Colour modelling as a tool for wood grading

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ABSTRACT

Colour is a property of wood which influences its quality. The colour, as a scalar quantity, is represented as a dot in a colour space. From the view point of wood species wood is a non-homogeneous material, thus a cluster of data represents wood colour of one wood species. The colour of wood does not solely depend on the colour of macroscopic features but also on the colour of defects. This fact can be utilized in wood grading according to colour. The grading of wood according to colour requires detailed description of a wood colour. An attempt to give a precise definition of wood colour is it's modelling, which is based on statistical approach. This approach is widely used in the description of other wood properties. In the article we distinguish three models of beech and spruce colour – parallelepiped, sphere and ellipsoid in CIELAB space. We used these models for distinguishing species colour at given alpha level. We devoted special attention to beech wood which contained false heartwood and the wood colour models were evaluated with this defect.

INTRODUCTION

Beech (Fagus sylvatica L.) and spruce (Picea abies L.) are widely used species in industry. These species are processed in many branches of the wood industry due to their availability and properties. Especially, beech wood is processed into high value products, furniture, flooring, etc. Sometimes the emphasis is put on the colour of high value product which is standard without discolouration. Wood colour is influenced by wood species, wood defects, conditions of illumination, effects of high temperature or radiation, chemical substances and so on. If the discolouration does not occur on the whole surface of the material the grading is one of the processes to homogenize and maintain its colour. The other advantage of grading is the possibility to rearrange the stack of material according to demands of customers and designers. On the other hand we can perform grading according to colour only to some extent because wood colour is a non-homogeneous quantity from the viewpoint of wood species. From the viewpoint of machine grading according to colour we need to define wood colour. Statistical approach is an attempt to solve this problem. Fast grading of surfaces that utilized statistics of colour coordinates was described by López et al. The modelling of colour was the aim of work Babiak a Hrčka (2005) and Hrčka (2008). The following articles Katuščák and Kučera (2000), Babiak et al. (2002) dealt with the statistical data of the colour coordinates of some wood species. Grading of beech parquets according to the reflection in the visible range was the subject of interest of Vienonen et al. (2002).

The aim of the article is to outline the possibilities of wood grading according to its colour.

MATERIAL AND METHODS

The colour space CIELAB is defined by three coordinates L*,a*,b*. Lightness L* is directly proportional to luminance (Habel et al. 1995) and characterizes grey colours. If the lightness value is zero then the colour is black. If the lightness value is 100 then the colour is white. All the grey colours are between black and white. The coordinate a* represents hues between red (positive values of a*) and green (negative values of a*). The coordinate b* represents hues between yellow (positive values of b*) and blue (negative values of b*). The plane a*b* in polar coordinates is defined by hue h_{ab} (the angle with the positive part of the axis a*) and by saturation C^*_{ab} (distance from the coordinate L*), Fig. 1.

