Seminar on HyMo measurement and data processing techniques in regulated waterbodies, Trondheim

Assessing hydraulic and morphological conditions using UAS

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Outline

- Introduction
- Hardware
  - UAS
  - Sensors
- Applications
- Summary
- Outlook

Why UAS?

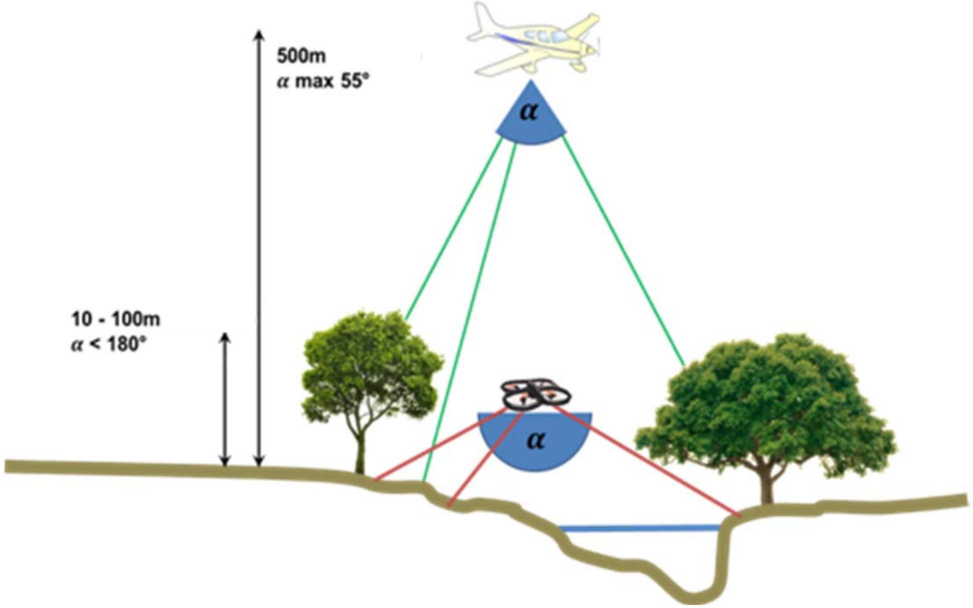
Current Monitoring strategies:

- No monitoring
- Modelling
- Single Point/ Data

Requirements of Monitoring:

<u>Monitoring strategies/ tools need to picture natural processes in time and scale!</u>

New/ additional Monitoring tools and strategies required:



Low altitudes/ fast repeatability

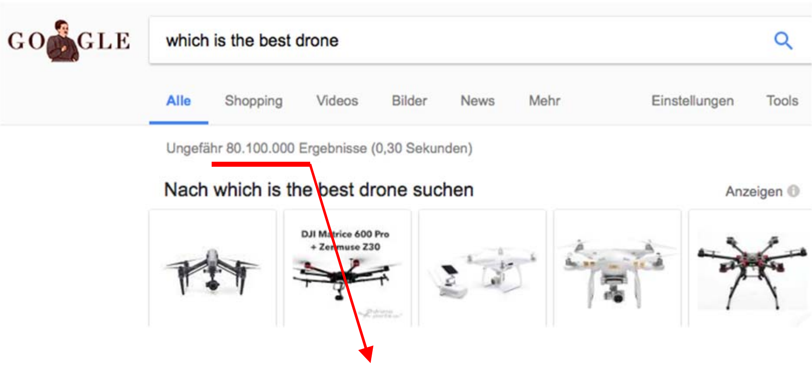
→ High resolution (spatial and temporal)

→ Better learning/ understanding?

Which UAS?

...lets ask Google:

http://lmgtfy.com/?q=which+is+the+best+drone



80.100.000 results

What does experience show?

- There is **no best drone** in general!
  - Hardware must be reliable
  - Data must be sufficient
- The investment is not correlated to the outcome but to knowledge!

→ inexpensive equipment + knowledge = high quality output

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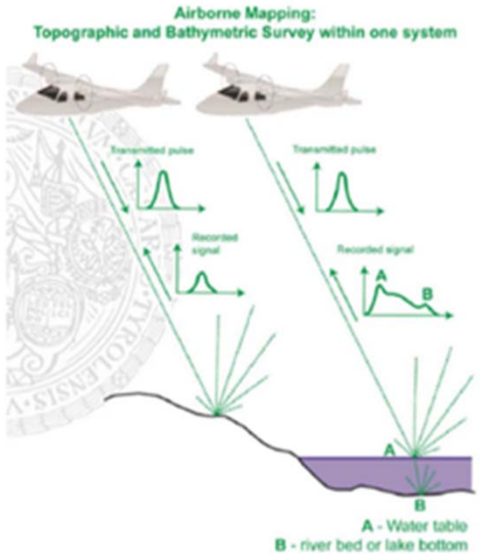
Sensors

- Cameras
  - Post Processing
    - **RGB**
    - **NIR**
    - **Thermal**
  - Real Time Data
    - SLAM - Simultaneous Localization and Mapping
    - **RAPTOR – Real Time Particle Tracking**
- LIDAR (Light Detection and Ranging)
    - IR LIDAR
    - Green LIDAR



