

Analysis of color variations on sunflower crop images, owing to changes in environmental illumination

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Abstract: Computer vision can be applied to precision agriculture but the problems caused by open environments must be solved: changes in illumination, uncontrolled conditions, etc. To characterize the influence of illumination, an analysis of color variations was made with sunflower plants. Lots of samples were acquired by a digital color camera along enough hours of the day under direct sunlight. Several parameters were measured from histograms of three color spaces, RGB, rgb and HSI. The analysis showed that H plane (hue) and g plane (normalized green component) are the most immune planes to changes in environmental illumination.

1 Introduction

Precision agriculture uses several technologies and techniques to achieve objectives such as increasing the performance of crops, reducing environmental impact and improving working conditions. Computer vision participates in precision agriculture together with others (positioning, sensors). In industrial environments, computer vision is well and successfully implemented, the same way as in laboratories, because of controlled conditions. Quite the opposite, in open farm fields, the variability of environmental conditions makes very difficult to apply computer vision without finding problems. It is necessary to apply more complex techniques to process and analyze digital images. One of the greatest sources of variability is the changes in environment illumination. The illumination goes from direct solar light to diffuse light caused by clouds, from sunrise light to sunset light or from sloping winter sunlight to straight summer sunlight. Sometimes the illumination can be controlled by parasols and artificial lighting under them (ASTRAND & BAERVELDT 2002, AITKENHEAD *et al.* 2003), but it is not always possible in realistic applications of computer vision in crops.

One of the most important aims of the computer vision applied to precision agriculture is to develop algorithms immune to illumination influence or, in any case, to counteract this effect (TIAN & SLAUGHTER 1998, RUIZ-RUIZ *et al.* 2009). To do this, we must know how lighting affects to digital images and specifically in this work it is analyzed the influence

of illumination in color variations in crop images. Once we know the connection between quantity and type of natural illumination and color changes in digital images, we will be able to remove or reduce this influence.

2 Materials and methods

2.1 Sunflower images acquisition

Crop plants used to carry out this study were sunflowers (*Helianthus Annuus*) in their middle growing stages, with around 8 to 12 leaves (**Figure 1**). They grew from sunflower seeds in a seedbed under controlled conditions to avoid the sort season of sunflower crops in the authors' region (Castilla y Leon, Spain).



Figure 1: Some sunflower plants used in the study

The camera used to acquire the images was an AVT Marlin F131C, with a 1280×1024 pixels CMOS color sensor. It uses a Bayern pattern to decode color information into YUV color components, which are later transformed into RGB components by the vision software. The camera was mounted in the perpendicular angle to the ground, over the sunflower plants (**Figure 2a**). The acquisition process was automated by using a computer application developed with LabVIEW[®] 8.6 from National Instruments, the same development system employed for image analysis. The application run in a laptop and the camera was connected to the laptop through an IEEE 1394 (FireWire) controller card and an appropriate FireWire cable.

During each acquisition period, the parameters of the color camera were kept fix and configured as manual parameters to avoid their automatic adaptation. One of the most important parameters to keep fix was the shutter speed or the exposure time. In this

way, the quantity of light that reach to the camera sensor only depends on the natural sunlight in each moment, and not on the exposure time.



(a)

(b)

Figure 2: Acquisition system: (a) cameras over the plants; (b) light meter and acquisition card

The plants were grouped to obtain a high ratio of image area for the leaves. The background was chosen to simplify the segmentation process; instead of using earth as image background, it was used some uniform ground, red or white. The images were acquired for several hours from the morning to midday or from the afternoon to the evening, always under natural illumination. The time between images was 10 seconds. During the acquisition time the movement of the sun produced changes in the illumination, the same way as the presence of clouds. In some cases images taken under cloudy illumination were removed from the image set to analyze only direct sunlight.

Simultaneously to the image acquisition, the illuminance information was measured by a light meter. It was also connected to the laptop through a data acquisition card, NI-USB 6008, supplied by National Instruments (**Figure 2b**). The magnitude provided by the light meter is lux, that is, lumen by square meter, and its spectral response corresponds to the visible spectrum according with the sensibility of the human eye. This response approximately matches with the sensor response of the color camera. The illuminance information will be useful for trying to establish a relation between it and color information from sunflower plants provided by the camera.

