CHAPTER 2

UAV platforms for semantic scene analysis in agricultural applications

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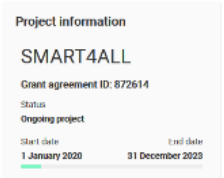
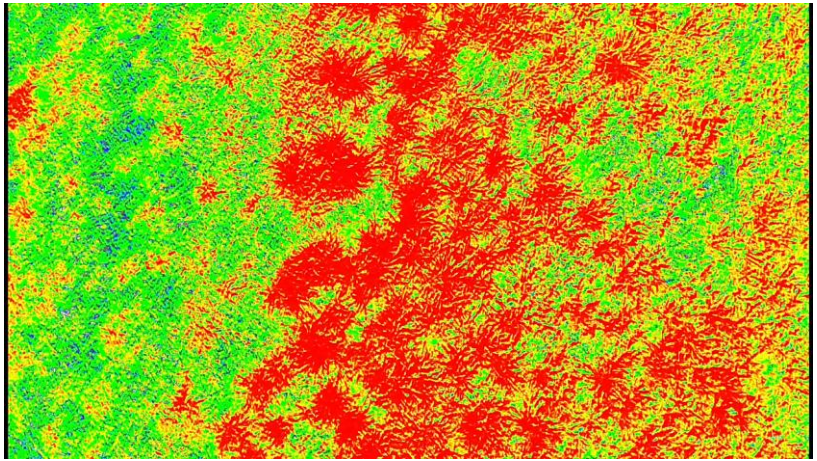
Talk overview



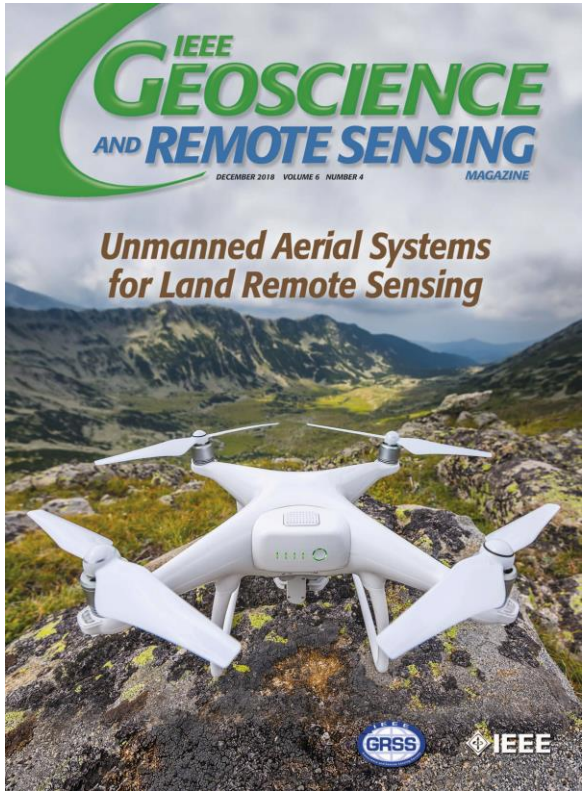
H2020

SMART4ALL

- UAV imaging platforms
- Image analysis and scene understanding
- Practical challenges and possible solutions
- Processing workflows
- Interoperability and inform. fusion
- FTN’s internal PAE – „Ambientura“
- Related projects and experiments
- Embedded vision platforms



UAV or UAS



How will drones impact business?

Predicted commercial applications and market value by industry

Infrastructure
Investment monitoring, maintenance, asset inventory
$45.2 bn

Agriculture
Analysis of soils and drainage, crop health assessment
$32.4 bn

Transport
Delivery of goods, medical logistics
$13.0 bn

Security
Monitoring lines and sites, proactive response
$10.5 bn

Entertainment & Media
Advertising, entertainment, aerial photography, shows and special effects
$8.8 bn

Insurance
Support in claims settlement process, fraud detection
$6.8 bn

Telecommunication
Tower maintenance, signal broadcasting
$6.3 bn

Mining
Planning, exploration, environmental impact assessment
$4.3 bn

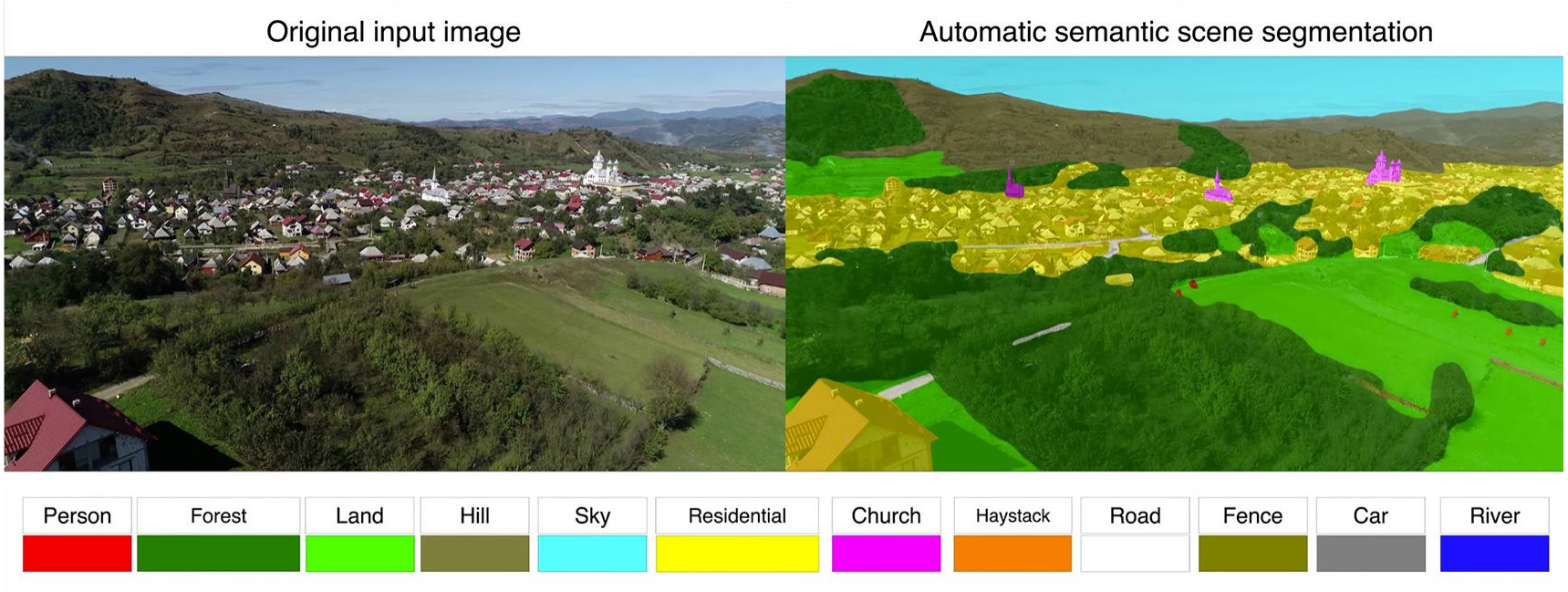
Source: PwC (2016)

Semantic scene analysis

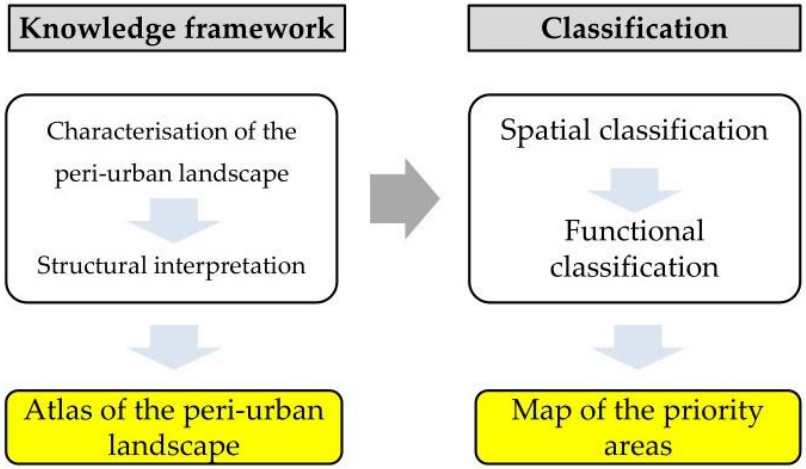
- Detection, segmentation and context (inference goals)

Input Image | Semantic Segmentation | Instance Segmentation

Example # 1 – Mapping inventories of rural and peri-urban agricultural environments