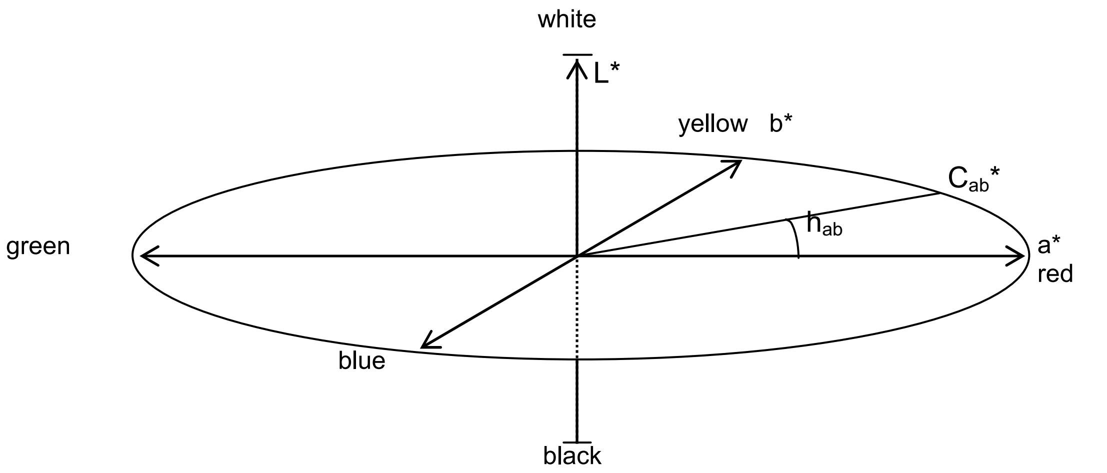

Figure 1: CIELAB colour space (constant saturation)

The colour change in the CIELAB space is defined by the equation:

$$E_{ab} = \sqrt{(L^*_1 - L^*_2)^2 + (a^*_1 - a^*_2)^2 + (b^*_1 - b^*_2)^2} \qquad (1)$$

The wood colour is a heterogeneous quantity and it represents a cluster of data in the CIELAB space. We interpret this relation (1) as the surface of a sphere with its centre in the colour 1 and with radius E_{ab} (Hrčka a Babiak 2004). Let's put the centre of the sphere to the mean of the wood colour coordinates $\left[\bar{L}^*, \bar{a}^*, \bar{b}^*\right]$.

The radius is determined by the equation:

$$E^2_{ab} = \frac{(L^* - \bar{L}^*)^2 \sigma^2_{L^*}}{\sigma^2_{L^*}} + \frac{(a^* - \bar{a}^*)^2 \sigma^2_{a^*}}{\sigma^2_{a^*}} + \frac{(b^* - \bar{b}^*)^2 \sigma^2_{b^*}}{\sigma^2_{b^*}} \qquad (2)$$

where $\sigma^2_{L^*}, \sigma^2_{a^*}, \sigma^2_{b^*}$ are the variances in the coordinates.

Let's suppose the normal distribution of the wood color coordinates, then:

$$E_{ab}^2 = u^2\left(\sigma_{L*}^2 + \sigma_{a*}^2 + \sigma_{b*}^2\right) \quad (3)$$

u is the critical value of uniform normal distribution

This consideration is extended by the consideration with an ellipsoid with its center in the mean of the color coordinates. Its axes are identical with the directions of the eigenvectors of the data co-variation matrix:

$$1 = \frac{(q*-\bar{q}*)^2}{3u^2\sigma_{q*}^2} + \frac{(r*-\bar{r}*)^2}{3u^2\sigma_{r*}^2} + \frac{(s*-\bar{s}*)^2}{3u^2\sigma_{s*}^2} \quad (4)$$

where $(q*, r*, s*)^T = V^{-1}(a*, b*, L*)^T$ (5)

V^{-1} is the inverse matrix of the eigenvectors of the co-variation matrix, $\bar{q}*, \bar{r}*, \bar{s}*$ are the average values of the transformed coordinates, $\sigma_{q*}^2, \sigma_{r*}^2, \sigma_{s*}^2$ are the variances in the coordinates.

We used spruce and beech radial boards of the dimensions of 25x250x1000 mm^3 (TxRxL) with unusual color as a longitudinal narrow streak. Beech samples with unusual coloration were distinctly dark brown and easily distinguished from the slightly red beech wood. The boards were dried by microwave drying. During 10 days we took samples 25x250x100 mm^3, which were measured for color coordinates with the digital camera KODAK 256 Zoom under illumination D65 – Atlas TLL 1200 using the method described by BABIAK et al. (2002). One observation represented an area of 4,5x4,5 cm^2.

RESULTS AND DISCUSION

Table 1 lists the statistical data of colour coordinates of spruce and beech wood in CIELAB space.

