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| **COST-Action:**  | OPTIMISE (ES1309) |
| **Workshop:**  | Challenges of UAV spatial sampling |
| **Venue:**  | Free University of Bozen/Bolzano, Italy |
| **Dates:**  | 17. - 20. October 2016 |
| **Host:**  | Enrico Tomelleri (EURAC, Italy) |
| **Participants**:  | Michal Chilinski *(University of Warsaw, Poland*); Jaroslaw Chormanski (*University of Warsaw, Poland*); Petra D’Odorico (*ETH, Switzerland*); Marco Dubbini (*SAL Engineering, Italy*); Mario Gattelli (*SAL Engineering, Italy*); Charles George (*CEH, UK*); Angela Harris (*University of Manchester, UK*); Alasdair Mac Arthur (*University of Edinburgh, UK*); Abraham Mejia Aguilar (*EURAC, Italy*); Eyüp Selim Köksal *(Ondokuz Mayıs University, Turkey*); Frank Veroustraete (*University Antwerpen, Belgium*). |

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| **DAY 1: Monday 17.10** |

* Welcome by host Enrico Tomelleri
* Introduction of the participants
* Introduction to OPTIMISE by Alasdair MacArthur
* Introduction to the Piccolo System by Alasdair MacArthur. The Piccolo System is a lightweight dual-field-of-view spectrometer system (400-1000 nm) for deployment on rotary-wing UAVs. A cosine corrected fore optic is employed to capture down-welling irradiance and the upwelling channel can be configured with a view angle limited fore optic to capture up-welling radiance. As the Piccolo doppio is fibre optic based it can be configured to measure from any view angle required (e.g., off-nadir measurements).
* General issues discussed:
	+ Advantages of UAV *vs.* other sensing platforms:
		- Possibility of obtaining different ground spatial resolutions suiting the particular application by adjusting flight height. Novel application: improvement of spatial upscaling.
		- Possibility of acquiring with different view geometries (off-nadir) by adjusting pitch, yaw and roll axes through a gimbal. Novel applications: determination of leaf angle distributions and modelling of canopy structure.
		- Great flexibility to fly during desired weather conditions as compared to planes or other platforms requiring flight control registration.
	+ Rotary *vs.* fix-wing UAV systems:
		- Rotary systems are inefficient systems in terms of energy consumption and their payload is limited, leading to battery weight constrains determining the maximum flight duration which is currently in average 15 min, while fix-wing systems can fly several hours without intermediate landing.
		- Rotary systems have the advantage that a higher IT can be programmed to acquired several spectra over the same target allowing for averaging and decrease of SNR. Stabilization of gimbal is very important for this purpose.
		- The type of application will determine the platform, in general for point reference sampling rotary systems are most suited, while fix-wing systems should be employed for monitoring purposes.
		- Hybrid systems are currently being developed.
	+ Geo-referencing of UAV based measurements:
		- Importance of teaching (again) photogrammetry and in particular stereophotogrammetry and triangulation techniques of stereo-images in University study programs.
		- GPS currently employed:
			* Hand-held GPS have usually too low accuracy (2-5 m)
			* DGPS uses a network of fixed, ground-based reference stations to broadcast the difference between the positions indicated by the GPS satellite systems and the known fixed positions.
			* Real Time Kinematic (RTK) systems: use a single base station receiver and a number of mobile units. The base station re-broadcasts the phase of the carrier that it observes, and the mobile units compare their own phase measurements with the one received from the base station.
			* GPS recordings included in the Avionic system are not always accessible due to encryption to protect from liability in case of crashes.
		- Accurate GPS recording are key for both, steering the UAV platform to desired locations and record the exact position during data acquisition.
		- Use of GCPs is a feasible method for imaging but not for beam spectrometers and only for small areas as it becomes expensive for large areas. A set of GCPs should be used for the calibration of the georeferencing model (about 1/3), a set to validate the model (about 1/3) and the remaining set to assess its accuracy.
	+ Redundancy of spectral information in hyperspectral datasets: if for the specific application the diagnostic spectral bands are already known, it is sufficient to employ multispectral cameras and possibly custom spectral filters.
	+ BRDF effects of pushbroom scanners: these are artefacts due to the different sun-sensor-target geometry characterizing edges vs. central pixels positions in the scan line. Among the approaches to quantify and potentially correct for this effect are:
		- Study the same object appearing in different positions in the scan line in consequently acquired overlapping images.
		- Employ beam spectrometers acquiring at different angles (off-nadir) to simulate the effect across a pushbroom system scan line.
* Planning of field experiments:
	1. Experiment 1: investigate BRDF effect from hyperspectral imagers
	2. Experiment 2: estimates of spatial variability with increasing spectral information
* Visit of test site and set up of equipment:
	+ Jeniesen area 1200 meters above Bolzano to the North, covering a mixed ecosystem with predominant grassland cover and sparse larch trees.
	+ Light condition: predominantly diffuse light (overcast sky).
	+ platform used for flights was large multi-purpose octocopterfrom EUR.AC manufactured by Soleon Germany.
	+ Sensors mounted were 1 RGB camera and 1 hyperspectral Rikola camera (500-900 nm).
* Execution of experiments: GCPs were distributed over the flight area and a hand-held GPS was used to acquire their position; a white reference panel was used to acquire reference measurements with the hyperspectral camera already mounted on the UAV for reflectance computation; a flight plan was generated and executed as a programmed mission acquiring standard line patterns with images acquired every 2 sec (ca. 80% overlap) and around 1.5 cm ground resolution obtained with a constant platform altitude of 50 meters.
* Issues for discussion: acquisition of white panel reference spectra should not be influenced by shadowing of the operators holding the UAV platform over a panel, alternative to acquire in-flight at low altitude.
* Return to the lab and presentation of the MAIA system by Mario Gattelli (SAL Engineering, Italy). MAIA is a multispectral camera designed to be employed on board the UAV systems, entirely made in Italy and jointly developed by SAL Engineering - Modena and by EOPTIS - Trento. It is based on an array of 9 sensors with 1.2 Mpixel (1 RGB and 8 monochrome with relative band-pass filters) for the analysis of the VIS-NIR spectrum from 390 to 950 nm. Each camera is designed to have a series of band-pass filters and it can be equipped with customized filters on request. It can communicate and can be interconnected with various devices including GNSS for an accurate log of synchronized shutter positions and GIMBAL for attitude and balance control.

