

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
23 December 2004 (23.12.2004)

PCT

(10) International Publication Number
WO 2004/111944 A1

(51) International Patent Classification⁷: **G06T 11/00**,
G01J 3/46, H04N 1/60

(21) International Application Number:
PCT/GB2004/002542

(22) International Filing Date: 11 June 2004 (11.06.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0313593.6 12 June 2003 (12.06.2003) GB

(71) Applicant (for all designated States except US): **UNIVERSITY OF SOUTHAMPTON** [GB/GB]; Highfield, Southampton SO17 1BJ (GB).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **DONNELLY**,

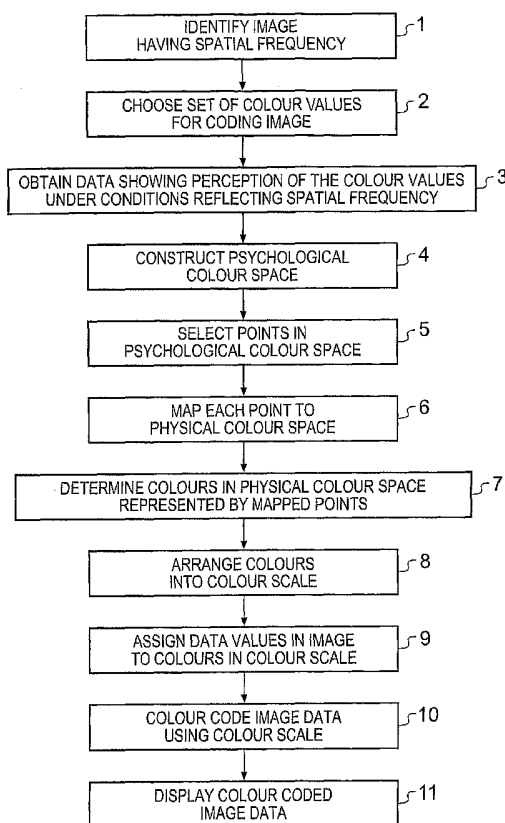
Nicholas [GB/GB]; Centre for Enterprise & Innovation, University of Southampton, Highfield, Southampton SO17 1BJ (GB). **CAVE, Kyle, Ray** [US/US]; c/o Centre for Enterprise & Innovation, University of Southampton, Highfield, Southampton SO17 1BJ (GB). **WELLAND, Michael, John, Patterson** [GB/GB]; Centre for Enterprise & Innovation, University of Southampton, Highfield, Southampton SO17 1BJ (GB).

(74) Agent: **MCGOWAN, Cathrine**; D. Young & Co., 120 Holborn, London EC1N 2DY (GB).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM,

[Continued on next page]

(54) Title: COLOUR CODING OF DATA



(57) Abstract: A method for colour coding of image data comprises providing image data having associated spatial frequencies, choosing a colour set in which to code the image data, providing a psychological colour space constructed from colour values in the colour set that are positioned in the colour space with reference to effects of the spatial frequencies on human colour perception of the colour values, and selecting points in a psychological colour space that represent a range of colours for a colour scale for colour coding of the data. Each point selected in the psychological colour space is mapped to a corresponding point in a physical colour space to enable a colour represented by each selected point to be determined, and the determined colours are then arranged into a colour scale. Defining a colour scale with reference to a contextually tailored psychological colour space allows the colour scale to be linear or nonlinear with respect to human colour perception; this can be achieved by using a regularly or irregularly distributed selection of points in a linear or nonlinear psychological colour space. Once data values are assigned to the colours in the colour scale, the data can be colour coded according to the scale, and presented to an observer for interpretation.



TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

TITLE OF THE INVENTION**COLOUR CODING OF DATA****5 BACKGROUND OF THE INVENTION**

The present invention relates to the colour coding of data, using colour scales.

A variety of different sensing and imaging technologies produce image data in the form of two- or three-dimensional spatial arrays. The values represented by the numbers in these arrays vary according to the technology. For instance, in functional
10 imaging of the brain, the values represent the amount of blood flow measured at each location in the spatial array. These data are often made available for interpretation by a viewer in the form of a two- or three-dimensional image typically displayed on the screen of a workstation or other computer, on a “visualisation facility” or produced in some form of hard copy. To aid interpretation, the data may be coded to reflect
15 variations in attributes of the data using colour and colour contrast, with the colour of each pixel (or set of adjacent pixels) in the image representing one of the values from the data array. The interpreters of such displays seek to identify continuity, discontinuity, patterns, anomalies, changes, differences and contrasts in the data. Efficient interpretation requires an avoidance of bias in review of the entire data set
20 and specific features within it. Whether this can be readily achieved depends at least in part on the colour coding employed in displaying the image.

Before the image can be created using colour coding, a colour scale must be constructed, with a particular colour assigned to each possible value (or a range of values) in the data array. To select the colours for a colour scale, the first step is often
25 to organise the possible colours as points in a unidimensional or multidimensional colour space, in which each point represents a particular colour, and in which colours that are similar to one another are generally near one another in the space. The

-2-

dimensions of the colour space may correspond to hue, saturation, and lightness, although many other organisations are possible (e.g. red, green and blue (RGB)). The colours within the colour space and the relative spacing between them may be governed by the properties of the imaging device, such as a video display or printer, used to create the images. In many cases, the colour scale is defined by simply selecting two points from within the colour space, and computing a straight line connecting them. A set of points is positioned along this line, usually with equal spacing between each pair of points, and the locations of these points within the colour space determine the colours that will make up the colour scale. Some colour scales are more complex, with the scale split up into different ranges, and each range coming from a different region in the colour space.

If the colour space from which the colours are taken is defined by the capabilities of the imaging device, then the differences in colour between two locations in a displayed image will depend on the peculiarities of that specific device. This tends to affect interpretation of the image. Even if the colour space is defined by physical properties of light waves, such as intensity and wavelength, peculiarities in the response of the human visual system can produce anomalies in the differences in the image perceived by human observers. For example, a property of the response of the human visual system is that two colours that sit on either side of a colour boundary (e.g. red to yellow) are more readily perceived as different than two colours that differ in wavelength by the same amount but that both sit on the same side of a colour boundary (e.g. two shades of yellow). Stated simply, because the human visual system classifies colours into different categories, and perceived differences are greater across category boundaries than within category boundaries, the presence of category boundaries in the colour scale may cause the perception of sharp differences between regions of the image when the corresponding differences in the data points are in reality small.

The issues of how humans discriminate and categorise colour has been investigated previously and forms the basis of the so-called Munsell colour solid (other systems are also available). The Munsell colour solid has been applied to many circumstances where colour matching to a standard system is required, for example in
5 the coding of rock colour in the Geological Society of America rock-colour chart, or to normalise a recorded image to achieve correspondence to human colour perception regardless of the illumination and measurement conditions used for recording [1]. However, research in human colour vision has suggested that the Munsell system may not produce colour scales with the desired level of uniformity for human viewers [2].
10 Regardless of the shortcomings of the Munsell system, most imaging applications (with a few exceptions [3, 4]) typically do not use it or any other system to correct for human colour perception. Instead, colour is often used in an arbitrary way in the coding of images of spatial (including space-time) arrays.

There are, however, significant problems with those few schemes that do use
15 psychological colour space to code image data (e.g. [3, 4, 5]). All existing psychological colour spaces like the Munsell colour solid (or any such equivalent) are monolithic and it is considered doubtful that any is able to generalise across the many real instances of types of colour coding (e.g. [5, 6]). Colour perception is affected by context, but the Munsell colour solid and its equivalents are computed in ways
20 designed to remove all contextual factors. Therefore, despite the fact that these colour spaces are intended to represent the general structure of psychological colour space they are constructed without regard to important factors that impact on human colour perception. With respect to the colour coding of image data some of these problems are acknowledged (e.g. [3]), but previously proposed solutions have taken the form of
25 devising expert system-type approaches where choices have to be made by expert interpreters to modify the coding of data (e.g. [9]). These approaches are cumbersome and time-consuming and require skills generally outside the capabilities of those interested in observing and interpreting colour-coded images.

Approaches that allow arbitrary selection of colours for coding of images of spatial data arrays have the consequence that equivalent changes in the dimension(s) being coded by colour will be visible when one region of the colour scale is being used but invisible when another is used. The result of this is that the same spatial features will be visible (or invisible) when coded using one scale (or part of a scale) but invisible (or visible) when using another scale (or part of a scale). Furthermore, it is well known that perceptual organisation (as defined by the Gestalt laws of organisation) is highly sensitive to colour [7, 8]. Therefore, given that colour selection is a factor affecting detection of spatial features, it will also influence the detection of more global spatial structures, of the type typically found in noisy images generated from, for example, seismic data. In summary, arbitrary selection of colour for coding specific dimensions of spatial data arrays leads to images that, to the human eye, are biased, distorted and contain interference.

There is therefore a need for colour scales that can be used for coding dimensions in arrays of spatial data that take a more realistic account of the characteristics of human colour perception..

SUMMARY OF THE INVENTION

Accordingly, a first aspect of the present invention is directed to a method for colour coding of image data comprising: providing an image or images represented by image data, the image or images having an associated spatial frequency spectrum;
5 selecting a colour set comprising a plurality of colour values; obtaining a psychological colour space constructed from colour values in the colour set, the colour values being positioned within the psychological colour space with reference to effects of spatial frequencies in the spatial frequency spectrum on human colour perception of
10 the colour values; selecting points in the psychological colour space, the points representing a range of colours to be included in a colour scale for colour coding of the image data; mapping each point selected in the psychological colour space to a corresponding point in a physical colour space to determine a colour represented by each point selected in the psychological colour space; and arranging the determined
15 colours into a colour scale suitable for colour coding of the image data.

The method addresses the drawbacks of previously proposed colour coding techniques by coding using a psychological colour space that takes account of contextual parameters that affect human colour perception. This is done by choosing a colour set that is to be used to code and display an image or images, and which will
20 typically be a small subset of all possible colours, and then obtaining a psychological colour space that is constructed from colour values in the chosen colour set by taking into account the effect of spatial frequencies that occur in the image data on human perception of those colour values. Spatial frequencies, which have an impact on image interpretation, are perceived differently according to the colours in which they are
25 presented to an observer; the method of the present invention allows this to be taken into consideration. In other words, coding is performed using a psychological colour space based on the range of colours intended to be shown in the images and on the spatial frequency properties of the images. This approach takes account of the context

-6-

in which images are displayed and observed, leading to better appreciation and interpretation of the images. The distortions to monolithic colour spaces such as the Munsell colour solid that occur through contextual factors can be quantified and their impact placed within the structure of the psychological colour space itself. The psychological colour spaces used to derive colour scales for coding image data are constructed from colour perception experiments where only the colour range intended to be shown in the image is presented to observers and those colours are presented in a fashion comparable to how they will appear in the coded image, i.e. with reference to spatial frequency. These conditions cannot be met, in principle, by any monolithic colour space such as the Munsell colour solid, the CIE LUV space or the CIELab space.

The method results in a colour scale that is specifically defined with reference to fundamental parameters of human colour perception and factors known to influence those parameters. Colour scales can be established that correct for the nonlinearity of human colour perception by considering both fundamental colour perception parameters and contextual parameters known to influence these parameters. Thus, data can be colour coded for display as an image for interpretation in a way that takes the characteristics of human colour perception, including the effect of context into account. The present invention allows non-arbitrary colouring that is constrained according to known psychological principles of the human perception of colour space. This is in contrast to known methods of colour coding, in which colour is generally used in an arbitrary manner. The latter approach can lead to coded images in which important details are missed by an observer because they are presented in an insufficiently perceivable manner, and minor changes appear as major steps, which therefore seem to be significant, and may also detract from features of particular interest that are presented in a less noticeable way. Instead, the present invention offers colour coding that allows these disadvantages to be overcome; colour scales can be tailored to avoid such artefacts because it is known how the human visual system

-7-

will respond to the scales. This offers greatly improved image interpretation, which is of benefit in many sectors. For example, medical diagnosis and subsequent treatment can be enhanced, which is good for patients, but also potentially cost-saving for hospitals in terms of improved recovery and reduced need for repeat or corrective
5 treatments. Better weather forecasting is made possible, which allows shipping and transportation to be more efficient and organised, for example, and security can be tightened because potential threats in baggage, vehicles and shipping containers are more likely to be identified from scans.