2.2 Segmentation

Thanks to the uniform background of the scene, most of the times a matt white background, the segmentation of sunflower leaves was simple enough. It was used intensity version of the RGB color images, calculated with (1).

$$I = \frac{R + G + B}{3} \quad (1)$$

After that, a clustering process was followed to obtain two groups or classes, sunflower leaves and background. The seeds for clustering initialization were 0 and 255, the limits of intensity value using 8 bits per pixel. The white background caused the corresponding pixels in the CMOS sensor to be saturated; meanwhile pixels representing sunflower leaves had medium intensity values. In this way, clustering segmentation was highly efficient. **Figure 3** shows an example of segmentation.



Figure 3: Segmentation process: (a) color image; (b) binary segmented image

2.3 Color analysis

After extracting sunflower leaves pixels, several parameters were calculated for the histogram of the planes of three color spaces: RGB (red, green, blue), rgb (normalized RGB) (2) and HSI (hue, saturation, intensity). The 14 parameters are enumerated in **Table 1**.

Table 1: Parameters calculated from the histogram of color planes

Parameter	Description
MIN	Minimum value
MAX	Maximum value
RNG	Range, MAX–MIN
AREA	Ratio of sunflower pixels in the image
MEAN	Mean value
VAR	Variance value
STD	Standard deviation, $\sqrt{\text{VAR}}$
MAD	Mean absolute deviation
MOD	Mode, most frequent value
MED	Median, middle point
P25	Percentile 25, value with 25% of points on its left
P75	Percentile 75, value with 75% of points on its left
IQRNG	Range inter-quartile, P75–P25
MOD-MAX AREA	Ratio of pixels between mode and maximum value in the image

$$r = \frac{R}{R+G+B}; \quad g = \frac{G}{R+G+B}; \quad b = \frac{B}{R+G+B}; \quad r+g+b=1 \quad (2)$$

The evolution of all the parameters in **Table 1** was visualized and evaluated. To obtain a clear representation of parameters in graphs, the data was filtered using a low-pass filter, specifically a mean filter using the previous six samples and the following six samples of the value to be filtered. With 10 seconds between images, it consisted of averaging images within two minutes. Finally, filtering allowed to identify easier the trend of the parameters. In *Results and discussion* section will be explained which parameters had a significant evolution with time and illumination and the characteristics of that evolution.

3 Results and discussion

From the 14 parameters described above in *Color analysis* subsection, the first four do not have a meaning in color analysis: minimum and maximum values, range and area. For example, area should be constant if sunflower plants had not movement, but in uncontrolled natural conditions some wind can appear. The 10 remaining parameters do have a trend along the time, as seen below for each color space. However one of them, variance, is totally dependent on standard deviation, so it will not be analyzed.

Most of graphs and analysis below correspond to the acquisition of images along the morning, when the illumination increases as the sun raise to the zenith. **Figure 4a** shows the measurement of light meter along a sunny morning without any clouds or mist. The evolution of illuminance is equivalent during the afternoon but it decreases with time. It is shown in **Figure 4b**, where there are some sudden variations owing to the presence of light clouds.

