Utilization of Multispectral Images for Meat Color Measurements

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Abstract. This short paper describes how the use of multispectral imaging for color measurement can be utilized in an efficient and descriptive way for meat scientists. The basis of the study is meat color measurements performed with a multispectral imaging system as well as with a standard colorimeter. It is described how different color spaces can enhance the purpose of the analysis - whether that is investigation of a single sample or a comparison between samples. Moreover the study describes how a simple segmentation can be applied to the multispectral images in order to reach a more descriptive measure of color and color variance than what is obtained by the standard colorimeter.

1 Introduction

The ability to measure color is important within meat product development and production due to color's great impact on consumer acceptance. The traditional method of assessing color by using either a colorimeter or a spectrophotometer is cumbersome and does not have the ability to capture the color variation across a sample [4]. Measuring color from images is a way of overcoming this issue. Earlier studies have shown that RGB images can be used for color assessment in the CIELAB color space as reviewed in [6]. The disadvantage when using RGB images is that they depend on the sensitivity of the camera employed and cannot be directly transformed to sRGB in a consistent manner [2]. The use of multispectral images for color assessment has previously been shown in [5]. Here, multispectral images are used to gain the advantage of additional spectral information compared to the three bands of the RGB images. The multispectral information also gives the advantage of simple mapping to the CIELAB color space. In [5] it is also shown how the meat colors assessed by the multispectral vision system were less dependent on the nature of the sample – samples of both fresh and processed meats were considered.

In this paper an extension of the study performed in [5] is presented. It will give examples on how the multispectral image information can be utilized in the color assessment of meat products. This involves visualization, segmentation, and quantification based on the segmentation. The segmentations are aimed at being applicable in the daily work of a meat scientist.

2 Materials and Methods

The study employs a VideometerLab for acquisition of the multispectral images and established statistical methods for data analysis. A standard colorimeter is applied for comparison with the measurements of the multispectral imaging system.

VideometerLab VideometerLab is a multispectral imaging device that illuminates a given sample under an integrating sphere, which causes diffuse illumination and a minimum of shadows on the sample. 19 spectral bands are considered ranging from 410 nm to 955 nm with 12 bands in the visible range. The resulting images have a spatial resolution of 2056×2056 pixels. Each spectral band is generated by a number of LEDs equally spaced at the equator of the sphere.

Color is measured by mapping the multispectral information from the visual bands to the CIE XYZ color space. This mapping is determined by finding a linear fit of the spectral bands to the CIE XYZ color matching functions. This simple idea is illustrated in Figure 1. The mapping, also denoted *photometric imaging model* (PIM), is described and validated in [5]. By mapping to the CIE XYZ color space it is possible to use standardized transformations to any other color space. In food science the CIELAB color space is often used, and will therefore also be considered in this study. In this case the transformation is given as [3]

$$\mathrm{L}^* = 116 f\left(\frac{Y}{Y_n}\right) - 16 \tag{1}$$

$$\mathrm{a}^* = 500\left(f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right)\right) \tag{2}$$

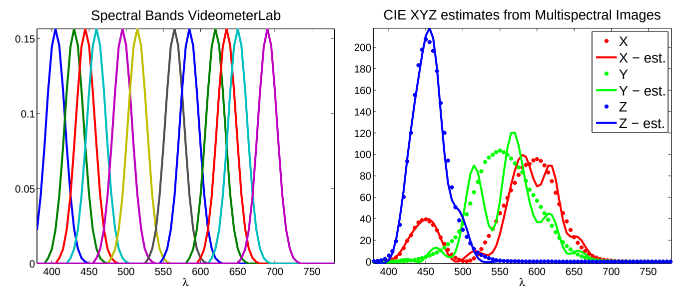
$$\mathrm{b}^* = 200\left(f\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right)\right) \tag{3}$$

with

$$f(q) = \begin{cases} q^{1/3} & q < 0.008856 \\ 7.787q + 16/166 & \text{otherwise.} \end{cases} \tag{4}$$

Colorimeter The colorimeter we apply in the experiments is the Minolta CR-300 chroma. Four circular sites with a diameter of 11 mm are measured with the chroma meter. When performing measurements with the chroma meter it is important to hold the instrument perpendicular to the surface of the object. The pressure of the instrument can also influence the measurement, so the operator has to be careful when handling the instrument. The chroma meter returns the L*, a*, and b* values of each point measurement.