Example # 1 – peri-urban agriculture

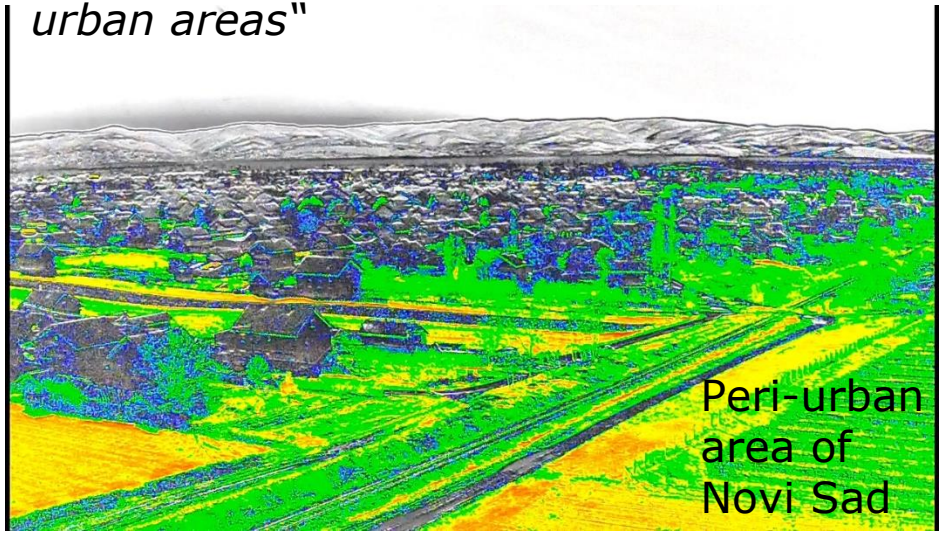


Article

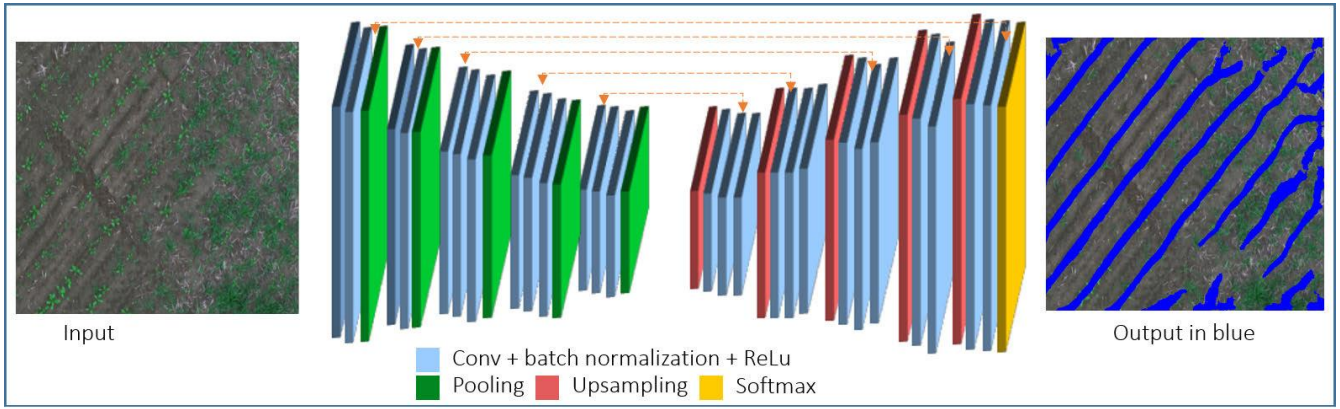
Planning Peri-Urban Open Spaces: Methods and Tools for Interpretation and Classification

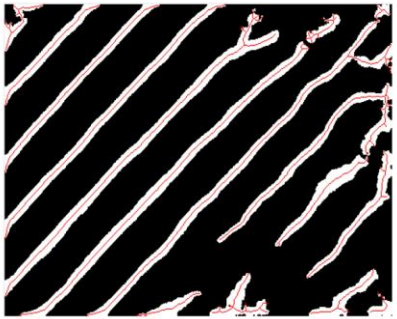
Enrico Gottero [1,*], Claudia Cassatella [2] and Federica Larcher [1]

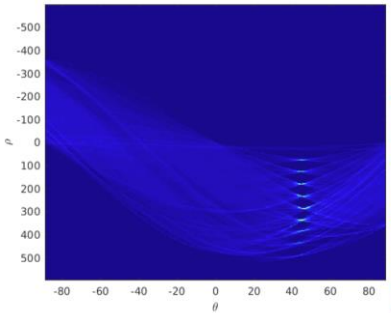
- *„A peri-urban-area is a zone of contact between city and countryside characterized by material and immaterial relationships, where a system of functional, socio-economic, spatial and ecosystemic relations is recognizable between rural areas and urban areas"*

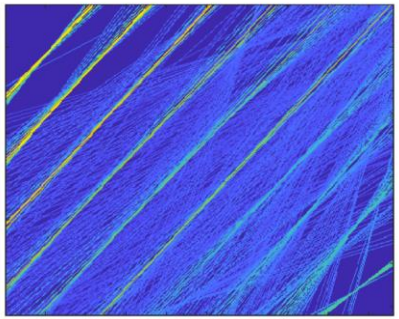


Example #2 – Precise field navigation







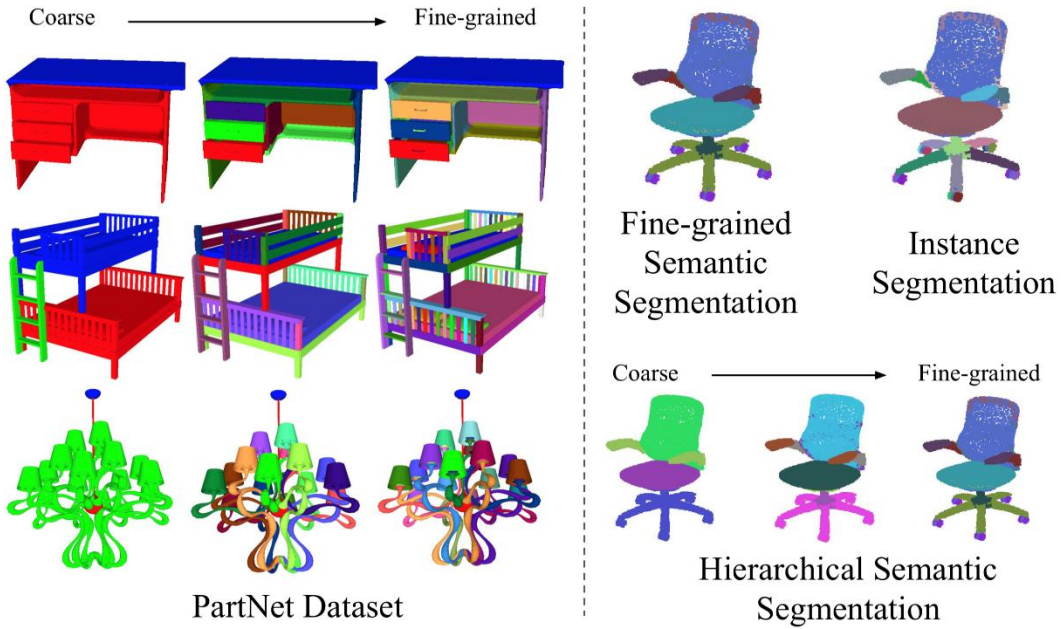


CRowNet: Deep Network for Crop Row Detection in UAV Images

MAMADOU DIAN BAH[1], ADEL HAFIANE[2], AND RAPHAEL CANALS[1]
[1]University of Orleans, PRISME, EA 4229, F45072 Orleans, France
[2]INSA Centre Val de Loire, PRISME, EA 4229, F180222 Bourges, France

Example #3 – Object understanding

- *„fine grained“, „instance-level“* and *„hierarchical 3D“*



Deep Segmentation of Point Clouds of Wheat

Morteza Ghahremani[1,2*], *Kevin Williams*[1], *Fiona M. K. Corke*[1], *Bernard Tiddeman*[2], *Yonghuai Liu*[3] and *John H. Doonan*[1]

[1] National Plant Phenomics Centre, Institute of Biological, Environmental and Rural Scienc Aberystwyth, United Kingdom, [2] Department of Computer Science, Aberystwyth Universit [3] Department of Computer Science, Edge Hill University, Ormskirk, United Kingdom

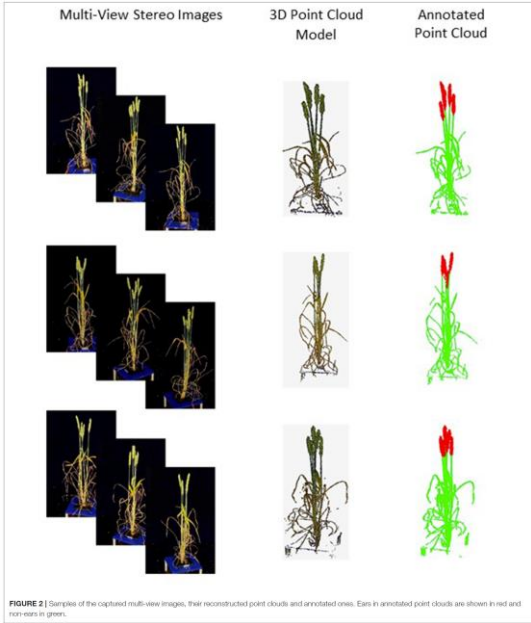


FIGURE 2 | Samples of the captured multi-view images, their reconstructed point clouds and annotated ones. Ears in annotated point clouds are shown in red and non-ears in green.