(Jocham et al., University of Innsbruck)

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3D Reconstruction

Georeferenced Imagery

Hydropeaking on a gravel bar at river Lech, Germany

- temporal and spatial measurements of up- and down ramping events
- Control and investigate altered ramping rates for mitigation

Classification of UAV Imagery

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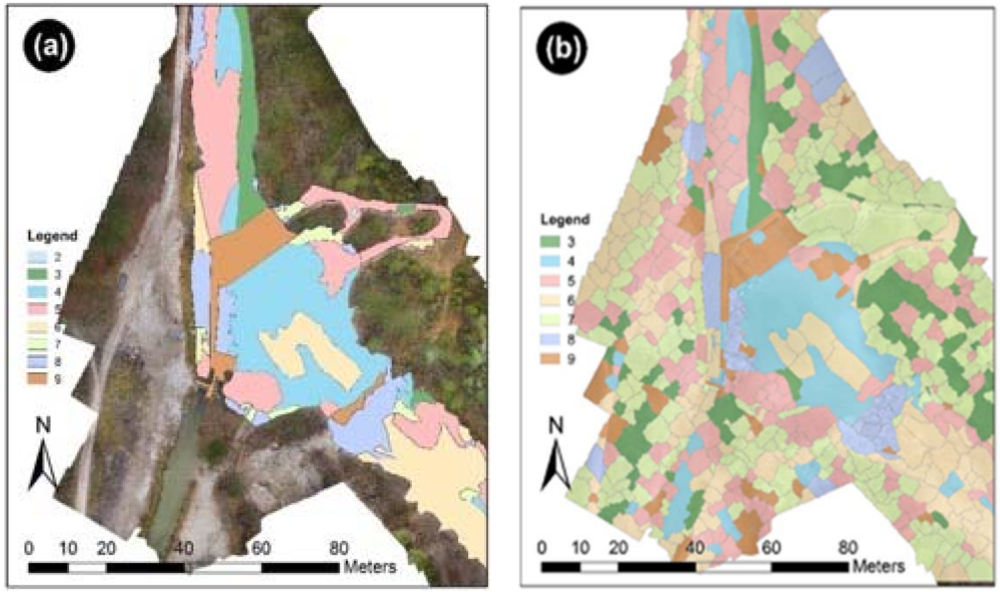
Classification:

- Supervised & unsupervised classification
- Threshold classification
- Masking
- Segmentation based classification
- Validation and analysis

Software for this approach: ERDAS IMAGINE, Matlab, eCognition & Arc GIS



Comparative illustration of substrate classified map showing spatial distribution of the sediment types:

a) Manually mapped substrate
b) Automatically mapped substrate

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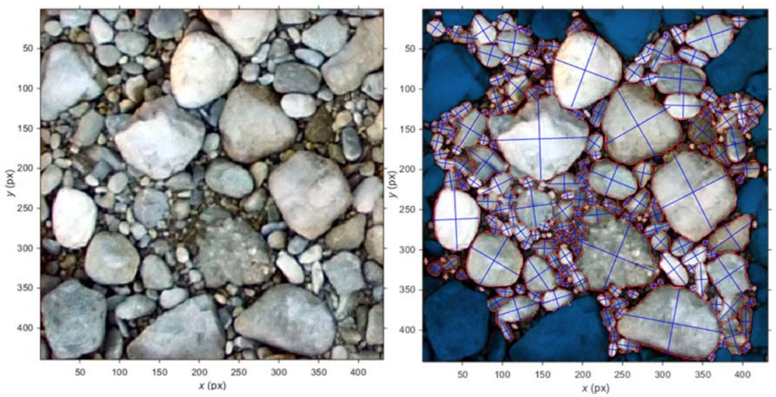
Sediment Mapping & Grain Size

Photo Sieving

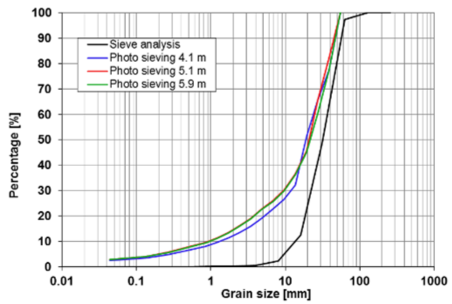
BASEGRAIN (Detert & Weitbrecht, 2013)

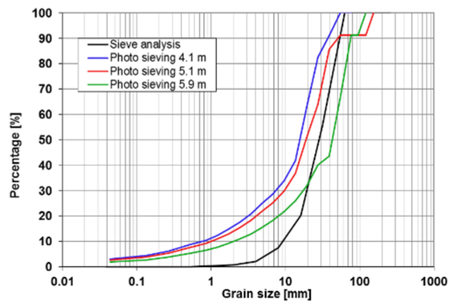


BASEGRAIN:

MATLAB-based automated object detection software tool (Detert & Weitbrecht, 2013)

