EXERCISES IN CARTOGRAPHY AND GEOINFORMATICS: TEACHING THE COLOURS

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1. Introduction

1.1. Exercises As a Part of Engineering Education in Geomatics/Surveying

Exercises are an important part of the learning process, as the Turkish proverb says "Things I hear, I forget – things I see, I remember – things I do, I know".

Being a universally accepted methodology in teaching, every curriculum includes exercises. In some fields, it is more essential that the student performs given tasks, other then being able to answer the anticipation-related questions. Engineering is one of them.

In each sub-field of Surveying(Geomatics, Geoinformatics) education, a significant percent of the courses require exercises, be it theoretical or applied subjects. While the theoretical ones require mathematical problem settings and their solutions, today the "applied" courses would require computer classrooms and an instructor present. And naturally most subjects have both a theoretical and a practical part.

Given these facts, when we discuss about education, we always include exercises in the discussion. This paper deals with such a discussion based on the practice in HUT, and focuses on one of the harder exercise subjects, colours.

1.2. The Significance of the Colour to Cartography

Surveying(Geomatics, Geoinformatics) Science deals with modeling, so does Cartography as a part of this field. The object of the modeling may vary, although it is most often understood to be the earth itself. However the object's scale may change from the whole space to earth, from bird-view maps to city models, from indoor measurements to a microscopic elements; the result may always be called a "map". And when the goal is to produce a graphic output (a map) then everybody who gets this education finds her/himself dealing with some output design where the colour may bear (and often does bear) important information.

The necessary expertise more focused on single tasks, make people work in different stages of this modeling process, and the output design requirement comes at the end of a complex chain of process. That means, some of us become more of an expert also in this part of the process.
Besides colour being a cosmetic design element for cartographers, several Cartographic elements employ colour as ***information***. In a Remote-Sensing data based forest classification map, the classes are attached to the colours, in a population density map the ranges are expressed in colours, the depth of the seas and the height of the mountains are also colour coded.

It is arguable that the extensive knowledge about colour theory are necessary for all surveying students. While some basic knowledge how the additive and subtractive colours communicate, would be useful to all, the perceptional approach would be necessary for those who are constantly dealing with colouring the maps.

Thus, it is significant that all map-makers can communicate with the publishing houses, can interpret the digital colours, have an idea about the effects of colours. It is especially significant to those who work at the later stages of the map production.

2. What is Colour

2.1. Definition

Colour is light. In other words, it is a side product of the light-spectrum. The light is reflected or absorbed by the objects, and we "see" the reflected ones as the colour of the object.

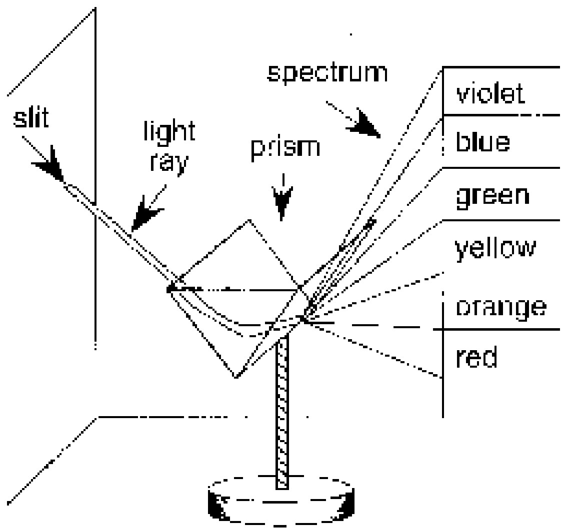

Image 1. Spectrum. (Taken from [9])

Human eyes do not percept all wavelengths of the light. Visible light is made of seven wavelength groups (between the wavelengths of 400 and 700 nm (nanometers = billionth of a meter). These are the colours that can be seen in a rainbow (red, orange, yellow, green, blue, indigo, violet). The long wavelengths would carry the "red family", while the mid-sized ones are the "greens" and shorter ones "blues". White is a combination of all the visible spectrum.