Table 1: Colour coordinates of spruce and beech wood in CIELAB space

Species		a*	b*	L*	$C*_{ab}$	h_{ab}
spruce	mean	1,51	10,68	92,92	10,79	81,93 °
	var. coefficient/ [%]	24	4,75	0,47	4,51	2,49
beech	mean	3,85	9,36	90,33	10,16	67,47 °
	var. coefficient/ [%]	23,22	13,33	1,3	11,58	8,33

The rectangular parallelepiped is constructed by means and standard deviations of the colour coordinates at given alpha level assuming normal distribution of these colour coordinates.

Fig. 2 contains the histograms of distance E_{ab} from the average values of spruce, beech and beech with discolouration.

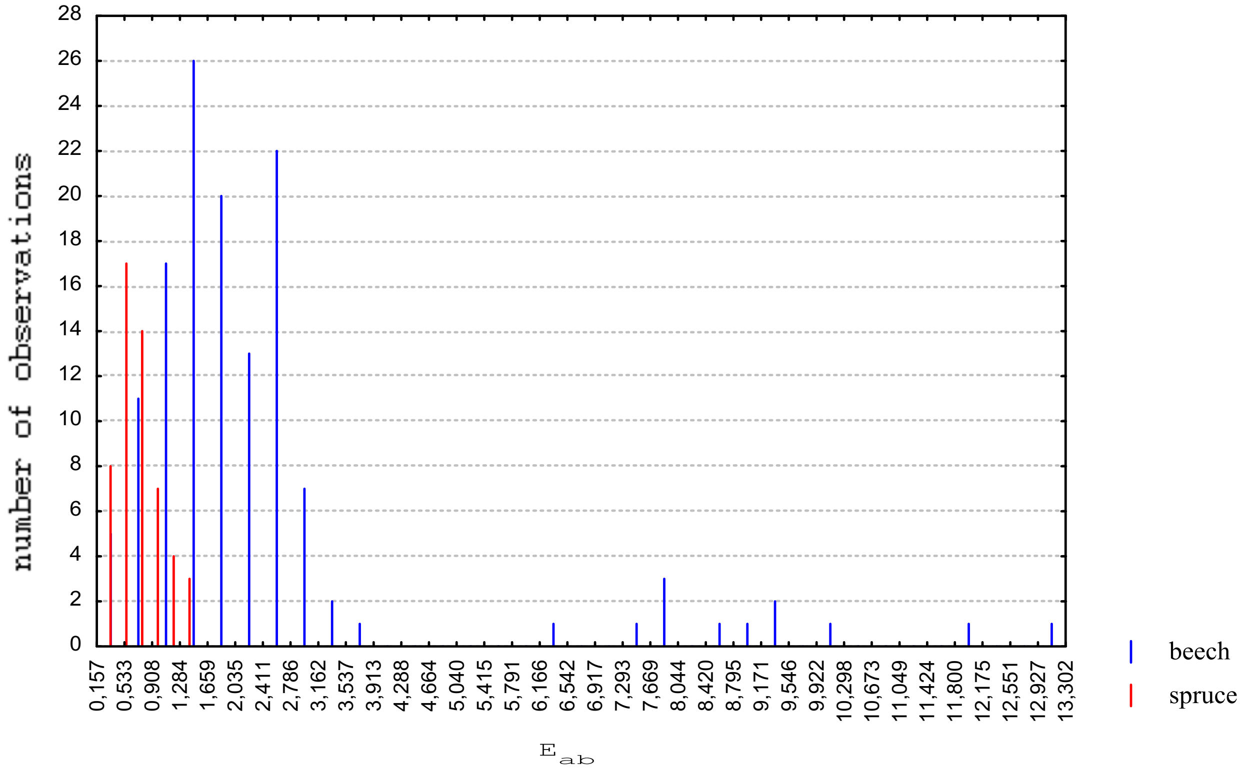

Figure 2: Histograms of distance E_{ab} of spruce, beech and beech with discolouration

