Environmental Conditions Causing Change of Colour on the Packaging of Products

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Abstract The primary task of the packaging of goods is to preserve the quality of goods. During distribution it is unavoidable that the products are exposed to harmful environmental effects but the intensity of these effects may be different. We are able to avoid applying the time-consuming and expensive product analyzing methods if we can estimate the quality of the product by examining the quality of its packaging. Our study wants to find out whether we can select those products in which quality deterioration processes might have started due to external environmental effects via the examination of the colour change of the packaging material.

Keywords: packaging, ageing, colour space, rg-histograms,

1. Introduction

The basic concept of our study is to elaborate such a procedure that makes it possible to show the environmental effects on the packaging of food and, indirectly, on the product itself via the change of colour of the packaging.

During transportation of the goods, it is impossible to avoid that they are exposed to harmful environmental effects such as mechanical effects, solar radiation, humidity, moisture, temperature, oxygen, physical contamination, chemical contamination, microorganisms, insects, rodents and people, for a shorter or longer time.

We are to examine the effects of solar radiation on the products through the possible alteration of the colour of the packaging.

Apart from opening the packaging of the products, the technology that is described and tested by us can help to decide what type of environmental effects have reached the given product and for how long, whether quality deterioration has been caused by these effects. If we can show it on the packaging that the product has been exposed to harmful effects, the product has to undergo further inspection.

1.1. Elements of packaging

First and foremost, it is important to set the basic terms of packaging. Packaging has two meanings. In the one hand it means all the processes with which the cover of the goods is made, on the other hand, it means all the materials and devices that make up the cover. Traditionally, packaging has three functions:

- the protection of the product against external environmental effects
- encasing the product into a safe and practical unit
- satisfying the costumers' needs and product promotion

These functions may predominate the phases of the distribution chain with different emphasis. When we talk about packaging it is essential to distinguish between packaging materials and packaging devices. Materials include metal, wood, glass, paper and plastic, which are used in packaging. The packaging devices are packets that you can close, tubs, hollow-ware, pots, boxes, drums, etc. that are made of the above mentioned materials and become waste after the product has been consumed. [1]

2. Elements of colorimetry

Second, it is essential to define the basic colorimetry terms in order to understand the process of our new method.

Colour can be defined as a perception in our brain. We need optical radiation (what we commonly refer to as light) which, after entering our eyes and being absorbed by our retina induces nervous signs. In case of monochromatic radiation the perceived colour depends on the wavelength of the radiation in case of complex radiation the perceived colour is determined by the amount of energy the radiation transfers in different wavelength ranges. Colour can be defined as a property of an object and this property shows in what ratio the object absorbs or reflects the different-wavelength components of the light that shines it. However this refers to a property of surfaces.

The spectrum of a light source, the reflectance function of a colour sample, can be defined as the amount of energy transferred on a given wavelength or rather how big its radiated power is. Any spectrum as colour stimuli can be described with three values, R (red), G (green), B (blue), because of the types of receptors in the human eyes. One of these cones is sensitive in the short, the other in the medium, and the third in the long wavelength domain. In case of displays, printers and digital cameras, we are using now the sRGB (standard RGB) system developed by HP and Microsoft instead of the CIE RGB colour space which was developed by the International Commission on Illumination in 1931 because it fits better to the modern hardware [2]. The gamut of the sRGB system in other words the group of colours that can be presented in the colour space is shown in figure 1.

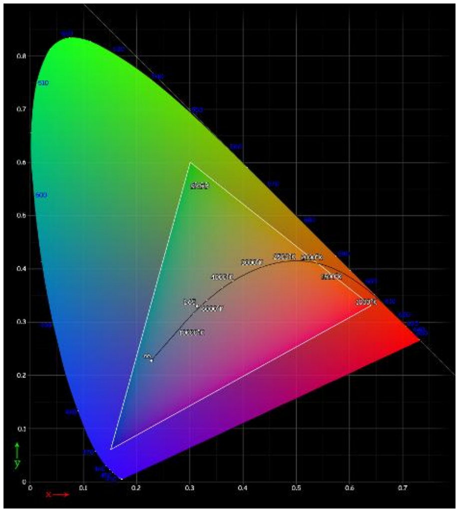

Figure 1. The gamut of the sRGB colour space

Although the metamer colours are perceived in the same way, their spectral power distribution is different. The sameness may be true for more colours. If colour A is identical with colour B, and colour B is identical with colour C, then colour A is identical with colour C as well. Therefore, it means that the colour determined with values R, G, B can be provided with several spectra.

