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Giving Colour to Contextual Hypermedia

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Design development evolves within design contexts that require expression as much as the design itself, and these contexts often constrain any presentation in ways that are not usually explicitly thought of. The context of a design object will therefore influence the conceptual ways of thinking about and presenting this object. Support in hypermedia applications for the expression of the colour context, therefore, should be based upon sound theoretical principles to ensure the effective communication of design ideas. Johannes Itten has postulated seven ways to communicate visual information by means of colour contrast effects, each of which is unique in character, artistic value, and symbolic effect. Of these seven contrasting effects, three are in terms of the nature of colour itself: hue, brightness, and saturation. Although conventional computer graphics applications support the application of these colour properties to discrete shapes, they give no analysis of contrasting colour relationships between shapes. The proposed system attempts to overcome this deficiency. The remaining four contrast effects concern human psychology and psychophysics, and are not supported at all in computer graphics applications. These include the cold-warm contrast, simultaneous contrast, complementary contrast, and the contrast of extension. Although contrast effects are divided into the above seven aspects, they are also related to one another. Thus, when the hue contrast works, the light-dark contrast and cold-warm contrast must work at the same time. Computational support for these colour effects form the focus of this paper.

Introduction

Design development always evolves within design contexts that require expression. These contexts constrain presentations in ways that are not usually explicitly thought of. The presentation of studio project work by design students requires the expression of relationships between drawings of different types. Such relationships can be expressed in hypermedia environments with support for the expression of design contexts [Szalapaj, 1993]. Design contexts include those of design influences, design concepts; various contexts for viewing designs (e.g. walkthroughs), detailing, and early sketch ideas. The focus of this particular paper is on the context of colour use in design. Providing such a context allows the description of design proposals in terms of alternative colour schemes. A hypermedia system that offers this facility can be used in studio crit situations, in which the reasons for rejection of proposals can be presented along with actual adopted proposals. It is very often this type of information that is missing from conventional crit presentations.

Conventional hypermedia applications have been preoccupied with the presentation of causal relationships between drawings, often in the form of an idealised sequence of images that bear no relation to the contexts in which the design was actually developed. The technological perspective that is typically adopted by many conventional hypermedia applications, results in the presentation of images as if they were unrelated and independent of design contexts and constraints. By contrast, designers work in the world, they view and reason about the world from perspectives within it, and they interact with the very situations about which they reason. By *contextual hypermedia*, therefore, we mean the development of hypermedia systems when these aspects are taken into consideration. Contextual hypermedia has to do with the fact that design is a situated activity, an activity carried out by people situated in a complex environment about which they reason.

One obvious advantage of contextual hypermedia is that the environment in which a design is developed, and toward which design thinking is directed, is richly structured and law-like. It obeys "constraints". Designers can exploit these constraints in countless ways. The other advantage is the fact that designers can control and manipulate their design environment. It is these positive aspects of contextual hypermedia that are interesting and exciting. It seems that in idealising away from the situatedness of design, we ignore some very powerful properties of design that can be used to good effect by design students, initially for purposes of presentation, and perhaps subsequently for actual design development. But first we need to understand them and to develop hypermedia tools for modelling them.

Contextual Colour

> "*A design relates to its context, to whatever surrounds it; this can be demonstrated on the computer by moving a design element from context to context. With even the most rudimentary display of alternative environments, the relation of an object to its context, of figure to ground, is apparent on the computer screen.*" [Norman, 1990]

Many undergraduate studio projects have been spoiled by the application and overuse of fully saturated colours and inappropriate colour schemes. When students are faced with the problem of colour selection, a useful starting point might be to exploit the phenomenon of complementary contrast in order to achieve some sort of harmony in their design. However, in computational approaches, contrast effects such as the complementary effect are not presently supported. The only facility that is typically available to students is the mere selection of *individual* colours from a colour palette or colour wheel. The support for contrast effects within a contextual hypermedia system, therefore, could potentially be a very powerful design tool.

