A Visual and Numerical Tool for Color Naming
The Munsell Color System

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Abstract

Color is one of the main visual cues in the recognition of an object or image. High-level color descriptors are important as these descriptors provide valuable insight into the understanding of the object and its color, or the content of an image. Color naming is used to select objects (by color), describe the appearance of an object, and generate semantic annotations.

A vivid orange color that we see in pumpkins this time of year describes the color so well we can see it in our mind's eye. When someone says "olive green" we envision in our minds eye the color of green olives. These color descriptors not only describe an object but convey an impression of the object or scene.

This paper presents a computational model for color categorization. In this work we start with a spectral or trichromatic data set and compute the National Bureau of Standards - ISCC recommendation for color names and notations from the Munsell Book of Color. This develops color vocabularies and an appropriate syntax. Next, we attach to the color name a representation of those values on screen including RGB values. This realized perceptual color representation ties the perceptual name and the color name together.

In testing this method, the human color categorization in known color regions in different color spaces were identified accurately. These are also consistent with human observations.

Introduction

We all use descriptors for color to describe objects and colors of objects every day. The important thing about describing the color of an object is the ability to communicate to the hearer in a language that is understandable and meaningful. There are times when an accurate description of color is essential; for instance, in describing another person - the color of eyes, hair, skin, and outfit are important characteristics that aid in identification. Another important example in commerce is describing to the owner of a large commercial building the color of the walls, carpet, and interior that is being installed.

There are several attributes about color communications that are of vital importance. For instance, does the color language;

1. Communicate to the general public
2. Provide a large number of separate yet distinguishable categories
3. Correlate with visual descriptors
4. Correlate with instrumental values.

Munsell Color System[i]

Background

In colorimetry, the Munsell Color System is a color space, sometimes called a psychological color solid, that specifies colors based on three color dimensions; namely, hue or color, value or lightness, and chroma or color purity sometimes called colorfulness. Professor Albert H. Munsell published this system in 1905[ii]. His objective was to have a system that had numerical values and a physical exemplification. Albert Munsell was the first to create an embodiment of a perceptually uniform color space with three independent axes. This system is based on human's visual responses to color which makes it a scientific system and one that is based upon perception.

Explanation

The Munsell Color System consists of three independent, orthogonal axes, designated Munsell hue, Munsell value, and Munsell chroma. This system is best visualized as a three dimensional cylinder. H*ue* is measured by degrees around horizontal circles; *chroma* is measured radially outward from the neutral (gray) axis; and *value* is measured vertically from black to white. Munsell's quest for a numerical system led to him dividing each of these axes into divisions of 10.

Hue

Each horizontal circle Munsell divided into five principal *hues*: **R**ed, **Y**ellow, **G**reen, **B**lue, and **P**urple, along with 5 intermediate hues halfway between adjacent principal hues. This leads to 10 principal hues; namely (R) red, (YR) yellow-red, (Y) yellow, (GY) green-yellow, (G) green, (BG) blue-green, (B) blue, (PB) purple-blue (P) purple, (RP) red-purple. Each of these 10 steps is then broken into 10 sub-steps, so that there are 100 hues. This system is exemplified by 1R, 2R, 3R, . . . 10R. Munsell reasoned that when two colors of equal value and chroma, on opposite sides of a hue circle are mixed additively they make a neutral gray of the same Munsell value - customarily called complimentary colors.

Munsell determined the spacing of colors along these dimensions by taking measurements of human visual responses. In each dimension colors are nearly perceptually uniform. Because our visual system is more sensitive in different areas, this makes an irregular shaped cylinder.

Value

Value, or lightness, varies vertically along the color solid, from black (Munsell value 0) at the bottom, to white (Munsell value 10) at the top. Neutral grays or achromatic colors lie along the vertical axis. The visual spacing of the achromatic colors is defined by their luminous reflectance. Achromatic colors are notated with the prefix N; for example, N0, N1, N2, . . . to N10. The perceptual spacing and the lightness across the horizontal axis is what distinguishes the Munsell Color System from other previously developed systems.

Chroma

Munsell Chroma is measured radially from the center and this is sometimes termed color purity. Here lower values of Munsell chroma are less pure than fully chromatic colors. A lower value of Munsell Chroma is exemplified by artists' pastel colors. Here Munsell deviated from the system to the 10 base. For instance, there is no intrinsic upper limit to Munsell chroma. The reason is due to psycho-physics of the eye-brain, and the maximum chromatic color created in object color. This phenomenon is easily seen in light yellow colors. They have considerably more "potential chroma" than blues for instance. This system has a wide range of possible chroma levels around the Munsell hue circle.

Specifying a Color

A color is fully specified by designating the values for Munsell hue, Munsell value, and Munsell chroma. For instance, a saturated red (R) of medium lightness would be 5R 5/10. Here 5R meaning the color in the middle of the red hue band, 5/ meaning medium Munsell value or lightness, and a Munsell chroma of 10.

The Munsell Color System has undergone significant revisions since its first embodiment in 1915[iii]. For instance, there are the Munsell Book of Color Glossy1 and Matte Editions1, the Munsell Student Set1, The Neutral Value Scale in Matte1 and Glossy1. The first refinement occurred in 1929. The latest being a recalculation of values for the Munsell Color System with the re-assignment of the perfect diffuser and its associated values.[iv] The correct values for the Munsell Color System are published in D-1535[v]. Additionally this standard site the mathematics necessary to transforms the Munsell Color System whose notation is in terms of the CIE[vi] 2° Observer Function under Illuminant D50 to nine different Observer-Illuminant conditions.

