such as projection Xenon lamp system is covered. These systems can increase the energy available while still maintaining the strict geometric restrictions of the retroreflection geometry. Repeatability and reproducibility results of some of the laboratories participating in an international intercomparison are displayed. The relationship between daytime and nighttime conditions is described. The influence of the spectral outpsuts of HID lamps on chromaticity are plotted. Examples of the relation of calculated nighttime chromaticity to experimental visual observations are presented for some materials. The presentation will show that measurement techniques are improving and that specification of color at night is now realistic.

Friedhelm Brücker:
Colour measurement and quality control on coloured liquids in the chemical industry

In many fields of the chemical industry, especially for tensides and glycols, colour assessment is still carried out by visual comparison of the product with the relevant colour standards although as early as 1931 the DIN 5033 laid down the basis for objective colour measurment. The new DIN 53 995 as well as CEN 61557 define the colour measurement on transparent liquids as a substitute for visual colour measurement (e.g. Iodine DIN 6172, Hazen DIN ISO 6271, Gardner DIN ISO 4630 or Lovibond^{R}-yellow/red values). The colour measuring instruments LICO 200, Liquid Tester LTM 1 and LICO 50 of Dr. Bruno Lange GmbH combine the objective colour measurement according to these DIN methods with the also objective measurement by conventional visual colour numbers. Obsolete colour systems and visual colour assessment do not longer satisfy today's demands for an objective quality assurance systems. The combination of simplified modern measuring technology and visual colour systems has paved the way for a uniform colour measuring system. LICO 200, Liquid Tester LTM 1 and LICO 50 measure the colours of transparent products in accordance with international standards and therefore make the result an objective test criterium. Being tested with certified test media, these systems are an optimum basis of a quality system as defined by DIN/ISO 9000-9004.

David Alston, R. Feld:
Camera colorimetry, new instrumentation for appearance and spatial color

Most reflectance color measurements are made with Colorimeters or Spectrophotometers. These instruments view the sample as an integrated area, providing a single color measurement which represents the entire viewing area. While this is an acceptable procedure for samples that are intended to be a solid color, it will not be representative of samples that have a pattern. Samples like that must be measured with an Instrument, that can maintain the spatial nature of the area as well as the color. The only type of device that can accomplish a spatial color measurement is a color camera. The lecture will tell about "The positive attributes of a camera" as well as about "Important considerations when using a camera". It will discuss the question "Why use a color camera" and will give some examples for "Industrial uses of a color camera". At the end of the lecture an example of "Current camera technology" offered by the C.A.T./CAMS Camera System will be given. In this section it will be looked into items like illumination, measurement accuracy, repeatability, inter-system agreement, calibration and possible image sizes.

James T. DeGroff:
Developments in color instrument design utilizing LED technology

Color measuring instruments are becoming a necessary requirement to control the color of a wide range of industrial products. The high cost of color instruments has prevented many companies from standardizing on color instruments as a gauge for all color operations. The development of a low cost instrument that is truly portable, that can be used on the factory floor as an aid to start up and monitor the production process, gather color data for later statistical analysis and yet be cost effective and tough enough to live in the production environment ist the subject of this paper. Light Emitting Diodes (LED) are a low cost, long life, stable light source which are available in the visual spectrum in wide band ranges (Blue, Green, Yellow, Orange, Red, etc.). Attempts have been made to design and build practical color measuring devices in the past with LED, but normally they have been limited to the Orange or Red range because of the low energy output of the Green and Blue LED and instability to thermal change. This paper will detail the design and development of a low cost practical LED based full spectral color analyzer and present data showing the integration of spectral sampling to calculation of accurate tristimulus (X, Y, Z) simulations and presentation of the device with output of colorimetric data results in a rugged portable instruments suitable to meet the color measurement requirements in plastics, painted surfaced materials, textiles, foods, paper and printed materials.