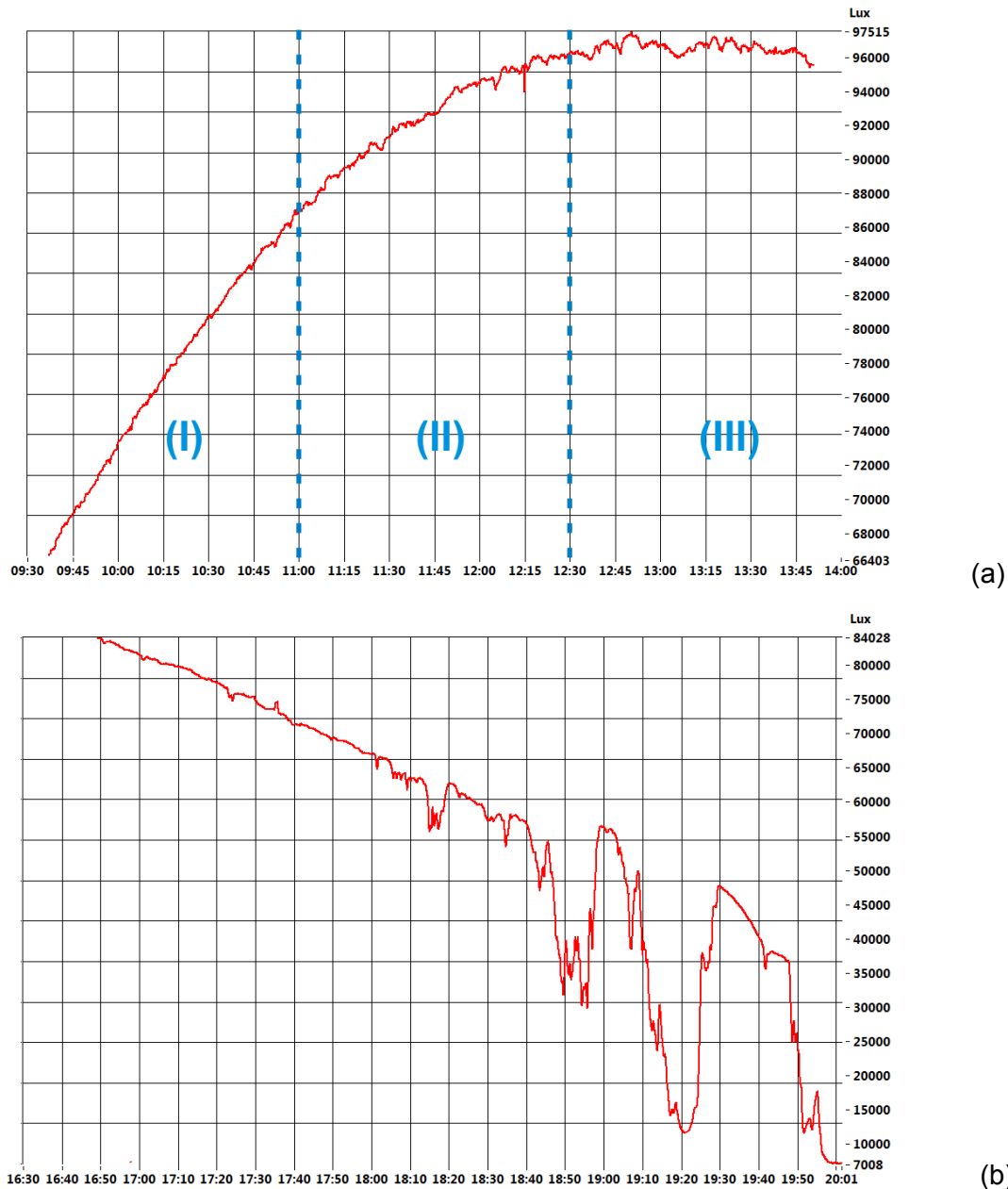


Figure 4: Illuminance variation during the morning (a), with three regions (I, II, III) and the afternoon (b), with the effect of clouds

In **Figure 4a** there is a linear region (I), approximately from the beginning of the acquisition to 11:00. Then, from 11:00 to 12:30 the growth decreases (II) and finally the illuminance is almost flat from 12:30 to 13:45 (III). From this flat period, illuminance starts to

decrease and, finally, reaches a new linear region, at least from 16:50 as shown in **Figure 4b**.

3.1 Mean, median and mode

Mean, median and mode have a similar behavior along the time so in **Figures 5** and **6** are shown the means for the histograms of the three color spaces: RGB, rgb and HSI. In **Figure 5a**, the means for R, G, and B planes have the same trend, each one at one level. In region (I) (linear increase of illuminance) the means grow approximately in a linear way. It is logical since each component in RGB space contain intensity information. In region (II), where the growth rate decrease for illuminance, the same happens for means. Finally in region (III), even though illuminance is almost flat, means for R, G and B decrease.

The evolution of means for the histograms of planes r, g and b is slightly different: the mean of b plane changes in the same way as B plane does; the mean of g plane remain constant along the time; finally, the mean of r plane have the inverse behavior of that one for R plane, it decreases in regions (I) and (II) and increases slightly in region (III). However, the level variations for rgb planes are smaller than variation for RGB.

