RGBI IMAGES WITH UAV AND OFF-THE-SHELF COMPACT CAMERAS: AN INVESTIGATION OF LINEAR SENSOR CHARACTERISTICS

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ABSTRACT

UAVs are able to close the gap between ground-based (total station, Global Navigation Satellite System - GNSS) and airborne data acquisition. Usually, cameras in the visible range of light are used for this purpose. Until now, only a few sensors have been commercially available for the capturing of non-visible wavelengths, e.g., of the near infrared for vegetation analysis. Almost all common camera sensors can be used and be modified through small interventions for the near infrared to make a RGBI (red, green, blue, near infrared) sensor head. Vegetation parameters like *NDVI* can be calculated from this data.

At the Frankfurt University of Applied Sciences, a sensor head has been developed to collect RGBI data. The sensor head consists of two Sigma DP2 FOVEON-sensor cameras. One of them is modified for the near infrared. This sensor head is mounted to an octocopter UAV with a maximum take-off weight of 3.5 kg. The cameras are triggered simultaneously. In the post-processing, the image channels are registered to each other by a self-developed software script and a radiometric adjustment based on reference targets in the field is carried out. The resulting multispectral images are processed to multispectral orthophoto mosaics in standard photogrammetric software. A spectrometer and various test panels are available for the investigation of linear characteristics of the cameras.

This paper briefly presents the construction of the sensor head. In particular, the radiometric characteristics of the sensor should be considered. The Sigma cameras have a poor colour separation due to the installed FOVEON sensors. This is balanced by the algorithms implemented in the raw data software Sigma PhotoPro, offered by the manufacturer. However, the linear sensor characteristic is destroyed by gamma correction and white balance. Freely available raw data converters can process the Sigma data without these photographic corrections and preserve the linear characteristic, but the image quality suffers from the poor spectral separation.

INTRODUCTION

UAVs are able to close the gap between ground-based (total station, Global Navigation Satellite System - GNSS) and airborne data acquisition. Cameras in the visible range of light are often used for this purpose (1). For the capturing of non-visible wavelengths, e.g. of the near infrared for vegetation analysis, only a few sensors have been commercially available until now, for example the Tetracam MCA (2) or the Tetracam ADC (3).

Certain conditions have to be fulfilled to use such sensors on rotary wing UAVs. Due to the limited UAVs payload the sensors have to be lightweight. At the octocopter MR-X8 used by the authors the payload should not exceed 750 g. Exposure times of 1/1000s are necessary because of the UAVs shaking and vibrations. Under these conditions high quality images should still be received. Sensors with a slow read-out speed produce rolling-shutter distortions in the images (4).

Many of the cameras could be used for the near infrared photography by removing the hot mirror (5). Due to this modification, the capturing of multispectral data with a maximum of three channels using a single camera (6) or several channels using more than one camera (7) is possible. Ritchie et al. (8) investigated a RGBI camera system consisting of two Nikon 4300 compact cameras and showed the nonlinearity of the imagery produced by the internal processing in the camera. The application of such data has already been demonstrated. Bernie et al. have investigated in vegeta-

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tion indices of olive trees with UAVs (9) and Gini et al. have carried out classifications of tree species in a park area (10).

Figure 1: UAV Multirotor MR-X8 with Sigma DP2 sensor head.

SENSOR DEVELOPMENT

The sensor head developed at Frankfurt University of Applied Sciences consists of two compact cameras Sigma DP2. The FOVEON sensors used in Sigma cameras produce high quality images at short exposure times due to their special sensor design (11). One camera is modified for the near infrared by removing the hot mirror and mounting a 720 nm infrared filter (Figure 1). The total mass of approx. 600 g meets the payload limit of the UAV.

The raw data mode is used for capturing images. This allows the best possible correction of the images afterwards (12). The manufacturer provides the software Sigma PhotoPro for raw data processing. This software produces “beautiful” images. Photographic corrections like white balance and gamma correction cannot be switched off. On the other hand, freely available raw data converters like DCraw from David Coffin can be used (13). This software allows photographic corrections to be deactivated. However, this results in worse images due to less powerful algorithms and the poor colour separation of the FOVEON sensor (14). A comparison will be discussed below.