2.1. Gamma correction

In CRT (Cathode Ray Tube) monitors, the light intensity varies nonlinearly with the applied anode voltage (Figure 2). Altering the input signal by gamma correction can cancel this nonlinearity, such that the output picture has the intended luminance [3].

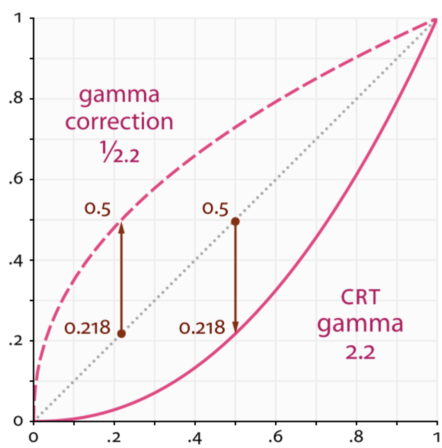

Figure 2. The gamma correction of CRT monitors

3. Tests on product samples

Our tests have the starting assumption that the colour of the packaging of different product samples that are exposed to different environmental effects will change even if slightly, differ from the original one. This change may be unperceivable for the human eyes, so the original and the altered samples are metamers for us. It is possible to reveal the difference between the original samples and the ones altered by external effects with our method.

As the first step, we examined how a bus season ticket and a luncheon voucher had changed in the bright sun and in a freezer. The samples spent 8-8 hours in the sun and in the freezer, then, they were digitalized and compared to the original reference samples.

Second, the changes on a chocolate wrapper and on a milk carton were tested. The products were lit to simulate the fading effect of the Sun in the laboratory. We used an *Accelerated Weathering Tester*, *QUV Spray* machine and a device called *Xenonstahler*. The former device was used to examine the effect of the UV-light. The samples were lit for 8 hours, they were conditioned for 5 hours, and they were lit for another 8 hours. The samples spent 21 hours altogether under the Xenon-light in the other device. Then the samples were photographed in the same conditions and the digital images underwent a comparative process.

Furthermore, it was examined how the packaging had changed after being lit with UV-light for different time periods. In this case, a fruit juice carton and a medicine carton were lit for 8, 24 and 48 hours and digitalized every time. After digitalization, we compared the samples with our method.

3.1. Testing method

The essence of the method is to make a digital fingerprint of every picture and to compare these fingerprints. The method shows the difference between the samples which are metamers for the eyes. This digital identification is determined as it follows.

The R, G, B values of each pixel of the image under examination are read and these values are normalized (1).

$$r = \frac{R}{R+G+B},\quad g = \frac{G}{R+G+B},\quad b = \frac{B}{R+G+B} \tag{1}$$

$$r + g + b = 1 \tag{2}$$

It is enough to have two data to describe the colour of a pixel as the third value can be calculated with the help of equation (2).

$$V_{linear} = \begin{cases} \dfrac{V_{srgb}}{12.92}, V_{srgb} \le 0.04045 \\ \left(\dfrac{V_{srgb} + 0.055}{1.055}\right)^{2.4}, V_{srgb} > 0.04045 \end{cases} \tag{3}$$

In order to eliminate the effect of the gamma correction and to obtain linear R, G, B colour space, inverse gamma transformation of the scanned values is performed. The sRGB gamma cannot be expressed as a single numerical value (3), where V_{linear} is R_{linear}, G_{linear} or B_{linear} and V_{srgb} is R_{srgb}, G_{srgb} or B_{srgb} .The frequency of the read and normalized r-g value pairs appearing in the picture are fixed in a two-dimensional matrix. The row and column indices of the matrix are corresponding to the r g values, so the value in the rth row and the gth column of the matrix shows that how many of the given r-g pairs can be found in the picture. Making a graphical presentation of the matrix gives the unique digital fingerprint of the given photograph. This r-g plot is an important property of the pictures.

For the sake of a better comparison, we even derived the difference between the rg-histograms of the original and the examined image, the positive and the negative differences are shown with different colours.

The program was written in Python [4] language with the OpenCV modul. The reason why this language has been chosen is that it makes easy to code the algorhythm quickly and efficiently, moreover, it has the necessary tools to handle digital images.