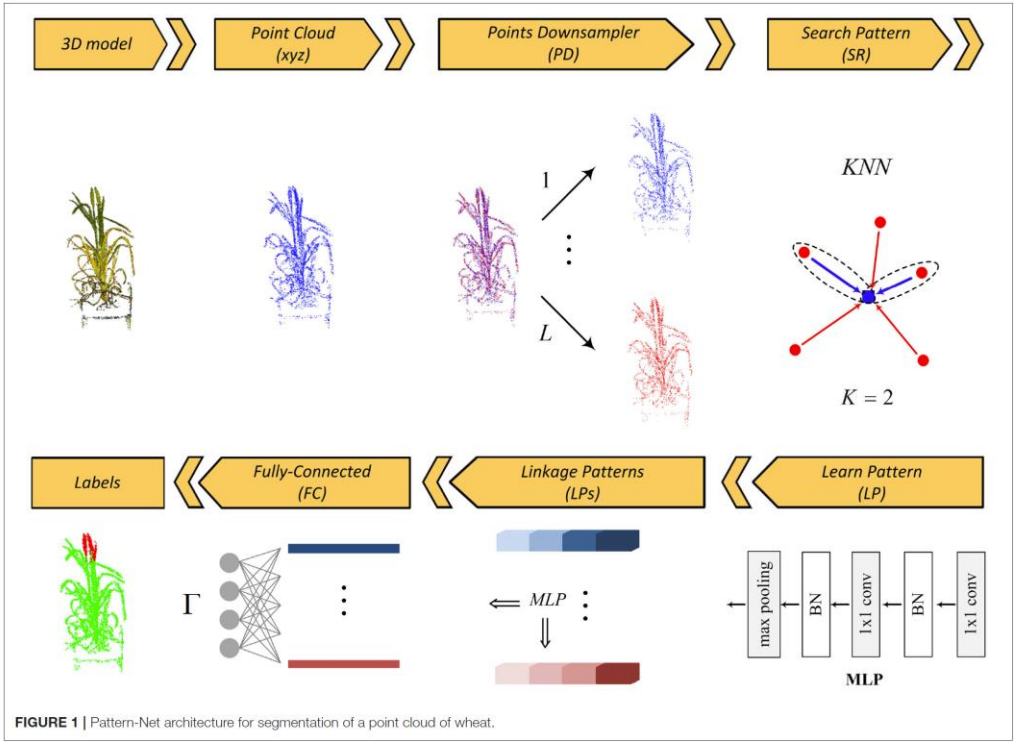


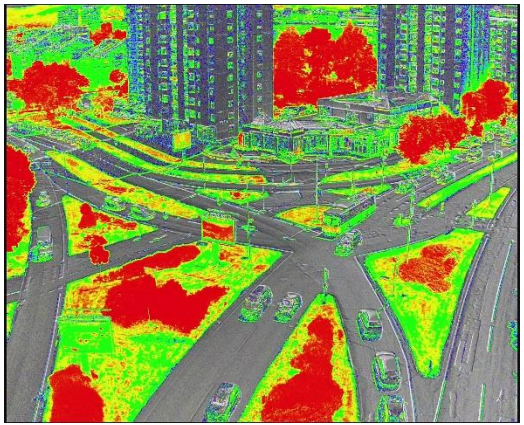
FIGURE 1 | Pattern-Net architecture for segmentation of a point cloud of wheat.

Field work challenges and UAV capabilities

Unpredictible weather conditions

High resolution imaging

- Visible
- Multispectral
- Hyperspectral
- Thermal
- Lidar



On-site and edge processing

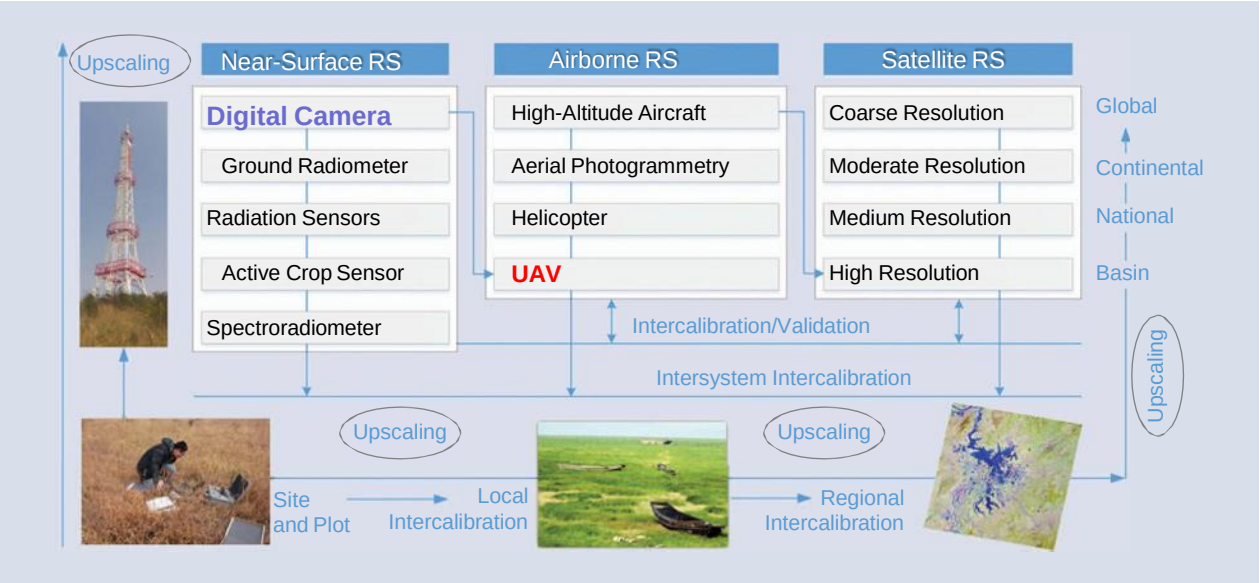
- Exploiting existing agricultural equipment and infrastructure as sensor platforms for spatial information collection

Information fusion

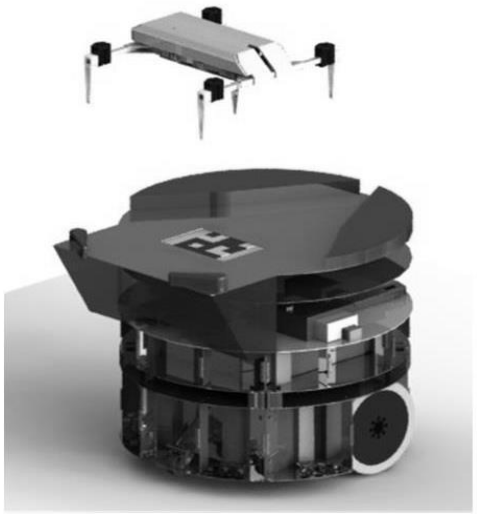
- At sensor, feature and decision level
- Results validation

Measurements interoperability

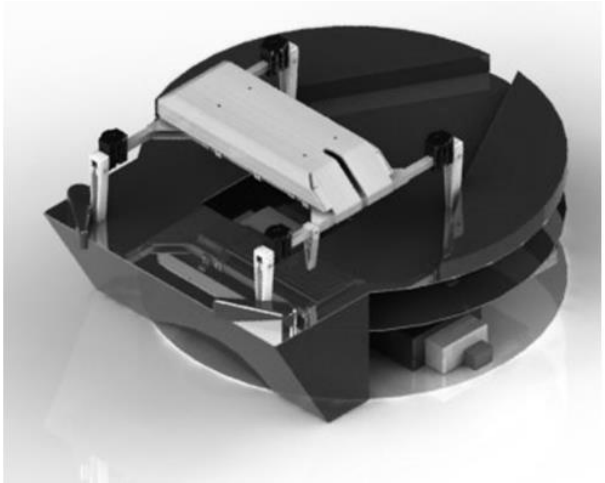
- E.g. NDVI intercalibrations among data acquired from near-surface, airborne, and satellite remote sensing