Tasso Bäurle:
DIN-Standardization of metallic and perlescent colors

In the presentation the tests and results are shown, which have been made by the DIN standardization committee FNF 24 "color tolerances in the car-painting industry" for the determination of the color tolerances for metallic and pearl colors.

Allan Rodriguez, L. Steenhoek:
Measurement of metallic & pearlescent colors

ASTM Task Group E-12.03.02 has been studying the goniochromatic effects of metallic and pearlescent colors in order to standardize their color measurement. This is a brief status report of thas committee's work, emphasizing experimental results to-date. Working Groups cover various aspects of the problem: (1) Terminology (2) Instrument Specification and Calibration (3) Pearlescent Colors (4) Experiments on goniophotometric behavior of metallics (5) Color Tolerancing Experiments.
The group has prepared a variety of metallic color difference pairs differing in flake size, pigment content, panel preparation, etc. Observations under a wide range of viewing geometries have been analyzed indicating which angles are important for different effects in these colors. In studying color tolerancing, observers have made pass/fail judgments on increasing color differences shown to them in random order. Observations were under customary viewing conditions through a range of aspecular angles, as well as at 15°, 25°, 45°, 70°, and 110°, available in

current commercial instruments. Logit analysis has been used to analyze the data in terms of CMC and CIE 94 color difference equations, indicating color difference tolerances at each commonly used angle of view. CIE 94 lends itself to better uniformity of tolerance as a function of angle.

Peter W. Gabel, A. Eberle, H. Pieper:
Goniochromatic quality control of pearl pigments

For many years now, pearl pigments, also known as mica pigments IRIODIN, have been used as important colourants for automotive, technical and cosmetic applications. Because of their composition and the resulting multiple reflection of light, pearl pigments create an attractive optical effect which, however cannot be measured with classical instruments. Goniospectrophotometers with different measurement geometries and different concepts are commonly used. This presentatin describes E.MERCK test methods for typical colour measurement problems, as e.g. the validation of an analytical procedure or the current goniochromatic colour control of pearl pigments. Explanations will be given for the interpretation of the test results, comparison of draw-down cards and panel spray-outs, and for the consequences concerning analytical work. Furthermore, results of a Round-Robin Test will be presented and with regard to all these informations requirements to a goniospectophotometer will be discussed.

Gerhard Rösler:
Multigeometry color measurement of structured plastic surfaces

Beside effect paints with effect pigments - where multigeometry color measurement is the only way to describe the effects - many other samples such as leather, leather imitation, plastics etc. are difficult to characterize with one measurement geometry only. A systematic comparison of measurement data for d/8 and 45/0 geometry and visual results under different viewing conditions is given. Also a recommendation is given for best measurement results.

Michael Stein:
Principles and possibilities of colorimetric formulation for dyes and pigments on wood

Depending on their chemical nature there is a totally different influence of stains to wood. Stains based on solvents like esters or ketones will create a contrast between the hard and the soft parts of wood. On coarse-porous wood like oak or ash a solvent based stain will emphasize the prores: on strong-grained wood like pine or spruce it will create a negative picture of staining. Waterbased stains or stains based on a combination water and alcohol will make the color looking more unique without creating a big contrast. Dyes in a stain will achieve a more brilliant color, pigments will make the color more pale. The influence of the wood-structure is one of the most important items for the measuring of wood. Wood is a natural inhomogeneous material, so that it is impossible to measure its exact color. It is only impossible to keep its mean variation as mall as possible and to compensate the irregularities. There are two important methods to achieve this: measuring on a fine-structured part (regular grain with an equal distance of the annual rings) and using a great aperture. Working with a color formulation system the best results will be achieved on wood frome one and the same tree, which is not always possible. Small differences in the appearance can be compensated by measuring the actual substrat. It is not possible to calculate a formula on a totally different wood (database on oak, standard on mahogany). The described system is able to calculate reasonable good matches with regard to one type of wood. It will find the relative concentrations of colorants and will be quite close to the absolute concentrations. A visual correction will be necessary. Nevertheless the calculation system will save about 60 % of time compared to a complete visual match.

