MEASURING INCIDENT IRRADIANCE ON-BOARD AN UNSTABLE UAV PLATFORM – FIRST RESULTS ON VIRTUAL HORIZONTALIZATION OF MULTIANGLE MEASUREMENT

Juha Suomalainen [a,*], Teemu Hakala [a], Eija Honkavaara [a]

[a] Finnish Geospatial Research Institute, National Land Survey of Finland, Geodeetinrinne 2, 02430 Masala, Finland
(juha.suomalainen@nls.fi, teemu.hakala@nls.fi, eija.honkavaara@nls.fi)

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EXTENDED ABSTRACT:

Most advanced UAV remote sensing camera systems are calibrated to produce images in radiance units. In order to take full advantage of the radiometric data, it is usually necessary to convert the images further to reflectance factor units. For the reflectance factor processing it is necessary to have as an input the incident irradiance either from a direct incident light measurement, from a reference panel measurement, or from an atmospheric simulation. In varying atmospheric conditions and especially with long lasting mapping flights, the direct measurement on-board the UAV is often the only reliable solution. On-board the UAV, the irradiance can be measured using a simple photodiode installed behind a diffuser, which produces a (near-)Lambertian field of view for the sensor. By implementing the measurement using a spectrometer or RGB photodiodes, the blue sky effects can be taken into account to better produce irradiance reading for different spectral bands of the camera system. Such irradiance sensors are nowadays a standard feature in many UAV remote sensing camera systems.

In a typical UAV application, the main problem in such a simple setup is that the irradiance measurement is highly tilt sensitive. This is the case especially in illumination with low solar elevation, where already a tilt of a few degrees can cause significant (>10%) errors. As especially the multicopters are continuously tilted in order to have airspeed, this often causes systematic errors in image calibration between flight lines. Also the instability of the UAV causes errors in calibration of individual frames. The instantaneous tilts of the sensor can be filtered and possibly even corrected for if the orientation of the sensor is recorded with each irradiance reading, but currently the only solution to the continuous tilting problem has been to mount the irradiance sensor on a stabilized gimbal. Although such a mechanical solution can be effective, it adds extra weight, may be troublesome to install on some UAVs, and requires relatively sophisticated Inertial Measurement Unit (IMU) and actuators to produce accurate enough results.

To provide accurate absolute irradiance, tilt, RTK GNSS position, and timing for our UAV imagery in real time, we are currently developing the *FGI Aerial Image Reference System* (FGI AIRS).

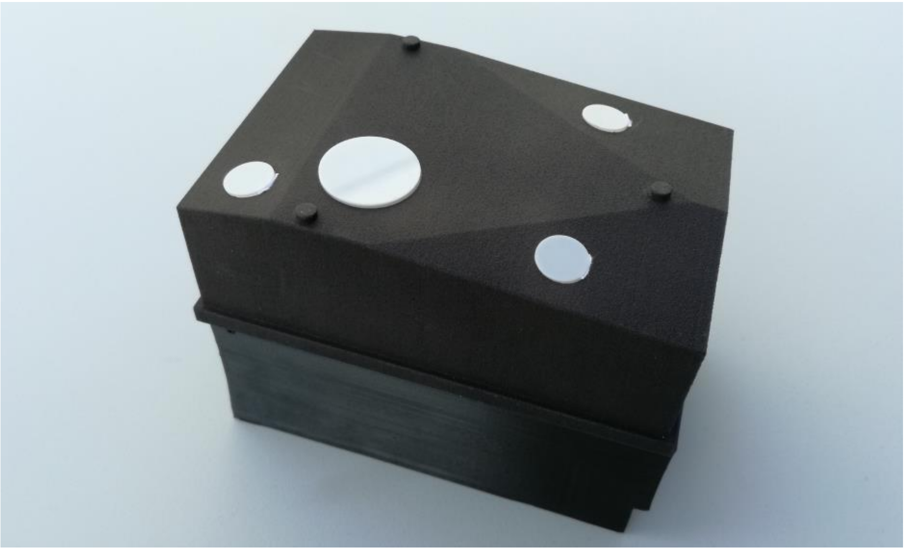

Figure 1. Photo of the *FGI Aerial Image Reference System*. The three small cosine collector optics belonging for the RGB photodiodes are all tilted 10° to opposite directions.