In order to describe the differences between the rg-histograms numerically, the embedded functions of OpenCV were applied. Correlation, chi-square [5] and optical flow [6] were calculated. The latter described the differences due to the shift of the samples and of the patterns on the samples. The average length of the vectors of optical flow was weighted with the values of the rg-histograms, so the shifts of the brighter parts were considered with higher weight. Besides numerical description, the vectors of optical flow were given graphically. The following figure shows the graphical presentation of the optical flow with an enlarged section (Figure 3). Further on, these figures will not be displayed owing to lack of space. The smaller value of correlation refers to a bigger difference, on the other hand, the higher values of the chi-square and the optical flow refer to bigger differences among the tested samples.

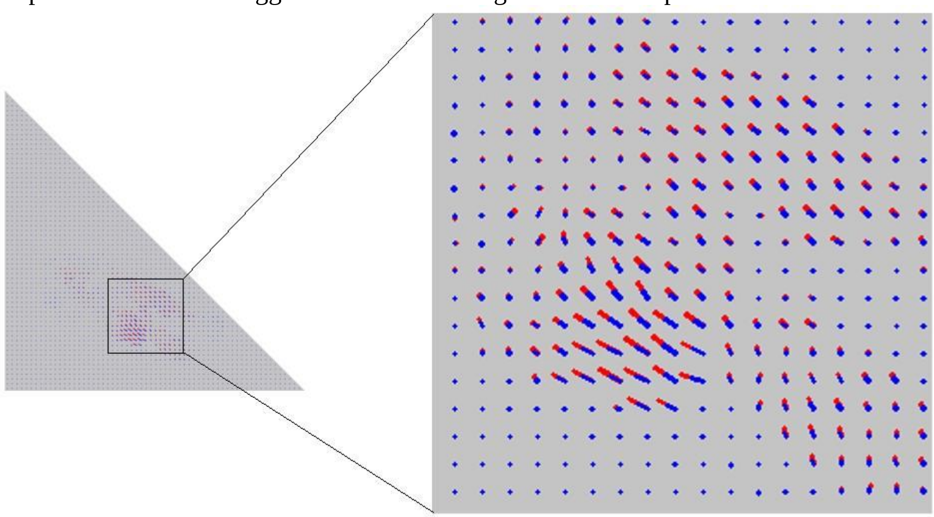

Figure 3. Graphical representation of optical flow

3.2. The results of the tests

The final results of the tests are as follows. Examining the season ticket and the voucher first, it became unambiguous that the method helps to show the changes of colours. (Table 1). The second rows of the tables show the samples, the third row shows their rg-histogram, and the fourth one shows the rg-histogram of the difference from the original sample. The values for *r* are plotted on the horizontal axis, from left to right, the values for *g* are plotted on the vertical axis. It is clear from the numbers in the last row that the method reveals the difference that is not perceived by the eyes. There is a significant, numerical difference between the sample lit by the sun and the reference sample. In case of freezing, the difference is less significant, but verifiable.

Table 1: Bus season ticket

<table>
<tr><td colspan="2">Sun-lit</td><td colspan="2">Original</td><td colspan="2">Frozen</td></tr>
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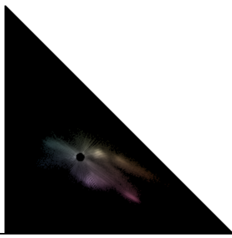
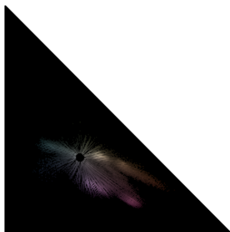
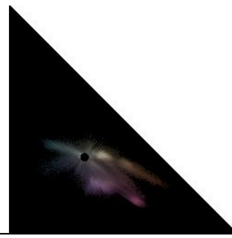
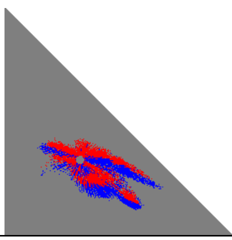
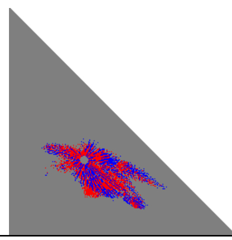
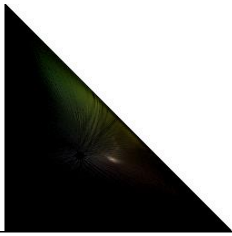
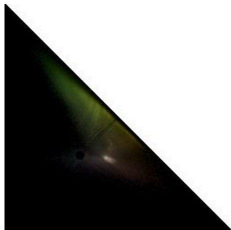
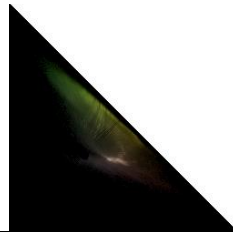
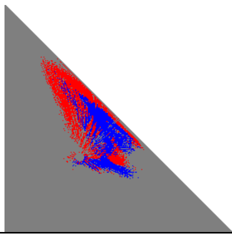
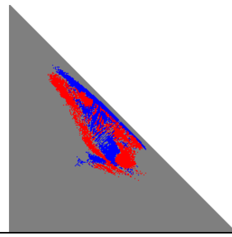
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">correlation: 0.6836
chi-square: 1.4661
optical flow: 3.6516</td><td colspan="3">correlation: 0.9544
chi-square: 0.1565
optical flow: 0.8370</td></tr>
</table>

