

Simple colour design, and colour in L^AT_EX2_ε

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Abstract

This article reviews some basic principles underlying the use of colour. We start by a review of the functional use of colour, explaining how it can help to focus attention, explain relationships, guide the viewer/reader through the presented information so that its contents is easier to absorb and appreciate. Some common rules for optimizing communication using colour elements in documents are discussed. We then explain the colour support in L^AT_EX2_ε and give some examples.

Introduction

When considering the use of colour in a document, we should think about it as a tool, not a gadget to merely make the page look “pretty”. The painter Eugène Delacroix wrote

“La couleur est par excellence la partie de l’art qui détient le don magique. Alors que le sujet, la forme, la ligne s’adressent d’abord à la pensée, la couleur n’a aucun sens pour l’intelligence, mais elle a tous les pouvoirs sur la sensibilité, elle remue des sentiments.”

This sentence summarizes perfectly the rôle that colour plays in the construction of the visual image. By choosing the right colour, the typographer can add an affective value to the message, thus helping it to be understood more clearly.

The world of colour

The Greek philosopher Aristotle had already, in the 4th century B.C., studied the mixing of colours by letting daylight shine through glasses of different colours. But it was only in the 17th century, thanks to experiments with glass prisms by Sir Isaac Newton, that the spectral theory of light was discovered, thus ending a period of almost 2200 years in which colours were ordered on a straight line from the lightest to the darkest colour, starting with white and ending with black. Newton ordered the colours on a closed circular ring, a representation still in use today¹.

¹ Gerritsen (1988) gives an overview of the theory of colour from antiquity to the present. He reviews several models that have been proposed over the years in order to classify colours. He shows that

Light can be decomposed into three “primary” components, from which one can build all possible colours. On a cathode ray tube, these colours are red, green and blue, and one of the more popular colour models is therefore called the **RGB** model. The printing industry does not use these primary colours, but rather their complements: cyan, magenta and yellow. This is because inks “subtract” their supplementary colours from the white light which falls on the surface, e.g., cyan ink absorbs the red component of white light, and thus, in terms of the additive primaries, cyan is white minus red, i.e., blue plus green. Similarly, magenta absorbs the green component and corresponds to red plus blue, while yellow, which absorbs blue, is red plus green. In fact, for practical purposes in the printing industry a process called “undercolour removal” takes places. In this procedure a fourth “colour”, black, is added to the printing process, with an intensity equal to the equal amount of cyan, magenta and yellow present in the sample. This way one creates a darker black than is possible by mixing the three coloured inks. This colour model is called the **CMYK** model, where the final “K” stands for the black component. Color Example 1 gives a simplified view of the relation between the RGB and CMYK models.

Colour harmony

Harmonies are arrangements of colour that are pleasing to the eye. Scores of books giving the opinions of experts have been written on colour harmony, and the conclusions of many of these works are often

choosing a suitable model depends clearly on the application area, e.g., mixing properties, human perception, hue values, gray levels.

contradictory. Reasons to explain this are not hard to find (Judd and Wyszecki 1963):

- (a) Colour harmony is a matter of emotional response, likes and dislikes, and even the same person can change her/his mind over time, since old combinations can become boring, while frequent exposure to some new combination can make us appreciate it.
- (b) Colour harmony depends on the absolute size of the areas covered by the colours as well as on the design and the colours themselves. For instance, a nice looking mosaic pattern can look completely unattractive when viewed *magnified* by a factor of ten.
- (c) Colour harmony depends on the relative sizes of the areas as well as on their colours.
- (d) Colour harmony depends on the shape of the elements as well as on their colours.
- (e) Colour harmony depends on the meaning or interpretation of the design as well as on their colours. It is important to note that colour harmony for a portrait painter is quite a different subject from colour harmony in abstract design or typography.

Therefore one can only try and formulate a few principles for the construction of colour harmonies.

- (a) Colour harmony results from the juxtaposition of colours selected to an orderly plan that can be recognized and emotionally appreciated.
- (b) When comparing two similar sequences of colour, the observer will choose the one most familiar as the most harmonious.
- (c) Groups of colours that appear to have a common aspect or quality are considered to be harmonious.
- (d) Colours are perceived as harmonious only if the combination of colours has a plan of selection which is unambiguously recognizable.