Colour Properties

The conventional colour properties of hue, brightness and saturation are becoming increasingly available on conventional computing and CAD environments. Norman [Norman, 1990] argues that there is some advantage to the computational manipulation of these properties, primarily due to the speed with which it is possible to make and observe *changes* to the colours of depicted objects. The way in which colours are experienced by most computer users is typically by means of combinations of three colour values called RGB values. An RGB value may be represented by three numbers, each within a strength range. The first number represents a value for red, the second represents a value for green, and the third represents a value for blue. Such a schema can be used to generate a colour wheel from which users can select individual colours. Coincidentally, however, the same colour wheel can also be generated in terms of the more colour-theoretic concepts of hue, saturation, and brightness. In other words, looking at colours in terms of hue, saturation, and brightness is just another way of combining red, green, and blue values in a computational colour wheel.

Hue

The concept of hue is what distinguishes one colour from another. For painters, hue is the pure substance of a pigment. For scientists, hue is light of a particular wavelength. On very basic colour monitors, the selection of different hues is just about the only kind of colour manipulation available to users, since a basic colour palette of say, 16 colours allows few choices. Itten talks of the hue contrast in painting as involving the juxtaposition of colours of different hue, and cites Mondrian as a prime exponent of this technique (Itten, 1967]. In Itten's colour theory, the contrast of hue is regarded as the simplest effect in his seven contrasting effects. The primary colours are the extreme instance of contrast of hue, and the secondary colours are weaker and less distinct in their contrast effects.

Brightness

The colour-theoretic concept of brightness is often referred to as "value", and determines whether individual colours are lighter or darker. Itten talks of*value contrast* as meaning that pictures can be produced which successfully exploit the use of shades of the same colour.

Saturation

A colour is fully saturated when it is at maximum brilliance. Saturation on computers is achieved from the phosphors that form the colour image. Red, green and blue, the pure phosphor colours, display the highest possible saturation. Mixing them can only reduce their intensity.

The selection of colours based upon the contrast of hue, brightness, and saturation provides a very basic colour selection method that can be used by designers. Such systems are becoming increasingly available on computers, and allow the selection of particular colours from a colour wheel or colour palette such as that in *figure 1.*

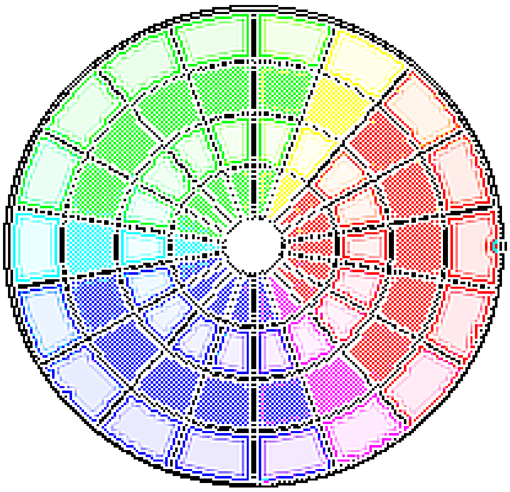

Figure 1: Hue/Brightness/Saturation Colour Space

In describing the types of colour contrasts that can be achieved by juxtaposing colours of different hue, brightness and saturation, Itten defined the three basic elements used in human colour perception [Itten, 1970]. These three elements are the basis of most current computer colour-models, and allow users to choose colours on the basis of these three characteristics. However, it is our view that although colour contrasts can certainly be achieved through the exploitation of these three basic individual elements, they are not sufficient in themselves to form the basis of computational colour design support systems that provide assistance to students and designers. Presently, only the selection of hue, brightness and saturation is available to users, and nothing more. Clearly, one cannot suggest that users use colours of certain value and not others. However, once users have begun to apply certain colours to parts of a design scheme, it is at this stage that computational support and advice might be given. Before describing what form this advice might take, it is essential to look at the psychophysical properties of colour that form the basis of Itten's psychophysical colour contrast effects.

Psychophysical Properties

Cold-Warm Contrast

The cold-warm contrast is identified by human sensation. Some colours feel warm while others feel cold e.g. yellow, red and orange feel warmer than blue, green and violet.

Complementary Contrast

In painting, if two pigments are mixed together, they yield a neutral grey-black. We call these two colours complementary. Complementary colours are always opposite to each other, require each other, and incite each other when placed adjacent to each other. The distinctive complementary colours in Itten's colour circle are: yellow/violet, blue/orange, and red/green. The eye seems to require a balance of complements. The use of complements is a commonly used method of colour harmony in interior design, and is probably the best understood of all colour principles. Used well, the power of one colour to demand another becomes an important design tool which can be incorporated into a hypermedia design support system by *suggesting* to the user which colour complements might be suitable for newly introduced design objects.