Dazun Zhao, Quanchen Li, Changlu Zhao:
Close-loop accurate color display on CRT

Color display on CRT is a technique that has been developed since the 1950's. Along with the progress in computer and monitor performances, this technique is used wider and wider due to its flexibility and controllability, as well as its abundunt color-display capability. Computer-aided color design and color vision study are examples of these applications. However, for some studies, e.g. color difference evaluation, the display accuracy in terms of the differences between the chromaticity coordinates of the actually displayed color and of the intended input color are critical. It has been found in those cases that the accuracy is not always sufficient when only conventional CRT colorimetry prediction methods are adopted. A variety of factors should be responsible for this fact, among them the violation of a set of assumptions about CRT, including some constancies and independencies, on which the prediction has been based might be of most importance. To improve this situation, we proposed earlier a CRT display system having a feedback loop, in which the color is first displayed on a CRT according to a conventional open-loop" prediction method, the displayed color is then measured with an accurate color sensor to produce error data regarding the differences between actual and intended chromaticity coordinates, after that the error data are fed back to the computer to modify the original input following an already set algorithm. This process is repeated until the color differences are reduced to within a predetermined tolerance range or a range limited mainly by the accuracies of the sensor and of the digital to analog convertor. In this paper, some improved treatments on the openloop prediction will first be discussed, then the close-loop system comprising a PR1980B Spectroradiometer as the sensor, a SONY PVM-1442 monitor, a PC-486 computer etc. will be described somewhat in detail. The experimental results showing the effects of the accuracy improving will be given.

William Thornton:
Colorimetry - then and now

The colorimetry system of 1931 is based solidly on the experimental visual data gathered by David Wright and John Guild; these data are unchallengeable even today. However, the 1931 colorimetry system, built on the Wright-Guild data necessarily included unproved assumptions. These assumptions were, at that time, not only essential but even inspired. Yet, in the intervening years, Wright, Guild, Stiles, MacAdam and others have offered warnings concerning these assumptions. Meanwhile, spectroradiometry developed by the 1970s to the point where truly accurate measurement of spectral power content of visually matchingt pairs of lights can now be done. With this accuracy, it is now no longer necessary to make any assumptions at all, in forming an improved colorimetry system. Strong metamerism in pairs of visually matching lights became important first in the lighting industry, then in modern transforming of colored images frome one medium to another. Our work, using accurate absolute spectral power distributions of strongly metameric visual pairs of lights, shows: (1) the now-traditional maximum-saturation color matching functions do not serve well as weighting functions. Computed chromaticities of visually matching pairs are too often very different (10-60 MacAdam jnds). This means that the CMFs do not yield correct results for any visually matching pair of lights, even when metamerism is weak. (2) The MacAdam result that "additivity of brightness" is far from valid is confirmed. (3) Transformability of primaries does not seem to hold in the normal human visual system. From a present database of 2000 strongly metameric, visually matching pairs of lights (field sizes 1.3° and 10°, luminances 4 to 100 candela/m²) improved weighting functions are being extracted. Errors in computed tristimulus values of visually matching pairs are, so far, reduced by as much as a factor of 20 from those by the CIE Standard Oberservers.