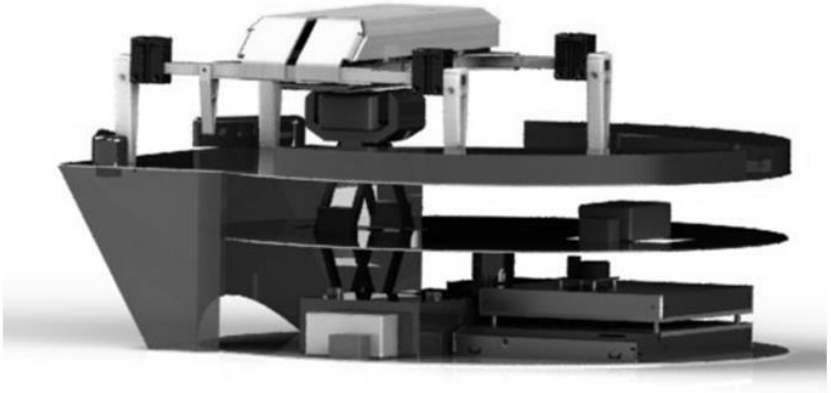


Data acquisition – challenges and constraints



From concepts to reality





Off-nadir multispectral imaging





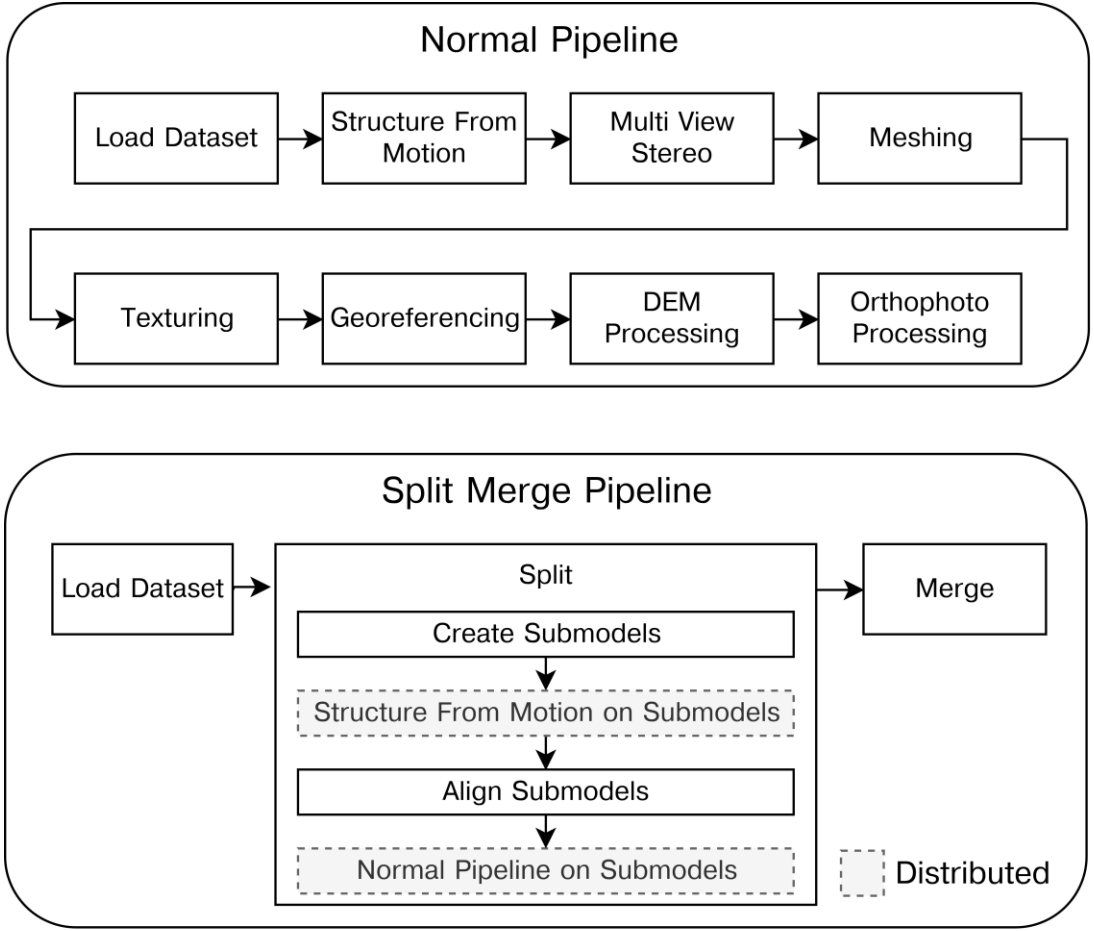

Technological advances

- 2010

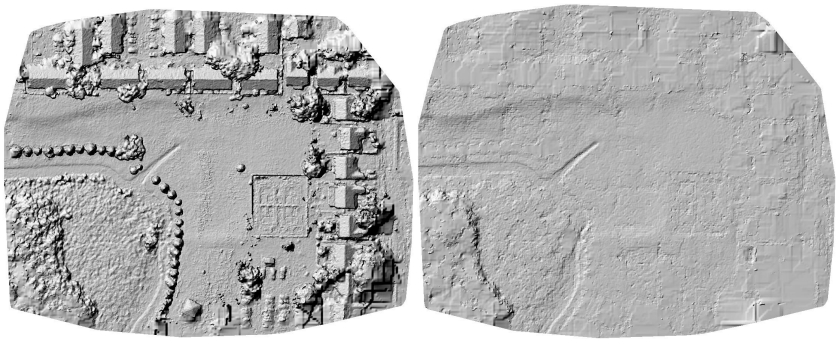
- 2022

2 Mpx, 16 bands, 460 -600 nm, cube acquisition speed up to 120/second

Processing Workflows



VI, maps, DSM, DEM …

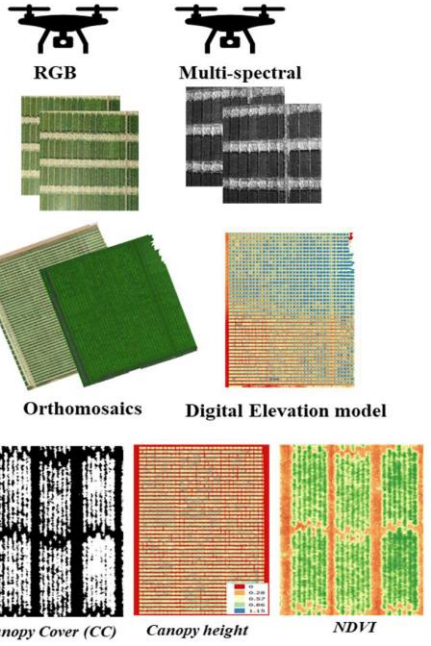


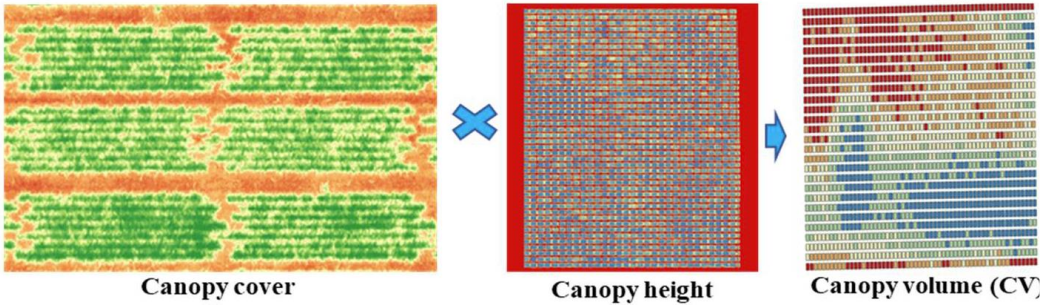
UAS data collection

Level 0
Raw UAS data

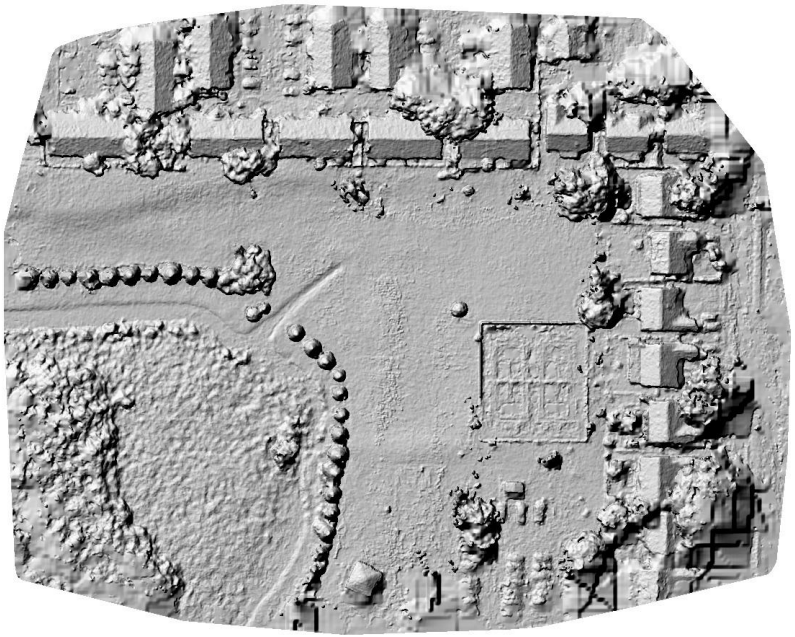
Level 1
Geospatial Data Products
Orthomosaic
Digital Elevation (DEM)

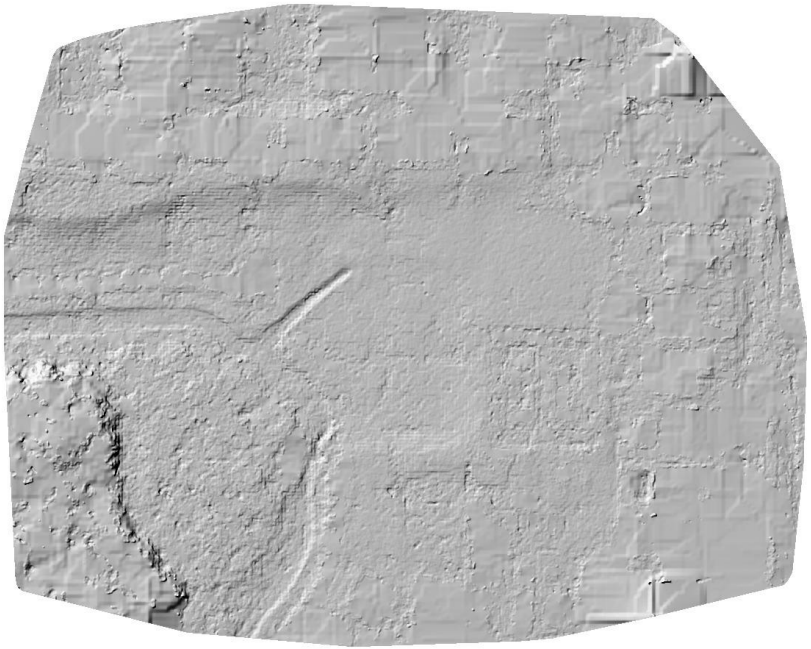
Level 2
Excess Green Index (ExG)
Normalized Difference RedEdge Index (NDRE)
Normalized Difference Vegetation Index (NDVI)
Canopy cover, canopy height, canopy volume





3D models



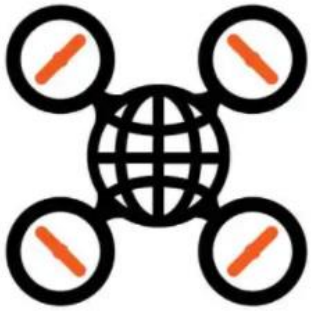


Different frameworks

COLMAP

Agisoft Metashape

PIX4Dmapper



WebODM

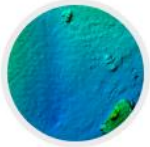
Features

Orthomosaics

Georeferenced, orthorectified maps.

Point Clouds

Georeferenced, filtered and classified dense point clouds.



Elevation Models