Both cameras are triggered simultaneously. A little offset of the trigger times results in different relative orientation parameters for each image pair due to the UAV movement. The coregistration of the images has to be carried out for each image pair with individual parameters (Figure 2). For this task a small Python script has been developed for the projective correction of the infrared image to the RGB camera. The calculation is done in a batch process calculating the projective transformation parameters by homologous points derived by a SURF operator (15) and a Gauss-Markov adjustment with blunder detection and removing. At this processing step, a radiometric adjustment for the four channels is done by a piece of spectralon photographed in the field.

The UAV moving with the non-simultaneous camera triggering cause margins with erroneous data in the 4-channel images. Therefore, mask files are automatically produced to exclude these areas from the further processing. The resulting 4–channel images are processed to multispectral orthophoto mosaics by the software Agisoft Photo Pro.

INVESTIGATIONS AND RESULTS

The differences of the two raw data converters, Sigma PhotoPro and DCraw, were investigated in a laboratory measurement. The investigation was performed for the non-modified camera only. White, grey and black foam rubber panels and a piece of Spectralon® were irradiated with tungsten halogen light sources. Reflection spectra were recorded with a Redtide USB600 spectrometer. According to Jaehne, formula 2.45 (16), the reflection spectra were converted to digital numbers (*DN*) for each spectral band with the relative spectral sensitivity of the FOVEON sensor (Figure 3). The following equation shows the calculation for the red image channel:

$$DN\_red = \frac{\sum_{\lambda=400\text{ nm}}^{700\text{ nm}} R_{red}(\lambda)\ \sigma_{\text{target}}(\lambda)}{\sum_{\lambda=400\text{ nm}}^{700\text{ nm}} R_{red}(\lambda)\ \sigma_{\text{Spectralon}}(\lambda)} 255$$

with $R(\lambda)$ the relative spectral sensitivity factor for each band at a discrete wavelength and $\sigma(\lambda)$ the relative spectrometer measurement at a discrete wavelength.