Roy Berns:
To optimize or not to optimize (l:c) ratios

Equations such as CIE 94 and CMC inlcude parametric factors, in theory, that account for changes in sample and observational conditions from a set of reference conditions. Defining these factors (i.E. the l:c ratio) is not obvious. Typical industry practice is to set the ratio to 2:1 for either equation based on the textile industry's experience with CMC. Because of the large difference in the lightness S_L weight between CIE 94 and CMS, this industrial practice may result in poor correlation between instrumental tolerances and visual assessment. A visual experiment was performed to generate a data set to be used in evaluating typical industrial practices. Twenty two observers performed a pass-fail color tolerance experiment for a single high-chroma yellow color center. Thirty two glossy samples varying in all three dimensions werde compared with a single standard. A near-neutral anchor pair was used to define the color-tolerance magnitude. The pooled "pass" response data were used to fit a trivariate normal 95 % confidence ellipsoid. The chromatiness dimension was well estimated by either CMC or CIE 94. The lightness dimension was poorly estimated by either equation. This was an unexpected result since the experimental conditions were similar to the CIE 94 reference conditions. Evaluating the sampling distribution of the thirty two test samples via a covariance matrix revealed a poor sampling, particularly in the L*b* plane This sampling confounded the visual experiment. The visual data were used to optimzhe CIE 94 and CMC equations where the l:c ration and the commercial factors were adjustable parameters. The resulting equations demonstrate the large difference in the lightness weight. Because industrial tolerances are usually based on a single observer, ellipsoids and optimized equations were fit for four observers with the same number of pass-fail responses. The results will be shown for the CIE equation. It was concluded that one should not change the parametric factors in a color-tolerance equation or derive a new equation (the emerging practice of derving "super ellipsoids") based on a single observer's visual responses. Care should be taken using historical or experimental data that the samples are well distributed in all three dimensions in color space. The use of covariance matrices and data visualization are convenient tools to evaluate sampling.

Klaus Witt:
Linearity of grey scale with small stepwidth

The perceptual magnitude of small colour differences and their relation to colorimetric measures very often is studied by grey scale assessment. The grey scale should provide for an equal perceptual lightness stepping as a measure of the wanted quantity. In many cases the Weber-Fechner law is taken to be valid, however, the experimental plan may provide for deviations due to background, sample size, sample separation etc. We started an experiment of scaling small colour differences with this method and constructed a grey scale with approximate logarithmic, small lightness stepping. The linearity of this grey scale was tested under the conditions of the experimental plan of colour-difference scaling. Several observers made judgments by magnitude estimation of steps against a reference step. Results will be discussed for linearity and variability of observers.

Ernst Rohner, D.C. Rich:
An approximately uniform object colour metric for industrial colour tolerances

Recently, CIE Technical Committees 1-27 "Parametric effects in colour difference evaluation" and 1-29 "Industrial colour differences" have issued reports and recommendations. The recommendations in these reports describe procedures for modifying the size or spacing of colour differences projected onto object colour space by the CIELAB colour difference metric. The modifications compensate for the texture of the object and for local non-uniformity of the CIELAB metric. These reports, along with the world wide acceptance of the CMC colour tolerance equation, have made possible the disclosure of a previously proprietary colour tolerance equation. This Datacolor equation has had many years of field testing with excellent results and several favorable published comparisons against the CMC and M&S equations. Within the last two years, several modifications have been added to the Datacolor colour tolerance equation. These modifications are both mathematically and psychophysically fundamental. The modifications are not merely empirical adjustments to the local CIELAB spacing, but are indeed, reversible mathematical transformations of the CIELAB metric that derive a more nearly uniform metric for object colour space. This results in a colour difference metric which conforms to the Weber-Fechner law and is both locally and globally approximately visually uniform. This implies that this metric, unlike CMC, M&S and TC 1-29 allows the interchance of the standard and batch in a colour difference pair with no change in predicted colour difference. The background and basis for this new metric will be presented along with results of calculations that illustrate both the uniformity of the metric and its utility in the setting and evaluation of industrial colour tolerances.