Human eye has a retina that contains four types of light sensors, "rods" would record the brightness/darkness, and there are three types of "cones" which are sensitive to the different spectrum of the visible light (reds, greens, blues). Brain gets the combined information from rods and cones, and we get the interpretation of what we see from our "central processing unit"!

2.2. Colour in Three Aspects

2.2.1. Colour in Theory (Colour models, specifications)

To be able to describe colour, some colour models have been developed and some of them became worldwide standards. (The definitions in this section are partly taken from [VIII]).

The tools used for projected colour and the printed colour are different then each other - Projected colour is ***additive***. Printed colour is ***subtractive***.

Additive colours are those that are commonly used in computer screens, TV monitors and the like. On-screen maps are also designed using additive colours. Within the additive colours description, the white light is a mixture of all the colours of the visible spectrum (primary colours RGB, secondary colours CMY, tertiary white).

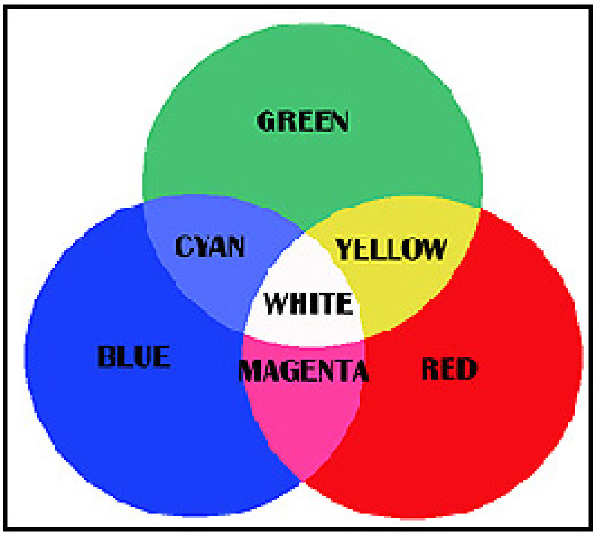

Image 2: Additive Colours (image taken from [XIII])

Subtractive colours The colour that is produced with ink on paper is created using a subtractive model, where the seen colour is the one that is reflected by the paper or by the ink. This is the opposite approach to additive, the mix of primary CMY gives secondary RGB and black in combination.

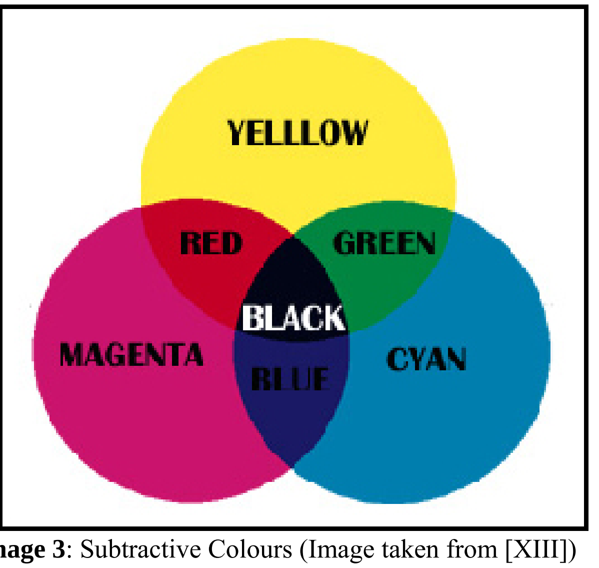

Image 3: Subtractive Colours (Image taken from [XIII])

A short description of the three most common specific colour models are also included here, respectively RGB, HSV and CMYK.

RGB (Red, Green and Blue): The RGB colour model is an additive model used for displaying images on a computer monitor or other screen device. This model employs RGB as the basic elements to produce other colours, either by percentages, or by their changing values between 0-256.

HSV (Hue, Saturation, and Value) [sometimes referred as HIS (Hue, Saturation and Intensity):

Hue is the name of a distinct colour of the spectrum -- red, green, yellow, orange, blue, and so on. It is the particular wavelength frequency. ***Saturation*** refers to the amount of white light (or grey paint) mixed with the hue. Pastels are less saturated colours. As saturation decreases, all colours become a value of grey. ***The value*** *(sometimes called* ***lightness*** *or* ***intensity*** *or* ***brightness****)* of a colour is the amount of light or white it contains.