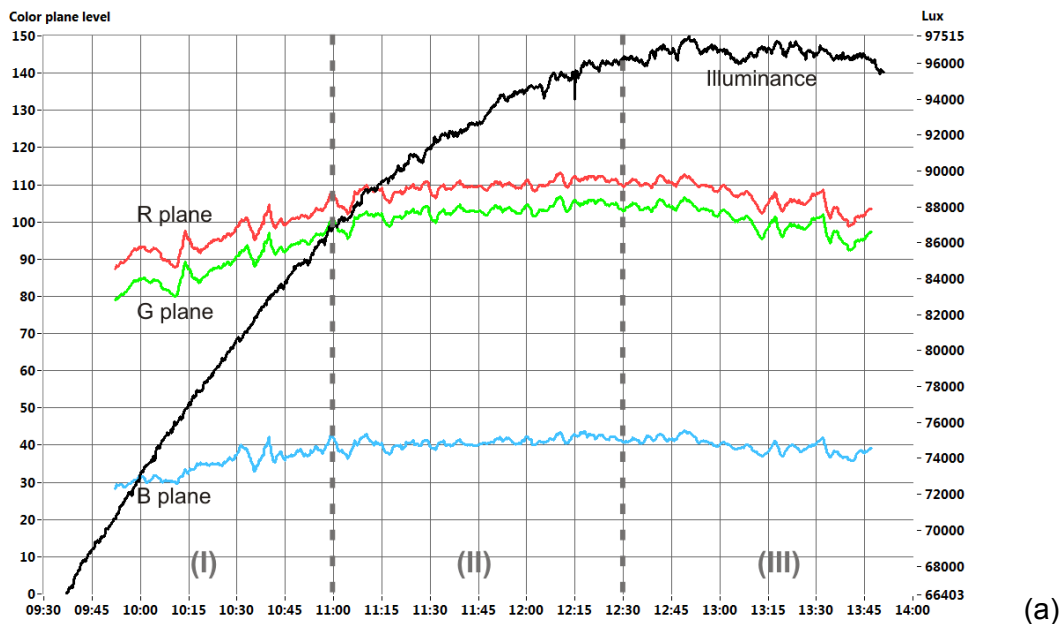


Figure 5a: Mean variation for the histograms of RGB planes

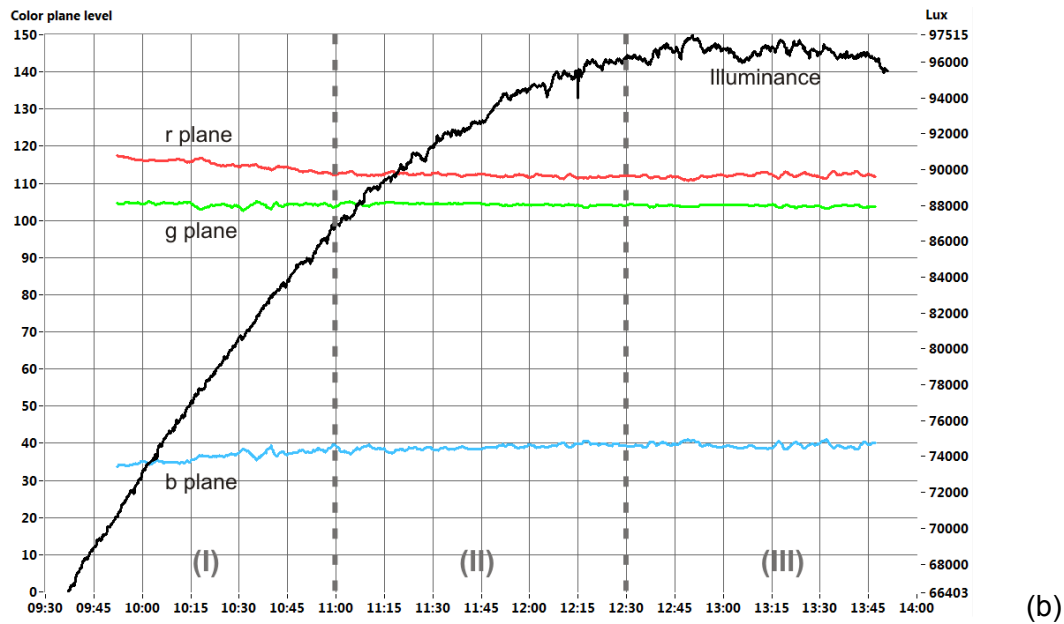


Figure 5b: Mean variation for the rgb planes

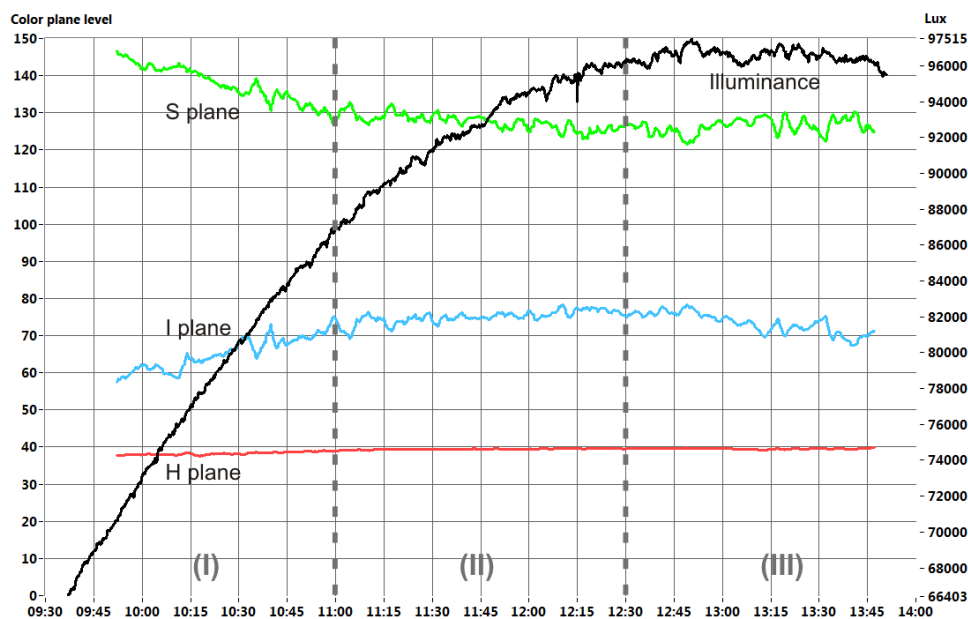


Figure 6: Mean variation for the histograms of HSI planes

Figure 6 shows that the means for S (saturation) and I (intensity) planes have inverse behaviors. Naturally I plane depends completely on changes in illumination. The evolution of mean for S plane says that purity of sunflower leaves color decreases when sun goes to the zenith. Finally, the H plane's mean is almost flat along the time. It increases very slightly in region (I) and is constant in regions (II) and (III).

As a conclusion, only means of g and H planes are immune to changes in natural illumination.

3.2 Standard deviation and mean absolute deviation

Standard deviation and mean absolute deviation are very similar, so only STD is represented in Figure 7. For RGB, rgb (**Figure 7a**) and HSI (**Figure 7b**) the standard deviation has very small variations. It and the mean analysis imply that the histograms move (mean variation) but do not become wider or narrower. Only when the sun is in the zenith the STD increases a little.