E. Bernabeu, J.M. Zoido, F. Carreno:
Some considerations on MacAdam's ellipses

A systematic analysis of the results obtained by MacAdam (1942) is presented. We repeat the calculations with the aid of a computer using the data supplied in his paper and the same equations. Significant differences emerge between the results obtained by us and those given by MacAdam. The discrepancies arise from the fact the straight lines on which he carried out the different color matchings around a given chromaticity do not have a common intersection that could be considered as the center of the ellipse. A detailed study of the data lead us to question the geometry and the size of the curves of equally noticeable chromaticity differences proposed in MacAdam's original study. From the results obtained by us in our study we conclude that from MacAdam's measurements it is not possible to deduce that the curves of equally noticeable chromaticity differences are ellipses. A question emerges that should be analysed from both a theoretical and an experimental viewpoint: should the curves of equally noticeable chromaticity differences be greater than those given by MacAdam?

Claudio Oleari:
Uniform-scale chromaticity diagram by von Kries-invariant-logarithmic transformations for foveal vision

The non-unformity of scale in the usual chromaticity diagram is an old practical problem in colorimetry. A solution is given by our new angular hypothesis about the co-tangents of proper angles defined on a plane of the tristimulus space that can be related to the cone-activation ratios. The results of first analysis our carried out on the MacAdam ellipses are confirmed by the new chromatic-discrimination ellipses, that we obtained by a CRT monitor in different viewing situations (different surround and test-field luminances and different surround chromaticities). The results are: 1) chromatic uncertainties properly evaluated on the ellipses are represented by Weber fractions of the cone-activation ratios; 2) each chromatic mechanism consists of two parts separated by a neutral point; 3) the chromatic response functions are logarithms of proper cone-activation ratios of the test field and of the surround; 4) these functions are von Kries-transformation invariants; 5) these functions for monochromatic stimuli seem like the potentials of the C-type horizontal cells of the retina; 6) a uniform-scale chromaticity diagram at constant luminance exists for each viewing situation; 7) the wavelength discrimination for trichromats, deuteranopes and tritanopes, the constant hue loci and the chromatic purity are predicted in agreement with the experience; 8) hue shift exists between chromaticity diagrams related to different viewing situations and recall the Bezold-Brück effect.

Wei-Yuan Zhang:
WYZ-colour storehouse

According to the colour law in itself, "WYZ-Colour Storehause" can distinctly and methodically hold 3 060 300 pieces of colour with the computer's ability of identifying the colours accurately. The numeric data of colour cell for each colour block can give the colours composition, which provide detailed data for colorimetry and computerization.

Jochen Antkowiak, L. Grambow:
A method of color renderings optimization of CRT-TV monitors by means of electronically generated test colours and test pictures

A method is presented to measure the colour rendering properties of monitors based on the EBU test colours. Thus the same test colours are used as for testing electronic cameras. This offers the possibility to evaluate the quality of rendering. The input signals for testing the monitors are generated by a programmable TSG. It provides signals corresponding to the defined colours and luminances of the original EBU colours. Additionally test colours of 10 % luminance are generated. After adjusting the white areas of the monitors to be tested according to D65 within narrow tolerances the measuring of the screen colours is carried out by a precision colour meter in darkness. Switchable combined test pictures are used to adjust brightness and contrast of CRT. These test pictures contain 100 % and 2 % luminance areas on the left/right of the picture middle (or vice versa) and a black surrounding. So it is possible to control the adjustment at the same defined place on the screen with a luminance meter exactly. To enlarge the peak luminance, up to now usually limited to 80 cd/m², by retaining a good colour rendering additional test pictures were created for estimating the permissible peak luminance. Therefore centred white areas with a 10 % to 100 % screen coverage are generated successively and the luminance is measured in the centre of the screen. If the luminance is chosen above the limit it is decreasing impermissibly in the consecutive test procedure. For the instance of a well adjustable high-end monitor it is shown how to vary the peak luminance from 60 cd/m² to 225 cd/m², to find out the optimum at 180 cd/m², and to achieve a Colour Rendering Index of 90 both for bright and dark EBU test colours. Using this adjustment both a 10 % colour bars test picture and a 50 step linear perception staircase signal picture give a correct reproduction. These last mentioned test pictures exhibit a high criticality and give the opponunity to percept unexact monitor adjustment just by subjective assessment of the pictures on the CRT screen. Finally, the influence of mismatching the brightness corresponding to a gradation failure is investigated concerning the decline of colour rendering.