HSV is a colour model that employs these three elements to define a colour. Hue is presented as an angle point, while saturation and value are measured as a percentage between 0 and 100.

CMYK (Cyan, Magenta, Yellow, Black) This is the standard subtractive colour set used in printing process. K is for black, as it was referred to be the "key" colour. Process printing is the printing of images on paper using overlapping dots of cyan, magenta, yellow, and black (CMYK) inks to create full colour, continuous tones.

Colour wheels are created to produce relations between the basic colours and their derivatives, which will be mentioned again in a later section of this paper when introducing one of the exercises given in HUT.

There are also several other specification systems that are introduced in Cartography text books, such as CIE (The Commission International de l'Eclarage), Munsell, Ostwald, etc.

"Colour Space" - is also a term commonly used for expressing the geometric representation of colours in three dimensional space.

Notice that this chapter is giving only a short introduction for some of the available theories, for we will refer to these later in the educational discussion. For more detailed information, please use the given list of references in the end of the paper.

2.2.2. Colour in Designer's World (On-screen design, publishing)

When today most (if not all) designs are made on-screen, still the majority of maps are published in hardcopy.

Softcopy maps do not need the same attention for translating the colours from additive to subtractive, although if they are going to be used on the WWW they need other considerations as "web-safe" colours. There are a set of different hardware with different limitations for producing colours, as well as different operation systems and browsers. It is relatively a young field of map publishing, but as in other design works, map designers are suggested to follow the defined set of web-safe colours (216 colours supported by all browsers and platforms).

Web-safe colours have six possible RGB hex values: 00, 33, 66, 99, CC, and FF. These
six values can combine to form 216 colours. There are several software that can be helpful to use these as "colour-palettes".

Printing the on-screen designed maps, one has to be able to communicate their perception, the additive screen colours and the probable ink sets that the publishing house would have. There are several methods, mostly based on the printed set of inks with their RGB and CMYK values printed next to each other (for example Pantone's colour fan) where the designer can tell the standard CMYK ink values to the publisher.

Therefore the cartography student must be introduced to the available systems.

2.2.3. Colour in Perception (Psychological & Cognitive Approaches)

As it is well known in the psychological and cognitive studies, the perception of colour for each individual may be considerably different, other than the fact that colours have cultural associations, and one may be mislead by a some illusion-like effects.

These illusion-like effects are common to most human perception. Some famous examples are termed as:

Simultaneous contrast (the way a colour object seems to change size and intensity based on the neighbouring colours).

Image 4: Simultaneous Contrast effect: The same colour can appear very different based on the surrounding colour. The example above, the black and white types are the same size, though one appears to be thinner [VIII].

Chromatic induction (the way adjacent colours alter the way the colour itself is perceived).

Image 5: Chromatic Induction effect: The grey boxes in the centre are the same colour although appears differently [19].

Afterimage (the way high contrast colours make you "see" their complementary colours after looking away).

Plus these cognitive approaches, there are some universal and local associations with colour. ***Colour temperature*** seems to be one of the universal ones, red family is perceived as warm and blue as cold. That is sometimes explained as the natural reflections of fire being a “reddish” colour and hot, while water is blue and cool.

Some local associations with colours representing emotions or symbols, can also be a point to consider when designing maps for local markets.

The conventional maps also represent the water as blue and temperature maps utilize the red family extensively. And some attempt to use the oceans as black was not well received by the users, according to Tyner [3].

3. Colour Related Exercises

As it is known that the colour perception is very individual, no one can really teach what is the *best* set of colours and which colours look *better* together. In this, the designer is to satisfy "the customer". That is what we can ***not*** really teach.

Even though so, of course there are some experiences which can be wise to listen to as a beginner. For example the market surveys about how the maps were received by the users, or what colours are traditionally employed and became like near-standards and if one will challenge that, they should be prepared for the risk.

Everything else that is mentioned in this paper earlier (and more) about colours can be thought and given with some exercises. Unfortunately the print will not have colour, so it loses the point to add graphics to this article, if you are interested in seeing the colour representations, please check out the references.

