Using computer vision for analysis of plant growth condition: what to consider?

This presentation will discuss what to consider using computer for monitoring of vegetation under outdoor condition for the image formation.

Computer vision (image analysis) is used increasingly for research and development of sensors. The price of cameras has during the last decades fallen dramatically and in the meantime the performance has increased. This is a development that is expected to continue in the coming years. In this presentation the focus will be on the possibilities, considerations, and limitations using computer vision under outdoor illumination conditions. How the image formation may be modelled and how this may be used for detection of suitable measurement locations will be presented. Finally, at the end the problem of second order reflection and how these may be modelled is briefly introduced. The ambition of the presentation is to give an overview and understanding of some of the conditions that influence images of vegetation captured under outdoor conditions.

For modelling of the image formation process it will be demonstrated how the dichromatic reflection and CIE daylight standard might be used for robust analysis of vegetation under daylight conditions. The dichromatic reflection model describes the reflected light of dielectric objects by two reflection components, respectively, a body and surface reflection. Analysing vegetation it is usually the body reflection that is of interest as this is the component that carries information about the vegetation, i.e. the green colour. In contrast the surface reflection does not carry information about the plant growth condition but instead it describes spectral information about the illumination source. Popularly, this is called the mirror reflection. Figure 1 illustrates how it possible to classify the reflection of a coffee plant into the contributions from the two reflection components (Andersen and Störring, 2004). Making a detail analysis of the reflection from a plant, it is now possible to either weight each pixel according to the contributions from the two reflection components or it is possible to choose a measurement area with predominant reflection from one of the two components.

Images captured under outdoor conditions also poses the problem that the objects in scene can potentially be illuminated by two light sources, respectively, direct sun light or skylight, which are two illumination sources of quite different nature. The illumination source skylight is an ambient source that does not impose surface reflection. In contrast direct sunlight is a point light source that due to its distance to the earth may be regarded as a uniform illumination source. More important is the different spectral compo-
sition of the two light sources. The sun will at daytime have a correlated colour temperature of app. 5,600 K. Skylight on the other side may vary between 5,000 and 25,000 K and even on a clear blue sky during winter reach a correlated colour temperature of 40,000 K. The correlated colour temperature (CCT) is a measure of how well a light spectrum from the sun fits a light spectrum from a black body. A high CCT corresponds to very bluish light. Normal room illumination will have a CCT of 3,200 K.

Analysing “normal” RGB or multi-spectral images, it is important to take changes of the illumination CCT into account, because if the CCT changes then the colour of the vegetation will change as well. We as humans are good at adapting to changes in CCT of the illumination we have a so-called Colour Constancy mechanism integrated into our vision. Different is it for cameras they do not have the same capability to adapt to the given illumination conditions. Unfortunately, this is a problem that does not have closed form solution. The problem is that it is impossible to know whether a pink wall is a white wall illuminated by a pink light source or it is a pink wall illuminated by a white light source. The only way to solve the problem is to take something for granted about the scene content.

For daylight-illuminated scenes the illumination may be modelled by CIE daylight standard. By this the change in colour of vegetation may be modelled from the case where it is illuminated by direct sun light to skylight, i.e. due to a building or machine shadowing the image field. Results show that by this modelling it is possible to correct for the changes in CCT of the daylight and as result obtain a robust analysis of the vegetation.

So far, only first-order reflection has been considered. For a more detailed analysis of the vegetation reflection of higher order also has to be taken into account. Figure 2, demonstrates how it by modelling of the end member spectra is possible to classify reflections further into 1. and 2. order contributions. The image is acquired with 26 10nm broad bands from 470 to 720nm. Methods for broader band sensors are under development, so the concept may be used both for dedicated sensors, as within remote sensing and sensors based on consumer-based cameras.

**Concluding remark**

The presentation has demonstrated how especially spectral consideration regarding the illumination has to been taken into account developing method for automatically analysis of image acquired under daylight conditions. The results show that using the above understanding and considerations computer vision may be used as valuable technology for future development of sensors for agriculture and support of Agro-robots.

**Literature**


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**Figure 2.** Specular and second-order scattering.