Patrick G. Herzog:
Analytical color space transformations

An analytical method for the transformation of color spaces is presented. It is shown that the method can be applied to the analytical representation of color gamuts of reproduction devices. The analytical transformation has the following advantages: 1. Representation of edges and corners is especially accurate in opposition to traditional methods like Fast Fourier Transform or Karhunen Loéve Transform. 2. The method contains an inherent interpolation as it is analytical. 3. No numerical methods like interpolation or inversion have to be applied, so output devices can be calibrated analytically. Using the method for the analytical representation of color gamuts has the following advantages: 1. Any of the known color spaces (e.g. CIELAB) can be used for the representation of color gamuts. 2. As the representation is very compact it is excellently suited for storage and transmission of gamuts together with color images. 3. No mathematical case discrimination between adjacent planes is necessary as opposed to other analytical methods. 4. Gamut mapping can also be carried out analytically in the future.

Raimondo Schettini, B. Barolo, E. Boldrin:
Cross media color reproduction by neural networks

Ideally, one would like to be able to objectively quantify and reproduce the appearance of an original on different media or devices. Unfortunatley, our knowledge of the mechanisms of vision and models derived from them have not yet enabled us to completely master the phenomenon of colour perception and deal successfully with all the subjective and environmental factors influencing it. A practical approach to the accurate rendering of colour images on displays, integrating colorimetric and interactive methods by means of artificial neural networks, is proposed here. This method could substantially benefit CAD and multimedia systems by offering an accurate cross-media colour matching requiring minimal low cost equipment, and little effort on the part of the user. To obtain cross-media colour reproduction the devices are calibrated colorimetrically and the CIELAB colour appearance model is adopted. We relate non-colorimetric scanner outputs with CIELAB standard coordinates by mean of a feed-forward neural network trained by back-propagation. The training set the algorithm uses is the ANSI IT8 colour target as this has been specifically designed for scanner calibration. Since the context in which colour images are viewed on the monitor is very different from the context in which originals are normally seen, this approach does not garantee that the colours will be perceived to be exactly the same. We have therefore applied the original Kanamori and Kotera's idea on selective colour editing and developed of a soft colour cluster editor based on visual interaction which allows the user to correct or modify, in a friendly and effective way, the image appearance on the display until a satisfactory visual matching with the original is obtained. A second feed-forward neural network is then trained to learn the user's corrections. The implicit mapping coded in the neural network is applied to correct subsequent colour images to be reproduced on the screen. The user is still allowed to modify the colours proposed: when a significant number of new mappings have been defined, the user can re-run the learning phase (this last step can be repeated during the image acquisition phase until no further corrections are necessary). Among the several factors not provided for to date and with which this method is be able to cope are: 1. calibration erros; 2. differences in colour appearance caused by the mode of perception, surface properties, the observer's state of adaptation, etc.; 3. subjective factors influencing the match which can not be explicitly taken into account.

Paola Campadelli, F. Castiglioni, R. Schettini:
Nominal color coding by Hopfield net works