Georeferenced digital elevation models (DSMs and DTMs).

3D Models

Textured 3D models in .OBJ and OGC 3D Tiles format.

Measurements

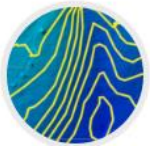
Make volume and area measurements with ease, track stockpiles.

Plant Health

Easily compute NDVI, VARI, GNDVI and many other indexes.

Ground Control Points

Create and use GCPs for additional accuracy.



Contours

Preview and export elevation contours to AutoCAD, ShapeFile, GeoPackage.

Any Camera

From consumer phones to professional cameras (standard, fisheye, 360°), single or multi-camera.

Any Format

JPGs and TIFFs (8bit and 16bit), with or without EXIFs.

Any Orientation

Process aerial and ground images, captured nadir or oblique.

Multispectral

Process multispectral images.

Rolling Shutter

Correction support.

Share

Easily share your maps and 3D models.

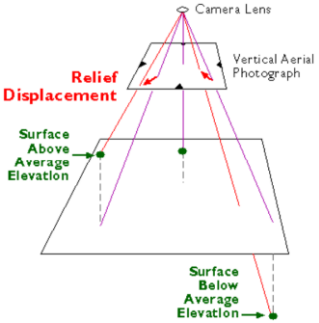
Rebrand

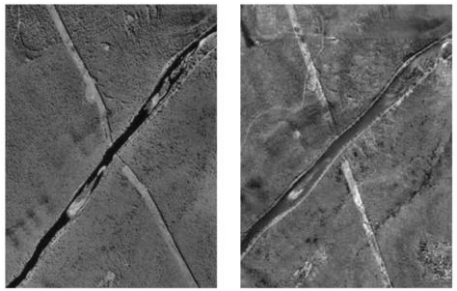
Choose a logo and color scheme that matches your organization.

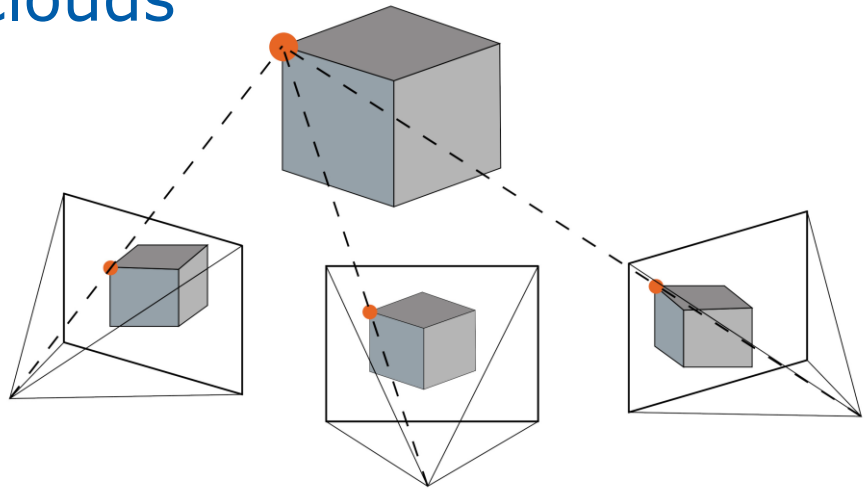
Scale

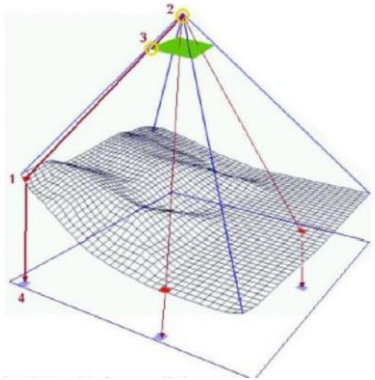
Run multiple jobs in parallel and single jobs distributed on multiple machines.