These histograms indicate the variability of spruce and beech colour, increased heterogeneity of beech in comparision with spruce and easily distinguished discolouration of beech wood. Let critical value of colour coordinates be 1,7 (0,1 alpha level). Then the sphere radius of spruce is equal to 1,68 and for beech wood is 3,29. The distance Eab of discolouration exceeded the beech sphere radius. This is depicted in the histogram fig. 2.
The ellipsoid extends the consideration with sphere. Transformation matrix V^{-1} for spruce is:

$$V^{-1} = \begin{pmatrix} -0,091391 & 0,825145 & -0,557480 \\ 0,724703 & -0,328840 & -0,605532 \\ 0,682973 & 0,459348 & 0,567932 \end{pmatrix}$$

and for beech:

$$V^{-1} = \begin{pmatrix} -0,297358 & 0,670042 & 0,680163 \\ -0,638859 & -0,669044 & 0,379788 \\ 0,709533 & -0,321595 & 0,627008 \end{pmatrix}$$

The change of the coordinate system is due to its turning around the origin and the directions of the new coordinates are the directions of the eigenvectors of the co-variation matrix. Then the ellipsoid for spruce is:

$$1 = \frac{(q*+43,07)^2}{1,88} + \frac{(r*+58,77)^2}{1,06} + \frac{(s*-58,73)^2}{0,52} \tag{6}$$

and for beech:

$$1 = \frac{(q*-56,97)^2}{4,60} + \frac{(r*+32,73)^2}{3,24} + \frac{(s*-62,81)^2}{0,82} \tag{7}$$

Fig. 3 depicts the colour of spruce and beech and ellipsoids' projections to planes of the CIELAB colour space.

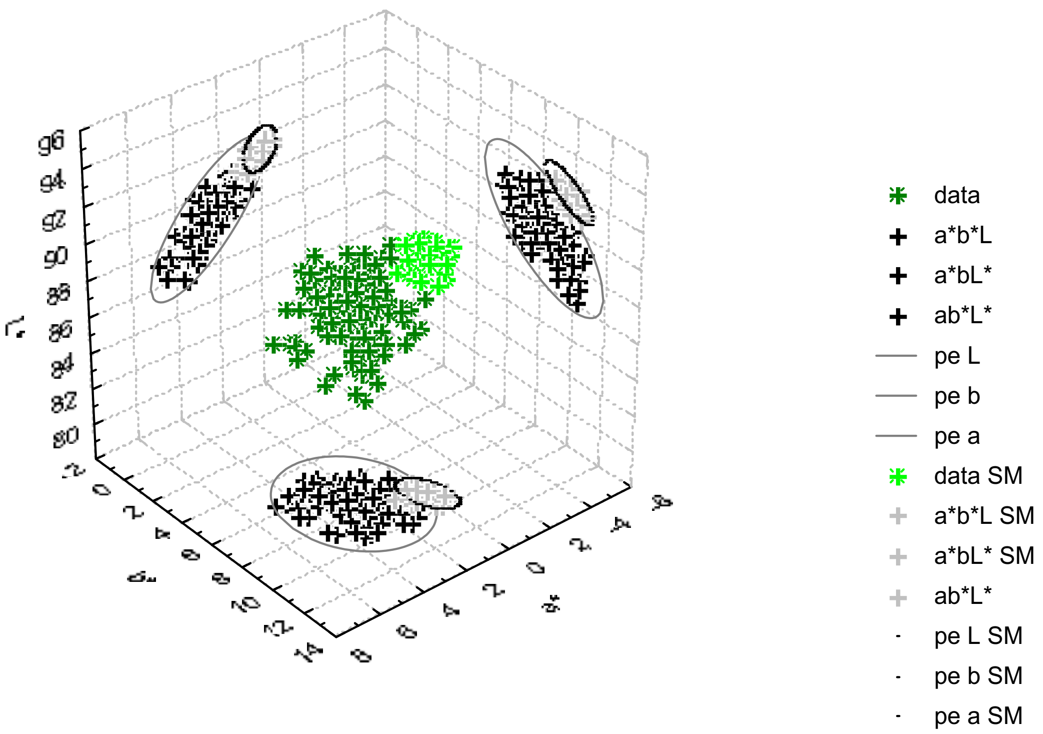

Figure 3: Spruce(SM) and beech colour data and projections of ellipsoids in CIELAB space

We conclude that spruce and beech can be distinguished according to colour because their ellipsoids do not overlap as it is indicated in the b*L* plane.
Fig. 4 depicts the colour of beech with discolouration and sphere’s and ellipsoid’s projection to the planes of the CIELAB space.