ISCC-NBS Color Naming System

Background

The Inter-Society Color Council[vii] (ISCC) and the National Bureau of Standards (NBS – NBS is now called NIST[viii]), developed a system of designating colors in the 1955.

The Universal Color Language[ix], UCL

The UCL is a system that is best envisioned as containing 4 levels of color descriptors. The level selected is appropriate to the degree of accuracy of the color designation needed in a particular application. The accuracy of course increases with the number of levels. A comprehensive description of the system is contained in the referenced literature and those interested are referred to it for a more complete description.

The ISCC-NBS Color Naming Descriptors

The divisions used for each block in the 4 levels are exacting and technically complex. However, for these purposes a generic description of each level is given. The most accurate description is contained in the reference publications. Let's start with a color of carpet, we will call brown.

Level 1

The psychological color solid is divided into 13 large color-name blocks. Since this is the least precise level, each block contains a large range of color. The 13 color-names are consistent with the designators used in the Munsell Color System; for instance, R (red), Y (yellow), etc. and the neutrals (black, white and gray). Each block is defined just as accurately as the smallest block contained in level 3. Our color would be designated orange at this level.

Level 2

The color solid continues division into 29 blocks. Four of the blocks in Level 1 remain unchanged. These new intermediate hues fall between two of the generic hues specified in Level 1. These intermediate hues have names such as, (O) orange (Br) brown. We can now specify our color as yellowish brown carpet.

Level 3

This level expands considerably as we divide the 29 blocks in Level 2 into 267 color name blocks. Here the Level 3 sub-blocks are assigned a generic or intermediate hue name with one or more adjectival modifiers that describes its lightness and saturation. The neutrals are divided into light, medium, and dark gray. We can further describe our color as light yellowish brown carpet, which is more accurate than before.

Level 4

The exemplification of the color solid at this level is similar to and based upon the Munsell Color System and its book of colors. There are ~1500 colors which illustrate visually, equally spaced, scales consisting of Munsell hue, Munsell value, and Munsell chroma. The boundaries of the Level 4 color blocks are specified by the Munsell Color System. The final color notation for our color is 10YR 6/4

Level 5

The most accurate method for specifying a color without metamerism is by using tristimulus coordinates; such as CIE XYZ or CIELAB for a particular observer under a specified illuminant. In this case the CIELAB values are 75, 5.0, and 45.3.

Summary

In summary we described a method or language of designating colors or color names in an easy, simple to use, but accurately defined system. At each level the psychological color solid is divided into a definitive number of blocks whose boundaries are accurately defined, and to each one of these blocks are assigned a unique, descriptive color name or designation. The system is adopted and used world-wide for many, many years.

An Embodiment

The foundation of this paper adequately describes the Munsell Color System and the ISCC-NBS Color Naming System. This system has never been implemented and hence never universally adopted. There are many reasons for this. First, the Munsell Color System is specified in terms of Munsell notation for CIE Illuminant C using the CIE 2° Observer function. Since the specification is in tristimulus terms (Munsell notation), it has not been possible to convert these values into another illuminant –observer combination. Generally, illuminants D50 and D65 are used in industry and commerce, not Illuminant C using the 2° Observer function. The conversion of tristimulus values into Munsell notation requires simultaneous non-linear interpolation in multiple dimensions, and the method(s) of interpolation(s) are unspecified. Another issue is the calculation of color difference in Munsell color space. This color space is based on cylindrical co-ordinates instead of the Cartesian co-ordinates used in CIELAB space.

A computer program is described that addresses and solves all of these and other significant issues not mentioned here. It begins with data entry. The data may be tristimulus values; such as CIE XYZ, CIE LAB or CIE Yxy in terms of ten different observer - illuminant combinations; or spectral data from 400 to 700 nm. The appropriate color descriptor name as defined by the full description of the ISCC-NBS Color Naming System is assigned.

The data may be entered manually one color at a time or a batch of infinite size may be entered as a file for conversion. When data are entered one color at a time the values for the Munsell Color Notation, the ISCC-NBS Color Name, the sRGB values, a representation in true color on screen in terms of sRGB, and a computer Hex value are displayed. It is envisioned that these data, particularly the sRGB values and the corresponding computer Hex values will be used for displaying an accurate representation of that color by computer displays. In the case of batch data, the data are sent to an ASCII file of the same name.

This program is useful for assigning a meaningful, unique, descriptive name that describes the color of an object for which the vast majority of people would agree with the descriptors, which are adjectival modifiers. In verbal communication, one can accurately describe the color such that every listener would understand. Imagine finding the desired color on a color card fan deck where names accurately describe the desired color and are not composed by creative types that create ambiguous and uncertain names.

[i] X-Rite, Granville, MI www.xrite.com
[ii] A.H. Munsell, *A Color Notation*, 1st Edition, Munsell Color Company, Baltimore, MD 1905
[iii] A.H. Munsell, *Atlas of the Munsell Color System*, Wadsworth-Hawland & Company, Malden, MA 1915
[iv] Brill, Fairman, Hemmendinger, and Ladson, *Leonardo 2000,* AIC 2000.
[v] D-1535, *Standard Practice for Specifying Color by the Munsell System*, ASTM, West Conshohocken, PA www.astm.org
[vi] CIE Central Bureau, Vienna, AT, www.cie.co.at
[vii] ISCC, Reston, VA www.ISCC.org
[viii] NIST, Gaithersburg, MD www.nist.gov
[ix] K.L. Kelly, D.B. Judd, *Color Universal Langua*ge *and Dictionary of Color Names*, NBS Publication 440,