The points selected in the psychological colour space may be equally spaced
10 within the psychological colour space, or alternatively may be irregularly positioned within the psychological colour space. This allows a colour scale to be tailored for a specific application, to emphasise features in an image that are important to pick out, for example, or to ensure that an image can be presented with a smooth gradation of colour such that equal differences in the underlying data will be perceived as being
15 equal right across the range of the data. To achieve various perceivable effects, therefore, the points may be selected in the psychological colour space to give a colour scale that is linear with respect to human colour perception, or alternatively to give a colour scale that is intentionally biased with respect to human colour perception.

In one embodiment, selecting the points in the psychological colour space
20 comprises choosing points in the psychological colour space, and calculating further points in the psychological colour space that lie along a line including the chosen points. This is a simple way of providing the required points; as few as two points can be selected, and the remainder determined by calculation. This can ensure that the spacing between the points is accurate in terms of the degree of linearity desired from
25 the colour scale, and reduces the arbitrary nature of colour selection.

To aid selection, the choosing points in the psychological colour space may comprise choosing points in the physical colour space, and mapping the chosen points to corresponding points in the psychological colour space. A user will typically be

better able to make a practical selection using a physical colour space, since by its nature it is more completely populated with known colour values than a psychological colour space, so a more informed choice can be made that is well directed to the nature of the data to be interpreted.

5 The mapping to a corresponding point in the physical colour space may comprise, for each selected point in the psychological colour space: selecting a set of mapping points in the psychological colour space in the vicinity of the selected point, where each mapping point represents a colour the position of which within the physical colour space is known; determining a function that maps each mapping point
10 to the appropriate position in the physical colour space; and using the function to map the selected point to the physical colour space to determine the colour that the selected point represents in the psychological colour space. The function may be determined using a data fitting algorithm, or linear interpolation, for example.

 Once the colour scale is established, the method may further comprise
15 assigning a data value or range of data values from the image data to each colour in the colour scale, and may possibly further comprise colour coding the image data by matching each datum to a colour in the colour scale according to the value of the datum. Finally, if desired, the method may comprise displaying the colour coded image data for viewing by an observer.

20 In addition, the method may further comprise constructing the psychological colour space by positioning colour values in the colour set in a one-, two- or three-dimensional space with reference to effects of spatial frequencies in the spatial frequency spectrum on human colour perception of the colour values, the colour values having known positions in the physical colour space and being separated by
25 measured differences in human colour perception. The measurements are made under conditions that approximate subsequently coded images, in particular by presenting the colour values in a way that reflects spatial frequency. A psychological colour space having a context and dimensionality appropriate for the colour changes required

in a particular colour scale can thus be created; this reduces the complexity of the construction process in the event that a one-dimensional space (a vector) or a two-dimensional space is deemed adequate, so the construction can be performed more rapidly.

5 With reference to the advantages of being able to provide colour scales specifically designed to be perceived as linear or intentionally biased, the colour values may be positioned such that equal measured differences in human colour perception are equally separated throughout the psychological colour space, or alternatively may be positioned such that equal measured differences in human colour
10 perception are unequally separated throughout at least part of the psychological colour space. The selection of points within the psychological colour space can be simplified by using an appropriately manipulated colour space; for example a biased or nonlinear scale can be simply obtained from a regularly spaced line of points in a suitably manipulated colour space.

15 The colour values are conveniently positioned using multidimensional scaling.

 Further, the method may comprise measuring differences in human colour perception between colour values in the colour set with known positions in the physical colour space, the differences being measured with reference to effects of spatial frequencies in the spatial frequency spectrum on human colour perception of
20 the colour values. Thus, experiments are performed to measure human colour perception of the colours in the selected colour set when those colours are used to show particular spatial frequencies, the frequencies being those in the image data. This allows a psychological colour space to be tailored for a specific imaging application, although it is important to appreciate that the invention is not limited to constructing a
25 colour space for every image or set of images. Experiments can be performed and colour spaces built with reference to a range of colour sets and frequency spectra, and a suitable space can then be chosen for a particular coding application. The overall procedure for colour coding according to the invention can be simplified by

-10-

determining in advance the extent and dimensionality required of the psychological colour space to produce a colour scale with a desired range of colours so that the process of obtaining data for building the colour space can be directed to the appropriate region of colour space.

5 Obtaining the psychological colour space may comprise selecting the psychological colour space from a library of different psychological colour spaces, each constructed from colour values in a colour set that are positioned within the psychological colour space with reference to the effects of spatial frequencies in a spatial frequency spectrum on human colour perception of those colour values so that
10 each psychological colour space has an associated colour set and spatial frequency spectrum. This removes any requirement to construct a colour space for every coding job that is carried out, and allows efficient re-use of psychological colour spaces by the same user or a plurality of users.

 A second aspect of the present invention is directed to a computer program
15 product carrying machine-readable instructions for implementing a method for colour coding of data, the method comprising: providing an image or images represented by image data, the image or image having an associated spatial frequency spectrum; selecting a colour set comprising a plurality of colour values; obtaining a psychological colour space constructed from colour values in the colour set, the colour
20 values being positioned within the psychological colour space with reference to effects of spatial frequencies in the spatial frequency spectrum on human colour perception of the colour values; selecting points in the psychological colour space, the points representing a range of colours to be included in a colour scale for colour coding of the image data; mapping each point selected in the psychological colour space to a
25 corresponding point in a physical colour space to determine a colour represented by each point selected in the psychological colour space; and arranging the determined colours into a colour scale suitable for colour coding of the image data.

The instructions may be operable to allow a user to select points in the psychological colour space, and possibly further operable to allow the user to choose points in the psychological colour space; and to calculate further points in the psychological colour space that lie along a line including the chosen points. Thus the instructions can be tailored to allow a greater or lesser extent of user input; this can remove any arbitrary selection of points resulting from user bias, while permitting an overall general region of colour space to be specified as desired.

This may be further aided by instructions that are operable to allow the user to choose points in the psychological colour space by allowing the user to choose points in the physical colour space; and mapping the chosen points to corresponding points in the psychological colour space. Users may find it more straightforward to work with the physical colour space, since it is more completely defined than the psychological colour space is likely to be.

In one embodiment, the instructions are operable to allow a user to select one of one or more colour scales previously defined using the psychological colour space as an alternative to the selecting points in the psychological colour space, the mapping and the arranging. This gives the option of a single computer program that allows colour scales to be used many times, to avoid the need to create one for every coding and display, and also allows predefined colour scales to be supplied to the user.

The instructions may be operable to colour code the image data by matching each datum to a colour in the colour scale according to the value of the datum, and then may be further operable to display the colour coded image data for viewing by an observer. Following this, the instructions may be operable to modify the colour scale in response to user input. Preferably, this is achieved by displaying the colour scale to the user, allowing the user to indicate a position on the colour scale, and updating the colour scale by introducing a nonlinearity at the indicated position. Then, the instructions may be further operable to colour code and display the image data using the modified colour scale.

-12-

The instructions may be further operable to obtain the psychological colour space by selecting it from a library of different psychological colour spaces, each constructed from colour values in a colour set that are positioned within the psychological colour space with reference to the effects of spatial frequencies in a spatial frequency spectrum on human colour perception of those colour values so that
5 each psychological colour space has an associated colour set and spatial frequency spectrum. The instructions may be operable to select the psychological colour space by allowing a user to provide information relating to the spatial frequency spectrum of the image or images and the selected colour set and comparing it with information
10 relating to the spatial frequency spectrum and colour set associated with each psychological colour space in the library to find a best match.

A third aspect of the present invention is directed to a computer system for implementing a method for colour coding of data, comprising: memory in which is stored: colour values from a selected colour set, the colour values having known
15 positions in a physical colour space and being separated by measured differences in human colour perception, the colour values configured as a psychological colour space and positioned within the psychological colour space with reference to effects of spatial frequencies in a spatial frequency spectrum associated with an image or images represented by image data to be colour coded on human colour perception of the
20 colour values; and physical colour values configured as the physical colour space; and a microprocessor operable to: select points in the psychological colour space, the points representing a range of colours to be included in a colour scale for colour coding of the image data; map each point selected in the psychological colour space to a corresponding point in the physical colour space to determine a colour represented
25 by each point in the psychological colour space; and arrange the determined colours into a colour scale suitable for colour coding of the image data.

The computer system may further comprise a user input device; the microprocessor being operable to select points in the psychological colour space by allowing a user to select points using the user input device.

5 The memory may further store one or more colour scales previously defined using the psychological colour space, and the microprocessor may be further operable to allow a user to select one of the one or more colour scales as an alternative to the selecting points in the psychological colour space, the mapping and the arranging.

The memory may further store the image data, and the microprocessor may be further operable to colour code the image data by matching each datum to a colour
10 scale according to the value of the datum.

The computer system may further comprise a display device, the microprocessor being further operable to display the colour coded data on the display device.

The computer system may further comprise memory in which is stored a
15 library of different psychological colour spaces, each constructed from colour values in a colour set that are positioned within the psychological colour space with reference to the effects of spatial frequencies in a spatial frequency spectrum on human colour perception of those colour values so that each psychological colour space has an associated colour set and spatial frequency spectrum; the microprocessor being further
20 operable to select the psychological colour space from the library. Additionally, the microprocessor may be operable to select the psychological colour space by comparing information relating to the spatial frequency spectrum of the image or images and the selected colour set provided by a user with information relating to the spatial frequency spectrum and colour set associated with each psychological colour
25 space in the library to find a best match.

A fourth aspect of the present invention is directed to a colour scale suitable for colour coding of data, comprising a plurality of colours each with a corresponding colour value, the plurality of colours arranged to form a scale in which colours

adjacent in the scale are spaced according to the positions of the colours in a psychological colour space, the psychological colour space being constructed from colour values in a selected colour set, the colour values being positioned within the psychological colour space with reference to effects of spatial frequencies in a spatial frequency spectrum associated with an image or images represented by image data to be coded with the colour scale on human colour perception of the colour values. In one embodiment, the colours are spaced so that any pair of colours with a given separation within the scale has a colour value difference that is perceived by the human visual system to be equal to the colour value difference of any other pair of colours with the same separation. This gives a colour scale that is linear with respect to human colour perception.

A fifth aspect of the present invention is directed to a psychological colour space constructed from colour values from a specified colour set, the colour values being positioned within the psychological colour space with reference to effects of spatial frequencies in a specified spatial frequency spectrum on human colour perception of the colour values, the psychological colour space having associated information relating to the specified colour set and the specified spatial frequency spectrum.

A sixth aspect of the present invention is directed to a library of psychological colour spaces comprising a plurality of psychological colour spaces each according to the fifth aspect, in which each psychological colour space in the library is constructed with reference to a different combination of specified spatial frequency spectrum and specified colour set.

Further features and embodiments of the present invention are set out in various of the appended dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention and to show how the same may be carried into effect reference is now made by way of example to the accompanying
5 drawings in which:

Figure 1 shows a schematic representation of a physical colour space;

Figure 2 shows a schematic representation of the relationship between colour values in a physical colour space and colour values in a psychological colour space;

Figure 3 shows a flow chart indicating steps in a method according to an
10 embodiment of the present invention;

Figure 4 shows a schematic representation of the construction of a psychological colour space according to an embodiment of the present invention;

Figure 5 shows a schematic representation of points selected in a psychological colour space according to an embodiment of the present invention;

15 Figures 6a and 6b show schematic representations of a mapping of points from a one-dimensional psychological colour space to a one-dimensional physical colour space according to an embodiment of the present invention;

Figures 7a, 7b, 7c and 7d show schematic representations of a mapping of points from a three-dimensional psychological colour space to a three-dimensional
20 physical colour space according to an embodiment of the present invention;

Figure 8 shows a schematic representation of the construction of colour scales from points in a physical colour space according to an embodiment of the present invention; and

Figure 9 shows a schematic representation of a computer system suitable for
25 implementing methods for colour coding of data according to embodiments of the present invention.

