UAS-based hyper-spectral imaging for estimation of water quality parameters in reservoirs

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Introduction

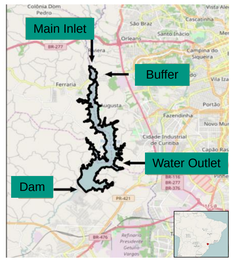
Motivation

- In-situ measurements: insufficient spatial / temporal resolution
- Spaceborne remote sensing: low spectral resolution and flexibility, cloud coverage
- Airborne remote sensing: high spatial resolution, but high costs & low temporal resolution
- ➢ Aim: UAV based monitoring of water quality parameters
- ➢ Challenges:
- ➢ Setup of multi-sensor system with innovative lightweight sensors
- ➢ Robust parameter estimation under changing conditions
- ➢ Geocoding and stitching of images over water without feature matching

Relevant water quality parameters	Optical active
Total Suspended Solids (TSS)	x
Turbidity	x
Secchi Disk Depth (SDD)	x
Chlorophyll-a (cl-a)	x
Colored Dissolved Organic Matter (CDOM)	x
Temperature (T)	x
Total Phosphor (TP)	-
Nitrogen (N)	-

Project

- German-Brazilian research project: Multidisciplinary Data Acquisition as Key for a Globally Applicable Water Resource Management (MuDak-WRM)
- Development of an autonomous monitoring system for drinking water reservoirs
- Ensuring the supply of high quality drinking water to the population through optimised management based on improved prediction models
- Study area: Passaúna drinking water reservoir near Curitiba, Brazil (population: ca. 1.8 mio)



Passaúna reservoir

- Water area: 9 km²
- Mean depth: 9 m
- Catchment: 150 km²
- Drinking water supply for 0.7 mio People

UAS and Sensor System

Octocopter

- Light-weight coaxial Octocopter
- Open-source/hardware autopilot
- Automatic flight and data acquisition
- Hardware trigger for all cameras

RTK-X8	
Weight	5.0 kg
Payload	max. 4.5 kg
Flight time	23 min
GNSS	Diff. RTK
Gimbal	2 axis, brushless
Safety	Self inflating float

Multi sensor imaging system

- Hyperspectral camera for water quality parameter estimation
- Upwards looking spectrometer for irradiance measurements
- Thermal camera for water surface temperature measurements
- RGB camera for enhanced pose estimation at shore

	Cubert FireflEYE (S185)	rgb photonics Qmini	Flir Tau 2	Mapir Survey 2
Wavelength [µm]	0.450 – 0.95	0.225 – 1.0	7.5 – 18.5	-
Channels	125	2500	1	3 (R,G,B; Bayer)
Resolution	8 nm @ 532 nm	1.5 nm	-	-
Sampling [nm]	4	0.31	-	-
Weight [g]	490	60	100	60
Sensor	CCD, Global	-	-	CMOS, Rolling
Sensorsize [Pixel]	50x50 1000x1000 (Pan)	1	640x512	4608x3456
Field of view [°]	33x33	Cosine corrector	45x37	82x60

Approach

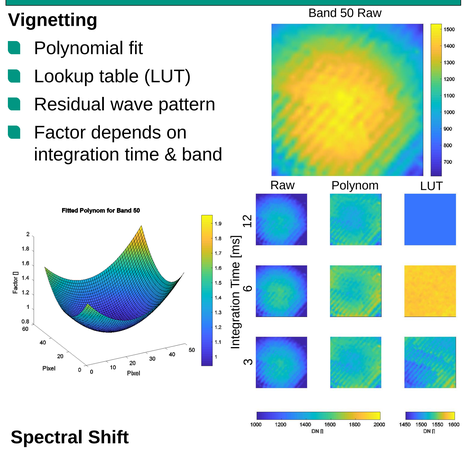
- Water quality parameters change reflectance spectra
- 2D-hyper-spectral remote sensing of the water surface
- Estimate optical active water quality parameters
- Adapt algorithms to infer optical inactive parameters

Sensor calibration (geometric, radiometric) → Data acquisition → Geometric correction, geocoding → Radiometric correction → Parameter estimation → Water quality parameter map

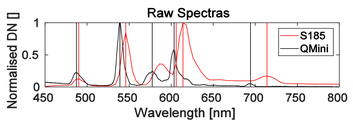
Radiometric Calibration

Vignetting

- Polynomial fit
- Lookup table (LUT)
- Residual wave pattern
- Factor depends on integration time & band



Spectral Shift

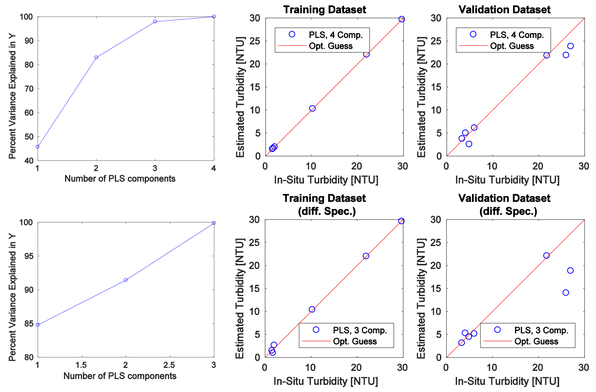


Parameter Estimation

Partial Least-Squares Regression (PLS)

- Using raw data from hyperspectral camera
- No irradiance correction
- Ground truth data from lab analysis
- Raw and differential spectra

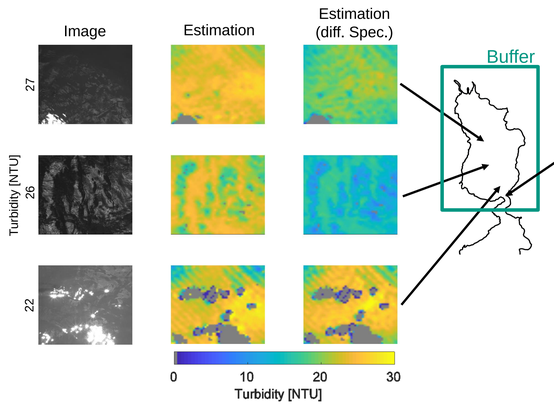
Mean Relative Error [%]	Training	Validation
Standard	0.19	21.42
Diff. Spec.	3.29	54.00



First Results

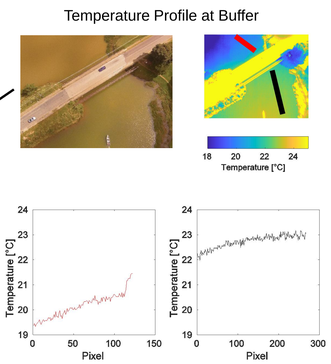
Parameter Estimation

- PLS Estimation of Turbidity
- Using raw spectra and differential spectra
- Residual wave pattern
- Not applicable for different conditions



Thermal Imaging

- Thermal infrared images show temperature gradients
- Water surface temperature as input parameter for numerical modelling
- Unveils water mixing and inflows



Outlook

- Geometric system calibration for precise geocoding of images
- Parameter estimation using Neural Networks and physical models
- Cross calibration of hyper spectral camera and upwards looking spectrometer to get reflectance
- Comparison with satellite data

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