Comparison with lab sieving curve of sample

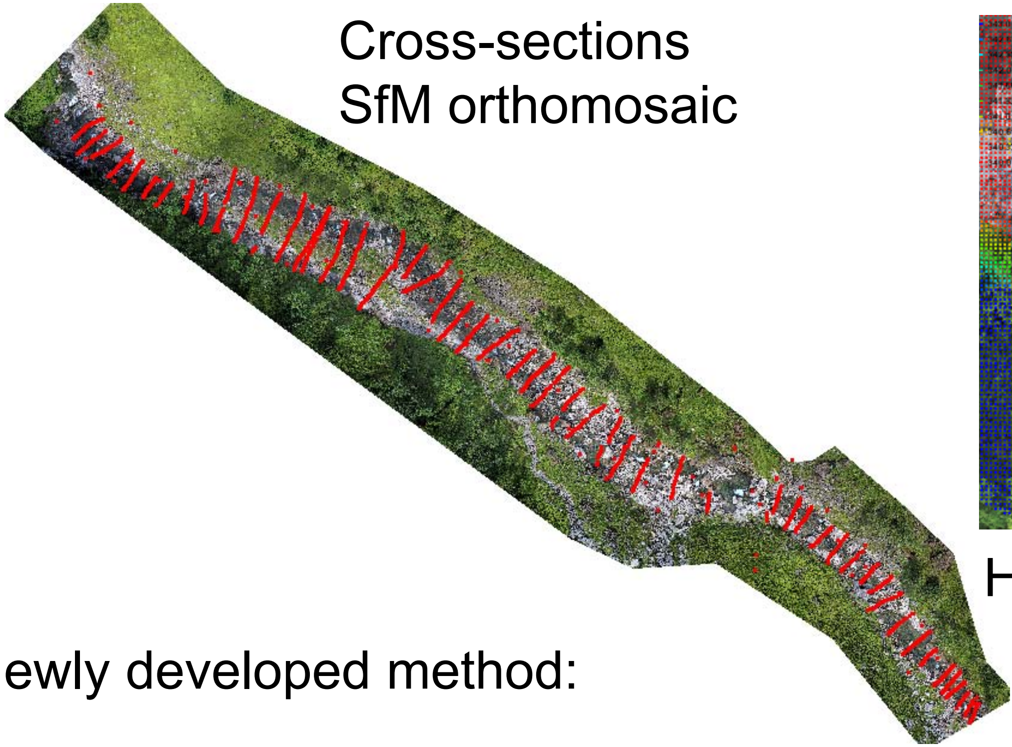




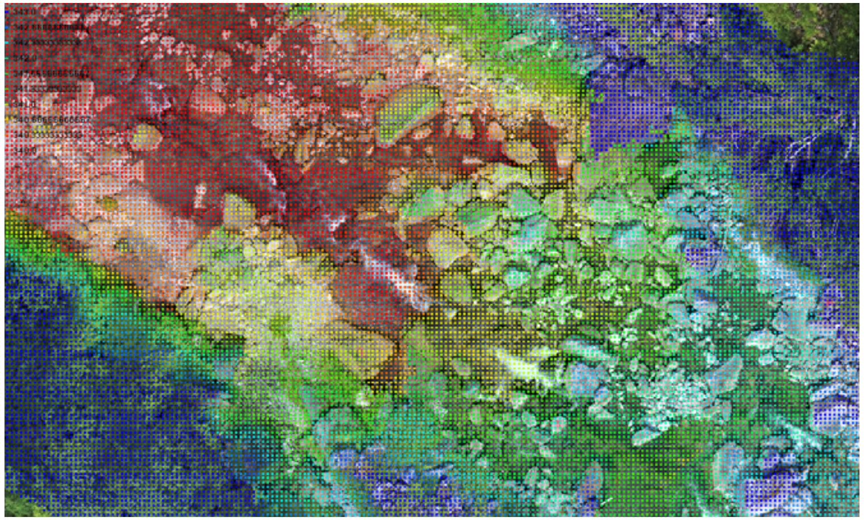
Good results in dry areas

More variation in submerged areas and areas with biofilm on sediment

Bathymetric Reconstruction Taigdalselva, Norway



Cross-sections SfM orthomosaic

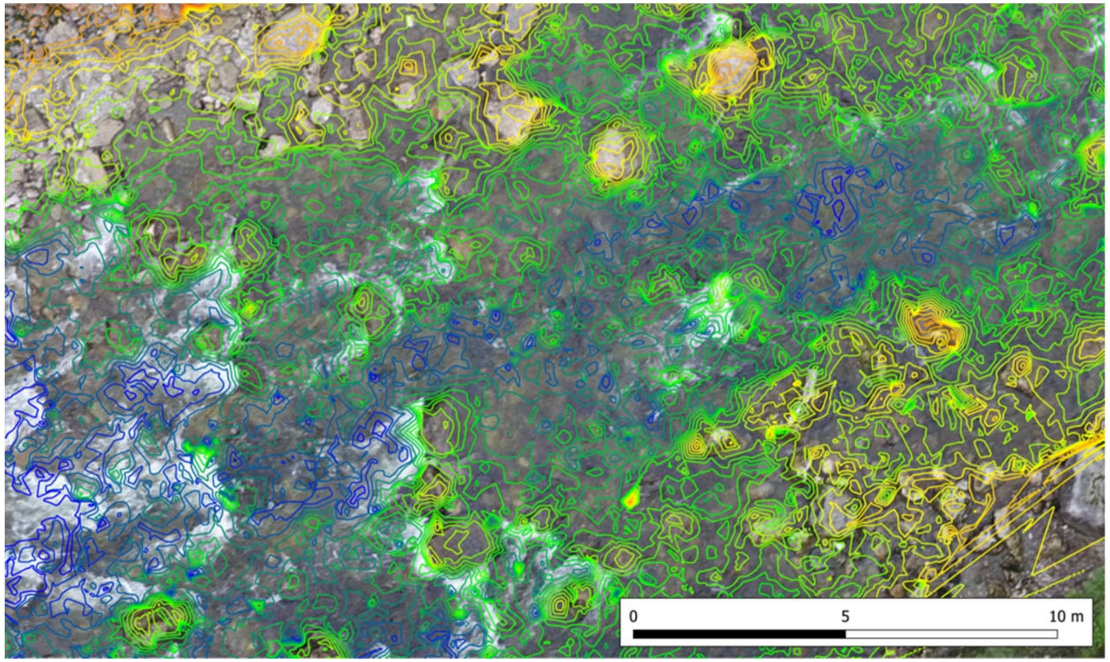


High-density point cloud + SfM ortho

Newly developed method:

1) Uses standard cross-section measurements + Structure from Motion (SfM) point cloud
2) Multivariate model of submerged regions from SfM + cross-section data