DETAILED DESCRIPTION

The present invention seeks to address the difficulties posed by currently available methods of colour coding of data arrays by making use of psychological colour space that is specified with respect to contextual factors known to influence human colour perception, which better represents the nonlinearities and other peculiarities of human visual perception than physical colour spaces governed by the properties of imaging and display devices or physical parameters such as wavelength or intensity.

10 A set of colours can be represented as a unidimensional or multidimensional colour space, with each colour represented by a point within the space, and with the spatial relationships between pairs of points representing the similarity between the corresponding colours. Throughout this specification, the term "colour" is used in its broadest sense, so that a set or range of colours may for example include many colours of differing hue, or colours that all have the same hue, but differ in saturation and/or lightness.

A physical colour space is typically a three-dimensional space (although one- and two- dimensional colour spaces are also possible) in which a range of colours are arranged according to the values of various distinguishing characteristics of the colours. The properties may be, for example, hue, saturation and lightness, or red, green and blue (RGB). In some colour spaces, only one property may vary; for instance, the space may be formed entirely of different shades of grey, or another hue. The extent of the space, and the relative spacings between the colour values within it may be defined by properties of devices that utilise the range of colours within the space, for example in recording an image (camera), displaying an image (monitor) or reproducing an image (printer). Alternatively, physical properties of the actual colours, such as wavelength, frequency or intensity, may be used. Hence a physical colour space can be thought of as an array of regularly and evenly spaced colour values in

-17-

which the spacing depends on some kind of physical property. This concept is represented schematically in Figure 1, in which a lightness, hue and saturation physical colour space 10 is depicted having a regular array of colour values 12 defined within it. The regular spacing within the physical colour space in general fails to
5 match the nonlinear colour response of the human visual system.

A psychological colour space, on the other hand, is defined without reference to physical parameters. Instead, the spacing between various colour values is defined with reference to human colour perception. In particular, a psychological colour space may be arranged so that a pair of points in the space is separated by the same degree of
10 difference perceivable to the human visual system as any other pair of points with the same separation within the space. Thus, a series of equally spaced points along a straight line gives a colour scale that has linear steps according to the human visual system. Colour coding with such a scale therefore allows equal differences in data value in a colour coded image to be detected equally well by a human observer no
15 matter where they appear on the scale.

However, human colour perception is affected by the context in which colours are presented, and this can have an impact on the way in which colour coded images are understood and interpreted. Firstly, perceived colour is influenced by the spatial frequencies contained in an image. In particular, perceived saturation is reduced as
20 spatial frequency increases [10]. Secondly, perceived colour is influenced by the neighbourhood relations between two coloured regions such, for example, that a red surrounded by yellow is not perceived as the same as the identical red surrounded by blue [11]. Thirdly, perceived colour is influenced by whether coloured regions abut on another or are separated by a neutral background. Thus, context can be understood as
25 referring to these three factors.

The present invention seeks to take account of context by coding using a psychological colour space constructed from a specific selected set of colours which are positioned in the space in accordance with the results of colour perception

experiments in which the colours in the colour set are presented to observers in a way that reflects one or more spatial frequencies. The colour space is thus suitable for coding images containing those spatial frequencies where it is desired to present the images in the colours contained in the colour set. This approach thus directly takes
5 account of spatial frequency and the neighbourhood relations of colours (by considering a specific set of colours), and also takes account the abutment or separation of coloured regions because this is linked to spatial frequency (the colour abutment and neutral background separation depends at least to some extent on the frequency and amplitude of changes in the data values across the image). The
10 psychological colour spaces are built using experimental data collected under conditions that reflect the fundamental properties of images that will be coded using the colour space, since these conditions will influence the similarity structure defining the colour space.

A consequence of the different arrangement of colour values within physical
15 and psychological colour spaces is that there is an irregular mapping of colours between the two spaces. Colours that are regularly spaced in physical colour space are unevenly distributed in psychological colour space. Figure 2 illustrates this, showing how a set of colour values 12 within the physical colour space 10 translates (as indicated by the arrows) to a completely different distribution in a psychological
20 colour space 14.

The present invention uses the concept of psychological colour space where colours are positioned in a similarity space following experimentation where pairs of colours are presented in context and ratings made of their similarity to define colour scales for colour coding, so that scales which are linear, or have some intended bias,
25 with respect to human colour perception, can be defined.

Figure 3 shows a flow chart outlining various steps in a method according to an embodiment of the invention. Other embodiments may include fewer steps, as will be described later. A first step in this embodiment, however, is to identify or provide a

image (or images) to be colour coded, the image having an associated spatial frequency spectrum (step 1). Next, a colour set is selected, this being a range of colour values in which it is desired to code and display the image (step 2). Then, human colour perception data is obtained. This comprises colour values from the colour set
5 that are separated by known, measured amounts with respect to human colour perception, where the measurements are made with respect to spatial frequencies in the spatial frequency spectrum associated with the image (step 3). These colour values are then used to construct a psychological colour space, with the result that the colour space reflects human colour perception of the colours in the colour set when observed
10 under spatial frequency conditions found in the image (step 4). To define a particular colour scale, a set of points is then selected in the psychological colour space (step 5). The colours within the psychological colour space that are represented by the selected points may not be known, so each selected point is then mapped to a corresponding point in a physical colour space fully populated with colour values (step 6). This gives
15 a set of points in physical colour space for each of which the colour represented is known, so that the colour represented by each selected point can be determined (step 7). The colours determined in this way are then arranged into a colour scale (step 8). To allow the colour scale to be used for coding data, a data value or range of data values from image data that represents the image is assigned to each colour in the
20 scale (step 9). The image data can then be colour coded using the scale (step 10), and then displayed (step 11). The various steps will now be discussed in more detail.

STEP 1: Initially, an image, set of images or type of image that is to be colour-coded is identified. The image or images are represented by image data. Further, the image or images have more spatial frequencies, depending on the nature
25 of the data and the image type; these contribute to context. The spatial frequencies present in the image or images are measured, calculated or otherwise determined. It may be decided that only one primary spatial frequency need be considered, or some or all of the frequencies may be utilised. The term "spatial frequency spectrum" will

-20-

be used to include these possibilities, and should be understood to mean the spatial frequency or frequencies that are specified as a contextual parameter for the coding, i.e. which it is considered should be taken into account when coding and displaying the image. Further, the spectrum may be determined for a particular known image or set of images, in which case the spatial frequencies can be measured directly if desired or not otherwise known. Alternatively, the intention may be create a colour scale for coding a particular type of image, such as scans of the brain or meteorological satellite pictures. Such images typically have characteristic spatial frequencies that are always or mostly present, so that these known frequencies can be used to define the spatial frequency spectrum without reference to any specific image.

STEP 2: Next, a colour set for coding the image or images is chosen. This is a range of colour values (including hue and saturation) in which it is desired to present the coded image. The colour set may be chosen with reference to any requirement. For example, aesthetic considerations, convention in a particular field, colour-blindness of a viewer, capabilities of image display apparatus, and/or colour realism considerations may be used. Also, the colours may be chosen with regard to how the image is to be interpreted, for example by choosing colours known to emphasise or diminish perceived contrast. This can emphasise or diminish changes in the underlying data, to make them more or less apparent to an observer.

The colour set can be chosen very simply by selecting two end points and including the colour values required to progress directly between the colours represented by the end points, for example, perhaps via a third colour value. More complex colour sets might include a selection of widely spaced colour values with no smooth progression from one to another, if a broader range of hues is desired, for example.

STEP 3: Since a feature of a psychological colour space is that the values in it are spaced according to human colour perception, it is necessary to take some measurement of human colour perception to construct a psychological colour space.

This can be done by asking human participants to distinguish between a variety of different colours which have known positions within a chosen physical colour space. For example, participants might be shown multiple pairs of colour patches and asked to rate the similarity in colour of each pair. Alternatively, participants might be asked
5 to determine just noticeable differences between multiple target colour samples and a range of colour probes. Any suitable technique that determines amounts of difference perceived in a range of colours can be used.. However, a feature of the present invention is that the colour perception experiments are performed using only colour values from the selected colour set, and these colour values are presented to the
10 participants in ways that reflect spatial frequencies in the spatial frequency spectrum of the image or images. In this way, the context in which the eventually coded image is to be observed is taken into account, so that any distortions that may otherwise arise from the particular combination of colour values and spatial frequencies are accommodated within the measured data and hence compensated for.

15 STEP 4: The results of the measurements made in step 3 can then be used to construct a tailored, application-specific psychological colour space. The consequence of using colour perception measurements made as described is to give a psychological colour space in which a specified range of colour values (from the colour set) are positioned with reference to effects of spatial frequencies on human
20 colour perception of those colour values. The extent of the psychological colour space will depend on the size of colour set and the number of colour values from it that were used to obtain the measurements. For example, a one-dimensional space can be generated if the participants are shown colours that all have the same hue, and vary only in saturation or in brightness. The colour values used might be selected with
25 particular reference to the type of colour scale that it is desired to produce. Alternatively, a full range of colour samples might be shown to the participants, and only a subset of the resulting data used to construct the colour space. As a further alternative, all of the data obtained using a full range of colour samples might be used

-22-

to create a full three-dimensional colour space, which can then be used to generate colour scales having any range of hue, saturation and brightness, as desired, so long as the conditions under which the colour data were collected reflect the fundamentals of the images being coded.

5 To create the psychological colour space, a mathematical procedure is applied to the measured data to determine the coordinates within the colour space of each colour value, so that each colour value is appropriately separated from the other colour values according to the perceived differences between them. Any suitable mathematical technique can be used, for example, multidimensional scaling.

10 Figure 4 represents an example of the process of constructing a psychological colour space in this way, in which collected colour value data 16 is subjected to multidimensional scaling (MDS) 18 that positions each datum within a three-dimensional psychological colour space 20.

 Several features of the resulting psychological colour space should be
15 emphasised. Firstly, the colours used in the perception experiments will invariably be represented by points that are irregularly distributed within the psychological colour space. Also, the amount of data used to construct the colour space will be limited by the finite quantity that is practicable to collect from human participants. There will consequently be voids in the psychological colour space for which the colour values
20 are not known from experiment. However, for each of the known colours, namely those used in the colour perception ratings, the positions in both the physical and the psychological colour spaces are known precisely. This correspondence allows mappings between the spaces to be made, so that colours that lie in the voids can be determined.

25 STEP 5: Once a psychological colour space is available, it can be used to generate colour scales for colour coding. To achieve this, a set of points is selected in the psychological colour space. The set of points encompasses a range of colours that it is desired to include in a colour scale, with one point being selected for each

-23-

different colour that is wanted in the scale. The actual set selected will depend on whether it is desired to have different hues within the scale, or if a variation in saturation or brightness alone will be satisfactory. The detail which is required to be revealed by coding the data may affect the extent of the set of points; more colours
5 will typically be needed to distinguish a high level of detail.

To obtain a colour scale that is linear with respect to human colour perception, the points are selected to be equally spaced along a chosen line that covers the range of colours to be included in the colour scale. This may conveniently be achieved by selecting a pair of points to define the two ends of the line, and then calculating the
10 positions of as many intermediate points as are needed for the colour scale by, for example, dividing the line into the appropriate number of equally sized sections.

Figure 5 shows such a set of points. Six points 22 are arranged in a straight line within the psychological colour space 20.

STEP 6: The selection of evenly spaced points for the colour scale
15 combined with the voids in the psychological colour space arising from finite measured perception colour data means the exact colours represented by each of the selected points are unlikely to all be known. This information is, however, needed for the colour scale. It is therefore obtained by mapping the selected points from the psychological colour space to the corresponding points in the physical colour space,
20 for which the colour values are known precisely.

Algorithms are used to achieve the mapping, the precise details of which may depend on the dimensionality of the colour space.

Figure 6a illustrates the process for a one-dimensional psychological colour space 24. The selected points (dots) and the points known from the measured colour
25 perception data (crosses) all lie along the single line 26 of the colour space, the former being regularly spaced and the latter irregularly spaced. The physical colour value corresponding to a selected point 28 can be found by identifying two known colour values 30a, 30b lying one on each side of the selected point 28, and finding the

-24-

corresponding points 32a, 32b in the physical colour space 34 (where the points map from one space to the other). Then the information known about the position of the selected point 28 relative to the known points 30a, 30b in the psychological colour space is used in a function to linearly interpolate between the points 32a, 32b mapped
5 in the physical colour space to locate the position of the colour value 35 in the physical colour space 34 that corresponds to the selected point 28. Repeating this for each selected point gives a set of points in the physical colour space that are irregularly spaced along the one-dimensional line, as shown in Figure 6b.