The tests on the luncheon voucher led to similar results. The changes were provable and the sample lit by the sun changed more in this case as well.

Secondly, we show how the samples have changed in the laboratory under the xenon light and the UV light (Table 2). Similarly to the above, the pictures of the samples are shown first, then the rg-histograms, third, the graphical presentation of the differences from the original samples, finally, the figures.

Table 2: Milk carton

Xenon light	Original	UV light
		
		
		
correlation: 0.2642 chi-square: 4.7413 optical flow: 2.6028		correlation: 0.6489 chi-square: 1.7879 optical flow: 1.3083

Our method resulted in such differences on the other sample that are well-described with figures, though the reference sample and the sample exposed to light seened to be the same.

Next, it is shown how the sample changed when it was exposed to UV light for different time periods. Even spending eight hours under the UV light caused a minor change, and the change of colour continued increasing monotonously (Figure 4). The tendencies were similar in case of the other sample and when the resolution was halved during digitalisation.

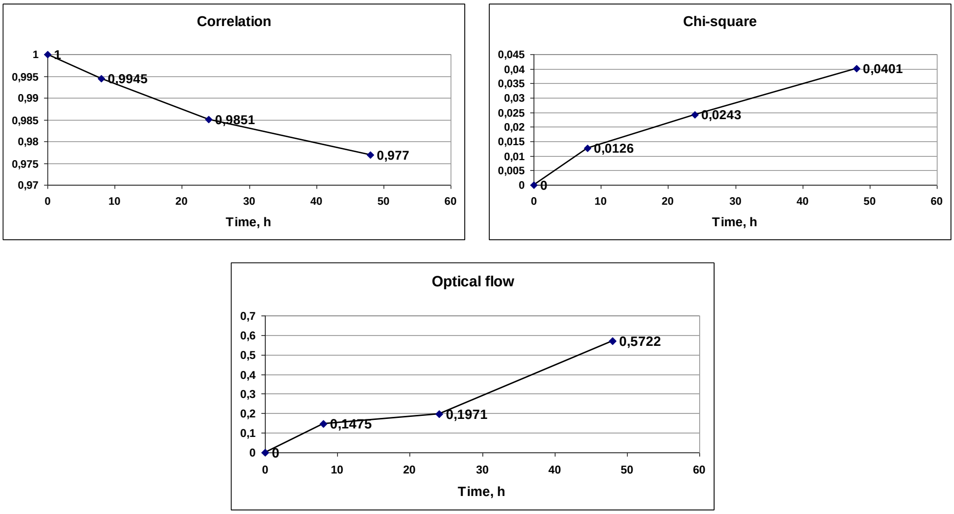


Figure 4. The changes of numerical data in time

Finally, we examined how big the differences were after having digitalised the same picture with a scanner or a camera three times. We wanted to know whether it causes a significant difference in the histograms if we modify the position of the sample on the scanner a little bit, or rotate it with 180°, what difference appears when we modify the position of the camera. Finishing these tests, we could claim that the correlation results, which were higher than 0.99, the chi-square results, which were under 0.01 and the optical flow results, which were around 0.1, proved that the method was less sensitive to differences due to measuring inaccuracy.

4. Summary

The method described briefly in the article makes it possible to decide whether a product has spent too much time in the sun. This method provides a pre-test in those cases when we assume that the product has not been stored properly. If the method shows that the product has not been stored in proper conditions, further examinations are necessary.

Acknowledgement

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