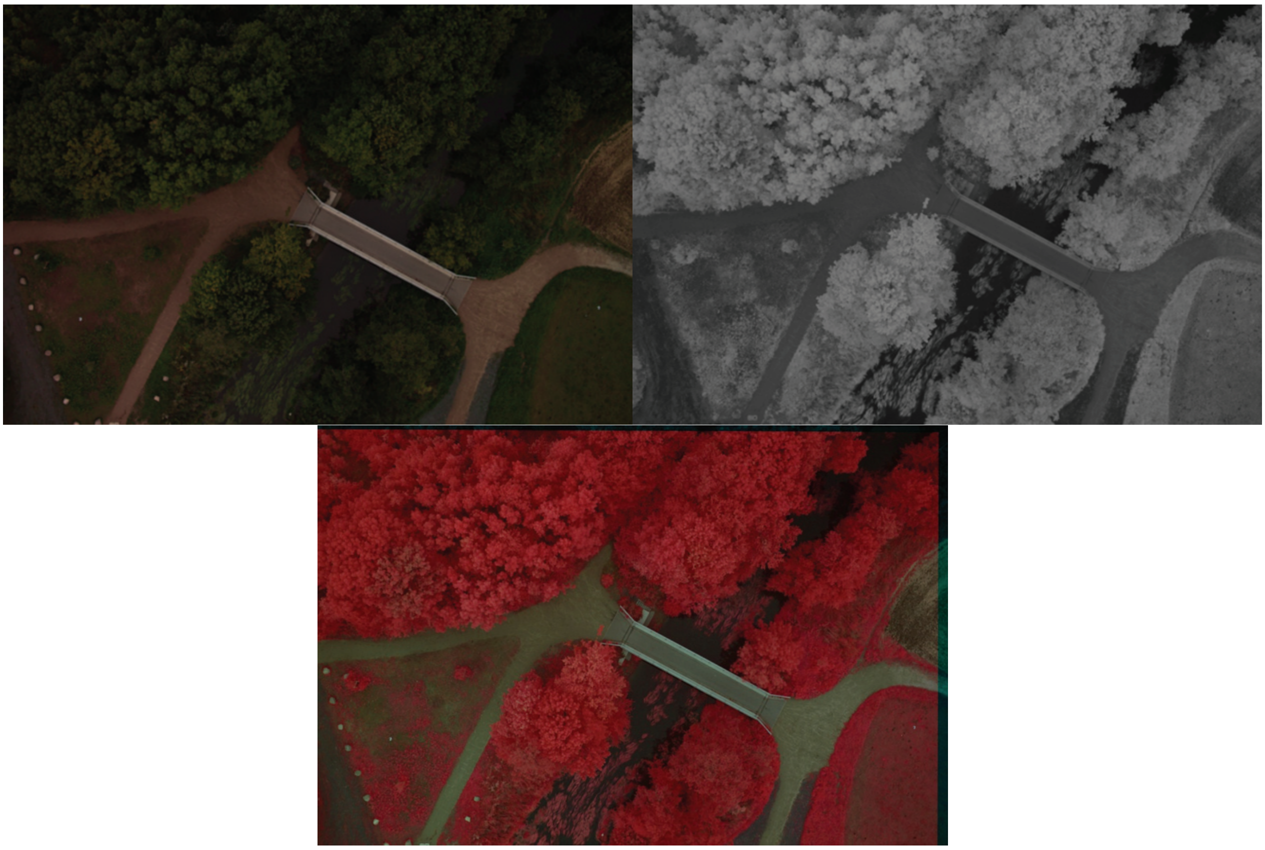

Figure 2: Coregistration of RGB and IR image.

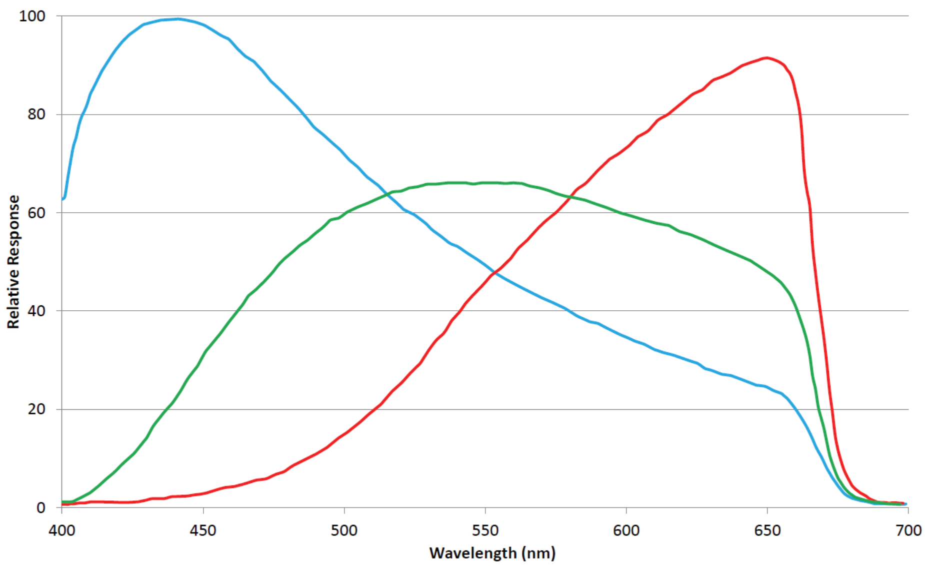

Figure 3: Relative spectral response of red, green and blue FOVEON sensor layers with hot mirror, according to data of (14).

Figure 4 shows the *DN* comparison for the targets black, grey, white, Spectralon® for raw data processing with Sigma PhotoPro and DCraw.

