Colour Picking - the Pecking Order of Form and Function

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ABSTRACT

Multimedia presentation generation has to be able to balance the functional aspects of a presentation that address the information needs of the user and its aesthetic form. We demonstrate our approach using automatic colour design for which we integrate relevant aspects of colour theory. We do not provide a definition of the relative importance of form versus function, but seek to explore the roles of subjective elements in the generation process.

Categories and Subject Descriptors

H5.4 [**Hypertext,Hypermedia**]: *Architectures, Navigation, User issues.* I.7.2. [**Document Preparation**]: *Hypertext/hypermedia*, *Multi/mixed media*.

General Terms

Design, Experimentation, Human Factors.

Keywords

Multimedia semantics, automatic colour design, colour harmonisation, style-driven multimedia presentation generation

1. INTRODUCTION

In this paper we illustrate how our experimental system utilizes colour, framing and composition to automatically pick appropriate colours to address the needs of the user with respect to the media content and navigation, retaining an overall balanced, coherent appearance.

We choose colour as the basis of our exploration of this new direction of multimedia generation because colour both functions as part of the visual rhetoric and refers to the sphere of decoration [6]. It thus forms part of dynamic aesthetic codes that are particular to social class and culture. Moreover, automatic colour design has the advantage above other design steps, such as the spatial or temporal layout of information units, that it allows maximal control of the system over the process itself, once the essential design constraints are formulated.

The aim of this work is not to provide a universal definition of the balance between form and function, but to recognize subjective elements, such as the emotional and symbolic meaning of a particular colour for a viewer, and to include these explicitly in the system architecture.

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2. A SCENARIO FOR AUTOMATIC COLOUR PRESENTATION GENERATION

We base our discussion on the generation of a presentation about the art movement "De Stijl". For the sake of clarity we explain the colour design process in the context of generating the introduction page of an evolving presentation, as portrayed in Figure 1.

Figure 1: Introduction page for a presentation on the art movement "De Stijl".

The Cuypers system, our experimental workbench, provides a framework for automatically generating such multimedia presentations [5]. The architecture includes 5 modules, namely the user module, the platform module, the discourse module, the domain ontology and the design module, covering the various knowledge representations in the form of facts and task-solving routines (mainly constraint solving) required during the presentation generation process. The presentation engine controls the organisation of this process. In this article we focus on the design module.

3. AN APPROACH TOWARDS AUTOMATIC COLOUR DESIGN

Our discussion starts at the point where the presentation engine has established the constraint-set on which the colour design process is based, as shown in the top line of Figure 2. The required steps up to this point, such as the design of the discourse structure, the semi-automated generation of metadata and the content retrieval process [3, 4], as well as the automatic design of the spatial layout for retrieved material [1] are described elsewhere.

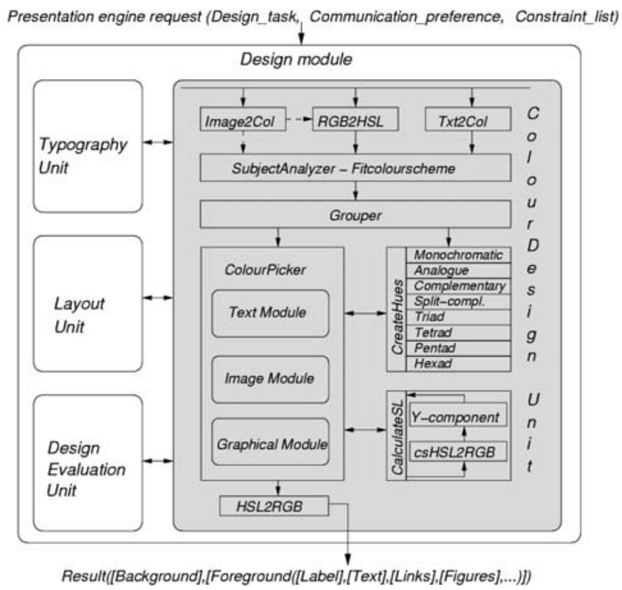

Figure 2: Detailed view on the colour component of the Design module.

