# Preliminary Study of the Influence of the Spatial Frequency on Colour Appearance.

***Olivier Tulet   Mohamed-Chaker Larabi   Christine Fernandez-Maloigne***

***SIC labotory FRE 2731***

***University of Poitiers***

***Blvd Marie & Pierre Curie, BP30179***

***86962 Futuroscope Cedex***

**{Tulet, larabi,maloigne}@sic.univ-poitiers.fr**

## Abstract

*Today, grant the colour quality of many products is a real challenge. It is for this reason that colours appearance models were developed. These models correct and return the perceived colour independently of the environment. It takes into account many phenomena that could alter the colour perception. However this model does not integrate the influence of spatial frequencies. In this contribution an approach based on psychophysical tests to resolve this problem is describe. These tests are based on a tuning of lightness, chroma or hue angle to quantify the influence of spatial frequency on observer vision. Encouraging results are obtained and described in this paper.*

## Introduction

Nowadays the colour quality is a very important challenge in the industry framework. According to the media, colour does not seem always identical as for example the printed image could be different than the same displayed on a screen. This problem concerns the wysiwyg (what you see is what you get) and for it a number of colour appearance models (CAM) have been developed [1].

The main objective of a CAM is to ensure a reliable reproduction of colours through various media by introducing some characteristics of the Human Visual System (HVS)[2].

A number of CAM exist and are dedicated to a number of applications (textile industry, printing, etc.).These models answer the request of industries which asked for standardized tools. The CIE (Commission Internationale de l'éclairage) has normalized in 1997 the CIECAM97 which was thereafter improved in order to lead to the CIECAM02.

The CAM normalized by the CIE takes into account the environment of a coloured object in order to balance its influence on our colour perception. These CAM are described by the diagram given in figure 1 [5].

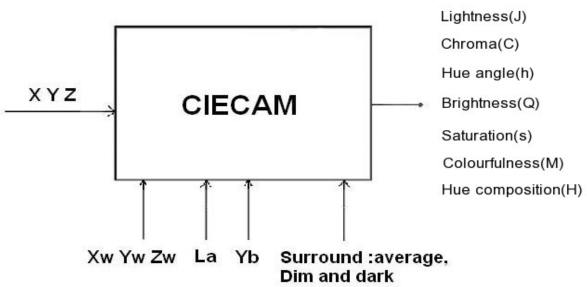



***Figure 1** - Diagram of input/output of a CIECAM.*

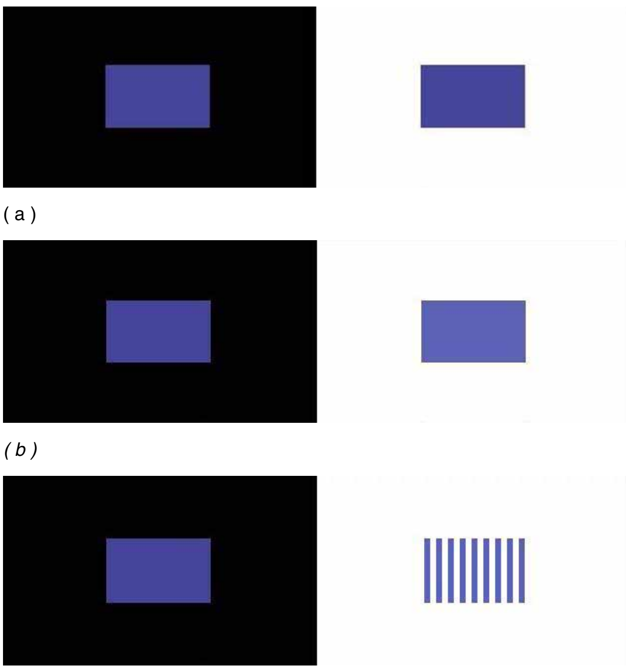
It describes the inputs/outputs of the CIECAM where coloured stimulus values (in XYZ colour space) are converted into perceptual features according to the given environment.

The aim of this transformation is to decorrelate the perception of the stimulus from its environment.

In order to do this transformation, the CAM carries out many complex stages such as chromatic adaptation, cones responses computation, in order to obtain the perceptual features.

The CIECAM02 takes into account a very large panel of phenomena related to the environment of the stimulus like the *Hunt* effect, the *Stevens* effect or Lightness contrast effect, etc [1]. Hence, spatial frequencies are not taken into account by these models.

Figure 2 illustrates this appearance correction thanks to the application of CIECAM02 model. The figure 2-a. shows two examples of the same colour in different backgrounds. These two examples seem different although they are physically identical. The results obtained by the CIECAM02 are given by the figure 2-b. On this figure it possible to notice that the two colours appear now quite similar.



