Bayesian modelling of impact of colour on web credibility

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Abstract. Colour plays an important role in web site design. The selection of effective chromatic combinations and the relation of colour to the perceived aesthetic and emotional value of a web site is the focus of this paper. The subject of the reported research has been to define a model through which to be able to associate colour combinations with specific desirable emotional and aesthetic values. The presented approach involves application of machine learning techniques on a rich data set collected during a number of empirical studies. The data obtained were used to train a Bayesian Belief Network which associated a simple chromatic model to perceived aesthetic and emotional dimensions. A set of tools that have been build in the process to support the methodological framework and ensure its reusability with minimal effort, are also described.

1. INTRODUCTION

The web has increased in complexity over the years and has gradually transformed from an online publication medium to a platform for carrying out complex tasks, such as shopping, learning, communication, and collaboration. Due to this transformation, additional research is required to support design of effective web sites. Various issues influence the effectiveness of a web site, such as structure, content hierarchy, styles, text format and navigational support. One of the most important design factors that influence the effectiveness of a web site is colour. Research and application of traditional human computer interaction methods and practices led to a significant improvement of web design quality. Yet, there is an open discussion about the specific elements that should be incorporated in a "well designed" web site. This question has particular significance during the development of web applications, considering the complexity of such a task [1].

Recent work [2], [3], has shown that the design space of a web site is affected by both engineering and aesthetic issues. Other work, suggests that the visual aesthetics of computer interfaces are a strong determinant of users' satisfaction and pleasure [4]. An effective web site design has to communicate well not only the content and the overall information architecture, but also wider values such as sense of professionalism, skilfulness and credibility. Furthermore, often the web site values are influenced by cultural beliefs, traditions, as well as goals and usage expectations [6]. The aforementioned criteria determine the *Perceived Value* of the site. Recent web based studies [5], showed a clear link between effective page design and credibility. Websites which seemed to have a more suitable visual appearance for the scope of the site were rated by the subjects as more credible. This reinforces the theory, established by social psychology research, that physically attractive sources have been perceived to be credible [7].

However, in general, there are not well established guidelines that affect the emotional aspects of interaction which, in turn, influence a web site's perceived credibility. As a result, various interaction values are implemented via ad hoc procedures and trial and error implementations. So, there is a need for a systematic development of models that can guide the design practice in this area. Most modelling approaches supporting human interaction with web sites have focused primarily on the cognitive aspects of interaction [8],[9]. However, the importance of aesthetics on websites is well accepted and models of their impact on credibility have been proposed [10]. In general, however, little is known about the influence of aesthetics and the role of the colour. The most prominent designer's tool to use colour in websites is that of guidelines. However, existing colour guidelines are often awkward, easy to misinterpret and of limited value. According to Schwier and Misanchuk [11], experiential advice tends to be non-representative, contradictory or even obsolete. This is due to the outdated equipment used in the experiments, the fact that some guidelines may be only applicable on display media other than CRTs, and the tasks are so different and unique from common situations, that their generalization may be impossible. Even assuming that relevant guidelines exist, they are of little value to novice designers with little experience with colour theory and art. Many issues remain untackled by existing guidelines, such as the relationship between colours, the optimal number of colours for each case etc. Following this, it is desirable to obtain a methodology, which is capable of proposing specific directives about colour usage in any web design problem.

In this paper, we use Artificial Intelligence techniques to define a model to aid us select the most appropriate colour combination for a web site of a given purpose. The goal is to identify methodologically the colour combinations which communicate effectively desired emotional values. For example, a news web site should effectively communicate values such as consistency, reliability, objectivity, etc. Due to the fact that a direct evaluation of each colour is heavily subjective, the methodology tackles this problem by indirectly evaluating the credibility influence of selected colour combinations, and then breaking down the underlying influence of each factor using a Bayesian Belief Network. The developed Emotional Colour Model has been used in a tool to suggest appropriate chromatic schemes according to the desired perceived web site values.