3.1 Constraints driving the colour design process

The constraint set from the presentation engine supplies the design task and the communication preference for the presentation. The identified preference guides the graphic design process by suggesting which general design orientation the process should follow. In our environment we utilize the following three: **function, form, neutral**.

A preference for **function** determines that constraints based on importance weights drive the design process. For the colour design process this might result in the dominant application of rules that compare colours based on contrast, as this affects the construction of legible text. On the other hand, favouring **form** will mainly employ rules that affect the appearance of colours, such as for achieving pleasing appearances based on colour harmony schemata as described in colour theory [2, 6]. **Neutral** means that either way is acceptable. In our example, where the presentation is aimed at an educational presentation, a functional colour design process is required.

The Constraint_list contains the relevant restrictions for the current design task and introduces particular constraints related to the user (e.g. colour blindness), the domain (e.g. a list of colours that are related to the domain the content is about), and the layout (e.g. a structured list of all areas available and the various information units, combined in them). Such constraints control the number of colours to be used and, more importantly, the automatic allocation of colours to the various elements provided by the spatial layout of a page, namely the different areas determined by frames and the related elements, such as white area with the text block bottom right in Figure 1.

The Result, at the bottom of Figure 2, describes the output of the colour design module, namely the description of areas and included elements with the corresponding colour allocations. The presentation engine then processes the outcome to generate the final presentation of the page.

Based on the given description of the input parameters of the colour design module we now demonstrate how the module creates the colour scheme for the presentation.

3.2 The generation of the overall colour design

The design module, as described in Figure 2, covers various design aspects, such as typography, layout and colour-design. In addition the Design Evaluation Unit provides high-level rules that are used to guide the design process or to evaluate intermediate results as a form of sanity check. Such rules might state, for example, for the colour design process:

A. If `Communication_preference`
```
   = function    => work on area elements
   = form        => work on area
   = neutral     => work on mix
```

Rule A determines whether the emphasis of the colour design is oriented towards the functionality of the information elements (foreground and legibility) or rather on a look and feel, emotionally oriented presentation (emphasis on background and colour combinations).

B. If there are multiple background areas, begin assigning the one with the largest size first and continue in descending order.

Rule B considers the overall importance of space within colour design. Larger areas are dominant with respect to perception and thus are more influential for the design process than smaller areas. Note, there are other rules related to space that consider the shape of an area and the depth of colour in colour combinations (foreground – background relationship) [11, pp. 120-124, 144 – 149].

These rules are required to organise the different steps within the colour design process, as described in Figure 2, which can be separated into:

- identification of available colours;
- detection of the colour scheme to be used;
- instantiation of the process order for the colour assignment;
- colour assignment.

These steps are described in more detail in the following sections.

3.2.1 Identification of available colours

The first step of the colour design module is to identify the potential number of colours to be used. For that the SubjectAnalyzer (see Figure 2) evaluates the Constraint_list on areas and the information units contained in them. If there is a constraint that the presentation should not contain more than a certain number of colours, the SubjectAnalyzer re-evaluates the constraint-set by trying to group units. Additionally, the SubjectAnalyzer identifies already selected colours, provided by the Domain_colour element of the Constraint_list.

3.2.2 Selection of the colour scheme

The next step is to identify the colour scheme used to assign colours. In our system four different schemata are implemented, namely achromatic, monochromatic, analogue and complementary (including split complementary), where each scheme represents a particular rule set for colour use. The schemata are inspired by the work of Tufte [6] and Itten [2].

Tufte's approach is oriented towards a minimal set of colours with a subtle distinction between them. Within a three-dimensional colour space, this leads towards the identification of adjacent colours and results in three possible harmony schemata:

Achromatic: lacks all colours. Here only black, white and all shades of grey in between can be used.

Monochromatic: uses only a single hue. Adjusting the saturation and lightness, which establishes different shades and tints, creates differences.