Experimentally it has been observed that the eye prefers combinations where primary colours are in equilibrium with their complementary colours, and that our perception of a colour changes in relation to the environment in which it is embedded. Color Example 3 shows effects of *saturation* or *absorption* of the three primary colours with respect to white (leftmost column) or black (second column) and with respect to its complementary colour (third column) or a gray tone of the primary colour itself (rightmost column).

Constructing colour harmonies

To explain his theory of colours Itten, in his book *The Art of Colour* (Itten 1974), uses a model based on a *harmonic colour circle* subdivided into twelve equal parts (see Color Example 2). It contains the

three primary colours yellow, red, and blue, 120° apart. Their complementary colours, purple, green, and orange, also called the secondary colours, are positioned diametrically opposite their respective primaries. The circle contains six more colours, intermediate between each primary and its adjacent secondaries. The harmonic colour circle is only a simplification. Indeed, all possible colours can be represented on the surface of a sphere, which has the harmonic colours at its equator, white at the north pole, and black at the south pole. Thus moving from the equator towards the south, respectively north pole yields darker, respectively lighter variants of a given colour. This also means that to each point on the colour sphere, there exists a diametrically opposed point with complementary characteristics, e.g., to light greenish blue one opposes dark orange red. Century long artistic experience has shown that a few simple basic rules allow artists to construct effective colour harmonies in their works. Following Itten, we shall discuss a few of them below.

Two-colour harmonic combinations. Complementary colours, lying at diametrically opposite points of the colour circle (sphere) define 2-colour harmonies, like the 2-tuples (red, green), (blue, orange), plus an almost infinite amount constructed using possible combinations on the sphere.

Three-colour harmonic combinations. When inside the colour circle one constructs an equilateral triangle, the colours at each edge form a 3-colour harmony. The most fundamental 3-tuple (yellow, red, blue) is well known in all forms of art, publishing, and the world of publicity, for its effectiveness, since it can be used in a wide variety of patterns, layouts, and in all kinds of light and dark combinations. The secondary colour 3-tuple (purple, green, orange) has also a strong character, and is often used. Other 3-tuples are also possible. One can also construct other 3-tuples by replacing the equilateral triangle by an isosceles one, or by working on the colour sphere and combining light and dark variants. As a special case, one can put one edge of the triangle at the white point (north pole), and create the harmony (white, dark greenish blue, dark orange red), or on the black point (south pole), yielding the harmony (black, light greenish blue, light orange red).

Four-colour harmonic combinations. One can construct a 4-colour harmony by taking the colours lying on the edges of a square, e.g., the 4-tuple (yellow, orange-red, purple, greenish blue). It is also possible to use a rectangle, combining two pairs of complementary colours.

Higher order harmonies (like six-colour) are equally easy to obtain using similar geometric models, by using the harmonic circle or the colour sphere. Note, however, that each combination has its own

character, and set of basic laws, and only a long experience will show which of the various sets of harmonies is most efficient for a given application.

Colour and readability

The readability of a message or sign is closely linked to how our visual system processes the information presented to it. Factors which influence the visibility of colours are:

- (a) *intensity*: pure colours of the spectrum have the highest intensity;
- (b) *contrast*: between the different colours;
- (c) *purity*: pure colours are more visible than graded variants, where white is added, making them fainter, or black, making them darker.

Color Example 4 shows some of the most effective colour contrasts, which can be used for maximum readability or visibility, e.g., on slides, road signs, or publicity leaflets.

Colour in the printing industry

A detailed discussion of problems encountered when producing books in colour with T_EX can be found in Michael Sofka's article in these proceedings. In this section, we merely present a short overview.

As already mentioned, the printing industry mostly uses the CMYK model to describe the colours on a page. Goossens and Rahtz (1994b, page 7) contains an example with the five Olympic rings and a multi-colour ellipse. It is shown how applying successively the coloured inks gives the picture its final colour. One starts with the cyan ink (top left), then applies the magenta (top right), yellow (bottom left), and finally the black inks (bottom right), to obtain the picture in full colour. The process is shown with the four separate stages, and the cumulative effect.

For high quality typeset output, the use of PostScript is now almost universal, and level 2 of the PostScript language offers full support for colour. In fact it not merely supports the RGB and CMYK models, but also the HSB (*Hue Saturation Brightness*), CIE (*Commission Internationale de l'Éclairage* standard) plus various special colour spaces; in industry and arts the Munsell and Pantone, and more recently the Focoltone and Trumatch systems, have become common for colour matching. The details of these, and algorithms for converting between colour models, are exhaustively discussed in Adobe Systems (1991, pp.176-199). Very useful discussions of using colour in PostScript are given in Kunkel (1990) and McGilton and Campione (1992), and our discussion is based largely on what we have learnt from these three books, and Reid (1986). It should be noted that full Level 2 PostScript provides a number of important new commands which considerably ease preparation of colour separations (see section

'Simple colour separation using dvips' on page 222 below).