Figures 7a, 7b, 7c and 7d illustrate a more general procedure that can be used
10 for a two- or three-dimensional colour space. For a selected point 36 in the psychological colour space 38, a set of known points 40 in the psychological colour space 38 in the vicinity of the selected point 36 is identified (Figure 7a). A data fitting procedure or algorithm is then used to produce a function F that maps the known points 40 from the psychological colour space 38 to corresponding points 42 in the
15 physical colour space 44, which can be done since the coordinates of these colour values in both spaces are precisely known (Figure 7b). The function F is then applied to the selected point 36 to map it to its corresponding point 46 in the physical colour space 44 (Figure 7c).

This is repeated for every selected point. Thus, a function F_a maps a selected
20 point 36_a, a further function F_b maps a second selected point 36_b, and so on for the whole set of selected points. The result is a set of irregularly distributed points 46 in the physical colour space 44 for which exact colours are known, as shown in Figure 7d.

The general procedure for mapping from the psychological colour space to the
25 physical colour space can be summarised as comprising the steps of:

- i. selecting a set of points (mapping points) in the psychological colour space in the vicinity of a selected point, where each mapping point is a known

-25-

point in the psychological colour space and therefore represents a colour the position of which is known in the physical colour space;

ii. determining a function that maps each mapping point to the appropriate position in the physical colour space;

5 iii. using the function to map the selected point to the physical colour space to determine the colour that the selected point represents in the psychological colour space; and

iv. repeating steps 1 to 3 for each selected point.

STEP 7: The mapping procedure gives a set of points in the physical
10 colour space; each of these points corresponds to a known colour value since the physical colour space is fully populated and has no voids. Therefore, the next step in creating the colour scale is to determine the colours that are represented by the set of points in the physical colour space, by using the one-to-one correlation between the coordinates of the points within the physical colour space and the colour values
15 encompassed by the physical colour space. This gives a set of actual colours.

STEP 8: The colours in the set are next arranged to form a colour scale. This will typically involve placing the colours in the order in which they appear along the line defined in the psychological colour space, but an alternative arrangement might be preferred for some applications.

20 STEP 9: To use the colour scale for coding the image data, or a particular type of image data, numerical values covering the range of values of that data are assigned to each colour in the colour scale. The maximum span of values likely to be present in the data needs to be covered, and then divided up into either individual values, or consecutive ranges of values. A value or range of values is then assigned to
25 each colour in the scale.

Figure 8 illustrates a simplified example of the implementation of Steps 5 to 7, in which a set of points 48 in a physical colour space 50, 'translated' from the equivalent linear set in the psychological colour space, is converted into its respective

-26-

colours 52 (represented by the arrows). The colours 52 are arranged into a colour scale 54, in this case a continuous smoothly graduated scale of constant hue and increasing saturation, and assigned numerical values 56 to cover a total range of 0 to 60. Also shown in an alternative discrete colour scale 60 that will result from using more
5 widely spaced colours. Again, the scale is of constant hue and increasing saturation, but a range of values 58 is given to each discrete colour 52, to cover a total range of 0 to 60.

STEP 10: Once the colour scale is constructed and assigned with numerical values, it can be used to colour code the image data. Each image datum is
10 allocated the colour from the colour scale whose associated value matches the value of the datum. This effectively gives a new, colour coded, array of image data in which each datum has a colour value instead of a numerical value.

STEP 11: The colour coded image data is then displayed as a colour image (in one, two or three dimensions depending on the nature of the data) that can
15 be studied and interpreted by a human observer. The displaying can be performed using any suitable colour display methodology, such as a computer monitor, a television screen or printing a hard copy.

The embodiment of the invention described thus far includes steps right through from choosing a colour set to code a particular image or images, through
20 collecting data from which to build a psychological colour space, to displaying a colour coded image. However, according to other embodiments, various steps can be omitted. For example, previously obtained perception measurement data can be used to construct the psychological colour space, so long as it was collected in accordance with requirements of the invention, i.e. that colour values from a colour set selected
25 for coding were used, and presented to participants so as to reflect spatial frequencies that are found in the images to be coded. The data may be have been obtained for an alternative purpose, or supplied by a third party. An extensive three-dimensional data set may be kept, and small parts of it used as necessary to construct various spaces

-27-

tailored for different coding applications. Indeed, these latter scenarios are likely, since it is not practicable or necessary to collect data from participants every time a colour scale is required. These remarks apply equally to the step of constructing the psychological colour space. There is generally no need to construct a new space for every colour scale needed, so there is the possibility that Steps 3 and 4 are performed only once, and the resulting colour space then used time and again to obtain various colour scales. Further, a preconstructed colour space could be obtained from a third party. However, it must be noted that such spaces will only be of value if the conditions under which the data from which they are built reflect the contextual fundamentals of the images being coded. Monolithic colour spaces such as the Munsell colour solid and the CIE LUV space cannot, in principle, be considered valid.

Use of preconstructed psychological colour spaces is considered to be of particularly advantageous significance. Many colour coding applications relate to groups of the same types of images (geological, medical, meteorological, etc.). Each image type has certain characteristics including typical spatial frequency spectra, and a requirement for interpretation in a particular manner that requires certain features to be emphasised or suppressed in the coded image so that a particular colour set is appropriate, or merely conventional. Therefore, it is possible to provide a catalogue or library of psychological colour spaces tailored to various types of image with particular contexts (spatial frequency spectrum and selected colour set). A user need then just specify the type of image, and an appropriate psychological colour space, or colour scale derived therefrom, can be provided to code the image or images.

A more detailed approach is to provide a library of psychological colour spaces each constructed with regard to a particular spatial frequency spectrum and colour set (as above but with each space identified directly with regard to frequency and colour set rather than with regard to an image type for which it is suitable based on the frequency and colour set conditions under which it was built). The user can then measure, calculate or otherwise determine the spatial frequency spectrum of an image

-28-

and specify a colour set in which it is desired to display the image. This information can be compared with the corresponding information describing each colour space in the library, and the best match from the available colour spaces can be provided for coding the image. To accomplish this, each colour space has associated information
5 that relates to the spatial frequency spectrum and colour set specified for its construction, and the library comprises a plurality of these spaces, each constructed with regard to a different combination of spatial frequency spectrum and colour set.

According to these techniques, steps 3 and 4 in Figure 3 can be considered as being replaced by a single step of selecting a psychological colour space from a library
10 of preconstructed psychological colour spaces, where the selection is either made on the basis of the type of image to be coded, that image type having an inherent associated spatial frequency spectrum and desirable colour set, or on the basis of a spatial frequency spectrum and colour set specified by a user. These approaches are advantageous in that a user need have no skill in or understanding of the building, use
15 or interpretation of psychological colour spaces; a suitable space is obtained merely by matching information provided by the user with corresponding information associated with each of a catalogue of psychological colour spaces.

The step of assigning data values to the colours in the colour scale might be performed separately from the preceding steps. For example, one or a few colour
20 scales can be produced for multiple usage, and then data values can be assigned and reassigned according to the range of data contained in various data arrays to be coded. Similarly, a single colour scale with assigned data values might, and commonly will, be used many times to code different data arrays. This is true, for example, in the case of a large number of similar images showing data of the same type, such as medical
25 scans of a plurality of patients, or meteorological images taken over time or of different locations. There is scope for generating suitable colour scales using embodiments of the present invention, and then supplying the scales to users either with or without assigned data values.

Once a colour scale is generated, it can be used at will to encode data, which can then either be displayed immediately, and possibly stored for subsequent further viewing, or be stored for viewing at a later time. Thus the final two steps in the embodiment of Figure 3 can be performed separately from the preceding steps, and
5 need not form part of various embodiments of the invention.

The description thus far has assumed that a colour scale that is linear with respect to human colour perception is desired. To achieve this, all the points selected in the psychological colour space are positioned in a straight line, and evenly spaced along that line. A colour scale of this kind allows an observer of a coded image to
10 distinguish equal differences in data value at any part of the scale, since all equivalent differences are separated by an equally perceivable colour difference. However, an alternative approach is to use the characteristics of human colour perception embodied in the psychological colour space to create a nonlinear colour scale that has a particular intended bias. This is achieved by selecting points that are unevenly
15 distributed in the psychological colour space, either along a single line, or in two or three dimensions. A bias of this kind can be used to emphasise various features embedded in the data array to be coded. For example, if it is desired that one or more thresholds in the data are readily apparent, two or more evenly spaced sets of points can be used so that data on either side of a threshold can be coded linearly but with
20 clear distinction, perhaps by using a different hue for each side. Alternatively, if particular detail in part of a data array is of more interest than other parts, a greater range of colours can be assigned to that part of the data, and the remaining data can be assigned a smaller range of readily distinct colours, so that the data of interest appears against a background of the other data. The selected points may then comprise a
25 tightly bunched group together with a few points a long way distant.

Thus, to achieve a linear or a biased colour scale, it is merely necessary to make an appropriate selection of points in the psychological colour space; all other steps can be performed in the same way for either type of scale. Points may therefore

-30-

be selected in accordance with any desired distribution, including lying equally or unequally spaced along one or more straight or curved lines, or with a wholly irregular distribution.

An alternative way of achieving a biased or otherwise nonlinear colour scale is to manipulate the psychological colour space before selecting points within it. Thus, the known colour values of the measured colour perception data can be positioned in an irregular distribution when the psychological colour space is constructed, to give a colour space that may conveniently be described as nonlinear; however, it is the arrangement of colour values in the space that is nonlinear, not the space per se (similarly, the psychological colour spaces discussed up to this point may conveniently be referred to as linear). Then, an evenly spaced set of selected points within the space has a nonlinear distribution in that adjacent points are not separated by equal perceived differences. Either approach to producing a nonlinear colour scale can be used to create psychological step changes in colour perception (i.e. a step change is perceived, even though according to physical parameters there is no step change in colour) to facilitate guided “walks” through data sets when it is important to search for image features generated by specific values of the variables being imaged.

Regarding implementation of the various embodiments of methods according to the present invention, this may conveniently be achieved using a computer system. The computer system may be operated via appropriate software, hardware or a combination of software and hardware. A computer system offers many advantages in connection with the present invention. Owing to the potentially large amount of data, the processes of handling two colour spaces and of coding and displaying a data array are computationally intensive. Additionally, the image data to be coded is likely to have been obtained via some form of imaging system that is integrated with a computer system. An example of this is a Picture Archiving and Communication System (PACS), now increasingly used in hospitals. Diagnostic patient images and measurements are recorded in a digital format and stored directly to a single central

archive. The archive is part of a computer network, so that the archived data can then be accessed as and when required from workstations around or outside the hospital, and any desired image manipulation and interpretation, such as may be facilitated by colour coding, can be readily performed.

5 Figure 9 shows a simple computer system that can be used to implement embodiments of the invention. The computer system 60 comprises a microprocessor 62, memory 64, a user input device 66 and a display device 68 such as a computer monitor or a printer. The memory 64 stores colour value data that makes up the physical colour space 70 and the psychological colour space 72, and also one or more
10 image data arrays 74 to be coded. The microprocessor 62 is provided with machine-readable instructions operable to implement various steps in the embodiments. The microprocessor 62 is connected to the memory 64 via a data transfer bus that allows the microprocessor 62 to access data in the memory 64 and to write data to the memory 64. The microprocessor 62 is also connected to the display device 68 such
15 that the microprocessor 62 can send images for display by the display device 68, and further to the user input device 66 so that a user can input information to the microprocessor 66. The user input device 66 may be a keyboard that allows the entry of alphanumeric information. The user input device may additionally or alternatively comprise a device such as a mouse operable to move a cursor over the display on the
20 display device 68, thus allowing the user to input information by "pointing and clicking" to items shown on the display. The computer system 60 may be arranged as part of a computer network, so that, for example, the memory 64 and the microprocessor 62 may be remote from the user input device 66 and the display device 68.