Analogue: uses colours that are next to each other within the HSL space. The distance between colours is restricted to the hues being used and the distinction between warm (e.g. red) and cold colours (e.g. blue), which should not be mixed.

Itten, on the other hand, suggests a harmony scheme that is based on contrast, such as the contrast between hues or the contrast between the saturation of colours. Itten introduces in particular the complementary scheme, which is based on the contrast of complementary colours in combination with the effect of the changing behaviour of colours depending on the surrounding colours [2, p. 118 – 119].

Complementary: makes use of two different hues opposite each other in the HSL space. The aim is to use cold and dark colours for the background and the contrasting colour for the foreground.

The simple complementary scheme can be extended, to allow for greater flexibility, for example into a split complementary (2 hues distributed unevenly within the colour space).

The aim of the SubjectAnalyzer is to establish the scheme used to pick and allocate colours for the presentation. The selection process applies the approach of growing complexity to support the time constraints of the overall presentation generation. Thus, the algorithm tries to apply the achromatic scheme first and, if that fails, it investigates the next more complex scheme. For the example screen in Figure 1 a split complementary scheme was chosen (red and yellow grouped on one side, blue on the other within the three dimensional colour space).

3.2.3 Instantiation of the process order for the colour assignment

The next step in the colour design process is to establish the order in which the different areas and their elements should be coloured. The order is of importance, as assignments for the most relevant area should be based on the largest colour set (see rule A in section 3.2). Established assignments will then act as further constraints in the ongoing colour picking process. The Grouper, as presented in Figure 2, performs this task.

The essential assumption of the Grouper is that areas usually provide the background within a presentation, whereas the associated elements supply everything that is layered on top of it (foreground). The Grouper can now either pay special attention to the size of areas (form), to the importance weights for the associated information units (function), or a mix of both (neutral). However, emphasising does not mean neglecting other relevant elements. For example, as the physical size of an area specifies its importance for the feel of a presentation, it has to be considered even though the main orientation of the presentation is functional. Thus, we work with three different ways of calculating the importance of an area.

$$I_{AT_{function}} = \frac{(I_A \times P) + \left(\frac{\sum_{i=1}^{n} I_{E_i}}{n}\right) \times 2}{2}$$

$$I_{AT_{form}} = \frac{(I_A \times P) + \frac{\sum_{i=1}^{n} I_{E_i}}{n}}{2} \quad \text{,with } I_A = 1$$

$$I_{AT_{neutral}} = \frac{(I_A \times P) + \frac{\sum_{i=1}^{n} I_{E_i}}{n}}{2}$$

I_{AT} represents the overall importance of the area, I_A is the importance weight of the area with respect to content, P represents the size of the area provided by the reverse position value in the Constraint_list, and I_E is the weight of an individual presentational unit.

We are aware that the current formulae do not fully represent the complex relationship between the foreground elements themselves, or all aspects of the relationship between foreground and background, especially when it comes to various layers of foreground elements. However, trials with changing numbers of areas (max 5), associated elements (max 20) and various levels of importance (in the range between 0.1 and 1.0) showed that the formulae establish a sensible hierarchy of areas, where areas are organized in decreasing order of importance value.

Once the order of areas is established the Colour Design Unit starts with the assignment of colours to the most important area, and then works its way gradually down the area list, where already established colours are reused.

3.2.4 Colour assignment

The relevant unit for this task is the ColourPicker as shown in Figure 2. The ColourPicker first separates background from foreground elements. If functionality is more important, as in the example of Figure 1, the ColourPicker tries to identify the colour for the foreground elements of the most important area first, e.g. the text and header of the bottom right area in Figure 1. As both elements are of type text, the TextModule of the ColourPicker attempts to establish the element colours using those colours that were provided by the Constraint_list. Note, the TextModule simultaneously establishes the background colour of this area too, as both colours depend on each other.