3.1. In Helsinki University of Technology

Relevant exercises offered in Helsinki University of Technology (HUT, hereafter) is summarized in this chapter. The students are given both computer based exercises and manual ones. In computer-based exercises they work with one instructor for 4 persons at a time, and two persons per work station.

Under a course called "**Map Production Techniques"** (obligatory, often 2nd year) there is a group of exercises related to every stage of map production, including the design.

In one exercise the students are introduced to Natural Colour System (E1 and E3) and they do these two exercises one in the classroom and one as a homework. This is not a computer-based exercise, it uses the printed sets of certain colours that they must relate to a colour development system.

The online "Colour Science Glossary" [V] defines this as follows:

"Natural Colour System (NCS) A colour notation system based on Hering's opponent theory of colour and developed in Sweden by Johansson, Hesselgren and Hard. The NCS colour space has six primary colours arranged in opponent pairs on three orthogonal axes. Colours are described according to their redness (r), yellowness (y), greenness (g), blueness (b), whiteness (w) and blackness (s) using a percentage scale. Any chromatic colour can be represented as a combination of two (or less) of r, y, g and b. Hues such as red and green or yellow and blue cannot be perceived simultaneously and are known as opponent hues. The total chromatic content, NCS chromaticness, is simply the sum r + y + g + b and describes the resemblance of a particular colour to another colour of the same hue having the maximum possible chromatic content."

Within a map publishing software (Intergraph's MapPublisher) the students design a map and when they are ready with their softcopy colours in RGB model, they meet the problem of hardcopy requirements on CMYK, and we introduce them with Pantone colours and CMYK values. This way the students get to learn the relations between the two colour models as they prepare their work to be sent to the publisher.

In another course (3rd year, optional) **Visualization of Geographical Information** the students learn more details about colours in the classroom and get more exercises.

In one exercise, they design some thematic maps on the screen using ranges, pie charts, dot density, bar charts etc. In all of these, they need to use the colour and there we talk about general design fashions, colour displays and again some colour models. In this exercise one interesting observation is about the *cultural associations with colours*. In a map where they need to represent the population in ethnical classification, 95% of the students chose blue to represent Finns, yellow to represent Swedish-Speaking-Finns, the “others/foreigners” category is different for almost all groups (often neutral colours, sometimes red).

They are demonstrated with the shortcomings of RGB by visualizing the results in two monitors and also printing them out with an ordinary printer. They find out the RGB and HSV combinations of their colours, as well as CMYK for hardcopy-publishing and HTML for softcopy publishing.

In this exercise they are also introduced to ***Itten’s colour wheel*** and they re-design that on screen. Itten’s colour wheel could be summarized as below:

“This colour wheel is based on a triadic mixture of pigments with red, yellow, and blue as the primary triad. All hues are formed from mixtures of equal or unequal amounts of primaries. Equal mixtures of two primaries result in the secondary hues and form the triad of green, orange, and violet. In this colour wheel, six intermediate hues are created by equal mixtures of primary and secondary colours and form two more triads. Intermediate colours vary greatly because of the infinite number of unequal primary and secondary mixtures).” [VII]

Constraints*:* The main problem is the ***expenses*** related to the colour systems. The “proper” monitors for on-screen design, the colour translating equipment, and colour reproduction is often pretty expensive for having them only for exercise purposes. But of course the students can be taken for excursions to the production organizations and that would be a good way of dealing with this problem.

Second problem to be taken into account is the ***colour blind students*** (and users in one step ahead) of course. The percentage of colour blind male is relatively high that in HUT we get at least one student who has a problem with colour recognition every year. The level if the impairment can be very different, thus different policies should be considered. The level of impairment could be detected by applying a simple test which is freely available on the WWW these days (one can be found at [VI]).

In HUT, it is planned that we are going to have an announcement in the beginning of the term for the colour exercises if someone doubts of their colour vision, they could come to meet the exercise instructor and take a test. If someone has real problems, they will get some other task that is as demanding as the colour exercises, but will not deal with colours – instead other perceptual/design issues. If the impairment is low-level, then the student may try with the help of the instructor or a team member.

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