Simultaneous Contrast

Simultaneous contrast results from the fact that for any given colour, the eye simultaneously requires the complementary colour, and thus generates it spontaneously if it is not already present. Since simultaneous contrast is a sensation of the human eye, it cannot be objectively present. It can only be experienced by observing the colour effects when analysing alternative colour schemes applied to building models. Computational analysis of simultaneous contrast effects can be explored through the phenomenon of after-image. One way of doing this is through the superimposition of alternative colour patterns and forms upon the surfaces of computer-generated building models - something that is very time-consuming with manual drafting methods. Exploiting the simultaneous contrast effect allows designers to add colours to a design *by implication*, to give emphasis to or to remove emphasis from any portion of the field of vision.

Contrast of Extension

The contrast of extension involves the relative areas of two or more colour patches. It is the contrast between much and little, or great and small. Itten listed his harmonious relative areas for the complementary colours, e.g. yellow : violet = 1/4 : 3/4, orange : blue = l/3 : 2/3, red : green = 1/2 : 1/2.

(a) (b)

Figure 2: Extension can affect experience of colour intensity.

In *figure 2*(a), the colour of the relatively small patches is intensified against their background, whereas in *figure 2*(b), the colour re-inforcement ceases to exist and the patches appear as paler in colour. The contrast of extension is concerned, therefore, with the contrast of colour *proportions*, and is potentially very significant in architectural design applications where proportional relationships play such an important role.

An Architectural Design Example: Colour in the Forbidden City

The example we have chosen to illustrate how colour contrast effects can be exploited in architectural design is the Forbidden City in Beijing, China. This complex of buildings was the imperial palace of the Ming and Qing Dynasties in China and is one of the most elegant, colourful, and characteristic buildings in Chinese history. Moreover, it is one of the best preserved historical buildings in China. Typically, historical buildings in western countries are built of stone, and elegant colour decorations are often applied *inside* these buildings rather than to the outside. In traditional Chinese architecture, on the other hand, both the interiors and exteriors are coloured, as in the interiors and exteriors of the Forbidden City. Though Itten's colour theory is based on modern western art, this example will show that it also has relevance to the colour effects in traditional Chinese architecture.

Colours of the Forbidden City

Most of the colours used in the Forbidden City can be found in Itten's colour circle, and most of the colour combinations used can also be defined by Itten's colour theory. By observing colour photographs of buildings in the Forbidden City, we can observe that the main colours used in decoration are: yellow, red, blue, orange, green, violet, white, and black. Among these eight colours, six are chromatic colours. They are the same as the three primary colours and the three secondary colours in Itten's colour circle (yellow, red, blue, orange, green, violet). In addition, their combinations also correspond to the principles of Itten's colour theory. According to Itten's explanation of contrasting effects, any two of the three primary colours, or the two colours chosen from the three primary colours and the three secondary colours are considered as contrasting with each other, for example, yellow and red, yellow and blue, red and blue, yellow and violet, red and green, blue and orange. They are all used frequently in the colour decoration of the Forbidden City, especially yellow and red, yellow and blue, and red and green (see *figure 3* below).