The experimental evidence that color greatly increases the observer's understanding of the information contained in a picture and his capacity for remembering it, has led to assigning color a fundamental role in conveying qualitative information in graphical environment. Nominal color coding is widely used by the image processing community to represent the output of a classification-segmentation process. In this contest a serious problem arises because the chosen color must be displayed together and assigned to classes composed of regions of different size and morphology. The user must take into account the characteristics of the image (the number of classes, the links between them, and the geometric and topological features of the regions that belong to the different classes) so that the association of classes with colors produces a readable, pleasant coded image. Although some systems have been proposed to support the user in color coding, these are mainly based on a trial-and-error approach and demand a concerted effort on the part of the user. In order to automate color-class association we have proposed a suitable description scheme for both the color set to be used and the image to be coded. Exploiting this description we have then defined a suitable energy function for Hopfield's neural networks. The aim is to assign more "conspicuous" colors to less "visible" classes, attributing highly contrasting colors to classes with an high "adjacency". We assume that the image to be coded contains N classes, that each class is composed of a variable number of regions having different characteristics, and that the color set to be used in coding has been already selected by the user according to some criteria. Since the lightest and most highly saturated area of a color display immediately draws the user attention, we define the evidence of a color as combination of its lightness and chroma. An automatic evaluation of the image to be coded obviously requires a description of the images itself. The data structure used to represent regions and their relationships is the Region Adjacency Graph, in which each node represents a region, and two noded are description of the region (relative area, perimeter, compactness and thickness) and a class label, while with each arc the degree of adjacency of that pair of regions (relative perimeter that the two regions share). Experimental results to confirm the feasibility of the method will be presented.

Thomas Keusen, B. Hill, F.W. Vorhagen:
A solution to color problems in open system architectures

A main problem of electronic color reproduction is that of color equalization between the reproduced and original colors of a document. Basic problems of todays electronik color systems with three-channel color analyis in scanners are the following:
- Spectral characteristics of the light source of a scanner cannot be seperated from the color analysis so that the results are device-dependent. - Systematic errors result from deviations of the three-channel filters from theoretical spectral matching curves. Error reduction by subsequent electronic signal processing is document-dependent. - Practical sensitivity curves deviate more or less from each other and from one scanner to another producing unkwown errors. Even if the sensitivity curves are correct, the anlalysis is only true for the standard obser-

ver. - Color interfaces using non-standard color description often lead to additional errors in todays systems. Even interfaces using standard tristimulus values X,Y,Z or CIELAB are illuminant-dependent. It is proposed to solve the essentaial problems by introducing a multispectral technology for scanning the spectral information of documents and transporting the complete multispectral information via communication net to the receiver, where a better reproduction from the spectral information with a common printer or display is possible. In future, it will perhaps be possible to reconstruct the remission curve of the document by multispectral printing. Then the reproduction will be correct for all observers under all illuminant. The document-independent and device-independent color analysis system is realized with a multispectral CCD-cmera, which samples the remission curves of each pixel in a document with 12 interference-filters rotating in front of the CCD-chip. It will be shown, that with 12 interference-filters used for sampling, all the sampled and reconstructed remission curves of investigated data show reconstruction errors lower than the threshold $\Delta E_{ab} = 1$ (CIE 1976) using a correction method called Modified Discrete Sinus Transformation (MDST). It is not possible to reduce the number of filters further as long as the simple spectral geometry of interference-filters is applied. Different technical realizations of such concepts of a multispectral color analysis are possible. The high amount of source data for multispectral color representation can be reduced remarkably by introducing data encoding. At the Technical Electronics Institute an efficient multispectral encoding format has been developed, which reduces the number of necessary values for one pixel remarkably to 6 on one hand and which is directly compatible to the conventional tristimulus color valus on the other. More compressing is expected if typical frame encoding methods are applied to the encoded multispectral frame information. An estimation of the increase of the data volume which results from an expansion of the compressed tristimulus to the compressed multispectral data format leads to a factor of only 1.5. With the specific feature of compatibility to conventional tristimulus color description, a conventional printer or monitor must only cut the first three values from the multispectral data set and for an easy and rough preview or a first look at a monitor, no complicated reconstruction and calculation is necessary. But it is possible also to reconstruct the complete reflection curve of each pixel and optimize the reproduction system, to get high quality color reproduction. A complete laboratory system with a multispectral camera is presently under investigation at the Technical Electronic Institute (ITE), Aachen University of Technology. Further optimized data encoding for image transmission is studied in cooperation with the Institute for Communication Engineering (IENT), Aachen University of Technology.