* Corresponding author

In the FGI AIRS irradiance concept, three RGB photodiodes with cosine collectors are tilted 10° to opposite directions (120° azimuth rotation to each other) and simultaneous measurements are taken with all of them. The system does not need to be stabilized with gimbal, but the multidirectional measurement allows accurate determination of irradiance also while slightly tilted. As the tilt of the system is measured with an IMU, it is possible to mathematically calculate the reading for a virtual horizontal sensor. The RGB bands of the photodiodes provide independent measurement of the incident radiance intensity and angular distribution. Firstly, this is necessary as the blue sky component of irradiance has different angular distribution than the longer wavelengths and thus reacts differently to the tilting of the sensor. Secondly, these RGB data allow semi-empirical modelling of the full irradiance spectrum.

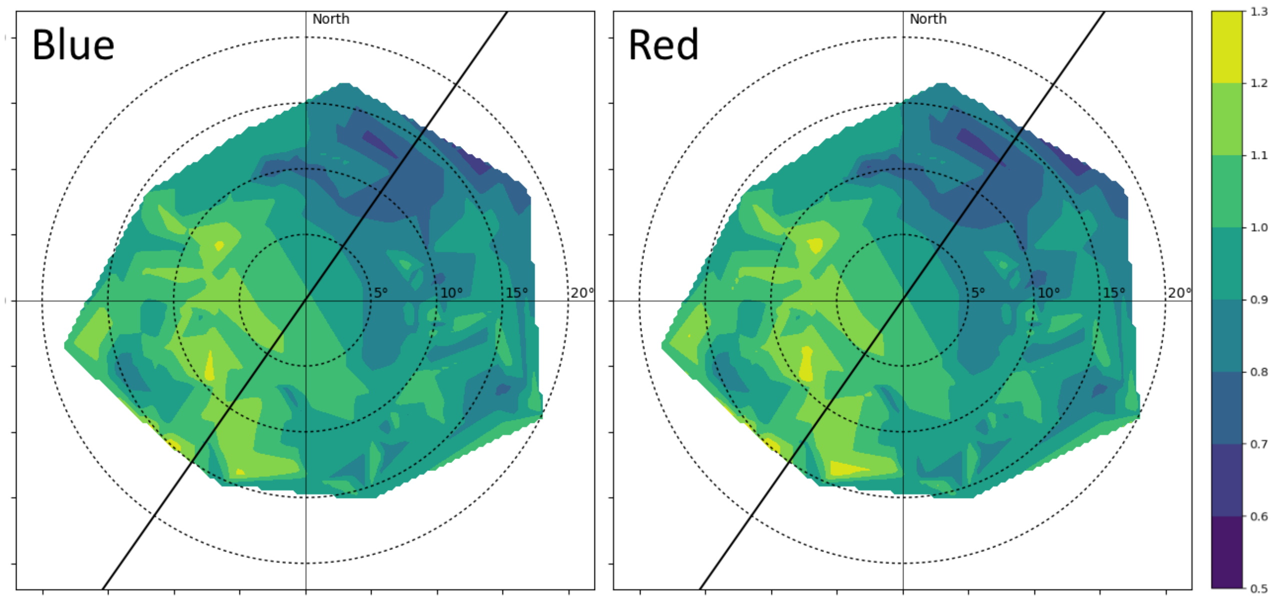

Figure 2. Reading of a single irradiance sensor vs its tilt as measured in a ground based experiment. During the measurement sky was mostly blue with thin cirrus clouds in front of the sun. Solar zenith angle was approximately 42°. The thick line across the plot indicates the solar principal plane. The intensity units are relative to horizontal measurement.

According to our first tests, this methodology allows stabilization of incident irradiance level with better than 1% accuracy with tilt angles up to 15°. In the conference we will present our first results with the new sensor hardware and evaluate its performance against the traditional non-stabilized method.