2. EMOTIONAL COLOUR MODEL DEFINITION

The proposed model is partially inspired from a similar research by Guerin et al. [12]. This experiment examined colour usage, in the frame of interior space design. The subjects of the experiment had to evaluate computer generated interior environments against a list of 21 words, selected for this purpose on a scale from 1 to 5 (1 when a characteristic described by a specific word was rarely present, 5 when its presence was very strong). A variation of this experiment has been used to recognize differences in colour preferences between the two sexes [13]. The methodology proposed in this study is built upon the same idea, but is applied on web pages instead of interior environments. Our ultimate research aim is to determine relations between colour characteristics and descriptors of the web site's perceived value. The benefit of such an approach is the elicitation of a formal methodological process to

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select the appropriate colour combination. Furthermore, the process could be applied reversely: For a web site of a given scope we can elicit the appropriate colour characteristics.

A Colour Model has been defined first, combining physical, aesthetic and artistic dimensions. This includes aspects such as dominant and secondary colour, number of colours, dominant colour and secondary colour attributes such as degree of saturation and brightness (see Table 1). This model contains attributes related to the physical properties of the primary and secondary colour (e.g. colour hue, degree of saturation and brightness), as well as psychological properties (e.g. perceived warmth of the primary colour, colour scheme). Any web page colour scheme can be described according to this. The model cannot be conceived as too restrictive or exhaustively prescriptive, in terms of explicitly describing the very exact nature of each colour, which a web site's layout contains. This is compatible with our scope: The purpose of the proposed methodology is to guide the designer selecting appropriate colour schemes, not to suggest the exact attributes of each colour contained in the layout to be designed.

Table 1. Colour Model attributes with typical values

Attribute	Description	Values
Dom_colour	Hue of the dominant colour	*Blue, Red, Grey, Green, Purple*
Sec_colour	Hue of the secondary colour	*Blue, Red, Grey, Green, Purple,*
Dom_atr_dark	Brightness of the dominant colour	*Dark, neutral, bright*
Sec_atr_dark	Brightness of the secondary colour	*Dark, neutral, bright*
Dom_at_muted	Saturation level of the primary colour	*Low, Neutral, High saturation*
Sec_at_muted:	Saturation of the secondary colour	*Low, Neutral, High saturation*
Dom_atr_warm	Dominant colour's warmth	*cold, neutral , warm*
Sec_atr_warm	Secondary colour's warmth	*cold, neutral , warm*
Contrast_Values	Shows if contrast between brightness levels of main colours are high or low	*high, neutral, low*
Contrast_colours	Shows if contrast between hues of the main colours are high or low	*high, neutral, low*
Colour_sheme	Shows the type of chromatic combination used	*Analogous, complementary, split-complementary, monochromatic*
Numb_col	Total number of colours	*(integer)*

The Model is correlated to a number of descriptors, describing the perceived value of a web site. According to our methodology, typical users of the web site are requested to provide their subjective feeling about different colour schemes applied on representative web page layouts. A questionnaire has been designed for this purpose. By simply asking the participants for their preferences in colours, their answers would have been highly subjective, thus leading to non meaningful or contradictory conclusions. For example, in the case of a sports news web page, a person's preferences is heavily biased by social and geographic influences (colour of local team, national team etc.). Therefore, we constructed an indirect approach to gather the perceived value of the site.

The Perceived web site value dimensions are based on a model used by Guerin, et al. [12], to describe the characteristics of interior environments. To reduce the ambiguity due to similarity between a number of the terms, the 12 most distinctive were chosen: *Pleasant, Formal, Fresh, Modern, Friendly, Aggressive, Professional, Attractive, Calming, Dynamic, Reliable and Sophisticated.* These values are compatible with the thirteen emotional dimensions that have been used by Kim et al. [14] to describe the emotional value of web site design, which were derived through a systematic process. The only dimensions missing from the model used in this study are those related to the web site structure and form (e.g. concise, simple) that are not related to the colour of a web page.