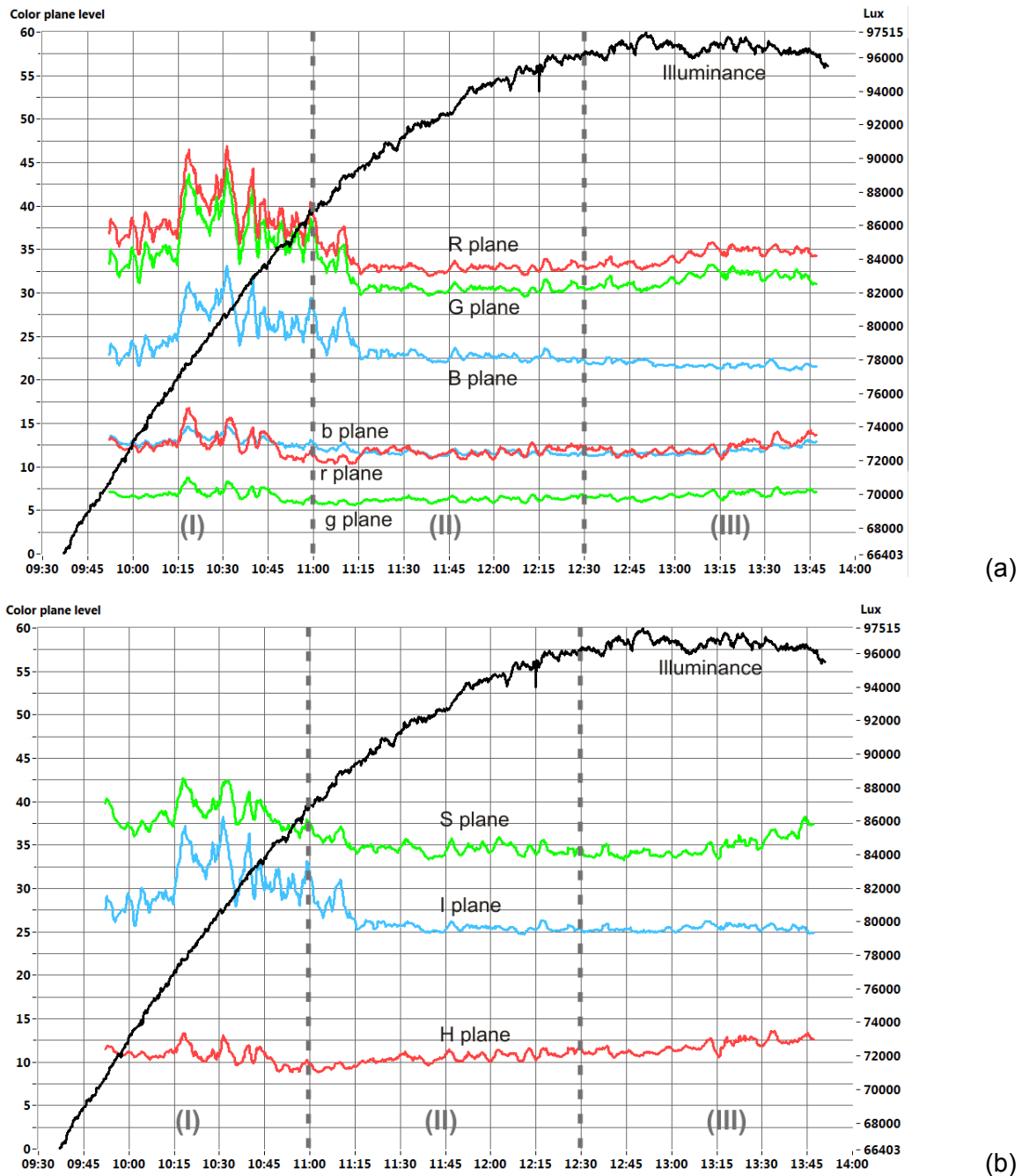


Figure 7: Standard deviation for the histograms of RGB and rgb planes (a) and HSI planes (b)

The peaks in the STD graphs in **Figure 7** from 10:15 to 10:45 were caused by wind; it moved and turned the leaves causing errors in the measurements. This effect appears again in Figures 8, 9 and 10.

3.3 Percentile 25, percentile 75 and range inter-quartile

The mean of a mono-modal histogram gives its position and the standard deviation gives its width. After analyzing mean and STD in 3.1 and 3.2, we know that changes in environmental illumination affect to histogram position but not to its width.