( a )

*( b )*

( c )

***Figure 2** – a: flat stimuli with identical colour and different background. b: corrected colours from (a), c: introduction of spatial frequency to (b).*

The figure 2-c where a spatial frequency has been added to a corrected pattern illustrates that the CAM does not correct the new effect introduced by this frequencies.

This problem is a real challenge because images are naturally constructed thanks to spatial frequencies (as in textures for example). This is why many authors write in their contributions that it would be interesting to integrate this kind of phenomena in the CAM [1, 6, 7].

The goal is to study the effect of spatial frequencies on colour appearance and to try to integrate them into the CAM standardized by the CIE.

The remainder of this paper is organized as follows:

Section 2 describes the proposed approach to achieve the goal described previously, and the experiments for the model construction. Section 3 is dedicated to the description of the results obtained by our experiments. We finish this contribution by some conclusions and we introduce some future works.

## Proposed Approach

As described in the introduction, the goal of this study is to quantify the influence of spatial frequencies on colour perception. This model aims to correct the variation on perception like the current models do with flat stimuli. To develop this model and to introduce the influence of the spatial frequencies on the perceptual features we conduct a psychophysical campaign.

The aim of this study is to extract a model of the behaviors of the HVS with regards to spatially modulated stimuli. These tests allow to measure the variation perceived between a flat pattern with a given colour and a pattern with the same colour, to which a given spatial frequency has been added, on the three output parameters of the CAM.

The experiments are conducted in a dedicated room which respects standardized conditions [3] (lightness, screen calibration…).

The following subsection describes the experiments to be run in order to model the spatial phenomena according to the approach described previously.

### *Psychophysical test room*

To obtain a good quantification of the influence of spatial frequency with psychophysical test we should use a normalized environment.

***Figure 3*** *– Psychophysical test room.*

With regards the recommendations given by standards ISO 3664 [4] and ITU-R 500-10 [3] this environment should respect many conditions as for example the colour of walls which should be neutral or the background chromaticity which should correspond to the illuminant D65.

Our psychophysical test room responds at all of the conditions of this standard and so was used for our experiment.

Another important condition is the choice and the calibration of the screen. For these experiments we use a SONI® FW900 with 16/10 of ratio and a diagonal 24. The colour calibration of CRT tube was realised by the screen calibrator EYE-ONE monitor Mach 1.1 colour calibrator of GretagMacbeth® and verify with help of a measures of a spectro-colorimeter PR-650 SpectraScan.

### *Test pattern*

The binocular vision is optimum for an angular cone of 10-12 visual degree. So for this study rectangular patterns of 10 angular visual degrees were used.

The modulating frequency varies from 1 cpd to 17 cpd. The patterns are constructed with three primary colours (red, green, blue). This property allows obtaining 63 configurations. The figure 4 gives an example of the test on the screen.

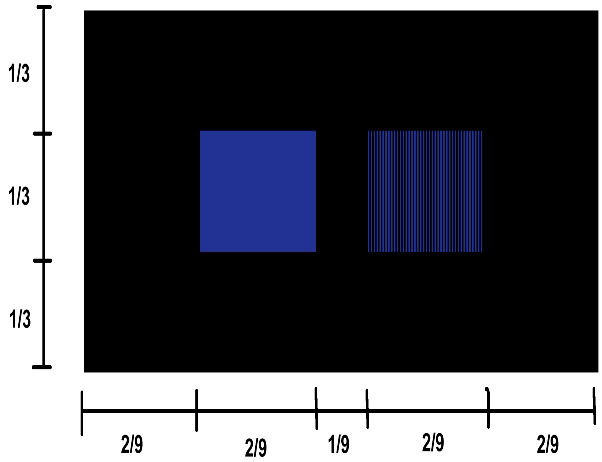



***Figure 4*** *– Example of Psychophysical Test with a blue stimulus and a high frequency.*

This figure shows the spatial repartition of stimulus on the screen for a given distance observers-screen and a screen resolution that corresponds to an angular cone of 18 degrees.

### *Test procedure*

In this psychophysical test, the observer is asked to tune some colour properties such as lightness (J), Chroma (C) and hue angle (h) in order to obtain a perceptual similarity between a flat stimulus and another modulated by a spatial frequency.

This preliminary study has been realized with one background in order to reduce the number of psychophysical runs that are very difficult to construct and are time consuming.

The test procedure is the following:

- Observer is installed in the psychophysical test room at a fixed distance (1m50) from the display after a measure of visual acuity and a verification of colour blindness.
- The test procedure is explained to him with the different tasks to do.
- When the test starts, the observer is asked to tune only one of the three criteria (J, C, h) of the modulated pattern in order to obtain similar colours with the flat one. During the test the criterion is not known by the observer.
- This last step is repeated 63 times with 7 frequencies, 3 primary colours and 3 criteria.