Segmentation The advantage of applying the photometric imaging model using a multispectral vision system is that it will be able to capture the color variation across a sample. One way to take advantage of this is to perform a segmentation



(a) (b)

Fig. 1. The spectral bands of the VideometerLab and the fit of these to the CIE XYZ color matching functions.

of the images. In this study a simple segmentation is performed by pixel-wise classification based on linear discriminant analysis. The classification rule for each pixel will be estimated by

$$S_i = \boldsymbol{x}\hat{\boldsymbol{\Sigma}}^{-1}\hat{\boldsymbol{\mu}}_i - \frac{1}{2}\hat{\boldsymbol{\mu}}_i'\hat{\boldsymbol{\Sigma}}^{-1}\hat{\boldsymbol{\mu}}_i + \ln(p_i), \quad i = \{1, \ldots, n\}. \tag{5}$$

$\boldsymbol{\mu}_i$ is the mean of the i'th class, $\boldsymbol{\Sigma}$ the pooled covariance of all classes and p_i the prior probability of observing class i. The segmentation uses information from all spectral bands. Training areas are used for estimating $\boldsymbol{\mu}_i$ and $\boldsymbol{\Sigma}$. A segmentation can lead to additional information as, e.g. a texture measure [1].

3 Results

This section presents how it is possible to change the color scale in order to enhance the purpose of the color assessment by the images, example results of the segmentation and a simple example on how to use the segmentation for quantification.

Visualization For the scientist working with color assessment it is important to be able to get a rapid feeling of the color variation across the sample of interest. Different ways of visualization can be of interest. First of all it is important to consider the three components of the CIELAB color space separately. Hereafter the color scale has to be chosen. For meat samples especially the a* component describing the amount of red color is important. Fig. 2 shows two different choices for displaying the variation of each color component. The first is based on the range of the CIELAB space – L* from white to black (0 to 100), and a* from green to red and b* from yellow to blue (-120 to 120), whereas the second is an arbitrary scale, enhancing the areas with a high or low L*, a* or b* value. The first scale is advantageous when comparing different samples, since the scale is the same for each image, whereas the second scale is preferable when only one sample is of interest.

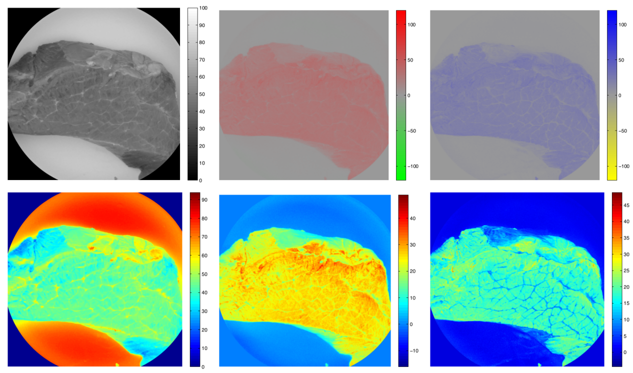


Fig. 2. Images of round of veal for each of the three color components L*, a*, and b* with two different color scales.

Segmentation The traditional method for assessing color with a colorimeter does not take full advantage of the spatial information that is gained by using a multispectral vision system. A segmentation is an excellent choice for highlighting the variance of color within a certain region of interest in the images. An appropriate segmentation for the meat color experiments could consist of segmenting background, fat and meat.

The segmentation will, as opposed to the photometric model, make use of all the multispectral bands, also the NIR ones. A simple segmentation by means of linear discriminant analysis is applied at the pixel level. An example of training areas used for estimation of mean and covariances of the three classes are seen in Fig. 3. The segmentation aims in this case at a mask only representing meat. Fig. 4 shows how the final mask is used on the CIELAB images to illustrate the distribution and variance of the L*, a*, and b* colors over the sample. Moreover L*, a*, and b* images for cooked ham, where only the background is removed, are shown. This illustration underlines the difference in consumers' view on the two types of products: For fresh meat the color of the meat excluding the fatty tissue is important, whereas for the processed meat types, the distribution of color across the entire sample is central.