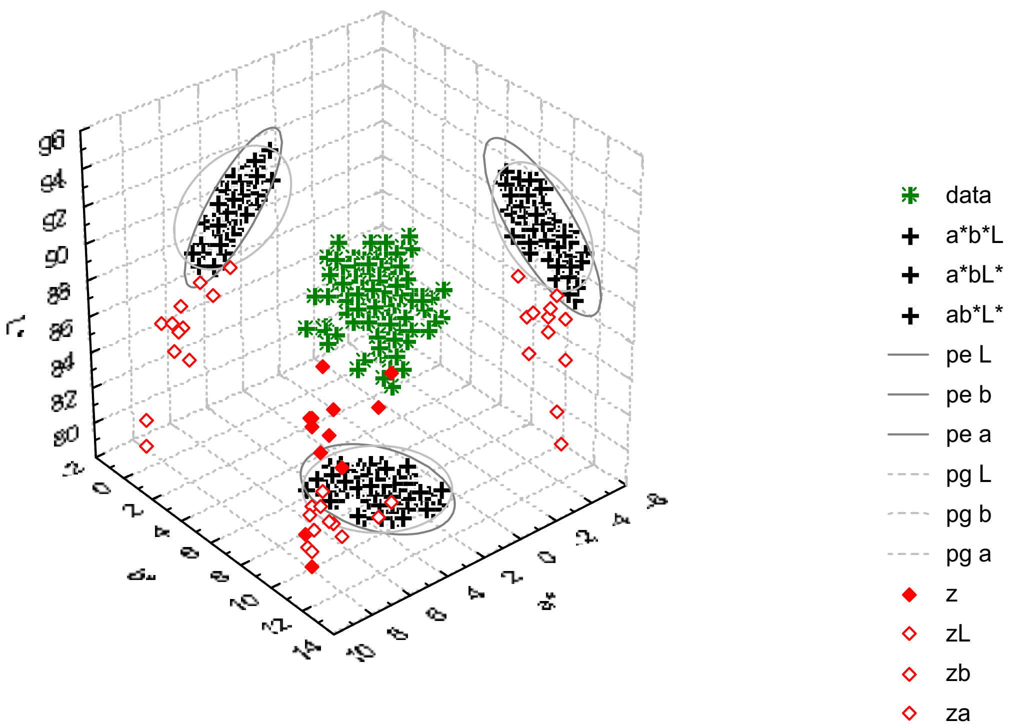

Figure 4: Beech colour data with discolouration (z), with their projections to the planes of CIELAB space. (sphere (g), ellipsoid (e))

Usually coloured samples fall into the ellipsoid area. Unusually coloured samples are outside of the ellipsoid. The colour data of beech wood are evenly distributed around the ellipsoid. Unusually coloured samples directs from the ellipsoid and we conclude, that at appropriate alpha level don't fall into the ellipsoid.

The data of lightness in this work are the highest from those in literature review. Vice versa coordinates a* and b* are the smallest. These facts can be explained by mixing of strike and return light which together fall into sensor.

CONCLUSIONS

In the article we described the possibility of grading of spruce and beech wood according to colour. Spruce and beech can be distinguished according to colour. Distribution of the colour data around the ellipsoid is distributed evenly for the usual beech wood colouration. Discolouration, as one-side buckling from ellipsoid, did not fall into it. The results can be used for pass/fail decisions during grading of spruce and beech wood.

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