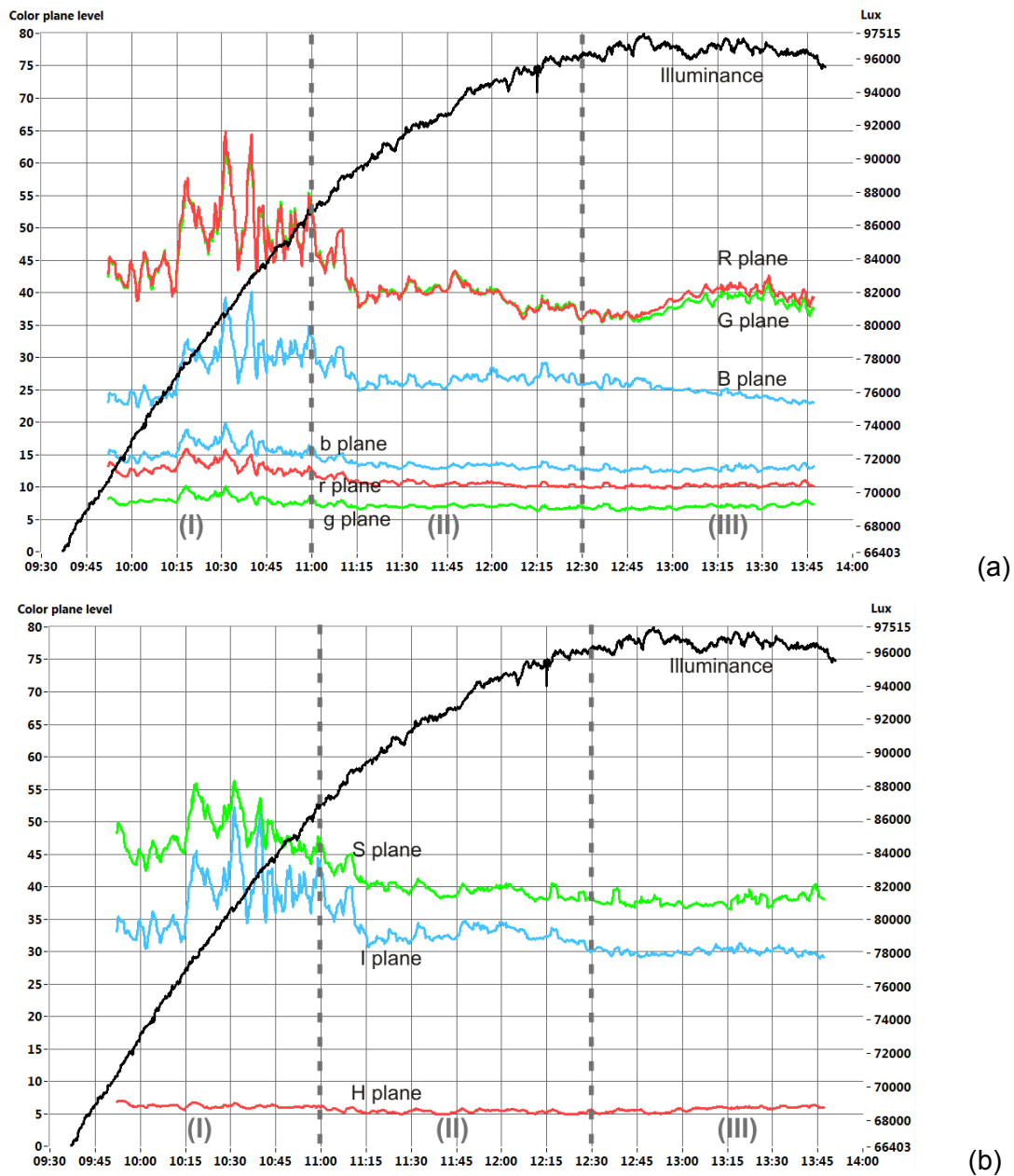


Figure 8: Inter-quartile range for the histograms of RGB and rgb planes (a) and HSI planes (b)

It implies that quantiles like the percentile 25 and the percentile 75 move when illumination changes but their relative position should be almost constant. It can be checked in **Figure 8**, the inter-quartile range (P75–P25) is almost flat along the time. It only presents the errors caused by wind and the same variations than STD at midday.

Like mean analysis in 3.1, the planes with higher immunity to changes in illumination are g and H.