3) High-resolution (10 cm/pt) bathymetric reconstruction (error < 10 cm)

UAS-based bathymetric reconstruction

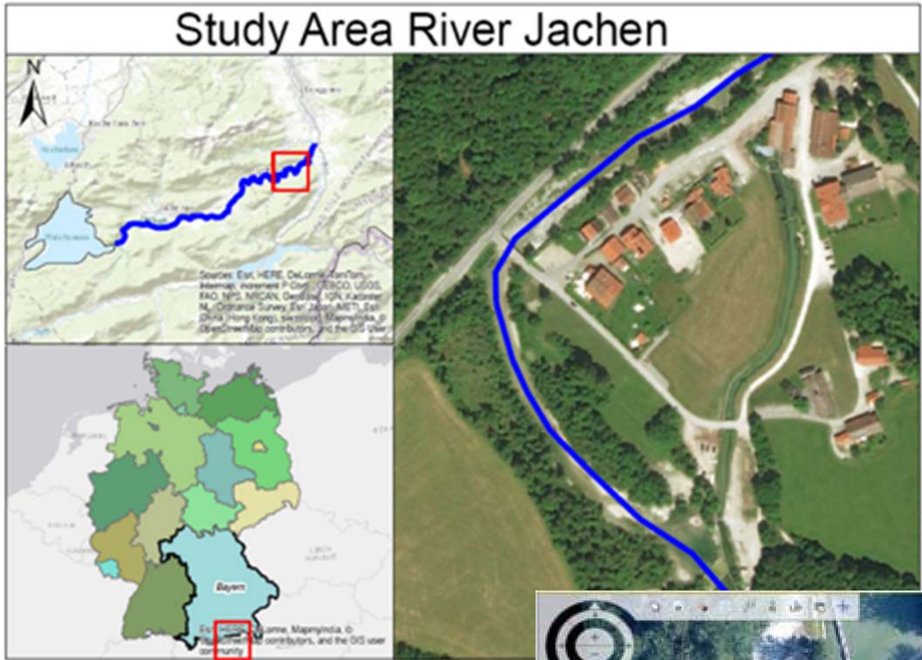


Overlay of contours and 2 cm/px orthomosaic

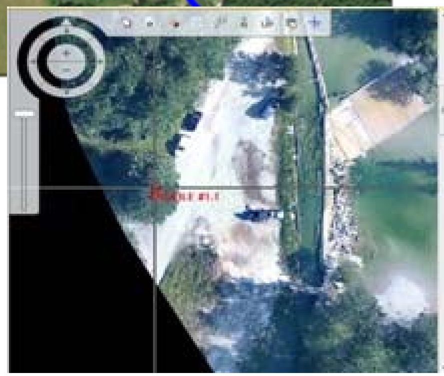
Can be used to generate highly accurate numerical models and DEM change maps

- Uses pre-existing data + UAS imagery products
- Low cost (~2k EUR / km)
- Same accuracy or better than LiDAR
- Applicable for reaches 50 m to 20 km
- Requires field measurements of submerged regions

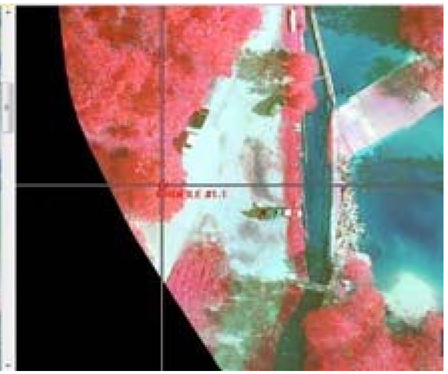
NIR imagery



Low-cost multicamera system
(Haas et al. 2016)