Quantification The segmentation above can be utilized by finding simple statistics such as mean and variance based on the mask. For the example of veal fillets in Fig. 4 and other types of meat we find standard deviations as seen in Table 1. The corresponding values from the four sub-samplings of the colorimeter measurements are stated as well. The standard deviation of the photometric imaging model is far higher than that of the colorimeter measurements and the vision system therefore gives a better assessment of the color variation of the sample. A test for the significance level of the differences in variance is performed

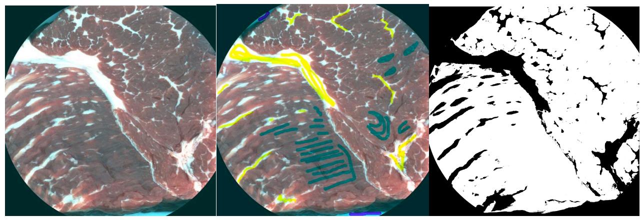


Fig. 3. Left: Pseudo RGB of round of beef. Middle: Training areas indicated. Right: Segmentation of meat and fat.

with a null hypothesis stated as $H_0 : \sigma_{PIM} = \sigma_{CM}$ vs. $H_1 : \sigma_{PIM} \neq \sigma_{CM}$. Since the number of observations is far higher for the multispectral images, the F-statistic for testing the differences in variances for the two methods is in all cases $F_{0.95,N_{PIM},N_{cm}} = 13.90$. Table 1 states the F values of the test and corresponding p values at a test level of 5%. The p values support or assumption, albeit the test values for the L* component are less significant than for the a* and b* values.

This simple analysis shows that the possibilities of working with multispectral images are far greater than the site measurements of a colorimeter. Additionally more complex segmentations can be done. For items with large color variation, e.g. minced meat or salami, a segmentation like this offers the opportunity to obtain actual measures of the color of e.g. meat and fat, in contrast to what the colorimeter can offer.

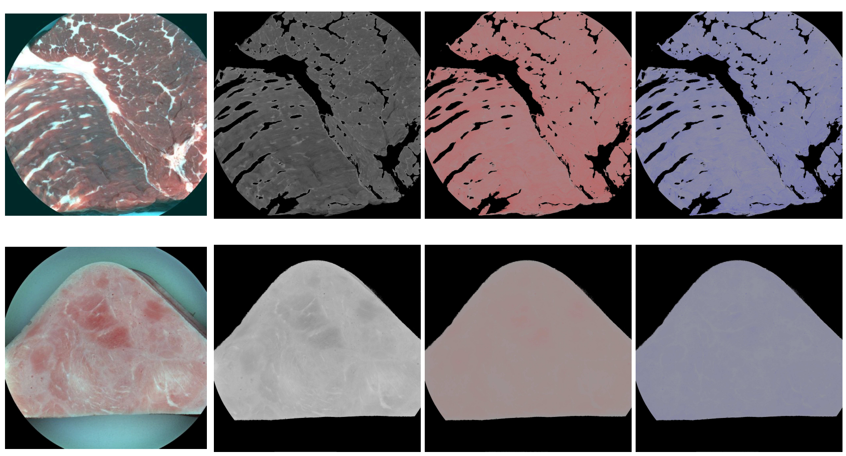


Fig. 4. Top row: Pseudo RGB, L*, a*, and b* images of the same sample as in Fig. 3 for only meat. The variance of the color components is clearly seen. Bottom row: Pseudo RGB, L*, a*, and b* images of cooked ham with background segmentation.

Table 1. Table of standard deviations for some of the 60 samples as found by the segmentation (PIM) or the colorimeter (CM)

Sample	$\hat{\sigma}_{L^*}$ (PIM)	$\hat{\sigma}_{L^*}$ (CM)	$\hat{\sigma}_{a^*}$ (PIM)	$\hat{\sigma}_{a^*}$ (CM)	$\hat{\sigma}_{b^*}$ (PIM)	$\hat{\sigma}_{b^*}$ (CM)
Round of beef	4.01	2.74	4.08	1.06	3.96	1.27
Round of pork	5.18	4.61	3.20	2.08	3.01	0.86
Filet of veal	6.5	2.07	5.11	0.50	4.61	0.62
Filet of beef	4.71	0.96	4.85	1.00	4.08	0.38
Turkey breast	5.32	3.59	2.33	0.41	2.13	0.98
	F value	p	F value	p	F value	p
Round of beef	2.36	0.13	14.87	0.002	9.55	0.006
Round of pork	1.26	0.35	2.3633	0.13	12.2624	0.004
Filet of veal	9.9537	0.04	104.6503	< 0.0001	55.3317	0.0001
Fillet of beef	24.0569	0.01	23.5502	0.0007	115.2350	< 0.0001
Turkey breast	2.1976	0.15	32.3855	0.0003	4.7136	0.03

4 Conclusion

This study has given a short introduction to the utilization of multispectral images in accordance with color assessment. The multispectral images can be used for color and color variation assessment in a precise and robust manner. Additionally it offers the opportunity for analysis enhancing the final results. The statistical analysis showed that the multispectral images gives a better view on the actual variance of the meat samples than the colorimeter.

Acknowledgments

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