The product of the method described above is the *Emotional Colour Model,* a knowledge body that can be interrogated, in order to extract useful recommendations on colour usage. We do not expect generalized conclusions from this Model, at least unless a very large number of representative users are engaged. However, specialized strategies for colour usage in certain layouts may be obtained. For every new web site of a given scope and with recognized typical users in terms of characteristics like age, sex, educative level and familiarity with the internet, the methodology attempts to propose the most suitable colours to be used.

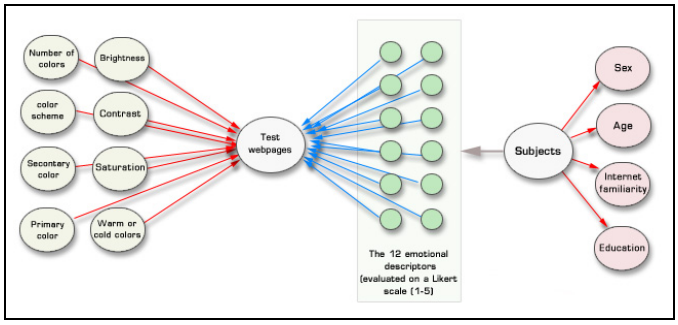

Figure 1. Overview of the proposed methodology

The data collected train a bayesian belief network. The variables of the network are not the layouts themselves, but their colour combination structural components. Thus, we can infer against most probable colour selections given specific credibility attributes which constitute the desired credibility for the designing web site to be designed. Reversely, given some colour scheme selections, we can predict the perceived credibility for given users.

Bayesian Belief Networks (BBN) are a significant knowledge representation and reasoning tool, under conditions of uncertainty. Given a set of variables $D = <X_1, X_2 \ldots X_N>$, where each variable X_i could take values from a set $Val(X_i)$, a BBN describes the probability distribution over this set of variables. We use capital letters as X,Y to denote variables and lower case letters as x,y to denote values taken by these variables. Formally, a BBN is an annotated directed acyclic graph (DAG) that encodes a joint probability distribution. We denote a network B as a pair $B=<G,\Theta>$, (Pearl, 1988) where G is a DAG whose nodes symbolize the variables of D, and Θ refers to the set of parameters that quantifies the network. G embeds the following conditional independence assumption:

Each variable X_i is independent of its non-descendants given its parents.

Θ includes information about the probability distribution of a value x_i of a variable X_i, given the values of its immediate predecessors. The unique joint probability distribution over $<X_1, X_2 \ldots X_N>$ that a network B describes can be computed using (1):

$$P_B(X_1 \ldots X_N) = \prod_{i=1}^{N} P(x_i \mid parents\ (X_i)) \qquad (1)$$

In order to construct a BBN from the training data provided, two processes should be unified: learning the graphical structure and learning the parameters Θ for that structure. In order to seek out the optimal parameters for a given corpus of complete data, we directly use the empirical conditional frequencies, extracted from the data [15]. The probability that the model gives to the data can be extracted using the following formula proposed by Glymour and Cooper [16]. Then, we follow greedy search with one modification: instead of comparing all candidate networks, we consider investigating the set that resembles the current best model most. As we shall discuss in the conclusions section, BBN are a significant tool for knowledge representation, visualizing the relationships between features and subsets of them. This fact has a significant result on identifying which features actually affect the class variable, thus reducing training data size without any significant impact in the performance.

The proposed model building process is supported by a tool aimed at facilitating data collection. The collected data are stored first in a relational database, together with the attributes of the Colour Model for each evaluated layout. A second tool realized, to allow the designer choosing which perceived value descriptor has to be present and at what degree on the web site to be designed. According to the designer's preferences, the system proposes a list of colour characteristics, by using the BBN obtained. Further explanations on the results, such as information for colour theory elements, are also provided. The outlined methodology and use of the derived model and tool is further discussed in a validation case study in the next section.