RGB orthomosaic

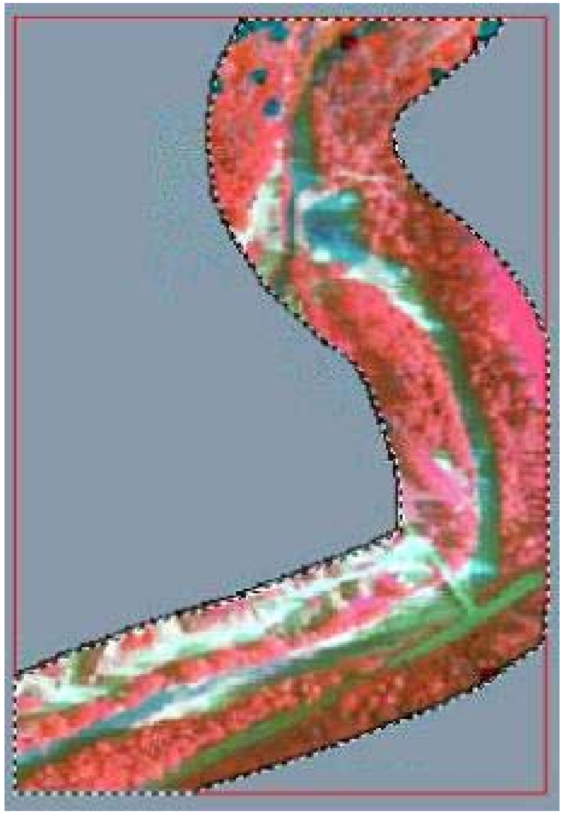


NIR orthomosaic

NIR imagery

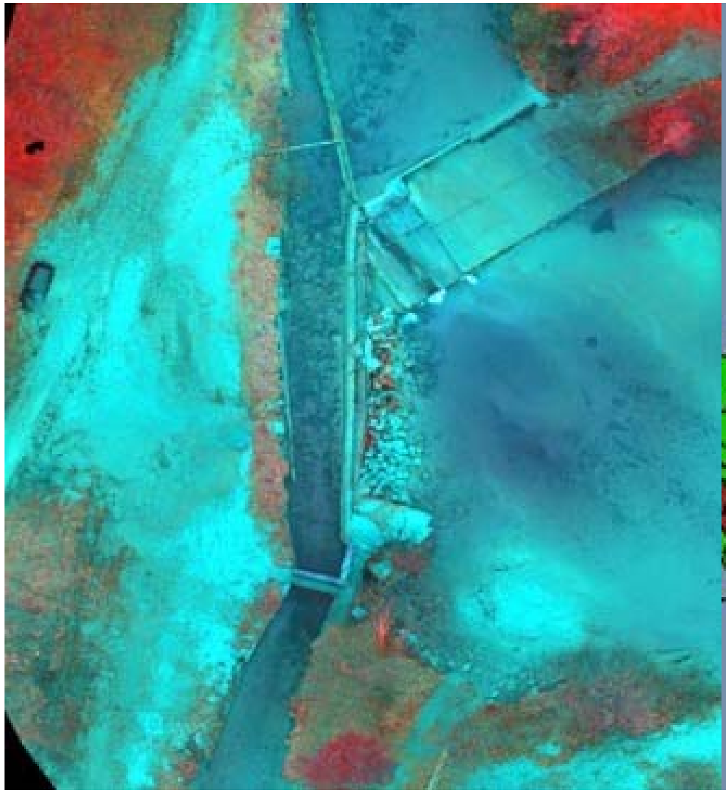
Vegetation indices from multispectral imagery*