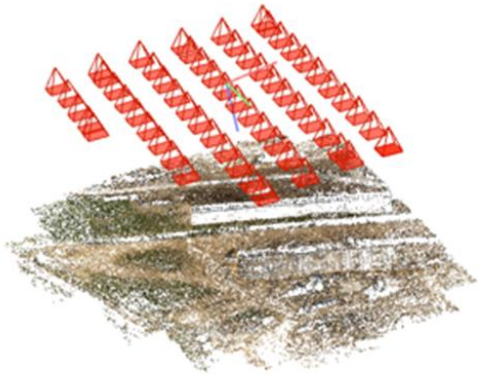
Orthomosaics and 3D point clouds

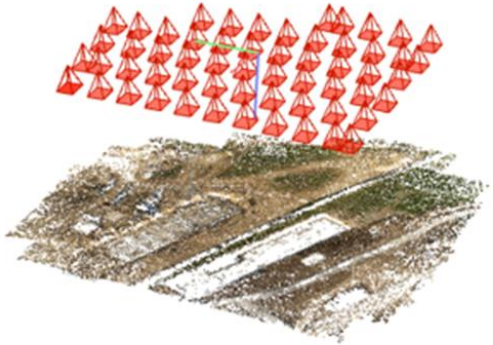












Large scale SfM

Dense feature correspondences

Pattern Recognition 113 (2021) 107821

Contents lists available at ScienceDirect

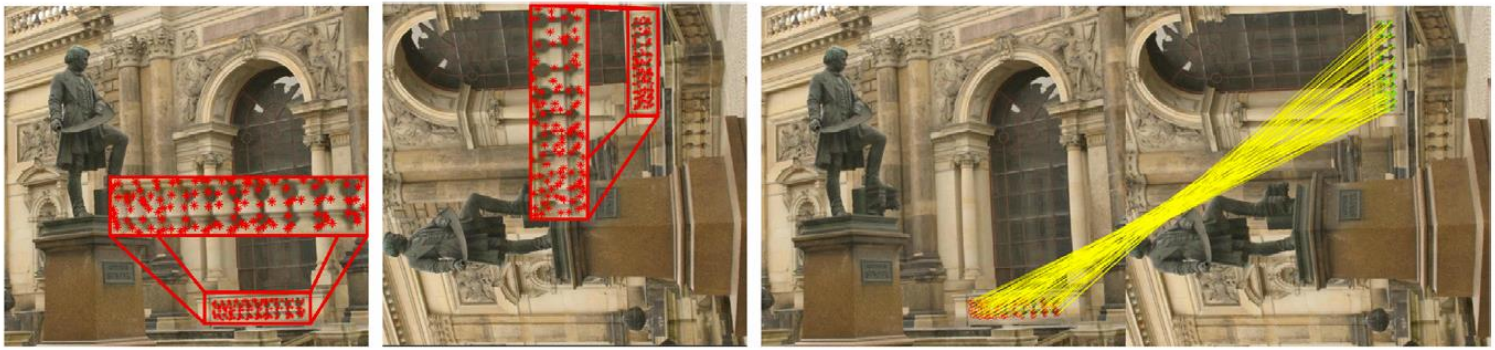
Pattern Recognition

journal homepage: www.elsevier.com/locate/patcog

Interwoven texture-based description of interest points in images

Morteza Ghahremani[a], Yitian Zhao[b], Bernard Tiddeman[a], Yonghuai Liu[c,*]

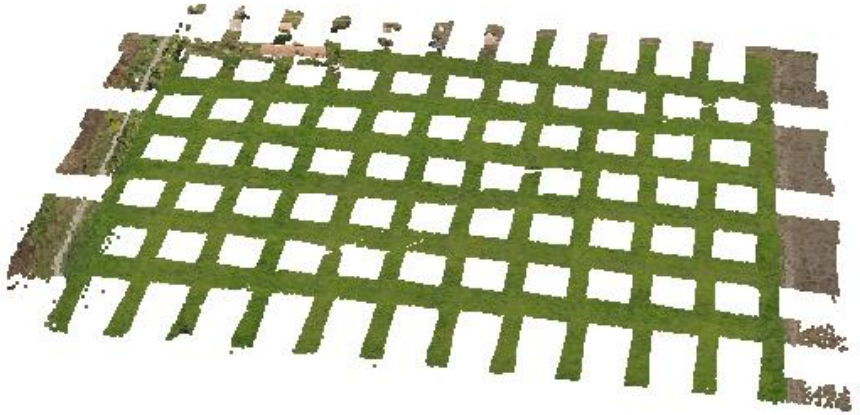
[a] Department of Computer Science, Aberystwyth University, Ceredigion, United Kingdom
[b] Cixi Instuitue of Biomedical Engineering, Ningbo Institute of Industrial Technology, Chinese Academy of Sciences, Ningbo, China
[c] Department of Computer Science, Edge Hill University, Lancashire, United Kingdom



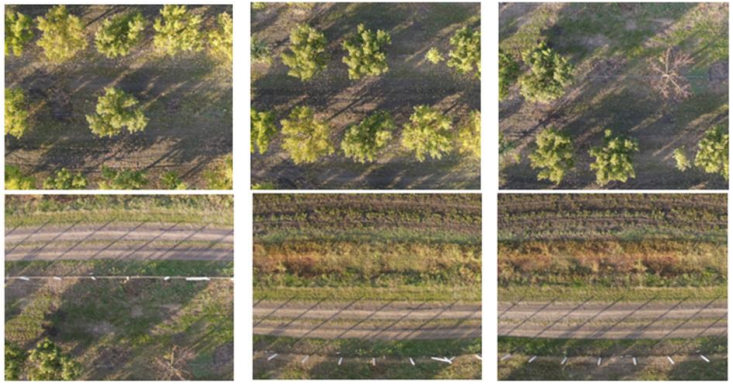
(a) (b)

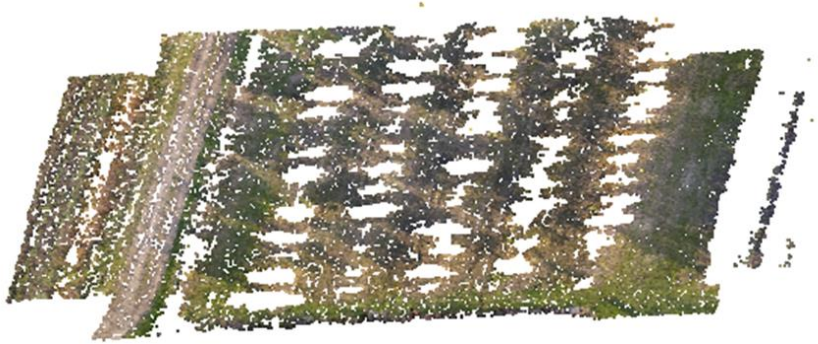
(d)