3. CASE STUDY

Two empirical studies were conducted, to identify the quantitative relations between emotional dimensions and colour usage in a specific layout. In the first study, we tested the methodology with 46 participants in a highly controlled experiment. Our goal was twofold. Firstly, to examine the soundness of the proposed methodology. Secondly, to proof the validity of the used emotional descriptors. It was also a good opportunity to evaluate the tools developed to support the proposed methodology, as well as to improve them. The conclusions of this preliminary experiment found to be very encouraging. The tool developed to make use of the data collected could be a very helpful addition in the web designer's toolbox [17]. However, to claim direct facilitation of the designer's task to pick the most appropriate colours, evaluation of a wider range of layouts and colour schemes by a larger sample of subjects should take place. That is, because the data are hardly sufficient to derive results of general value. In the second study, we conducted another experiment in which the objective was to overcome the weaknesses unveiled in the first one. The first problem was to recruit a respectable amount of participants for the goals of this study. To tackle this problem, we converted the tool with which the participants were called to identify the quantitative relations between the emotional descriptors and colour characteristics to operate online (Figure 2). By doing so, we were able to recruit more participants to carry out the evaluation but had also to deal with problems derived by a less controlled experiment. The tool developed for the experiment is a web application, which presents the layouts and the emotional dimensions on a Likert scale in the same window of a common web browser. The participants had to evaluate 10 out of 30 test layouts, in order to complete the experiment which is a sufficient number taking into consideration the user's weariness. Consequently, the application had to generate the layouts in a random order. Also the order of the descriptors appearance had to change from user to user, in order to avoid position related bias. Furthermore, the application has to provide sufficient documentation and techniques to avoid errors during the evaluation. Finally, it had to adapt to the users screen resolution and depict the appropriate layout.

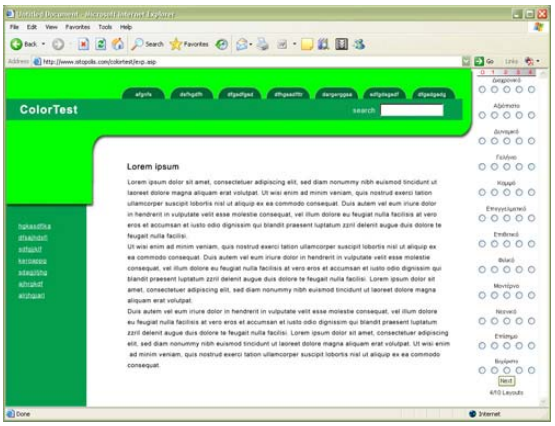

Figure 2. Tool to acquire users' subjective evaluations

In order to represent in our study a larger area of colours, colour schemes and their derivatives, we had to increase the number of test layouts considerably. We considered that 30 different layouts comprised of six dominant colours with five variations in brightness, saturation, colour scheme etc. managed to balance a representative sample. By taking user weariness in consideration we decided that each participant should evaluate no more than 10 test layouts.

Table 2. Most friendly dominant colour

	First experiment		**Second Experiment**	
1	Green	43.79 %	Green	20.04 %
2	Blue	35.77 %	Blue	17.74 %
3	Grey	17.23 %	Purple	17.24 %
4	Purple	1.61 %	Red	15.51 %
5	Red	1.60 %	Yellow	14.77 %
6			Orange	14.69 %

Overall, 214 users (64 male, 150 female) participated in the experiment, evaluating a total of 10 randomly selected layouts from the 30 available, which totals an average of 70 evaluations for each layout. The median age was 18 years old. Most of the participants were undergraduate students from the department of Educational Sciences and Early Childhood Education Department as well as from the department of Electrical and Computer Engineering at the University of Patras. The majority of the participants had average (65,45%) or frequent experience (27,44%) with the Web.