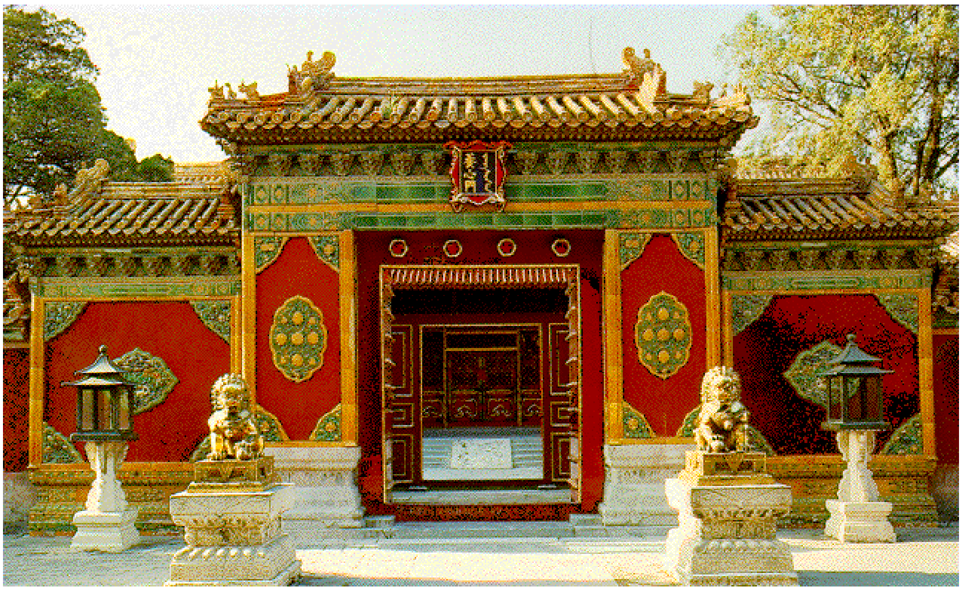

Figure 3: A facade in the Forbidden City using red, green, and yellow.

The three primary colours

The three primary colours are the main colours of the Forbidden City. The Chinese liked to apply them either on buildings or on the details of decoration. The yellow glazed roofs, the bluish bracket sets or beams, and the red mural walls or columns in the Forbidden City are linked by the three primary colours. The horizontal inscribed boards on buildings are also decorated by the three primary colours (*figure 4*).

Figure 4: Predominant use of Primary Colours in the Pavilion of Ten Thousand Springs

Combinations of the three primary colours are also found in the decorations of the Forbidden City, e.g.:

• yellow and red, on the details of decorations, such as red doors or windows which are decorated with golden lines or dots;

• yellow and blue, on the horizontal inscribed boards of the buildings, such as Taihedian, Ningshoumen, Yangxinmen, on which the names of the buildings are written in gold on a blue background;

• red and blue, which is used often in the *Hexi Colour Painting*.

The three secondary colours

The three secondary colours are also applied in the colour decoration of the Forbidden City. Among them green is used most frequently, such as in the green columns or window frames, green glazed roofs, and the greenish beams or bracket sets (as in *figure 4* above), etc. Orange and violet are less commonly applied in large areas. They are often used on the details of decorations with other colours. The contrasting effects between the primary and the secondary colours are obvious in the colour decoration of the Forbidden City:

- Red combined with green in paintings is the most typical combination. On a red wall green graphics are used, or beside a red wall there are green columns and green frame windows.
- For blue and orange, sometimes the orange in the decoration is difficult to identify. Most of the yellow glazed tiles are orangey in colour, and golden lines and graphics also appear orangey in colour because of the reflection of the reddish surroundings. Moreover, some reddish mural walls look orange under the sunlight. The blue and orange combination in paintings is also difficult to identify. The *Xuanzhi Colour Painting* mainly consists of blue, green, yellow, and white. It only gives an impression of the blue and orange contrast.
- The yellow and violet contrasting colours appear often on the details of decoration, such as paintings on ceilings, or on the ends of beams.

Contrast Effects in the Forbidden City

Hue

In the coloured decorations, the obvious colour combinations are:

- yellow/blue/red (e.g. a yellow roof, bluish bracket sets, and a red wall);
- blue/green/red (e.g. blue and green bracket sets, beams, and a red wall or columns);
- blue/green/yellow (e.g. *the Xuanzi Colour Painting*);
- red/yellow/green/blue (e.g. the Hexi Colour Painting); and so on. These combinations exhibit contrast of hue because these colours are the most intense in luminosity representing extremely pure colour contrast.

The contrasting effect of the primary colours is also obvious. Contrasting colours between the primary and the secondary are also widely used, such as yellow/blue/red, red/green/yellow (as in *figures 3 & 4*), and blue/green/yellow. However, some of them are less used, such as violet/yellow/red, orange/violet/red. Generally speaking, on the details of decoration less distinct contrast of hue is often applied, while on the large areas of the decoration a bigger contrast of hue is often used. In addition, as Itten pointed out, when single colours were separated by black or white lines, their individual characters emerged more sharply. Most of the colour paintings in the Forbidden City, such as the Hexi Colour Painting, the Xuanzi Colour Painting, have black or white lines to separate the individual colour, so they look even more colourful. On elevation the white marble balustrades also have an important colour effect when viewed from above.