25 The microprocessor 62 is operable to access the psychological colour space 72 so that points can be selected in it. The selection may be configured to be performed automatically by the microprocessor in response to a request from the user, such as a specification for a linear scale with a particular number of colours in it. Alternatively,

-32-

the user may be allowed to select the points directly. This can be achieved, for example, by displaying a representation of the psychological colour space 72 or the colour values therein on the display device 68, and having the user indicate the selected points using the cursor. In the case of a scale composed of colours along a single line, this can be simplified by requiring the user to merely choose two points. The microprocessor then computes a line connecting the two points, and determines the coordinates of a desired number of points along the line (which may be evenly or unevenly spaced depending on if a linear or nonlinear scale is required from a linear or nonlinear psychological colour space). Three or more points could be selected, allowing the user to indicate directly the size of separation between colour values wanted for the colour scale.

A still further alternative is to present the user with a representation of all or part of the physical colour space 70. This is a complete colour space, so is more “user friendly”; the user can directly see the range of colours that can be selected for incorporation in the colour scale. The user then chooses two points along a line covering the desired range of colours (preferably the end points). The microprocessor 62 is provided with an algorithm that maps points in the physical colour space 70 to the corresponding points in the psychological colour space 72, and uses it to map the two chosen points to the psychological colour space. Then the line between the two points is calculated, together with the intermediate points.

Once the points are selected, the microprocessor 62 calculates the mapping functions F , performs the mapping, determines the colours from the physical colour space 70 and arranges the colours into a colour scale (possibly with some user input). The microprocessor 62 then assigns data values to the colours in the colour scale, for example in response either to user input, or by using predetermined default options, or by interrogating the range of data values in the data array 74. The microprocessor 62 can further colour code the data array 74 according to the colour scale, and display the coded image on the display monitor 68 and/or store it in memory 64.

The microprocessor may be further operable to construct the psychological colour space 72 from measured colour perception data provided to it, perhaps as a retrieval from memory 64 or entered via the user input device 66.

A further feature that may optionally be included in the computer system is the provision of one or more previously defined colour scales based on the psychological colour space. When a user wishes to view a data array in a colour coded format, s/he is offered the choice between selecting one of the previously defined colour scales, or generating a new colour scale using the psychological colour space. The previously defined scales may be assigned with predefined data values, or may be merely a set of colours to which the user can assign data values according to need, depending on the data array to be coded.

Furthermore, it may be desirable to allow the user to modify the colour scale once the coded image has been displayed. A need for this may arise in circumstances in which the need for a nonlinearity or discontinuity in the colour scale only becomes apparent after the image is displayed, for example if it is then seen that particular features of interest are not readily distinguishable. Alternatively, it may be known that a nonlinearity is required, but the nature or position of the nonlinearity within the colour scale can only be properly determined after the image is displayed, perhaps using a linear scale as a starting point. This issue can be addressed by allowing the colour scale to be changed dynamically, to aid image interpretation.

To achieve this, the colour scale may be displayed to the user, preferably as a bar of colours next to the displayed image. The user is provided with a cursor (or similar indicating device) that can be positioned on the colour scale to indicate one or more positions where a nonlinearity is desired. The microprocessor then updates the colour scale by introducing a nonlinearity or discontinuity at the indicated position, perhaps by moving all the assigned data values on one side of the indicated position along the scale by one or more colour values, or by using linear or nonlinear interpolation to introduce one or more additional colour values to the scale at the

relevant position, and assigning data values to the new colour values accordingly. The microprocessor may adopt a default procedure for performing this, or a menu may be presented to the user to allow a choice of procedures. The microprocessor then recodes the data array using the updated colour scale, and displays the newly coded image to the user. This process can be repeated as often as necessary to achieve the desired colour coding. Additionally or alternatively, the user may be allowed to move the cursor so as to reposition the nonlinearity, the microprocessor then updating the colour scale and recoding the image as before.

Alternatively, the computer system can be used to generate colour scales that are then supplied elsewhere for use in colour coding of data.

In embodiments that rely on a library or catalogue of preconstructed psychological colour spaces, the memory of the computer system can retain the library. Alternatively, the library can be stored remotely from the computer system, and the microprocessor can be operable to access the library over a network connection when a colour space is required. This arrangement might be used by a supplier who has constructed the colour spaces and makes them available for third party use, for example. Each colour space in the library has associated information such as a label or other linked information that specifies the image type for which it is suitable and/or the spatial frequency spectrum and colour set which it was built with reference to. The user can enter information specifying an image type or a spatial frequency and colour set combination into the microprocessor, which then retrieves the most suitable colour space from the library according to the best match found as a result of comparing the label information and the user-specified information. This retrieved colour space is then used to create the colour scale.

The functions performed by the microprocessor of the computer system can further be defined by machine readable instructions; these can be provided as a computer program product comprising the machine readable instructions carried on

-35-

some form of carrier such as a machine readable carrier medium or provided over a network to allow a user to implement the invention on an existing computer system.

The present invention has wide application in many industries and commercial activities in which efficient interpretation of displays of complex digital data is
5 considered important. These include, but are not limited to:

- geological and related subsurface analysis in the oil and gas and mineral extraction industries
- remote sensing/satellite imagery for land use/agriculture/resource/urban planning, etc.
- 10 - medical imaging/scanning
- metallurgical and other materials analysis
- meteorological/climate modelling
- security scans examining the contents of baggage and shipping containers

REFERENCES

- [1] Cate, R. B. and Wulbert, D. E. (1992). US 5,089,976.
- [2] Indow, T. (1988). Multidimensional studies of Munsell-color solid.
5 Psychological Review, 95, 456-470.
- [3] Ware, C. (1998), Colour sequences for univariate maps: Theory, Experiments
and Principles. IEEE Computer Graphics and Applications, 8, 41-49.
- [4] Della Ventura, A. and Schettini, R. (1993), Computer Aided Color Coding. In
N.M. Thalmann and D. Thalmann (eds.), Communication with Virtual Worlds,
10 Tokyo, Springer-Verlag.
- [5] Levkovitz, H. (1995), Perceptual steps along color scales. International Journal
of Imaging Systems and Technology, 7, 97-101.
- [6] Takamura, S. and Kobayashi, N. (2002). Practical extension to CIELUV color
space to improve uniformity. Proceedings of IEEE International Conference on
15 Image Processing, 2, 393-396.
- [7] Baylis, G. D. and Driver, J. (1992). Visual parsing and response competition:
The effect of grouping factors. Perception and Psychophysics, 51, 145 -162.
- [8] Quinlan, P. T. and Wilton, R. N. (1998). Grouping by proximity or similarity?
Competition between the Gestalt principles in vision. Perception, 27, 417-430.
- 20 [9] Robertson, P.H. (1988), Visualizing color gamuts: A user interface for
effective use of perceptual color spaces in data displays. IEEE Computer
Graphics and Applications, 8, 41-49.
- [10] Bauml, K-H and Wandell, B. (1996), Color appearance of mixture gratings.
Vision Research, 36, 2849-2864.
- 25 [11] Lotto, R.B. and Purves, D (2000), An empirical explanation of color contrast.
Proceedings of the National Academy of Science, 97, 12834-12839

CLAIMS

1. A method for colour coding of image data comprising:
providing an image or images represented by image data, the image or images
5 having an associated spatial frequency spectrum;
selecting a colour set comprising a plurality of colour values;
obtaining a psychological colour space constructed from colour values in the
colour set, the colour values being positioned within the psychological colour space
with reference to effects of spatial frequencies in the spatial frequency spectrum on
10 human colour perception of the colour values;
selecting points in the psychological colour space, the points representing a
range of colours to be included in a colour scale for colour coding of the image data;
mapping each point selected in the psychological colour space to a
corresponding point in a physical colour space to determine a colour represented by
15 each point selected in the psychological colour space; and
arranging the determined colours into a colour scale suitable for colour coding
of the image data.
2. A method according to claim 1, in which the points selected in the
20 psychological colour space are equally spaced within the psychological colour space.
3. A method according to claim 1, in which the points selected in the
psychological colour space are irregularly positioned within the psychological colour
space.
25
4. A method according to any one of claims 1 to 3, in which the points are
selected in the psychological colour space to give a colour scale that is linear with
respect to human colour perception.

-38-

5. A method according to any one of claims 1 to 3, in which the points are selected in the psychological colour space to give a colour scale that is intentionally biased with respect to human colour perception.

5

6. A method according to any preceding claim, in which selecting the points in the psychological colour space comprises choosing points in the psychological colour space, and calculating further points in the psychological colour space that lie along a line including the chosen points.

10

7. A method according to claim 6, in which choosing points in the psychological colour space comprises choosing points in the physical colour space, and mapping the chosen points to corresponding points in the psychological colour space.

15 8. A method according to any preceding claim, in which the mapping to a corresponding point in the physical colour space comprises, for each selected point in the psychological colour space:

selecting a set of mapping points in the psychological colour space in the vicinity of the selected point, where each mapping point represents a colour the position of which within the physical colour space is known;

20 determining a function that maps each mapping point to the appropriate position in the physical colour space; and

using the function to map the selected point to the physical colour space to determine the colour that the selected point represents in the psychological colour space.

25

9. A method according to claim 8, in which the function is determined using a data fitting algorithm.

-39-

10. A method according to claim 8, in which the function is determined using linear interpolation.

5 11. A method according to any preceding claim, and further comprising assigning a data value or range of data values from the image data to each colour in the colour scale.

10 12. A method according to claim 11, and further comprising colour coding the image data by matching each datum to a colour in the colour scale according to the value of the datum.

13. A method according to claim 12, and further comprising displaying the colour coded image data for viewing by an observer.

15

14. A method according to any preceding claim, and further comprising constructing the psychological colour space by positioning colour values in the colour set in a one-, two- or three-dimensional space with reference to effects of spatial frequencies in the spatial frequency spectrum on human colour perception of the colour values, the colour values having known positions in the physical colour space and being separated by measured differences in human colour perception.

20

15. A method according to claim 14, in which the colour values are positioned such that equal measured differences in human colour perception are equally separated throughout the psychological colour space.

25

-40-

16. A method according to claim 14, in which the colour values are positioned such that equal measured differences in human colour perception are unequally separated throughout at least part of the psychological colour space.

5 17. A method according to any one of claims 14 to 16, in which the colour values are positioned using multidimensional scaling.

18. A method according to any one of claims 14 to 17, and further comprising measuring differences in human colour perception between colour values in the colour
10 set with known positions in the physical colour space, the differences being measured with reference to effects of spatial frequencies in the spatial frequency spectrum on human colour perception of the colour values.

19. A method according to any one of claims 1 to 18, in which obtaining the
15 psychological colour space comprises selecting the psychological colour space from a library of different psychological colour spaces, each constructed from colour values in a colour set that are positioned within the psychological colour space with reference to the effects of spatial frequencies in a spatial frequency spectrum on human colour perception of those colour values so that each psychological colour space has an
20 associated colour set and spatial frequency spectrum.

20. A computer program product carrying machine-readable instructions for implementing a method for colour coding of data, the method comprising:
providing an image or images represented by image data, the image or images
25 having an associated spatial frequency spectrum;
selecting a colour set comprising a plurality of colour values;
obtaining a psychological colour space constructed from colour values in the colour set, the colour values being positioned within the psychological colour space

-41-

with reference to effects of spatial frequencies in the spatial frequency spectrum on human colour perception of the colour values;

selecting points in the psychological colour space, the points representing a range of colours to be included in a colour scale for colour coding of the image data;

5 mapping each point selected in the psychological colour space to a corresponding point in a physical colour space to determine a colour represented by each point selected in the psychological colour space; and

arranging the determined colours into a colour scale suitable for colour coding of the image data.

10

21. A computer program product according to claim 20, in which the points selected in the psychological colour space are equally spaced within the psychological colour space.

15 22. A computer program product according to claim 20, in which the points selected in the psychological colour space are irregularly positioned within the psychological colour space.

20 23. A computer program product according to any one of claims 20 to 22, in which the points are selected in the psychological colour space to give a colour scale that is linear with respect to human colour perception.

24. A computer program product according to any one of claims 20 to 22, in which the points are selected in the psychological colour space to give a colour scale that is
25 intentionally biased with respect to human colour perception.