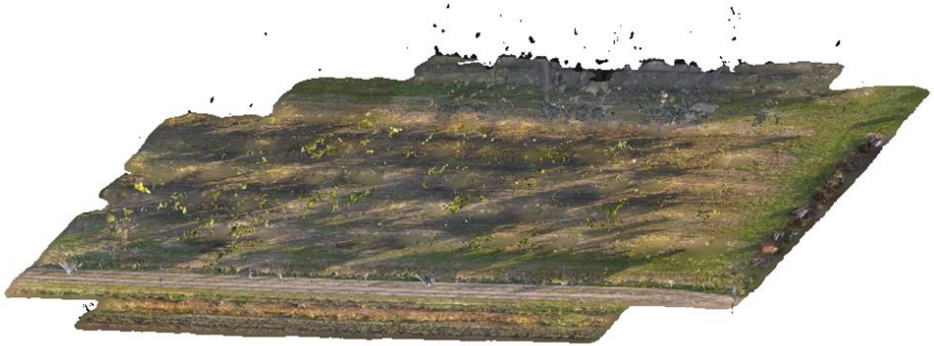
Unsuccessful reconstruction #1



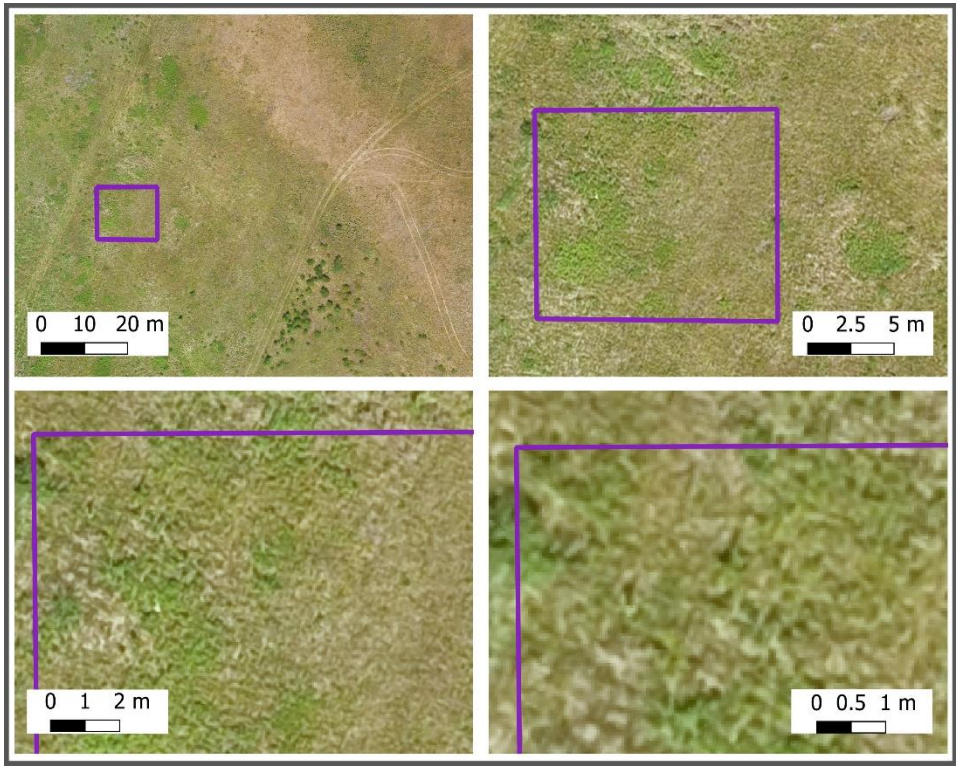
Unsuccessful reconstruction #2





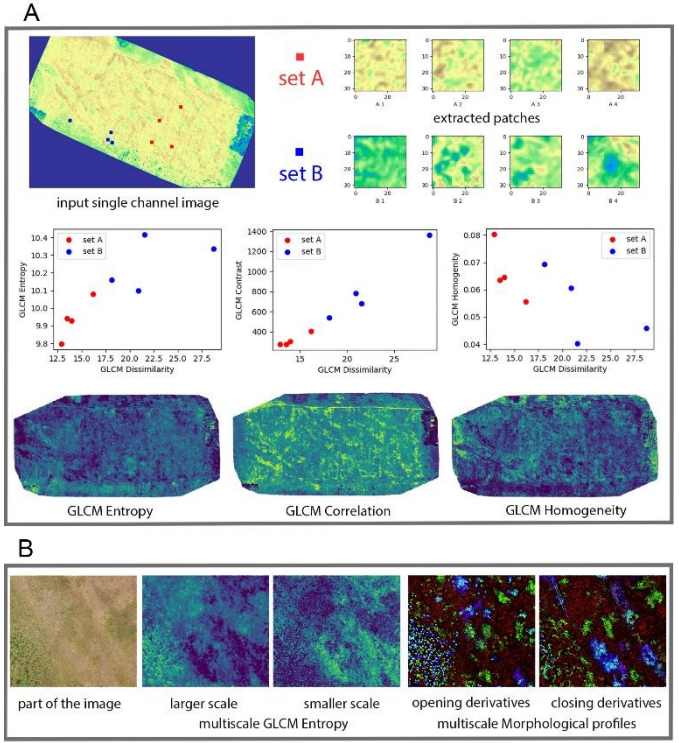


Computational complexity?



Potential of high resolution UAV optical imaging in biodiversity conservation – A case study of sandy steppe habitat renewal

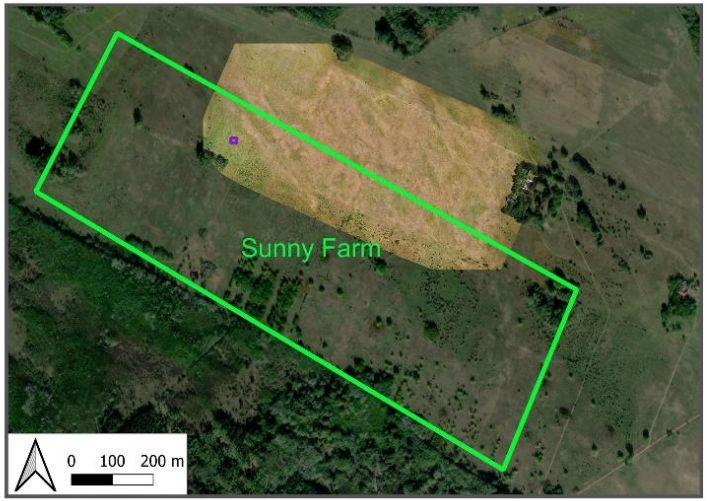
Branko Brkljač [1,*], Predrag Lugonja [2], Maja Arok [2], Bojana Ivošević [2], Milan Vukotić [3] and Tijana Nikolić-Lugonja [2]