3.4 Mode-maximum area ratio

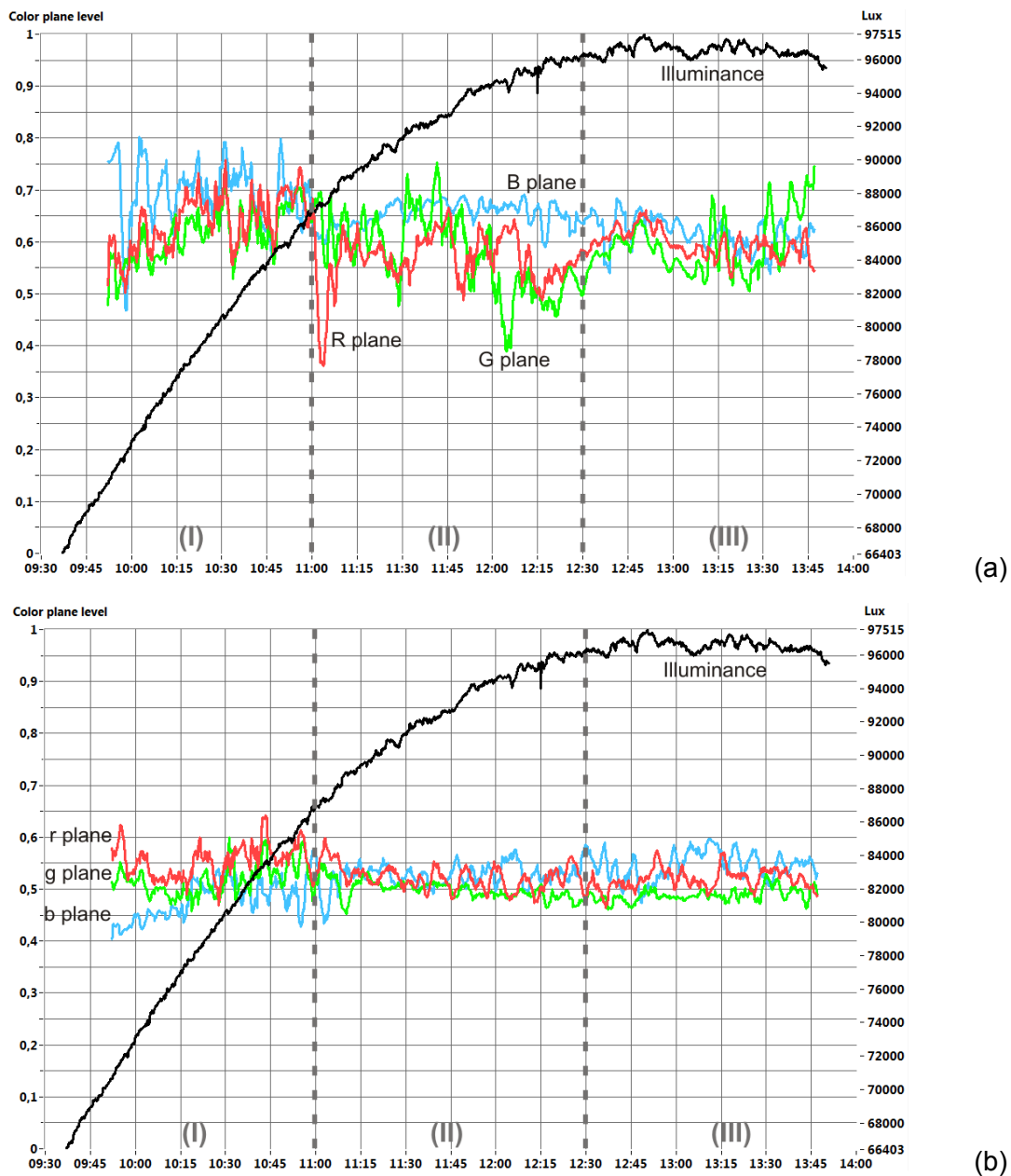


Figure 9: Mode-maximum area ratio for the histograms of RGB plane (a) and rgb planes (b)

This special parameter can be seen as a measurement of the symmetry of the histogram. For a completely symmetrical histogram the mode-maximum area ratio must be 0.5. It means that 50% of pixels are higher than the mode and the other 50% are lower. It also means that the mode is equal to the median.

The histograms of RGB planes are the less symmetrical since the parameter remains always above 0.5. Meanwhile, the histograms of rgb planes are quite symmetrical because of the normalization process. Finally for HSI color space, the histogram of H plane is very symmetrical; the histogram of S is a bit asymmetrical towards low levels and the histogram of I is highly asymmetric toward high levels.

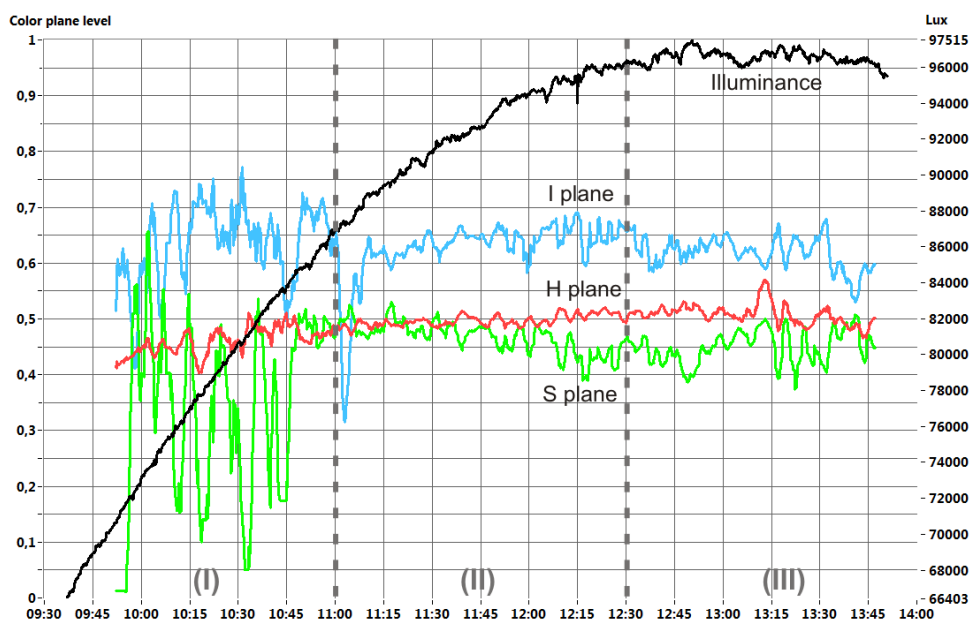


Figure 10: Mode-maximum area ratio for the histograms of HSI planes

4 Conclusion

The analysis of color in sunflower plants images along the day, under sunlight illumination, reveals that some color planes from different color spaces are more immune than others to changes in illumination. Representative parameters of the histograms for RGB, rgb and HSI color spaces were measured: mean, standard deviation, inter-quartile range and mode-maximum area ratio, etc. The histograms suffer variations with changes in illumination but the g and H planes are quite immune to illumination changes.

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