Brightness

According to Itten, an outstanding example of the light-dark contrast effect can be found in Chinese ink drawings. The light-dark effect in the decoration of traditional Chinese architecture is also distinctive. In the Forbidden City, under a yellow glazed roof there are greenish or bluish bracket sets and beams in the shade. This gives a sharper light-dark contrast between a roof and shaded areas. Moreover, the reddish wall beside the shade of a roof appears to be even brighter. The other distinctive phenomenon of the light-dark effect is the contrast between the white marble balustrades and the reddish mural walls. The light-dark contrast may also appear in the use of gold. The gold contrasts with other pigments and makes other colours look dull. Many doors in the Forbidden City are in red and are decorated by golden lines and dots. The details of structure, such as bracket sets, and ends of beams, are decorated with golden lines and graphics.

The light-dark contrast effect is not only about pure light and dark contrast, but also about the lightness and darkness of chromatic colours. For example, yellow is the lightest colour among all the chromatic colours. Red is much darker than yellow, but lighter than green and blue. In colour decoration, most paintings have used yellow, so that the contrast of the light-dark effect is always distinguished.

Saturation

The contrast effect of saturation was considered to be contrast of quality by Itten. In the Forbidden City, contrast between high and low saturation is seen when a yellow or green roof is combined with a grey wall (e.g. Tianyimen), or a red wall is combined with a black tile roof (e.g. the wall along the western alley to Ningshougong). The contrast between the red walls and the bluish bracket sets, or the yellow roofs and the bluish bracket sets is also obvious. One is in a pure and bright colour and the other is in a dull and dark colour. Contrast in different saturations of hues is seen in the Xuanzi Colour Painting, or the Hexi Colour Painting, where blue and green are used in various saturations.

Cold-warm contrast

It seems obvious that the cold-warm contrast effect is capable of having a profound effect on the mood of buildings. In the colour effects of the Forbidden City, the cold-warm contrast plays an important role as follows:

- In the landscape of Beijing, the Forbidden City presents a bright and warm contrast effect with the urrounding environment. The yellow glazed roofs and the red mural walls contrast well with the greenish and grey environment.
- The contrast effect between exteriors and interiors expresses the cold-warm contrast. On the exterior, the colour effect (a yellow glazed roof, red mural walls, and white balustrades) is warmer and brighter, while in the interior it is colder and darker. The colours inside are not as pure and bright as the colours outside. The columns, window frames, and furniture are in red or gold, while the walls and floors are white, grey, or black. There is less light inside than outside. Hence, the inside feels colder and darker than the outside.
- The cold-warm contrast in elevation is seen when the bluish or greenish bracket sets and beams under a roof express a cold effect, the yellow glazed roofs and red mural walls express a warm effect, and the white marble balustrades express a cold effect.
- The cold-warm contrast on the details of decoration are seen in both the Hexi Colour Painting and the Xuanzi Colour Painting which are painted in cold-warm contrasting colours.

Complementary contrast

A typical pair of complementary colours used in the colour decoration of the Forbidden City is red/green, such as in the green columns in front of the red walls, the red walls under the green glazed roofs, and the green decorations on a red mural wall. On the details of decoration, yellow/violet and blue/orange are applied. In addition, Itten emphasised the importance of the proper proportions when using complementary colours. In the Forbidden City, for the red/green complementary colours, the areas of the colours are never equal. The red characters on green door s(e.g. Hexiemen), or the green decorations on red walls (e.g. Yangxinmen) are arranged in proper proportions, resulting in balance and harmony.

Simultaneous contrast

The simultaneous contrast effect appears in the Forbidden City. For example, the colour of bracket sets under a roof is painted either greenish or bluish. When we move our eyes from the yellow glazed roof to the greenish bracket sets, they look bluish green; when we move our eyes from the red mural wall to the bluish bracket sets, they look greenish blue. In an interior, such as in the Taihedian, the floor actually is grey or black, but due to the simultaneous effect it looks greenish as the surroundings are in red. In the simultaneous contrast effect, Itten found that once a light-dark contrast was presented, simultaneous influences were diminished. In the Forbidden City the white marble balustrades and pavements, and the many of golden decorations have the same effect on the human eyes.