Using colours with L^AT_EX 2_ε

With the release of L^AT_EX 2_ε, colour macros are now a standard supported package (together with graphics file inclusion, rotation, and scaling). These are, of course, dependent on the abilities of the driver in use, as all colour is done using `\special` commands. Hafner and Rokicki's `colordvi` package (see Hafner, this volume) was the first to try and address some of the complexities of colour support — T_EX does not have internal support for colour attributes of text, and T_EX 'grouping' across pages, floats, footnotes etc will not always yield the expected results. L^AT_EX 2_ε has extended support to cope with most situations, and it is hoped that more driver support will make this even better. Tomas Rokicki's paper in this volume discusses the problems in more detail. The L^AT_EX 2_ε colour package builds on the experience of `colordvi`, both in terms of the `\special` commands themselves (allowing for an extensible set of colour models), and in the macros.

One of the important features inherited from `colordvi` is the use of a layer of colour 'names' above the actual specification given to the printer; Hafner worked out a set of 68 CMYK colours which correspond to a common set of Crayola crayons, and these are predefined in the header files used by `dvips`, and the user calls them *by name*, allowing for tuning of the header files for a particular printer. New colours desired by the user can, of course, be defined using CMYK, RGB or other colour models, but in our examples we will use the Crayola names.

The L^AT_EX 2_ε colour support offers a variety of facilities for:

- colouring text;
- colouring box backgrounds;
- setting the page colour;
- defining new colour names

We will look at the interface, and then consider some uses for them.

The new L^AT_EX 2_ε commands There are two types of text colour commands, which correspond to the normal font-changing macros. The first one is a *command*:

```
\textcolor{colourname}{text}
```

This takes an argument enclosed in brackets and writes it in the selected colour. This should be used for local or nested colour changes, since it restores the original colour state when it is completed, e.g.,

```
This will be in black
\textcolor{Blue}{This text will be blue}
and this reverts to black
```

The second type of colour command is of the form:

```
\color{colourname}
```

This colour command takes only one argument and simply sets a new colour at this point. No previous colour information is saved, e.g.,

```
\color{Red} All the following text
will be red.
\color{Black} Set the text colour
to black again.
```

The command does however respect normal T_EX grouping; if we write

```
We start in black, but now
{\color{red} all text
is in red, {\color{green} but this
should be in green} and this
should be back in red.}
And we finish in black
we will see2
```

We start in black, but now all text is in red, but this should be in green and this should be back in red. And we finish in black

The *background* of a normal LR T_EX box can also be coloured:

```
\colorbox{colourname}{text}
```

This takes the same argument forms as `\textcolor`, but the colour specifies the background colour of the box. There is also an extended form:

```
\fcolorbox{colourname}{colourname}
```

This has an extra *colourname* argument, and puts a frame of the first colour around a box with a background specified by the second colour.

The normal `\fboxsep` and `\fboxrule` commands vary the line width, and offset of the frame from the text, as the examples in Color Example 5 show.

Defining new colours. The colour names ‘white’, ‘black’, ‘red’, ‘green’, ‘blue’, ‘cyan’, ‘magenta’ and ‘yellow’ are predefined by all driver files. New colour names can be defined with:

```
\definecolor{name}{model}{spec}
```

where *spec* is usually a list of comma-separated numbers needed by the *model*. Typically, drivers can cope with the models *gray*, *rgb* and *cmk* (although the system is extensible), allowing, e.g.:

```
\definecolor{lightgrey}{gray}{.25}
\definecolor{cornflowerblue}{rgb}{.4,.6,.93}
\definecolor{GreenYellow}{cmk}{.15,0,.69,0}
```

² The small examples of colour like this will be set using gray scales in this paper.

If you know that the driver has predefined colour models, you can access these directly. Thus dvips has a header file of CMYK colours configurable for different devices (as discussed above), and supports the extra *named* model. We can access these colours in the normal way:

```
\definecolor{Strawb}{named}{WildStrawberry}
```

It is also possible to use the `\textcolor` and `\color` macros with an explicit colour model and specifications, to avoid the overhead of defining new colors and using up T_EX macro space:

```
\color[model]{specification}
\textcolor[model]{specification}{text}
```

This enables us to gray-out text like Expandafter by typing `\textcolor[gray]{0.5}{Expandafter}`.