25. A computer program product according to any one of claims 20 to 24, in which the instructions are operable to allow a user to select points in the psychological colour space.
- 5 26. A computer program product according to claim 25, in which the instructions are further operable: to allow the user to choose points in the psychological colour space; and to calculate further points in psychological colour space that lie along a line including the chosen points.
- 10 27. A computer program product according to claim 26, in which the instructions are further operable to allow the user to choose points in the psychological colour space by: allowing the user to choose points in the physical colour space; and mapping the chosen points to corresponding points in the psychological colour space.
- 15 28. A computer program product according to any one of claims 20 to 27, in which the instructions are operable to map each point selected in the psychological colour space by:
- selecting a set of mapping points in the psychological colour space in the vicinity of the selected point, where each mapping point represents a colour the
- 20 position of which within the physical colour space is known;
- determining a function that maps each mapping point to the appropriate position in the physical colour space; and
- using the function to map the selected point to the physical colour space to determine the colour that the selected point represents in the psychological colour
- 25 space.
29. A computer program product according to claim 28, in which the function is determined using a data fitting algorithm.

30. A computer program product according to claim 28, in which the function is determined using linear interpolation.

5 31. A computer program product according to any one of claims 20 to 30, in which the instructions are operable to allow a user to select one of one or more colour scales previously defined using the psychological colour space as an alternative to the selecting points in the psychological colour space, the mapping and the arranging.

10 32. A computer program product according to any one of claims 20 to 31, in which the instructions are operable to assign a data value or range of data values from the image data to each colour in the colour scale.

15 33. A computer program product according to claim 32, in which the instructions are further operable to colour code the image data by matching each datum to a colour in the colour scale according to the value of the datum.

20 34. A computer program product according to claim 33, in which the instructions are further operable to display the colour coded image data for viewing by an observer.

35. A computer program product according to claim 24, in which the instructions are further operable to modify the colour scale in response to user input.

25 36. A computer program product according to claim 34, in which the instructions are operable to modify the colour scale by displaying the colour scale to the user, allowing the user to indicate a position on the colour scale, and updating the colour scale by introducing a nonlinearity at the indicated position.

-44-

37. A computer program product according to claim 35 or claim 36, in which the instructions are further operable to colour code and display the image data using the modified colour scale.

5

38. A computer program product according to any one of claims 20 to 37, in which the instructions are operable to receive colour values in the colour set that have known positions in the physical colour space and are separated by measured differences in human colour perception, and to construct the psychological colour space by
10 positioning the colour values in a one-, two- or three-dimensional space with reference to effects of spatial frequencies in the spatial frequency spectrum on human colour perception of the colour values.

39. A computer program product according to claim 38, in which the colour values
15 are positioned such that equal measured differences in human colour perception are equally separated throughout the psychological colour space.

40. A computer program product according to claim 38 in which the colour values are positioned such that equal measured differences in human colour perception are
20 unequally separated throughout at least part of the psychological colour space.

41. A computer program product according to any one of claims 38 to 40, in which the instructions are operable to position the colour values using multidimensional scaling.

25

42. A computer program product according to any one of claims 20 to 41, in which the instructions are further operable to obtain the psychological colour space by selecting it from a library of different psychological colour spaces, each constructed

-45-

from colour values in a colour set that are positioned within the psychological colour space with reference to the effects of spatial frequencies in a spatial frequency spectrum on human colour perception of those colour values so that each psychological colour space has an associated colour set and spatial frequency spectrum.

43. A computer program produce according to claim 42, in which the instructions are operable to select the psychological colour space by allowing a user to provide information relating to the spatial frequency spectrum of the image or images and the selected colour set and comparing it with information relating to the spatial frequency spectrum and colour set associated with each psychological colour space in the library to find a best match.

44. A computer system for implementing a method for colour coding of data, comprising:

memory in which is stored:

colour values from a selected colour set, the colour values having known positions in a physical colour space and being separated by measured differences in human colour perception, the colour values configured as a psychological colour space and positioned within the psychological colour space with reference to effects of spatial frequencies in a spatial frequency spectrum associated with an image or images represented by image data to be colour coded on human colour perception of the colour values; and

physical colour values configured as the physical colour space; and
a microprocessor operable to:

select points in the psychological colour space, the points representing a range of colours to be included in a colour scale for colour coding of the image data;

-46-

map each point selected in the psychological colour space to a corresponding point in the physical colour space to determine a colour represented by each point in the psychological colour space; and

5 arrange the determined colours into a colour scale suitable for colour coding of the image data.

45. A computer system according to claim 44, in which the points selected in the psychological colour space are equally spaced within the psychological colour space.

10 46. A computer system according to claim 44, in which the points selected in the psychological colour space are irregularly positioned within the psychological colour space.

15 47. A computer system according to any one of claims 44 to 46, in which the points are selected in the psychological colour space to give a colour scale that is linear with respect to human colour perception.

20 48. A computer system according to any one of claims 44 to 47, in which the points are selected in the psychological colour space to give a colour scale that is intentionally biased with respect to human colour perception.

25 49. A computer system according to any one of claims 44 to 48, further comprising a user input device; and the microprocessor being operable to select points in the psychological colour space by allowing a user to select points using the user input device.

50. A computer system according to claim 59, in which the microprocessor is further operable to allow the user to chose points in the psychological colour space;

-47-

and to calculate further points in the psychological colour space that lie along a line including the chosen points.

51. A computer system according to claim 50, in which the microprocessor is
5 further operable to allow the user to choose points in the psychological colour space by: allowing the user to choose points in the physical colour space; and mapping the chosen points to corresponding points in the psychological colour space.

52. A computer system according to any one of claims 44 to 51, in which the
10 microprocessor is operable to map each point selected in the psychological colour space by:

selecting a set of mapping points in the psychological colour space in the vicinity of the selected point, where each mapping point represents a colour the position of which in the physical colour space is known;

15 determining a function that maps each mapping point to the appropriate position in the physical colour space; and

using the function to map the selected point to the physical colour space to determine the colour that the selected point represents in the psychological colour space.

20

53. A computer system according to claim 52, in which the microprocessor determines the function using a data fitting algorithm.

54. A computer system according to claim 53, in which the microprocessor
25 determines the function using linear interpolation.

55. A computer system according to any one of claims 44 to 54, in which the memory further stores one or more colour scales previously defined using the

-48-

psychological colour space, and the microprocessor is further operable to allow a user to select one of the one or more colour scales as an alternative to the selecting points in the psychological colour space, the mapping and the arranging.

5 56. A computer system according to any one of claims 44 to 55, in which the microprocessor is further operable to assign a data value or range of data values from the image data to each colour in the colour scale.

10 57. A computer system according to claim 56, in which the memory further stores the image data, and the microprocessor is further operable to colour code the image data by matching each datum to a colour in the colour scale according to the value of the datum.

15 58. A computer system according to claim 57, and further comprising a display device, the microprocessor being further operable to display the colour coded image data on the display device.

20 59. A computer system according to claim 58, in which the microprocessor is further operable to modify the colour scale in response to user input.

60. A computer system according to claim 59, in which the microprocessor is operable to modify the colour scale by displaying the colour scale to the user, allowing the user to indicate a position on the colour scale, and updating the colour scale by introducing a nonlinearity at the indicated position.

25 61. A computer system according to claim 59 or claim 60, in which the microprocessor is further operable to colour code and display the image data using the modified colour scale.

62. A computer system according to any one of claims 44 to 61, in which the microprocessor is further operable to construct the psychological colour space by positioning the colour values in a one-, two- or three-dimensional space.

5

63. A computer system according to claim 63, in which the microprocessor is operable to position the colour values such that equal measured differences in human colour perception are equally separated throughout the psychological colour space.

10 64. A computer system according to claim 62, in which the microprocessor is operable to position the colour values such that equal measured differences in human colour perception are unequally separated throughout at least part of the psychological colour space.

15 65. A computer system according to any one of claims 62 to 64, in which the microprocessor is operable to position the colour values using multidimensional scaling.

20 66. A computer system according to any one of claims 44 to 65, and further comprising memory in which is stored a library of different psychological colour spaces, each constructed from colour values in a colour set that are positioned within the psychological colour space with reference to the effects of spatial frequencies in a spatial frequency spectrum on human colour perception of those colour values so that each psychological colour space has an associated colour set and spatial frequency spectrum;

25

the microprocessor being further operable to select the psychological colour space from the library.

67. A computer system according to claim 66, in which the microprocessor is operable to select the psychological colour space by comparing information relating to the spatial frequency spectrum of the image or images and the selected colour set provided by a user with information relating to the spatial frequency spectrum and
5 colour set associated with each psychological colour space in the library to find a best match.

68. A colour scale suitable for colour coding of image data, comprising a plurality of colours each with a corresponding colour value, the plurality of colours arranged to
10 form a scale in which colours adjacent in the scale are spaced according to the positions of the colours in a psychological colour space, the psychological colour space being constructed from colour values in a selected colour set, the colour values being positioned within the psychological colour space with reference to effects of spatial frequencies in a spatial frequency spectrum associated with an image or images
15 represented by image data to be coded with the colour scale on human colour perception of the colour values.

69. A colour scale according to claim 68, in which the colours are spaced so that any pair of colours with a given separation within the scale has a colour value
20 difference that is perceived by the human visual system to be equal to the colour value difference of any other pair of colours with the same separation.

70. A psychological colour space constructed from colour values from a specified colour set, the colour values being positioned within the psychological colour space
25 with reference to effects of spatial frequencies in a specified spatial frequency spectrum on human colour perception of the colour values, the psychological colour space having associated information relating to the specified colour set and the specified spatial frequency spectrum.

-51-

71. A library of psychological colour spaces comprising a plurality of psychological colour spaces each according to claim 70, in which each psychological colour space in the library is constructed with reference to a different combination of
5 specified spatial frequency spectrum and specified colour set.