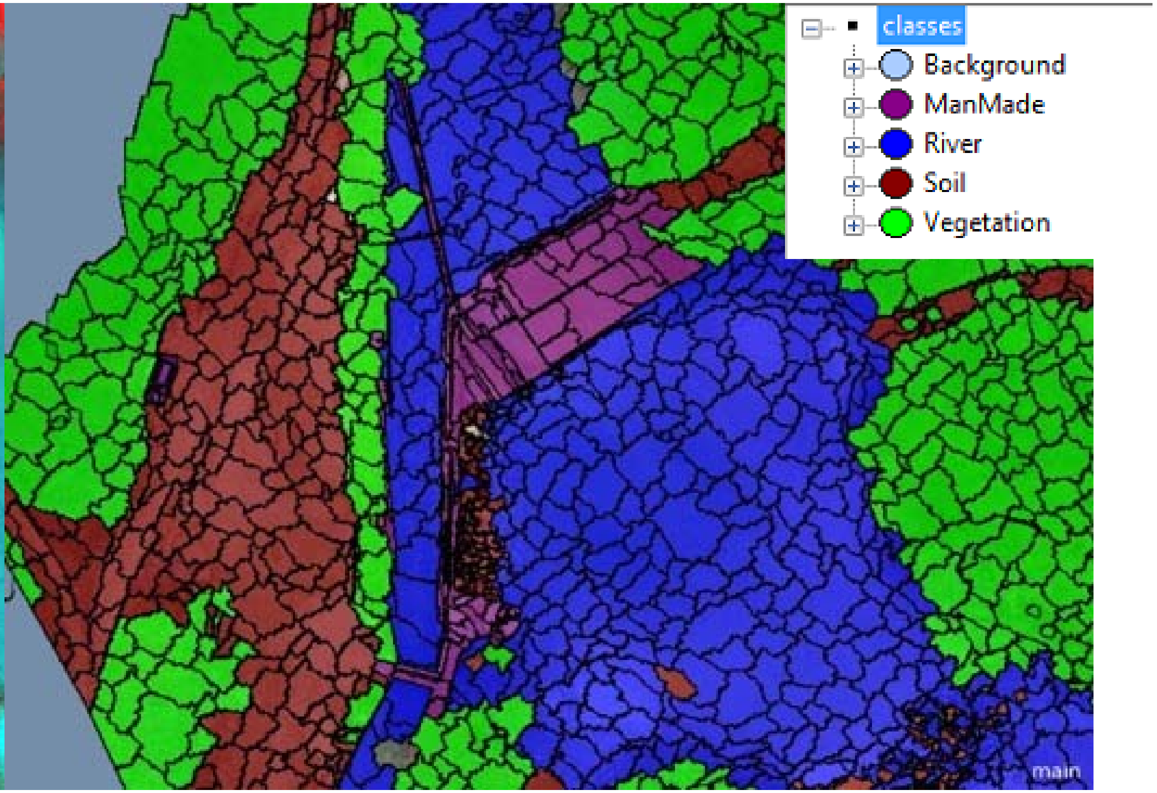
Index	Formula	Description
DVI	$DVI = \text{NIR} - \text{RED}$	**Difference Vegetation Index**, it is used to separate soil from vegetation. It is sensitive to illuminations conditions.
SR	$SR = \frac{NIR}{REd}$	**Simple Ratio Index** shows high values for vegetation and lower ones for soil. Compensates differences in lighting conditions
NDVI	$NDVI = \frac{NIR - RED}{NIR + REd}$	**Normalized Difference Vegetation Index** used to estimate amount of vegetation, good to distinguish vegetation from soil. More Robust applicable to both reflectance and Radiance. Reduces the effect of no uniform illumination.



(*Jones and Vaughan, 2010)

Multi-band imagery



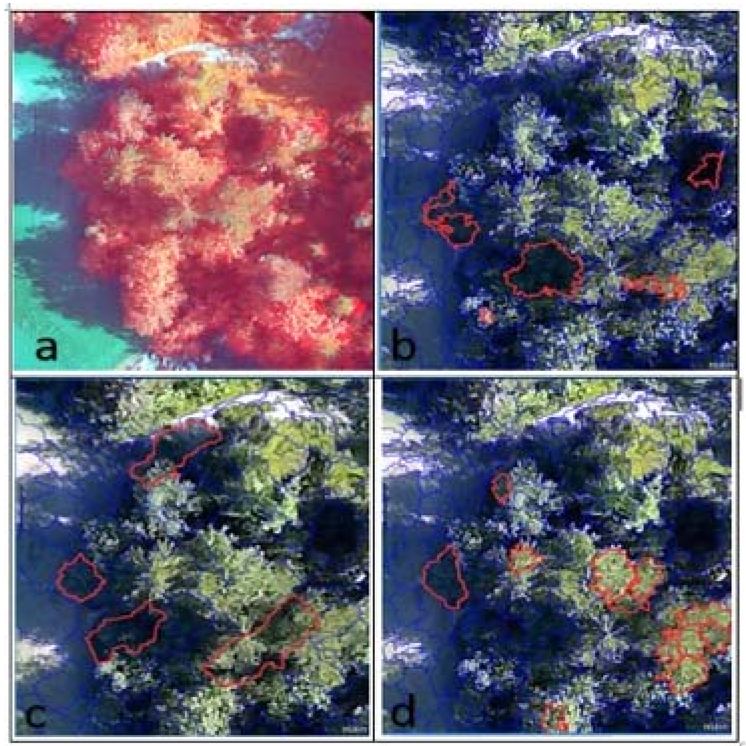


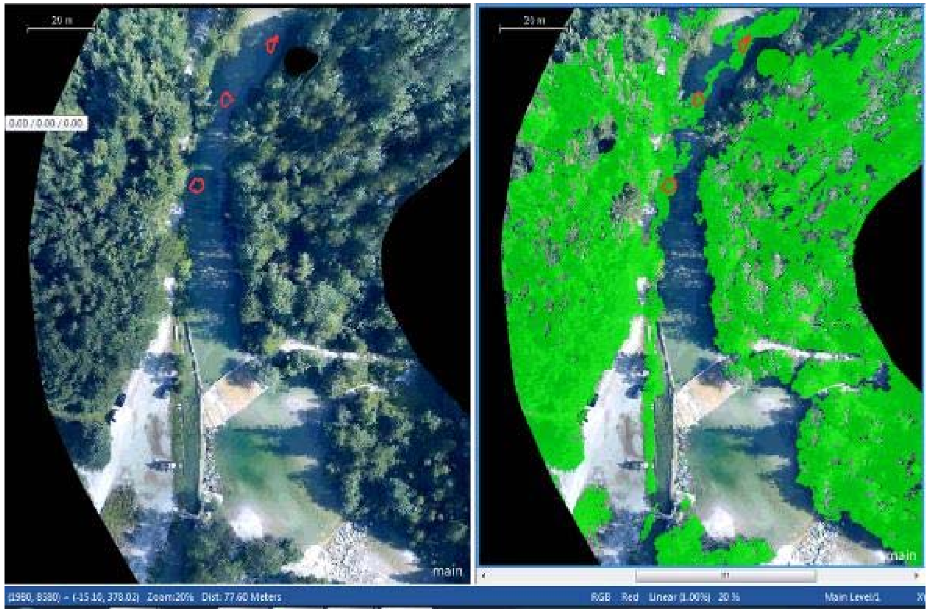
Multi-band image **combines visible RGB and NIR**