Examples of colour in document design. The simple text colouring described in the preceding section is moderately easy to implement and use. Color Example 6 shows how a simple formal specification can be enhanced with coloured keywords. Shading the background of boxes is also a common requirement, a simple example to emphasize some text might be:

 The grey-scale simulation of colour as printed here is also not ineffective. For more sophisticated use, the PSTricks package by Timothy van Zandt offers a more flexible set of commands (see the article by Denis Girou in the *Cahiers GUTenberg Girou* (1994) for a full discussion, and many examples, of PSTricks); the colour support in L^AT_EX 2_ε is compatible with PSTricks, so the same colour names and definitions can be used. The gradient colour fill in the background of Color Example 8 is an example of more complicated use.

A common requirement is to combine coloured text and shaded areas in a tabular format. This is surprisingly difficult to program in L^AT_EX, and cannot be undertaken lightly; however, another package by Van Zandt, *colortab*, takes care of almost all needs, utilizing the L^AT_EX 2_ε colour primitives. The full set of macros and syntax is described in the documentation (it works in plain T_EX, with L^AT_EX’s “tabular” tables, and in Carlisle’s “longtable” documents). Color Example 7 shows the results, with a real table taken from a travel brochure (the code is given in Goossens and Rahtz 1994b). This example shows how colour is used to highlight similar structural elements of a table to allow reader to navigate more freely and effectively through the information. It also shows a basic principle of colour work, namely not to use more than two or three different colours, since the codification (the meaning associated to each colour) will be lost. In this case we have used red for the heading, the alternation white/yellow to outline rows, and cyan to draw attention to the price column. It also

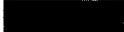
shows the efficiency of the fundamental 3-colour harmony, the 3-tuple (red, blue, yellow), as discussed earlier. For an interesting discussion of the use of colour in publishing, we recommend White (1990).

Another very common application area for coloured text or background is colour overhead transparencies. Color Example 8 shows a typical colour scheme for slides, using van Zandt's seminar package (see Goossens and Rahtz 1994b in *Cahiers GUTenberg* for more details), including the use of a graded colour fill for the slide frame. As well as coloured background, frame and lettering, we have used another colour for emphasis in the text, and highlighted the bullet lists with yet more colour. Most readers will probably agree that this represents distracting overkill, and that only one emphasis technique should be used at a time.

Simple colour separation using dvips

A document containing colour material can be typeset using $\LaTeX$ and run through dvips to create a colour PostScript document that can be previewed on screen, or printed on a colour printer. But if one wants to produce a "real" book using offset printing the printer will require four versions of each page, containing, respectively, the gray levels corresponding to the proportions of Cyan, Magenta, Yellow and Black. Colour work is usually typeset on special film, to high tolerances, since each page is overprinted four times, and registration must be exact. Some typesetting systems can produce the four separations automatically, but more commonly it is done with PostScript manipulation. A high-level professional quality requires sophisticated tools that are beyond the scope of this paper. Nevertheless, a $\TeX$ user can produce straightforward CMYK separations with dvips, using an approach that requires only PostScript Level 1 operators.

The principle of dvips separations is that each output page is produced four times (using the `-b 4` command-line switch, or `b 4` in a configuration file), and a header file which redefines the colour operators differently for each of the four pages. The header file (distributed with dvips, maintained by Sebastian Rahtz, and largely derived from Kunkel 1990 and Reid 1986), uses the `bop-hook` handle to increment a counter at the beginning of each page, and so check whether a C, M, Y or K page is being produced. The `setcmykcolour` operator is then redefined to produce just one of the four colours, in grey, and RGB colours are converted to CMYK before going through the same process. The `setgray` operator is only activated on the black ('K') page. A listing of the PostScript code is given in Goossens and Rahtz (1994b).

The output from separation can be seen (simulated) in Table 1 for the earlier example of .

Cyan	Warning!
Magenta	
Yellow	Warning!
Black	Warning!

Table 1: Separation output

where the box is set in 'ForestGreen', whose CMYK value is '0.91 0 0.88 0.12'. Notice that the 'M' page will be blank, as neither the green box nor the black text need any magenta.

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