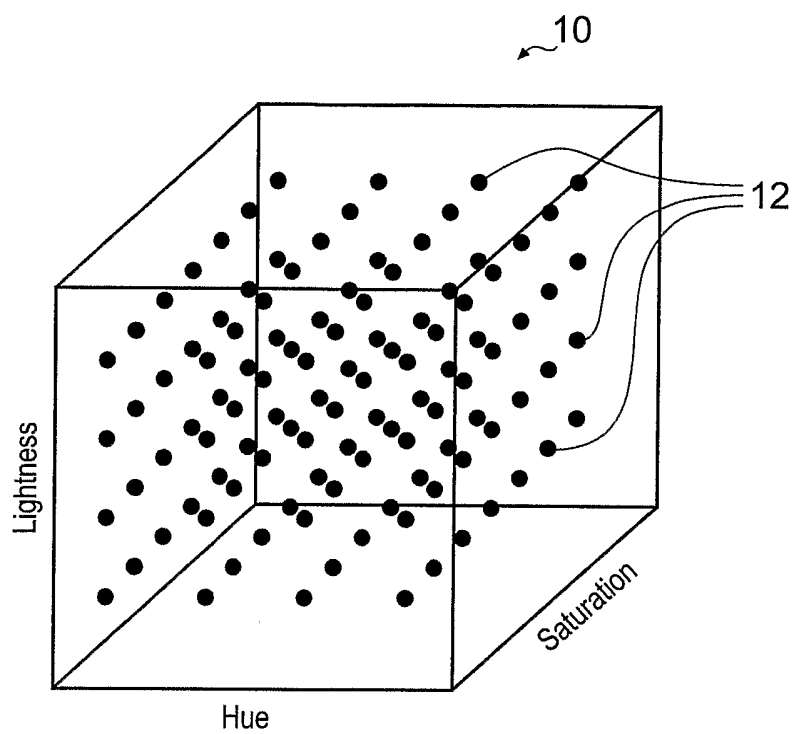


Fig. 1

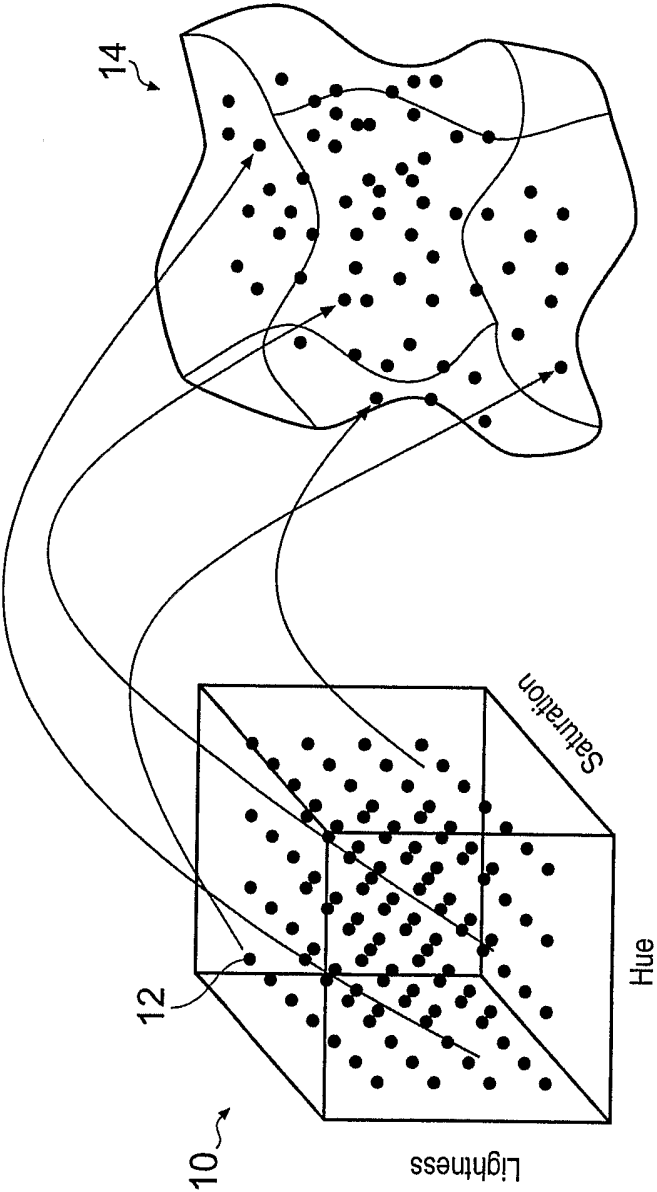


Fig. 2

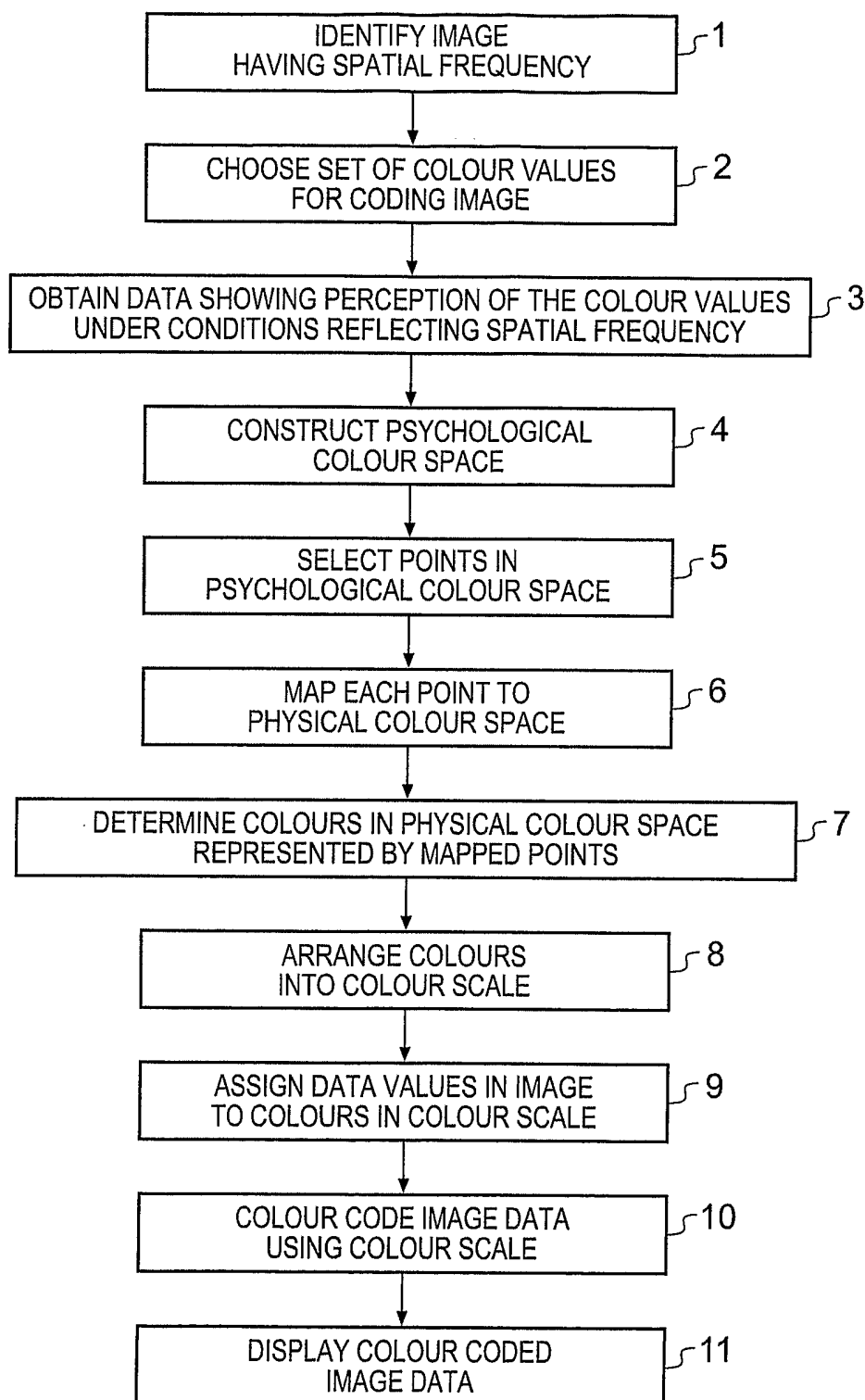


Fig. 3

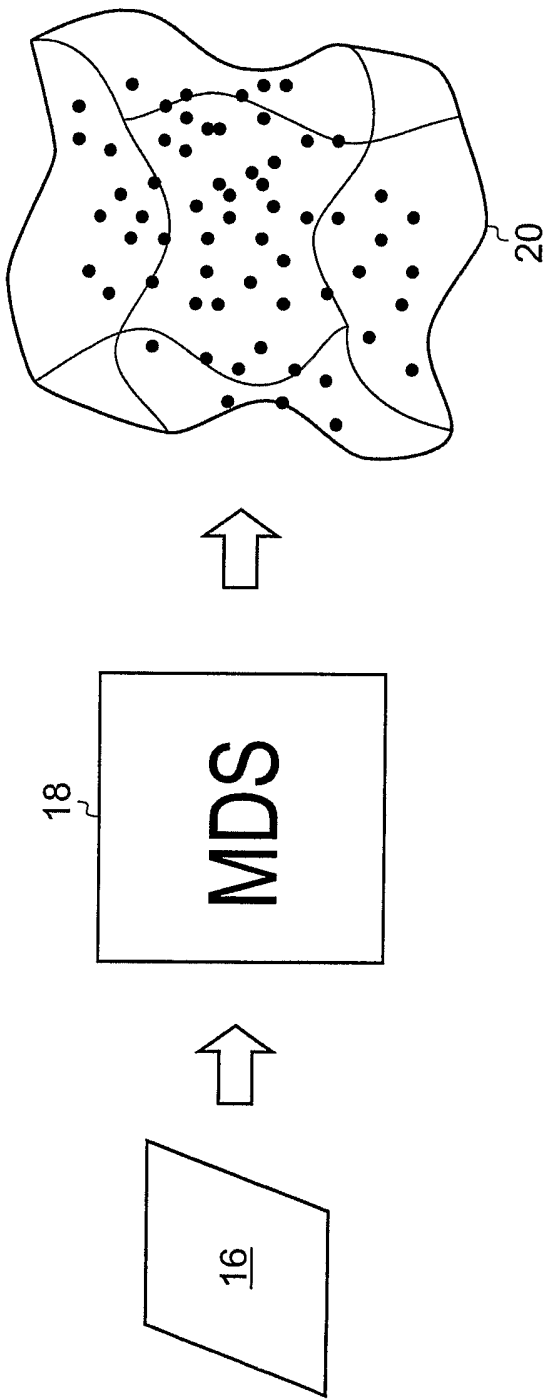


Fig. 4

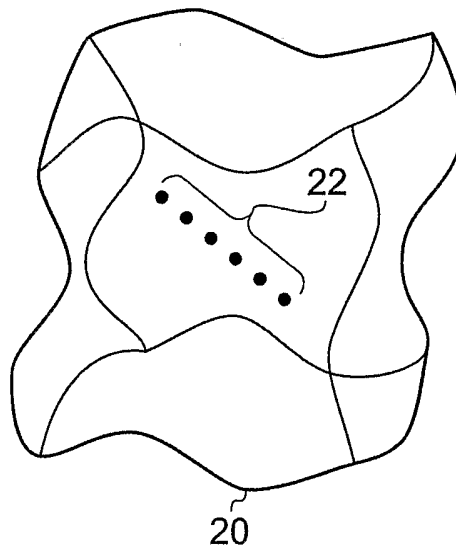


Fig. 5

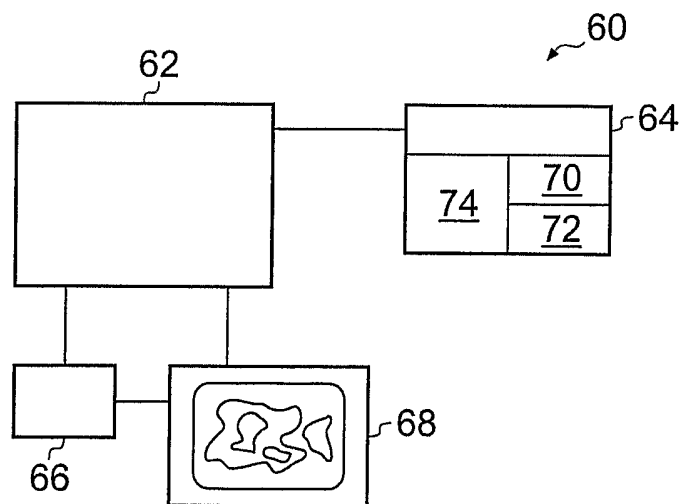


Fig. 9

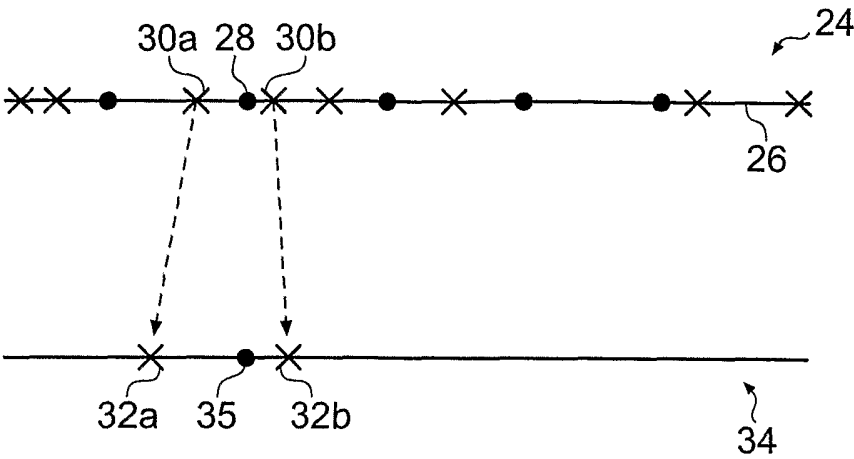


Fig. 6a

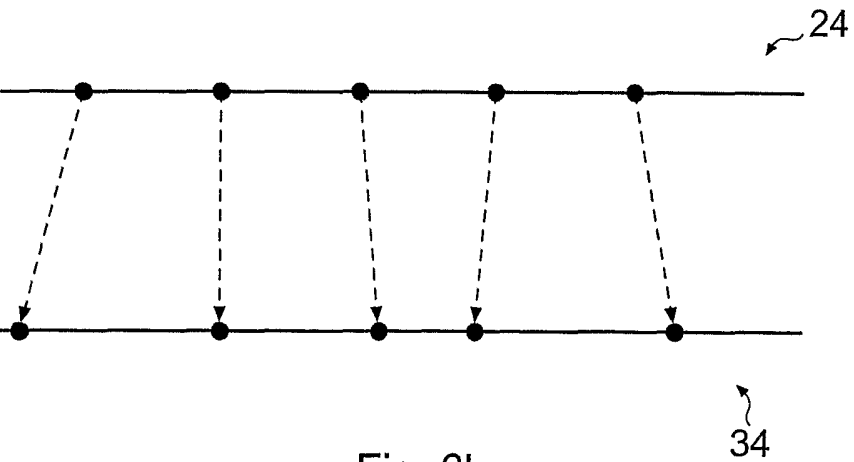


Fig. 6b

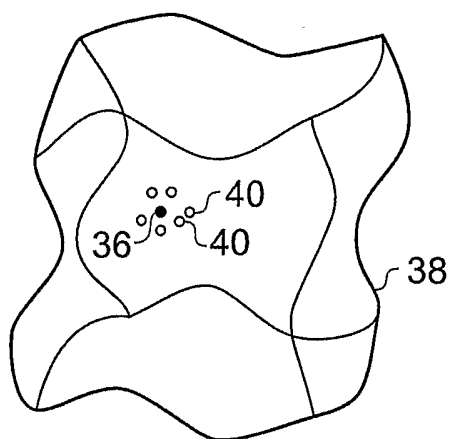


Fig. 7a

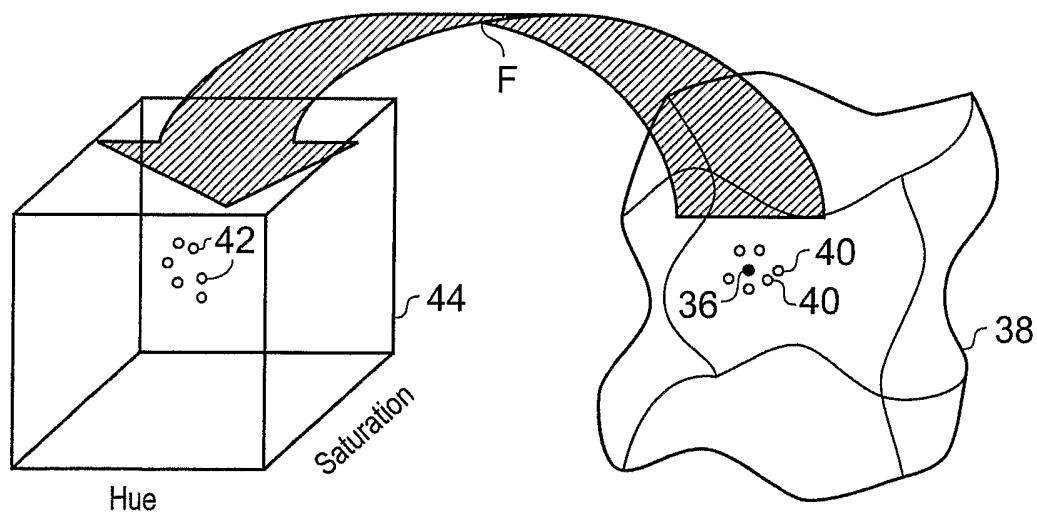


Fig. 7b

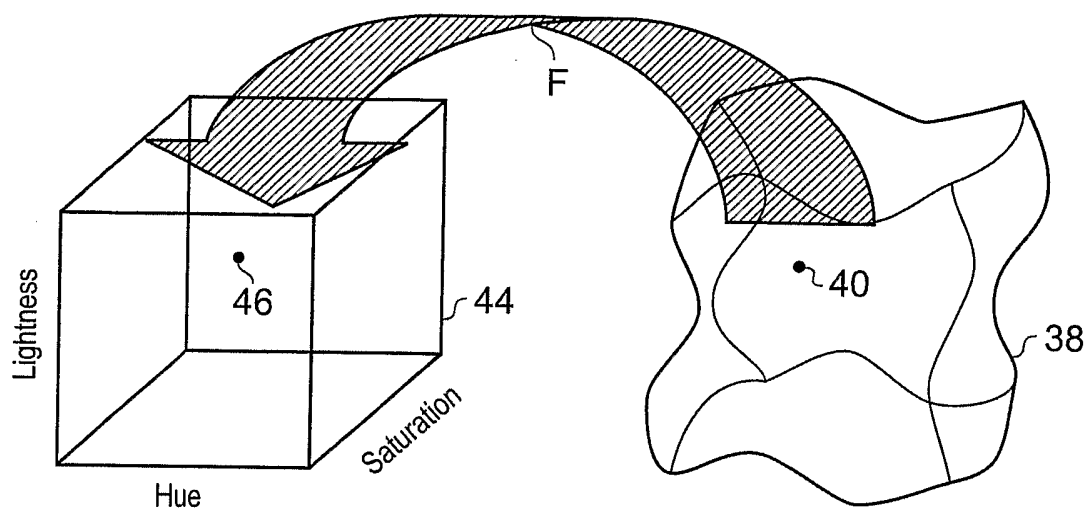


Fig. 7c

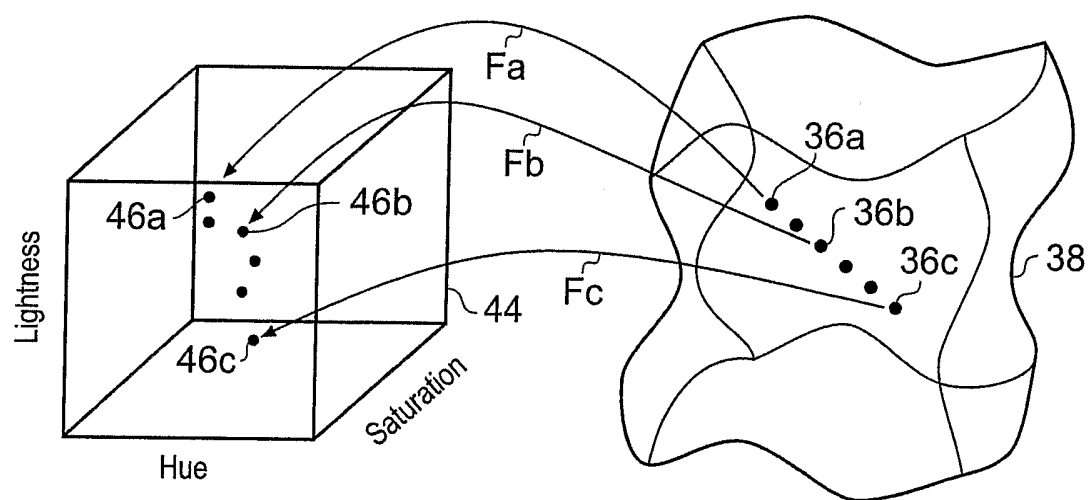


Fig. 7d

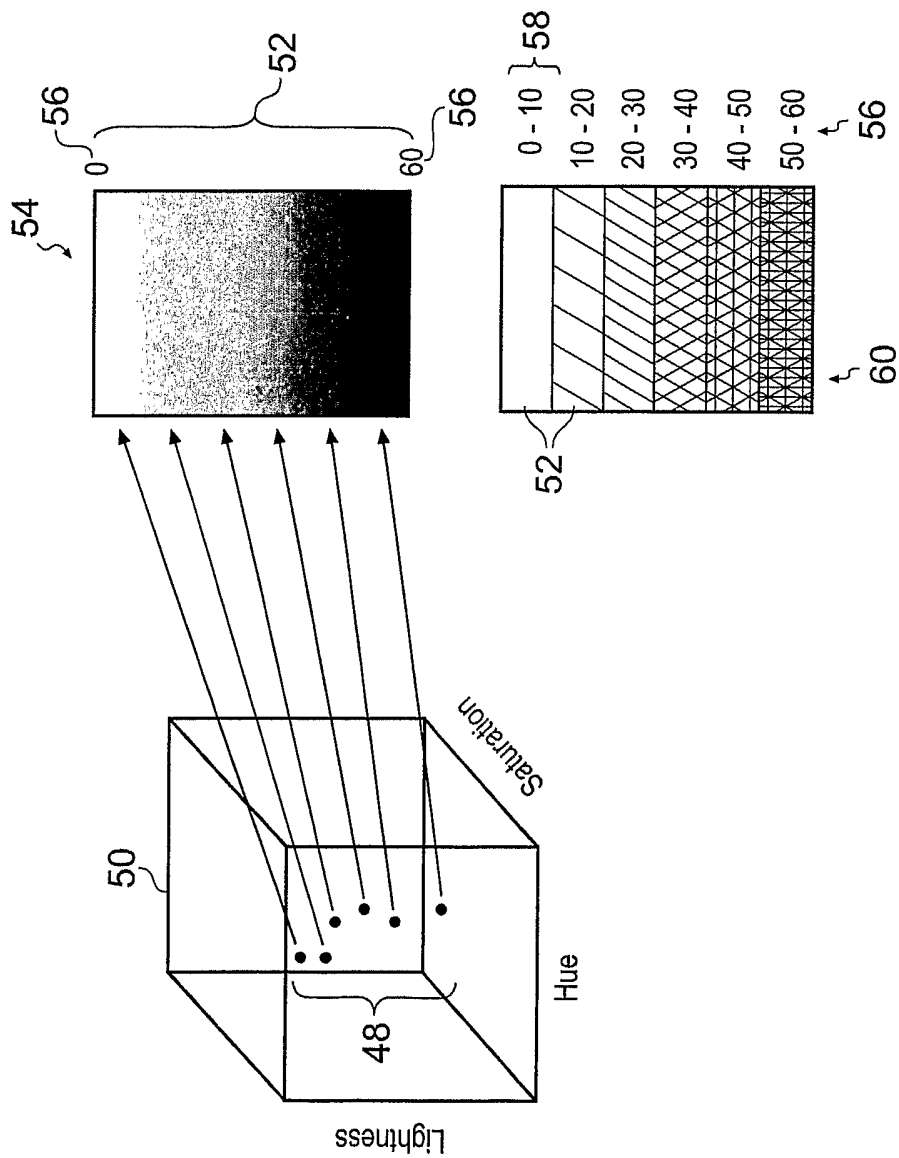


Fig. 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB2004/002542

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06T11/00 G01J3/46 H04N1/60

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G06T G01J H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GRANGER E M: "UNIFORM COLOR SPACE AS A FUNCTION OF SPATIAL FREQUENCY" PROCEEDINGS OF THE SPIE, SPIE, BELLINGHAM, VA, US, vol. 1913, 1993, pages 449-461, XP000567576 ISSN: 0277-786X page 454, column 456 ---	1,20,44, 68-71
X	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 14, 22 December 1999 (1999-12-22) -& JP 11 261740 A (RICOH CO LTD), 24 September 1999 (1999-09-24) abstract --- -/--	1,20,44



