A Computational Tool for the Use of Colour Harmony Rules in Facade Design

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The quality and availability of exterior paints has led to a new vernacular use of colour in Ireland and Scotland. Communal colour designs highlight the conflict between individual colour preference and the community desire for harmony. This is often expressed as a fixed colour design by an individual designer. The provision of the widest possible range of colour designs, all of which express communal harmony, can help to accommodate individual preferences.

This project uses computation to apply colour harmony rules within a chosen environment and to generate all the possible colour combinations which conform to these rules. The Colour Combinations program uses two steps to establish a colour design: palette selection and colour combination. The harmony rules can be adjusted for each step depending on the context for the design or the type of colour combination required. Once an appropriate palette has been selected all possible colour combinations for a terrace of six houses are generated. Each combination is then tested for harmony and the number of combinations which conform to the specified rules is displayed. Each harmonious combination can then be displayed in turn for manual selection. The program allows the effects of adjusted harmony rules to be tested and examined quickly. This could allow individual colour preferences to be accommodated within a communal colour design.

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Colour design

The geometry of colour systems has been used to develop harmonic combinations since the first colour circle was suggested in the 18th century. In the 20th century notable geometric calculations have included Johannes Itten’s colour wheel (1987) and the colour wheel developed by Gloag and Gold for their Colour Coordination Handbook (1978), which was to be used in conjunction with the Building Research Establishment’s architectural paint system. Definitions of harmony have developed from notions of emotional responses where different colours evoke complementary characters, such as those described
by Goethe (Matthaei, 1971), through the physical characteristics of light where different colours can be combined to provide white as demonstrated by Helmholtz in 1852 (Wyszecki, 2000). The perceptual nature of colour has led to the broad agreement that harmony implies an unambiguous relationship between colours, as described by Gloag and Gold in the Colour Coordination Handbook (1978). The relationships which Gloag and Gold describe use the Munsell colour system, whose perceptual basis reflects the way we experience colour. They use the geometric relationships for hues developed by Moon and Spencer (1944) and defined as “identity”, “similarity” and “contrast”. The identity relationship describes two colours which we perceive as identical; the similarity relationship describes two colours which we perceive as different but related (e.g. red and orange); and the contrast relationship describes two colours which we perceive as completely different, such as red and green. These relationships can be applied to hues alone alongside variations in lightness and saturation so that, for example, a pink and red can be seen as different versions of an identical colour.

Computation is now frequently used to develop and display colour combinations, generally for graphics applications, with sophisticated examples such as Coloroid Professional (www.flexiform.com: May 2007), but sometimes for interior colour schemes, as in the case of Dulux’s Colour Coordinator (www.dulux.co.uk: May 2007). We are unaware of colour harmony calculations which use exterior colour schemes as examples. The complexity of the exterior environment and the changing light level, from the broad spectrum and high light levels of daylight to the narrow yellow and low levels of street-lighting, produce a context with an enormous range of colours.

In residential settings the complex and changing preferences of residents must also be considered. These difficulties in producing harmonic combinations for exterior use are balanced against an overt desire for colour in the built environment. The increased availability and quality of exterior paints has led to the development of a new vernacular across Scotland and Ireland (McCarthy, 2000), as towns and villages have developed highly chromatic streetscapes, with Tobermory on the west coast of Scotland an iconic example of this (figure 1).

Figure 1
Tobermory, Isle of Mull, Scotland

Figure 2
Lenclos colour plan for Chateau-Doble apartments
The complex and chaotic nature of exterior colour has resulted in the continuing use of hand-produced bespoke colour designs, with designers such as JP Lenclos (2004) producing colour designs that are closely linked to selected environmental colours (figure 2). However, despite careful analysis and design, one can still encounter problems incorporating the desires of existing residents. The individual desires of residents must be incorporated into a harmonic whole. The prototype software Colour Combinations was developed as part of the first author's undergraduate dissertation to address this challenge for colour facade design.