The TextModule uses the domain specific colours in their HSL notation and tries all possible colour combinations with respect to all foreground and background groupings, where each combination is assigned with a legibility value (LV) based on:

- the relative brilliance factor ($Y_{colour1}$-$Y_{colour2}$);
- the contrast between both colours based on their classification as light and dark colours;
- the contrast between both colours based on their classification as cold and warm colours (cool colours should be used as background and warm colours for the foreground);
- the complementary contrast between both colours.

If none of the combinations make the threshold of 0.8, which is required by the DesignEvaluation Unit to accept a colour combination in the `function` mode, then the TextModule falls back on the default colour for text (black). Once the foreground colour is picked the system tries to establish the background colour for the area. In our example it uses a split complementary scheme, where the complementary colour for black in the HSL space is white.

Once colours are picked, the DesignEvaluation Unit performs a final test on lightness and contrast required for achieving "legibility". In fact, the extreme contrast between black and white should be avoided, as it can create extra shimmering effects that can strain the eye. Thus, the contrast-smoothing rule is applied, which adds 10% of each colour to the other, resulting in two grey values that still give the impression of being essentially black and white.

As the text body also contains links the TextModule assigns the colour for the link next. The aim is to distinguish both link and text from each other. The goal is to find among the depicted colours the one that provides the largest contrast to both the foreground and the background. In our example the best distance within the HSL colour space to black and white is provided by red. Thus, red will be assigned to the link. Note, the link colour comes with two values. One represents a non-visited link and the other a link that was already visited. The TextModule applies one of the split-item strategies for assigning two colours to a link. This rule diminishes the saturation of the established colour by 50%, which provides a sufficient difference to present the two states of a link.

Similar steps are performed for the other content areas. For the design as portrayed in Figure 1, the colour module tries to separate the various areas. It is also worth mentioning that the ImageModule considers images as being of colour `various`. This is a default within our current implementation, as the problem of matching the background with visual material such as images or a video area, are not yet fully implemented.

Once all colours are assigned, the resulting list is used in the transformation steps that generate the final presentation, e.g. generating a SMIL presentation, as described elsewhere [5].

4. Conclusion

The described process of colour design, the established rule sets and their theoretical foundation, all implemented in Eclipse Prolog and using the RDF-based domain ontology provided by the Rijksmuseum in Amsterdam, are best regarded as a platform that demonstrates the feasibility of our approach on the automated colour design within the generation of multimedia presentations (see also our test page at http://homepages.cwi.nl/~media/demo/colour/). The Colour Design Unit of the design module is in the position to generate, depending on the constraint set, user adapted pages with overall acceptable colour representations.

We are aware of the fact that the current system needs further fine-tuning. Further work is required on the relation on a micro-level between colour and links, colour and typography, colour and other visual information units, foreground and background colour, and more variations on how to choose between colour schemata.

Another relevant problem is the expression of various states and functionalities of a link through colour. This is a by far more complex process than the design module is currently able to solve. In this context the question of colour ranges becomes interesting too. In our current approach we work with strict HSL values due to domain constraints. If the system were allowed to alter the range of given colours we would gain in flexibility but have to pay with growing complexity in constraint solving. Exploring these questions is part of our ongoing research.

The important question we would like to answer, however, is not so much directed towards the scalability of our approach, but rather what it means to facilitate the system with resources to synchronise the various efforts of balance on the diverse micro-level during the evolving presentation design process.

We already introduce mechanisms to address this problem, such as

- adaptation of colour balance schemata based on functional or formal requirements;
- importance weights allowing to swap between functional and formal presentation strategies if necessary;
- providing sets of rules that increase the constraint space by applying aesthetic solutions to functional problems or vice versa (see for example the use of saturation variance in the determination of link colours).

These preliminary results, however, do not solve the problem per se but they focus our research on determining which level of autonomy can or should be achieved in automatically generated multimedia presentations. Further research is needed to determine how valid our hypothesis is that the automated generation of dynamic presentations can be improved by providing a balance between form and function.

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