Example usage: automated classification of the landscape into user-defined groups

Multi-band imagery

Vegetated regions identified and grouped using NIR and RGB imagery



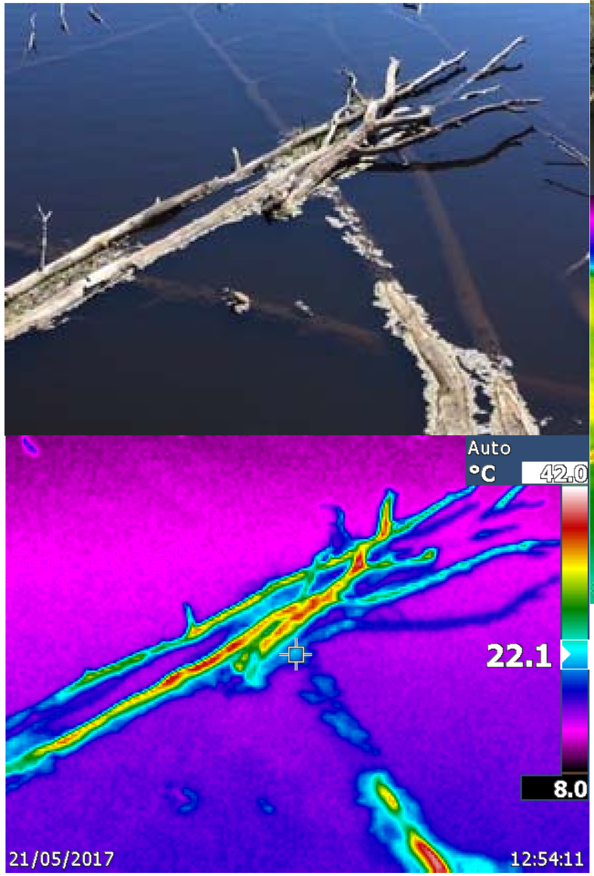


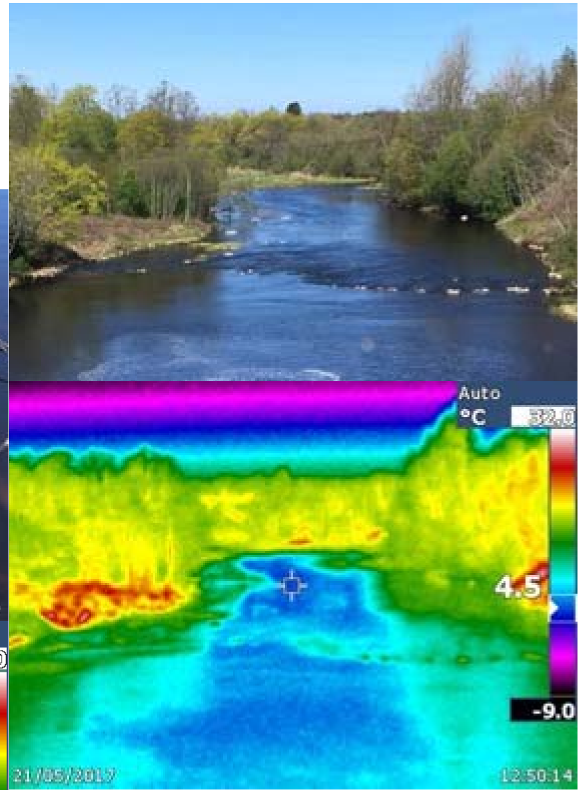
- Data used to compare changes in vegetation over different periods
- interpretation aided by overlay with aerial imagery

Thermal imagery

Used for:

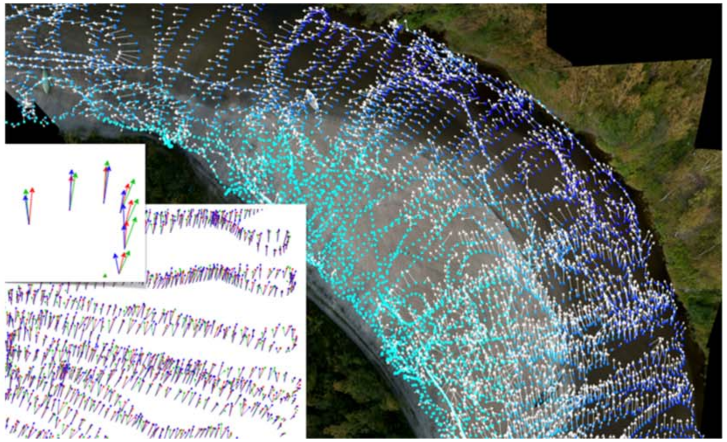
- Thermopeaking
- Discharge
- Upwelling and downwelling (heat stress)
- Persist “memory effects” of shading and illumination
- Effects of heat sinks (walls, boulders)