The test sequence is randomized and the starting colour of the modulated stimulus is randomized too.

### *Test observers*

With regard to the recommendations given by ITU [3] the number of observers must be at least 15.

Table 1 gives the repartition between men and women and vision affections.

| | Normal | Myopic | Other affections | Total |
|---|---|---|---|---|
| Men | 10 | 5 | 1 | 16 |
| Women | 2 | 3 | 0 | 5 |
| Total | 12 | 8 | 1 | 21 |

***Table 1***– *Table of observers.*

## Results and discussion

This section gives the results of the experiments described above. These experiments allow characterizing the variation of the colour perception according to spatial frequencies.

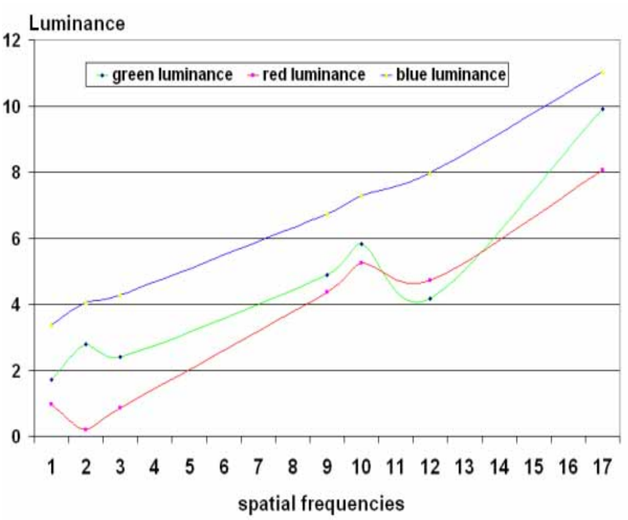



***Figure 5*** *– Perceived Luminance function of spatial frequencies on a black background.*

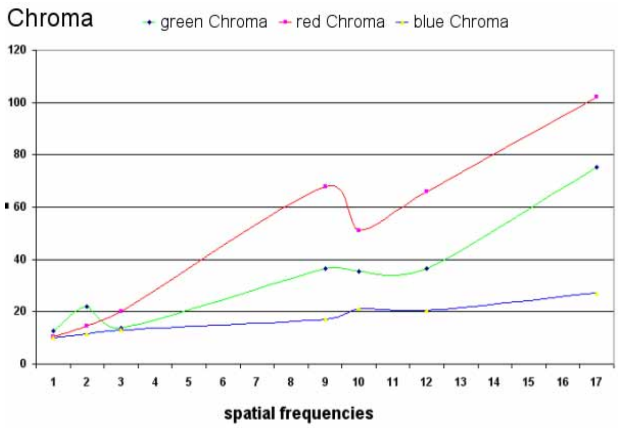



***Figure 6*** *– Perceived Chroma function of spatial frequencies on a black background.*

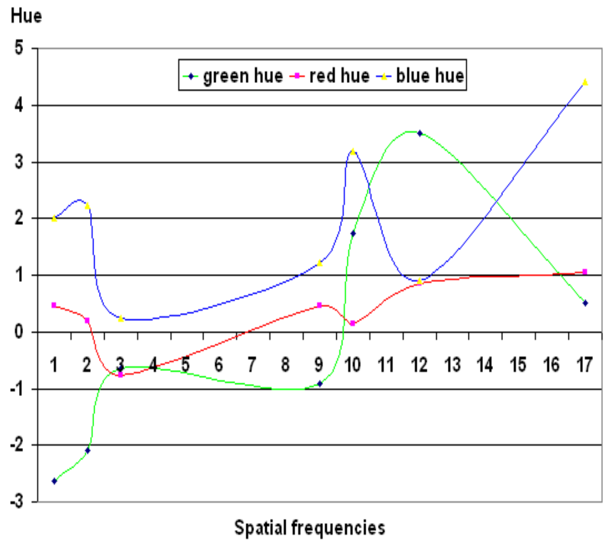



***Figure 7*** *– Perceived Hue function of spatial frequencies on a black background.*

Figure 5, 6 and 7 show the gap perceived by the observer between a flat pattern and a modulated one for the three criteria (J, C, h).

These figures illustrate that on a black background the perceived difference on luminance and chroma increases according to the increases of spatial frequency.

The figure 7 shows that the results obtained for hue should have an angularly behaviour.