Context

Existing colour matching systems or software produce colour combinations of two, three or sometimes four colours, all of which are mutually harmonious. Our software addresses a situation which, whilst not unique to the built environment, occurs frequently in exterior environments. In this situation a large canvas, such as a facade, contains multiple colours and is situated within a larger, uncontrolled, environment. The facade colours should harmonise with the environmental colours and with their adjacent colours, but all the colours do not have to be mutually harmonious. A basic and common example of this is a terrace of houses where the first house colour should harmonise with the second; the second should harmonise with the third, and so on; but the first does not need to harmonise with the third. In this situation the coherence of the whole colour design can be provided in a number of ways:

- the use of a limited palette, such as in the centre of Turin, where just eight colours are proscribed for use on building exteriors;
- the use of one type of colour, such as terraced housing in Glasgow, where extremely pale colours are used for building facades;
- the use of a standard colour for a common building feature, such as on the Venetian island of Burano, where a large variety of colours are used for the building facades but there is a universal use of terracotta roofs and white window surrounds.

This software was developed to test the possibility of generating sequential colour combinations for the built environment which acknowledge both environmental colours and the use of common colours for common building features.

To develop and test this software, a terrace in Glasgow was selected (figure 3). This terrace is typical of many post-war developments in the UK and demonstrates the problem of individual residents contributing to a communal colour scheme. In the existing situation this problem is solved by using pale colours of very low chromatic value which are extremely close to white. The environmental colours were analysed and simplified to two colours which
could be used to define the context, and thus establish a colour palette for the design. The predominance of vegetation within the context suggested the definitions of “tree” and “bush” for these colours. A third environmental colour was introduced to acknowledge the use of a common colour across all buildings. In the example selected, the colour of the roofs is common throughout the area, and so the common environmental colour was defined as “roof”. Analysis of external colour schemes also demonstrated that there are often specific colours which are unacceptable for a variety of reasons, and thus two colour ranges can be optionally defined as forbidden for colour selection.

For this initial development of the software only harmony between hues was considered. The saturation and lightness of colours can be adjusted on the display but does not alter the harmony calculations. The geometric definition of colour harmony developed by Moon and Spencer (1944) was used as the basis for calculations in the software, although the parameters of the calculation can be adjusted. Moon and Spencer’s harmony was based on the perceptual Munsell colour system (1975), whilst the initial software uses the RGB-based Windows HSL (hue, saturation, lightness) system. These two systems have different geometries (figure 4), which has produced distortions in the harmony calculations. The display of results of the calculations is diagrammatic and has been used to establish the viability of the calculations, rather than a realistic impression of the colours in context.

### Calculation

The software uses two steps to establish a colour facade design (figure 5). The parameters used for harmony calculations test generated colour combinations for identity, similarity and contrast. These parameters can be adjusted or, indeed, ignored. The software can use all 256 hues within the HSL system, but this generates an unwieldy number of combinations, so the number of hues can be limited by selecting only every nth hue.

### Colour palette

The three environmental colours and optional two forbidden colours are selected. The harmony parameters and number of hues are then selected. The software then tests all hues to see if they fulfil the harmony criteria. Those that do are displayed in rotation. This process can be run with different parameters until a suitable palette is selected.

### Colour combinations

Once the colour palette is selected the environmental and forbidden colours are not used in further calculations. The harmony parameters can be adjusted again – for example, to produce colour combinations with strong contrast but no similarity or identity. The software will generate all possible facade combinations using the selected colour palette, and it will then test each combination using the harmony criteria. The colour combinations which fulfil the criteria will be displayed in rotation. This process can be run with different parameters to test the effect of varying harmonic criteria.

### Presentation

The software presents the facade design in a diagrammatic form with information on the colours selected (described in both RGB and HSL format). As part of the development of the software, the colours selected were mapped onto the terrace that was used for analysis, using Photoshop to test whether the colours were practical and whether a more realistic display would be useful.

![RGB and Munsell colour wheels showing relative colour positions](image)
Further development

The software has demonstrated the possibility of using computation to test harmonic combinations, and further development is now planned to allow greater use and testing in real design situations. The inputs could be altered to allow more intuitive descriptions and options, such as colour picking from images. The outputs of the calculations could be provided in more realistic and varied views, with information on options such as paint references. The outputs could also be linked to existing visualisation software. Optimisation of the outputs and the display of multiple outputs would also allow easier selection of preferred options. The calculations could be developed to remove harmony distortions due to the different colour systems. The calculations could be
also be extended to include lightness and saturation as well as hue.

**Conclusion**

This software has demonstrated that calculation can sort harmonic colour combinations from the large number of colour combinations possible on building facades. The complex nature of the exterior environment has been acknowledged but simplified to produce useful results. The software does not replace individual or cultural preferences, but encourages the use of a large range of harmony types and colour combinations. The software is currently a prototype but has demonstrated the possibility for further development and greater use.

**References**