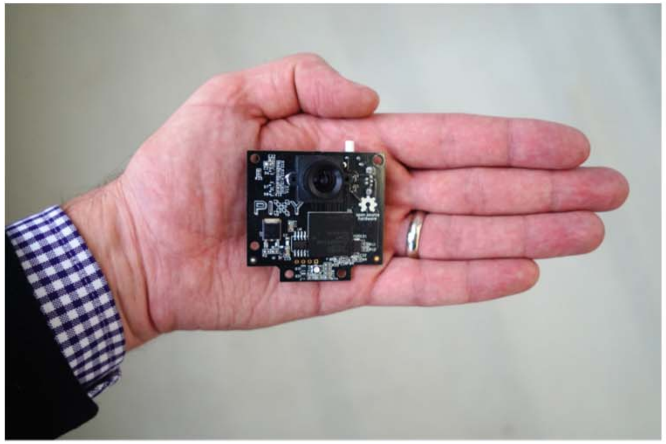
RAPTOR – Real-Time Particle Tracking of Surface Flows Using Unmanned Aerial Vehicles

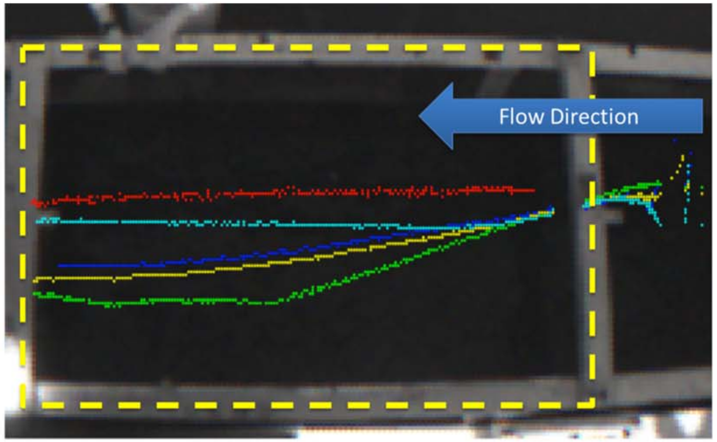




UAS tracks illuminated particles on surface

2D velocity vector, real-time





Light-weight embedded color vision controller

System can also be used in lab to track sediment, fish etc.

UAS Applications

less modelling, more measuring!

Hydrology and Hydraulics

- digital elevation models
- waterlines
- bathymetry
- Velocities
- …

Morphology and Morphodynam

- grainsi
- s
- alysis
- sion
- deposition
- …

Ecology

- Habitat mapping
- redd counting
- plant and macrophyte assessment
- …

Intersection: Ecohydraulics

→ very usefull tool for many of flow and morphology related tasks and questions

→ monitoring of **dynamic processes** with high spatial and temporal resolution

Some recent research...

- Alfredsen, K., Haas, C., Tuhtan J.A., Zinke, P., 2018. Brief Communication**: Mapping river ice using drones and structure from motion**. In: The Cryosphere

- Haas, C., Thumser, P., Tuhtan, J., 2017. **Unmanned Aerial Systems (UAS) - New opportunities for measuring, mapping and modelling rivers and lakes**. In: Joint Workshop IEA Hydropower TCP– European Commission DG RTD, Brussels, Belgium.

- Arif, M. S. M., Gülch, E., Tuhtan, J.A., Thumser, P., Haas, C., 2016. **An on image processing techniques for substrate classification based on dominant grain size on RGB images from UAV**. In: International Journal of Sensing.

- Thumser, P., Haas, C., Tuhtan, J.A., Fuentes-Pérez, J.F., Toming, G., 2017. **RAPTOR-UAV: Real-Time Particle Tracking in Rivers using an Unmanned Aerial Vehicle**. In: Earth Surface Processes and Landforms.

- Haas, C., Thumser, P., Seitz, L., 2016. **UAV based determination of grain size distribution at River Jachen**, Germany. Proceedings of the 13th International Symposium on River Sedimentation, Stuttgart, Germany.

Outlook

- The **internet of things** (IOT) allows for rapid integration of custom sensing systems (e.g. cameras, depth, temperature)

- **Long-term, persistent monitoring** of aquatic variables including depth, temperature, salinity, suspended load is becoming very inexpensive (< 1500 EUR / site)

- **Aggregation and real-time assessment** of large, multimodal unstructured data sets using statistical learning methods (e.g. deep learning, tensor flow, support vector machines)

- **Increasing availability of geospatial measurements** will in some cases begin replacing models (e.g. stream flow, satellite-based precipitation, ARGO network)

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