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *&* document member of the same patent family

Date of the actual completion of the international search

11 October 2004

Date of mailing of the international search report

03/11/2004

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Hambach, D

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB2004/002542

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 023 525 A (CASS TODD A) 8 February 2000 (2000-02-08) column 9, line 55 -column 10, line 7 ----	1,20,44
A	H. LEVKOWITZ, G.T. HERMAN: "The Design and Evaluation of Color Scales for Image Data" IEEECOMPUTER GRAPHICS AND APPLICATIONS,- vol. 12, no. 1, January 1992 (1992-01), pages 72-80, XP002300211 page 14, paragraph 5 ----	1
A	K.-H. BÄUML, B.A. WANDELL: "Color Appearance of Mixture Gratings" VISION RESEARCH, vol. 36, no. 18, 1996, pages 2849-2864, XP002300212 cited in the application the whole document ----	1
A	P.K. ROBERTSON, J.F. O'CALLAGHAN: "The Appllication of Perceptual Color Spaces to the Display of Remotely Sensed Imagery" IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, vol. 26, no. 1, January 1988 (1988-01), pages 49-59, XP002300213 page 52, column 56 -----	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB2004/002542

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
JP 11261740	A	24-09-1999	NONE	
US 6023525	A	08-02-2000	JP 11215392 A	06-08-1999