This behaviour was foreseeable because of the increase of the black repartition in the pattern. Nerveless this experiment allows quantifying this increase which is not linear. Some incomprehensible phenomena could be seen at medium frequencies (9 to 11 cpd). These problems will be investigated in the future experiments.

The second part of the study enables to look at the influence of the spatial frequencies on men and women. We can see on figure 8 that women seems more sensitive as men to the variation of the spatial frequencies on the red hue.

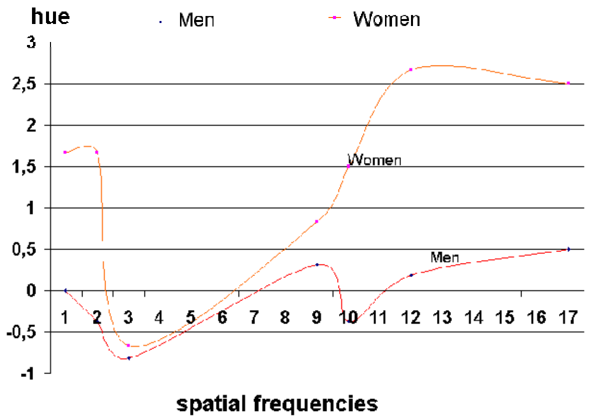



***Figure 8*** *– Red hue perceived by men and women function of spatial frequency on a black background.*

The data obtained by the evaluation campaign has allowed constructing, for instance, a simple model. Sometimes it was a high standard deviation between the data obtained so the Chauvenet criterion [8] was used to delete the incoherent results. The simple model chosen is a curve of degree two.

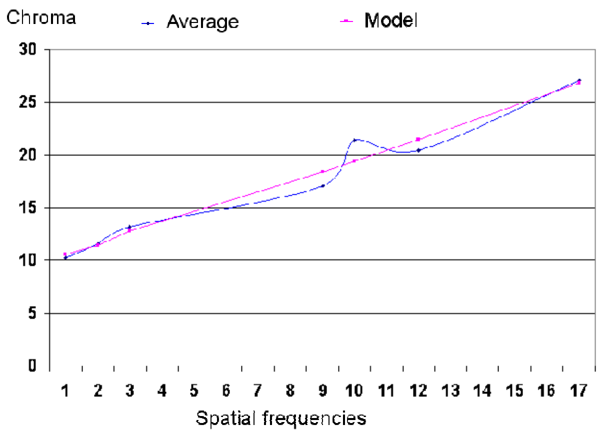



***Figure 9*** *– Curve obtain for Blue chroma and his model.*

Figure 9 shows an example of modelling for the blue chroma. We can see that the model follows the curve of results but there still some problems between frequency 10 and 12.

This model has been integrated to CIECAM02 in order to make a correction of modulated patterns. An example is given by the figure 10.

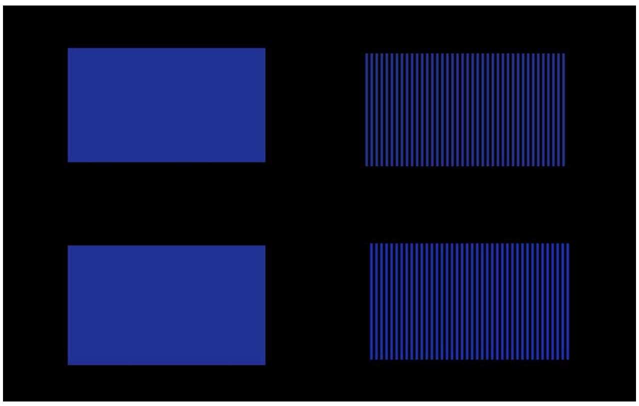


***Figure 10*** *– Example of corrected pattern.*

In this figure we can see on the top the two same colours. On the bottom at left it is the same colour that the upper patches but on the right the colour has been corrected by our model.

This new colour seems closer to the flat colour than uncorrected one.

## Conclusion

In this contribution, a method based on psychophysical tests which allows taking into account the influence of the spatial frequencies on the colour appearance and its results have been described. With these results a preliminary model has been obtained and integrated to the CIECAM02. The results obtained with this model are very encouraging.

It would be interesting to refine the results, the experiments and the model in order to take into account in a precise way the behaviours of the HVS regarding spatial frequencies.

We also should study the influence of the background with the same experiments and use sinusoidal pattern.

Once all these experiments carried out and the results obtained validated, it would be interesting to integrate a correction related to the temporal frequency, which is essential in the management of colour appearance for the moving images.

## References

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## Author Biography

*Olivier Tulet received his master degree in computer science from the University of Poitiers in 2005 and is currently a PhD student in colour models at the same university. His research focuses on the colour appearance modelling and human visual system characteristics.*