Contrast of extension

In the Forbidden City, the colour combinations both on elevation and in section, as well as the paintings, do not follow the harmonious proportions suggested by Itten, and this phenomenon needs further investigation.

Hypermedia Colour Support

Presently, student CAD project work in our department is modelled using Minicad+, in which extensive use is made of layering and classes in order to structure building models in terms of appropriate groupings of objects corresponding to building parts. These parts can then have colours associated with them. A typical structural CAD-generated building model of a classical chinese architectural form is shown in *figure 5*. At significant stages in the modelling process, students are encouraged to evaluate the colour schemes that have been applied to parts of these models by importing them into a Hypercard stack in which current colour schemes can be assessed. The colour component of the stack is based upon the XCMDs provided in *Colorizing Hypercard 1.0* which is sufficient for the application of basic colours to imported CAD drawings. The user-interface which supports analysis in terms of individual contrast effects is implemented in Hypertalk. The assessment is entirely user-driven in that users identify salient parts that have contrasing colours. A value is then given for each of the contrast effects, together with a textual assessment of which contrast effects need to be resolved further. Alternative colour scheme suggestions are provided by the system at this stage which can either be adopted upon returning to the modelling system, or rejected.

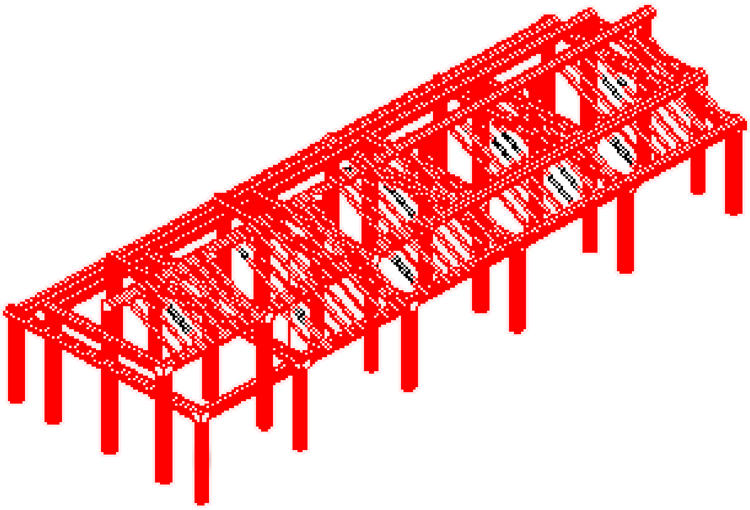

Figure 5: A typical structural CAD building model

The use of contrast effects in the colour decoration of building models always appears to involve questions of balance. There are always positive and negative aspects to each of the contrast effects. The psychophysical contrast effects affect each other and work together as a whole. We are currently working on the implementation of a system of *weightings* for each of the psychophysical contrast effects in order that alternative colour schemes for building models can be more readilly assessed.

Conclusion

This paper has illustrated how Itten's colour theory can be applied to buildings such as those in the Forbidden City, and suggest how it might be incorporated into a hypermedia design support system with knowledge of colour amongst other things. The psychophysical contrast effects have been chosen for discussion in this paper, primarily because they are potentially more useful than currently available computational colouring methods in a design support context. The gradual refinement and development of computationally generated colour schemes allow simple design statements by students to eveolve into very articulate images. Full colour drawings that illustrate both building and context become feasible.

Even though the colour effects in buildings may correspond to Itten's colour theory, not all colour phenomena can be entirely explained by it. In the case of the Forbidden City, for example, almost all roofs are yellow, but in the Altar of Heaven the roof of the main buildings are blue. The ancient Chinese believed that the place where emperors lived should be yellow, and the place where emperors worshipped should be blue. In the Qing Dynasty, there were particular customs and regulations in colour decoration which cannot be explained by any colour theories, and appear to be more easily explianed in terms of their symbolic effect. It is at this point that the contextual colour support system comes into contact with the cultural context of the design.

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