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| **DAY 2: Tuesday 18.10** |

* Organizing and processing data acquired during 1st field day. One group investigated the BRDF effect in Rikola images acrosstrack the scan line by evaluating the spectral signature of the same object (tree) located at the edge of the image and in the centre. A second group investigated the spatial variability with changing spectral information in Rikola scenes by using Moran’s I index available in ENVI, providing an estimate of the variability of neighbouring pixels.
* Planning of field experiments:
1. Experiment 3: comparison of MAIA, Rikola and onboard spectrometers
2. Experiment 4: repeatability of GPS flight plans
* Visit of test site and set up of equipment:
	+ Same test site as in day 1.
	+ Light condition: predominantly direct light (sun-cloud sky).
	+ platform used for flights was large multi-purpose octocopterfrom EUR.AC manufactured by Soleon Germany.
	+ Sensors mounted were 1 MAIA multispectral camera, 1 Rikola hyperspectral camera, 1 Ocean Optics USB2000+ spectrometer, 1 Ocean Optics STS spectrometers. One beam spectrometer was pointing downwards and the other upwards.
* Execution of experiments: GCPs were distributed over the flight area and a hand-held GPS was used to acquire their position; 3 reference panels (white-grey-black) were used to acquire reference measurements in-flight; the same flight plan as the previous day was used on this day.

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| **DAY 3: Wednesday 19.10** |

* Discussion on best solution for UAV data processing. Presented solutions included:
	+ ENVI OneButtom, with webinar chaired by Frank Veroustraete
	+ Pix4D
	+ MicMac (open source)
* Organizing and processing data of field day 2
* Wrap up of experiments combining flights on day 1 and 2:

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| **Experiment** | **Objective** | **Sensors** |
| BRDF | Assess scan line cross-track BRDF effect for overlapping scenes acquired with different acquisition geometries and under different illumination conditions (diffuse *vs.* direct) and for different land cover types (trees *vs.* grassland). | Rikola hyperspectral camera flown on two days. |
| Spatial variability | Estimate of spatial variability with increasing spectral information. Determine redundant and autocorrelated bands for the particular scene /target. | Rikola hyperspectral camera and MAIA multispectral camera flown on two days. |
| Geolocation | Investigate reproducibility of flight paths flown on day 1 and day 2. Comparability of different GPS systems mounted on the same UAV platform. | MAIA built-in GPS system, Rikola built-in GPS system+ autopilot system + ?? |
| End members | Evaluate the potential of endmember extraction for the particular scene for image classification from RGB, multispectral and hyperspectral imagery. Assess the potential of reconstructing information content from the hyperspectral imagery using the beam spectrometer. | Rikola hyperspectral camera, MAIA multispectral camera and 1 upward and 1 downwards pointing beam spectrometers (Ocean Optics USB2000+, STS). |

* Discussion of upcoming OPTIMISE activities and meetings (in Estonia and in Cyprus)
* Closing of the works: Alasdair MacArthur, Enrico Tomelleri
* Afternoon: Open UAV Event with talks by different UAV and UAV sensors developers.