Horst Scheibner, A. Orazem:
On a deuteranope's foveal opponent-color vision

By means of a visual Guild-type tristimulus colorimeter, which was operated with reference to W.D. Wright's trichromatic (R,G,B)-system, the missing colour (Fehlfarbe) of a deuteranope was measured. The interpretation of the missing colour as a one-dimensional mapping kernel allowed to map the trichromatic instrumental (R, G, B)-system onto a deuteranopic instrumental

(B', R')-system. The application of two perceptual criteria: a) "neither blue nor yellow", b) "heterochromatically equally bright", resulted in two deuteranopic referential confusion lines: 1) the neutral zone, 2) the (imaginary) alychne trace. This was equivalent to establishing a deuteranopic opponent-colour system (K,L), where K = blue-yellow chrominance and L = luminance. The introduction (from the literature) of a trichromatic fundamental system (P, D, T), where P = "red" cone excitation, D = "green" cone excitation, T = "blue" cone excitation, and the application of Arthur König's (1886) hypothesis of a "loss" deuteranopia (P, T) allowed to formulate a linear excitation transfer from (P, T) to (K, L). The quantities (K, L), "deuteranopic opponent distimulus values", correlate perceptually with blue-yellow chroma and brightness.

Anders Nilsson, T. Hard:
Upgraded quality for colour samples

NCS is a internationally used colour notation system and is the national standard in Sweden, Norway and Spain. The notation is based on normal language for colour, bis this reason it is a "natural", user-oriented and user-friendly colour notation system. The NCS notation can be obtained for any surface colour by use of the NCS measurement program. Scandinavian Colour Institute AB have produced the NCS colour samples since 1979. The NCS Edition 2 colour samples was released in January 1995. The main changes in the new edition are as follows: 1. Replacement of environmental harmful pigments in the colour samples (e.g. lead and cadmium) 2. Extension of the number of NCS colour samples up to 1750 different colours 3. Smaller tolerances against the aim point 4. Smaller reproduction tolerances. There are two different tolerance demands on NCS samples, first the nominal tolerances against the aim point, second the reproduction tolerances against the NCS primary standard. The nominal tolerances are defined in the NCS colour space around selected aim points. The NCS primary standard is produced to fall inside these tolerances. The NCS primary standard for each colour is stored at SCI and measurement values for it, traceable to the NCS reference spectrophotometer (Zeiss DMC26 at SCI), is stored in a database. These are the common reference for all production and control of the NCS colour samples. There are several steps in the control process when producing NCS colour samples: 1 The first step is the Mix. Draw downs from the mixing are checked and should be accepted before coating is started. Match is normally not accepted with higher deviation from the standard than 0.3 ΔE_{CMC}2. 2 The second step is the coating. Accepted difference is normally 0.5 ΔE_{CMC} 3 The third step is the control of the final production by sampling. 4 For the product NCS Standard, individual control of every delivered sample is performed, for other products delivery control is performed by sampling. "NCS-standard" is a new product since 1995. It contains individually measured and checked samples for every NCS standard colour.

Pei-Yu Zhang:
Error of HSB color model

The HSB color model widely used in the computer softwares was analysed in this paper. This paper has proved that the HSB color model mainly embodies the mathematical law and presents the property of color light. The numeric data of color cell of HSB color model can't reflect accurately the color's features and the appearances of color. There is a difference between the numeric data of color cell and human's visual sense.

Todor Kehlibarov, L. Yourukova, K. Kolentaov:
Brightness and color characteristics of chibrid AC EL structures

The so-called AC EL cells (Hybrid alternativy current electroluminescent structures) can be used for the purposes of the special lighting and advertising technique. In the paper the brightness and color characteristics of new developed AC EL cells with green, yellow, red and white emission will be reported. A comparison of the characteristics of the AC EL cells is made and factors for the changing of color and brightness parameters, as well as for stabile brightness and color. Using moderne colorimetry in our investigations give a new way for application and control in technology for thin layers and structures by measuring color and brightness.