Table 3. Most friendly brightness of the dominant colour

	First experiment		**Second Experiment**	
1	Dark	4.31 %	Dark	5.95 %
2	Neutral	27.03 %	Neutral	33.66 %
3	Bright	68.66 %	Bright	60.39 %

By comparing the data of the two experiments some findings seemed to be aligned. For example, the findings found to be similar both for the most "friendly" dominant colour, as shown in Table 2,

and the attribute brightness of the dominant colour as shown in Table 3.

The network obtained showed no significant differentiation in preferences between the two genders in both experiments. In the first one, no connection was found between the node user's gender and the other network, which lead us to believe that either our sample was inadequate or there is no difference in preference. In the second experiment the gender node found its way into the network but as shown in Table 4 there is only a slight difference between male and female preferences. This is mainly due to the unilateral sample of the participants.

Table 4. Differences between genders in dominant colour preferences

Men		Women	
Green	17.38 %	Green	17.43 %
Yellow	17.19 %	Yellow	17.30 %
Purple	16.59 %	Blue	16.50 %
Blue	16.36 %	Orange	16.32 %
Orange	16.27 %	Red	16.27 %
Red	16.21 %	Purple	16.18 %

By examining the structure of the tree, one may notice that the perceived values, the colour attributes and the demographical data were clustered into three large groups. The group of the perceived values has been placed at the bottom and the colour attributes at the top left of the tree of Figure 4. The only connection between the two sections of the model is made through the nodes "*modern*" and "*saturation level of secondary colour*". According to BBN's theory, if they're no direct connections between two nodes then there is no direct relationship between them. However, a relationship may exist if they are connected indirectly, via other nodes, but the former case is an indication of a stronger relationship. Therefore, conclusions can be carried out, based on the position of every node and their "distance" from the Perceived Value descriptor nodes.

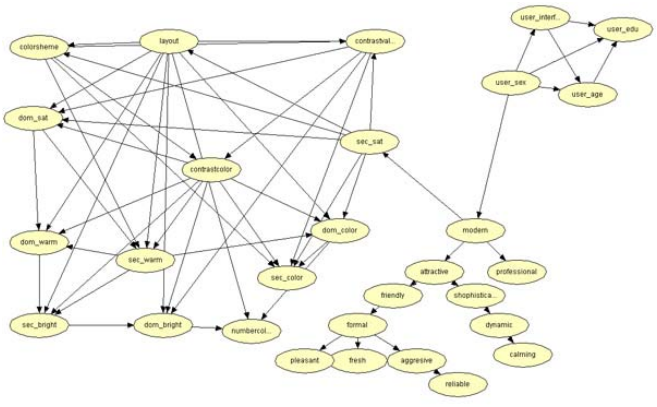

Figure 3. BBN obtained from user's evaluations.

So, according to the tree structure the *saturation* of the secondary colour has a stronger effect on the site's Perceived Value than its *hue*. Further analysis of the model structure, led to a categorization of influence of colour factors into 3 levels of importance: The ranking of the importance of the colour model aspects that influence the values perceived by the user seems to be the following:

(a) First, the *saturation* of the secondary colour.

(b) Secondly, the *Hue* of the dominant and secondary colour, *saturation of the dominant* colour, the *colour scheme* and the *contrast levels of brightness*

(c) Finally, the saturation of the dominant colour, brightness of the dominant colour and the type of the dominant and secondary colour (warm or cold).

By comparing the trees generated by the two experiments we found slight changes in the nodes positions and dependencies. In the first experiment, the top node in the perceived value section was the node *friendly* and for the colour attributes the node *brightness of dominant colour*. This is due to the different physical layouts used. These users were more sensitive to these values for this particular layouts.This ascertainment stress the need to include a variety of test layouts in order to have results of generalizable value

Table 5. A web site's colour model with respect to the emotional dimension 'professional'