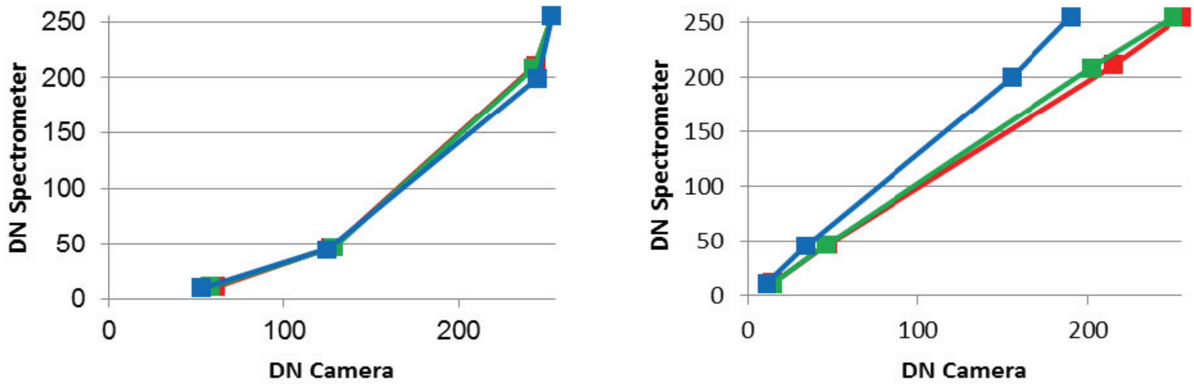

Figure 4: Comparison of DN from camera and spectrometer in Sigma PhotoPro (left) and DCraw (right).

The curve for Sigma PhotoPro clearly shows the influence of photographic corrections, while the evaluation in DCraw preserves the linear characteristic of the sensor. The latter can easily be radiometrically calibrated by linear brightness adjustments on a piece of Spectralon® in the field.

CONCLUSIONS

The use of the raw data converter DCraw preserves the linear sensor characteristic in contrast to Sigma PhotoPro. On the other hand, the poor spectral separation of FOVEON sensors without the application of sophisticated algorithms leads to worse results in the pictures (Figure 5). For *NDVI* analysis within a single mosaic (17), the "nicer" picture could be used. For multitemporal *NDVI* analysis, we recommend to use of linear data created by DCraw.

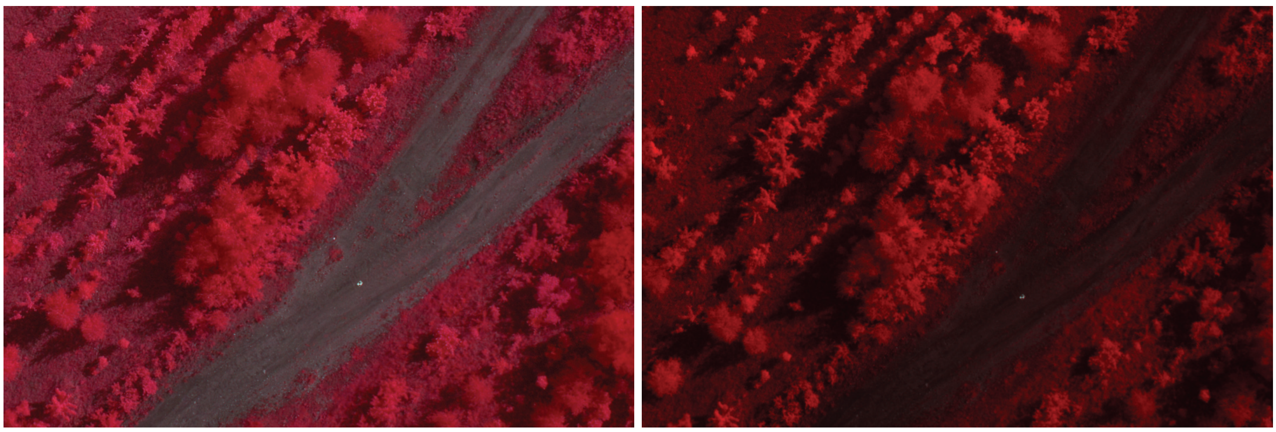

Figure 5: Colour infrared images (RGB image channels showing the spectral channels Green, Red, NIR) from Sigma PhotoPro and DCraw.

OUTLOOK

In future studies the infrared camera will also be investigated for its linear characteristic. Additionally, the investigations will be extended to coloured targets for both cameras. After laboratory testing the results will be verified through UAV-campaigns in the field with simultaneous radiation measurement of radiometric reference targets.

Furthermore, the quantitative impact of the software Sigma PhotoPro on *NDVI* evaluations will be studied.

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