Attribute	"Professional" web page	Less "Professional"
Dominant colour	Green	Purple
Brightness of dominant colour	Bright	Dark
Saturation of dominant colour	High	Neutral
Secondary colour	Blue	Yellow
Brightness of secondary colour	Neutral	Dark
Saturation of secondary colour	Saturated	Neutral
Contrast of brightness between colours	Low	High
Contrast between Hues	High	Low
Number of colours	3	4
Colour Scheme	Complementary	Monochromatic

Besides observations based on the structure of the network, or performing sensitivity studies on various nodes, other interesting conclusions have been derived. It is possible to get information for every emotional dimension and for combinations of them from the model. For example, a colour scheme comprising no more than 3 colours seems to be the most appropriate to use, and the best chromatic combinations are complementary and analogical. In addition, it seems to be suitable to use low contrast levels between colours. Warm colours are preferable for dominant colours and cold for secondary. Furthermore, if we choose to adopt a monochromatic colour scheme it is preferable to have neutral contrast in brightness. Finally, regarding saturation, it was deduced that the best combination is high-saturated dominant colour with low saturated secondary colour. In order to demonstrate the use of the derived model, the proposed ideal colour factors for a web page required to communicate a sense of 'professionalism' is presented in Table 5. Additionally to this, the differentiation of those colour factors is presented, in case where the complete opposite emotional descriptor is required to be communicated.

The aforementioned analysis results do not comprise the only approach to take advantage of the knowledge embedded in the network. A great analysis tool is the observation of the quantitative dependencies between the nodes of the network. For example, by choosing a combination of emotional dimensions if we desire the presence of the descriptor "attractive" to a high extent, and the presence of the descriptor "professional" to a medium level, the network suggests 'purple' to be selected as a dominant colour with a probability of 17,43%. Setting dominant colour's attribute value to 'purple' the network led us to recommendations related to the other attributes. It suggested using bright warm and highly

saturated purple, combined with a bright low saturated blue for secondary colour. It also purposed usage of a complementary colour scheme but with no more than 3 colours of low contrast. Therefore, the solution space for the designer is significantly reduced to a certain amount of layouts complying with the requirements set in the described example.

4. CONCLUSIONS

In this paper, we proposed an innovative approach to define a model of a web site's colour characteristics associated to desired perceived values. The proposed methodology involves a machine learning approach to create a belief network correlating the colour model of a web site with the values that are attributed to it by its users. We argue that the selection of appropriate colour schemes can lead to effective communication of the desired values for the web site users, thus enhancing the perceived credibility of the web site to be designed. In addition, we consider the proposed model-based approach to have significant advantages compared to the most common approaches, i.e. applying guidelines for colour usage.

The objective of the framework is to extract conclusions related to the specific colour selections and their emotional impact. To evaluate the proposed method we conducted two experiments: one preliminary with a small number of participants and a second one with a considerably large amount of subjects. However, the results reported in this paper, cannot be claimed to be of general value, since neither the number of subjects, nor the number of the test web pages was sufficient to justify general conclusions from the conducted studies. Despite that, it should be stated that many of the findings reported here, confirm earlier empirical rules related to colour's usage and current tendencies in web design, which is an encouraging indication of the validity of the proposed methodological approach.

As for future research, we indent to extend the nature of the forthcoming experiments by altering the physical layout of the used template by differentiating parameters such us different layouts, font sizes, white space used etc. in order to examine the effect of those parameters to the results obtained. Additionally, we intend to use the proposed methodology on actual web sites. Subsequently, to perform other experiments in which to make use of the developed models for the design of specific kinds of web sites, like e-learning applications. With regard to the colour model used, several attributes seem to have more practical usefulness than others, while using the methodology reversively, since the proposed colour model might be considered insufficient by many practitioners involved in web design.

Finally, as an extension to the reported study, one may view the issue of appropriate chromatic combination to a broader context and examine its impact to the perceived information gain in particular environmental conditions in dynamic Internet ecology [18]. We argue that various models of typical web user behaviour, like information foraging [19], based on cognitive models combined with AI techniques, should be extended to take into account colour issues.

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