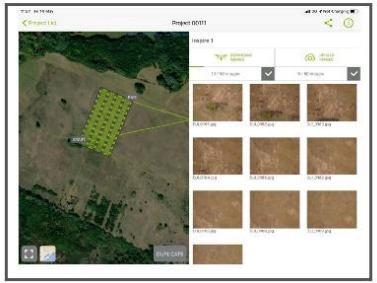
High resolution UAV time series

A

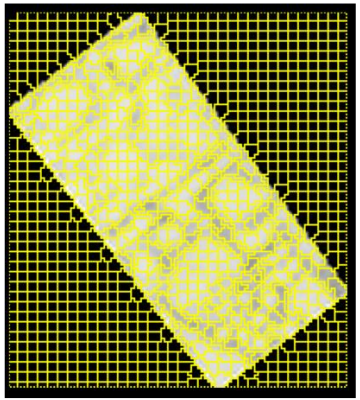
B

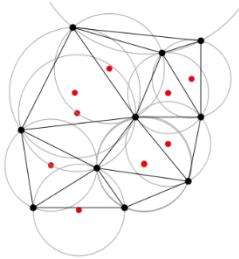


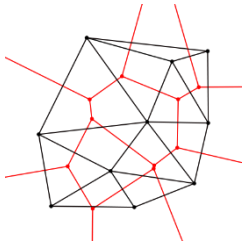
C

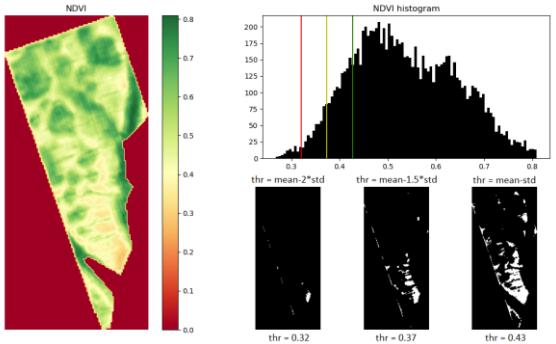


Object based methods



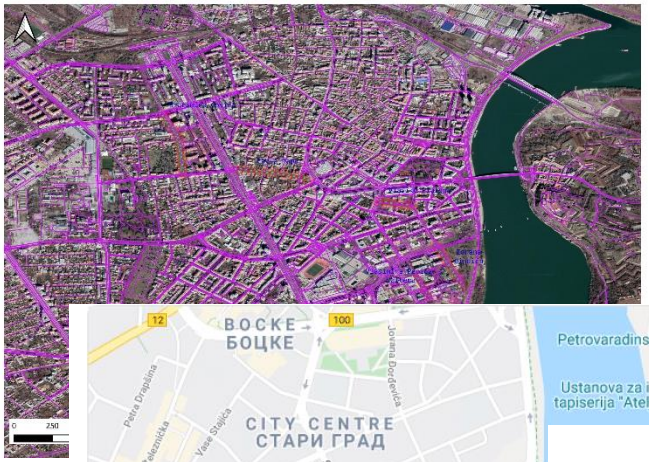


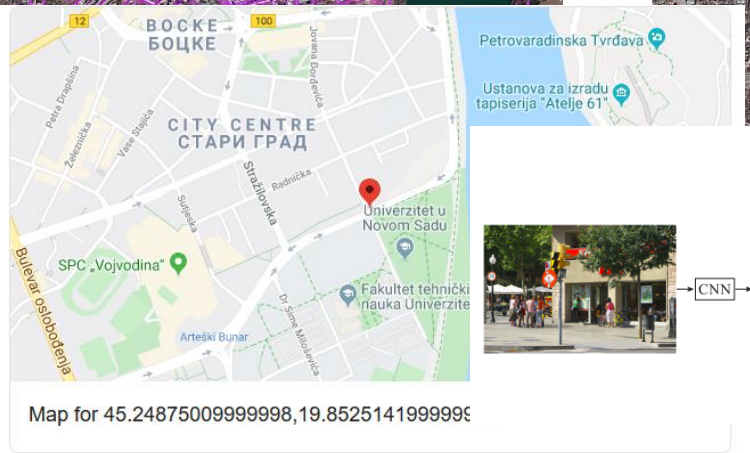


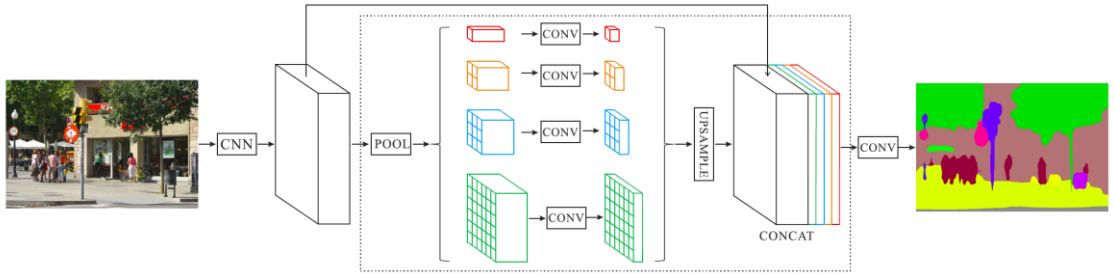


Street-level imagery

A perspective on semantic analysis of urban environments based on image and audio processing – B. Brkljač[1], B. Antić[1], D. Mišković[1], M. Janev[2]: [1]*UNS-FTN, Serbia*, [2]*MI SANU, Belgrade, Serbia*

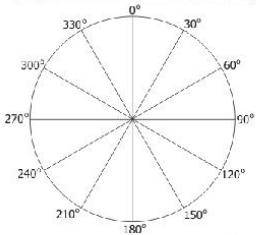


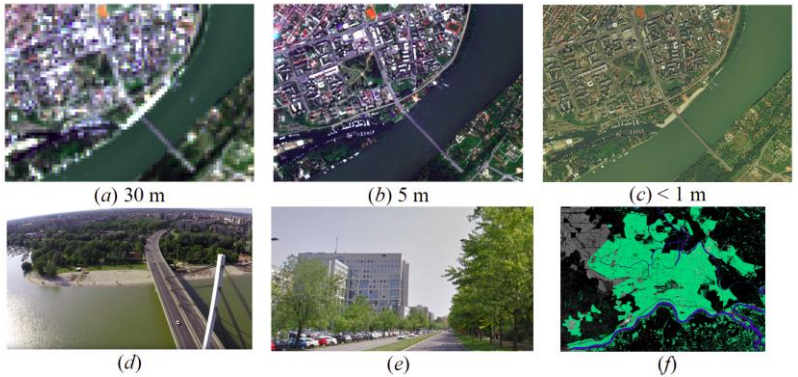




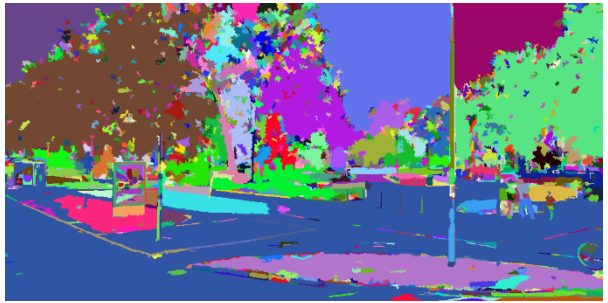
Greenness mapping

A perspective on semantic analysis of urban environments based on image and audio processing – B. Brkljač[1], B. Antić[1], D. Mišković[1], M. Janev[2]: [1]*UNS-FTN, Serbia*, [2]*MI SANU, Belgrade, Serbia*





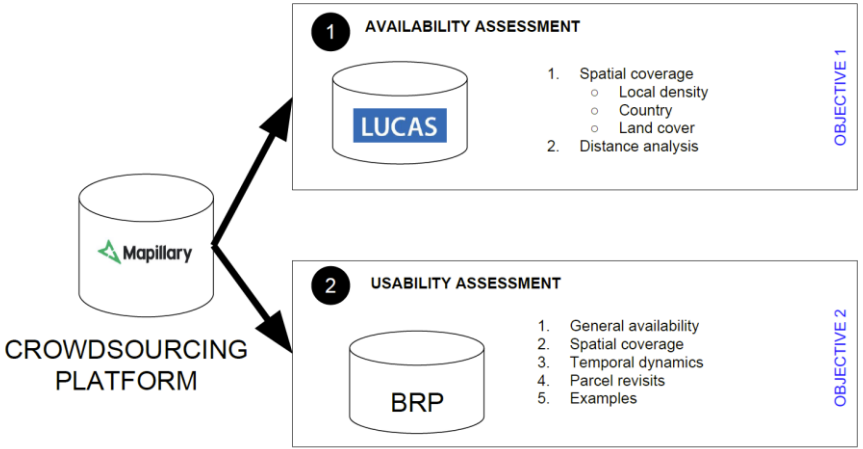
Vision cues ?



- Visual perception – task specific information

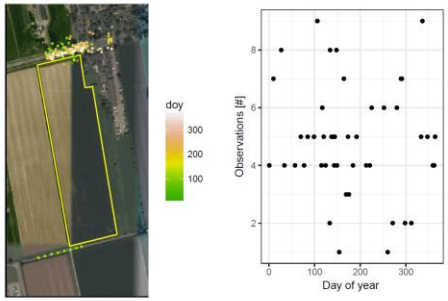
Related research projects

2019-IPR-D-000-012510	Computer vision to recognize and map crops and rural landscape management from street level imagery



EU-28
SAMPLING

NL
FULL DATASET



(a) Spatial (b) Time

(c) January (d) March (e) June

(f) July (g) August (h) December

Article

Crowdsourced Street-Level Imagery as a Potential Source of In-Situ Data for Crop Monitoring

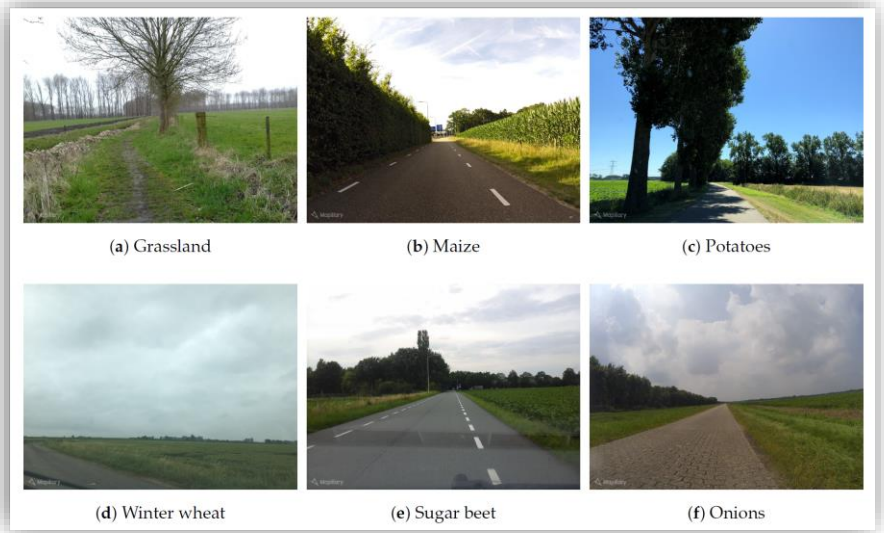
Raphaël d'Andrimont [1,*], Momchil Iordanov [1], Guido Lemoine [1], Janine Yoong [2], Kamil Nikel [2] and Marijn van der Velde [1]

[1] European Commission, Joint Research Centre (JRC)—Food Security Unit, 21027 Ispra, Italy; momchilyordanov@abv.bg (M.I.); Guido.LEMOINE@ec.europa.eu (G.L.); marijn.van-der-velde@ec.europa.eu (M.v.d.V.)
[2] Mapillary AB, 211 30 Malmö, Sweden; janine@mapillary.com (J.Y.); kamil@mapillary.com (K.N.)

Temporal variability

(a) 2017.05.06 (b) 2017.07.23

(c) 2017.10.10 (d) 2017.11.05



(a) Grassland (b) Maize (c) Potatoes

(d) Winter wheat (e) Sugar beet (f) Onions

Vehicle mounted cameras

- crowdsourced geotagged street-level imagery
- relevant and timely information along the growing season, crop type and phenology
- computationally intensive machine learning algorithms
- photographs according to crop type, phenology, landscape elements and farm activity
- novel source of in-situ data whose derivation is „easily“ applied to other sectors

Design, what to consider?

- Robust solutions for outdoor and uncontrolled environments
- 2D or 3D vision?
- level of details vs resources

- Application specific requirements

thematic maps

spatial variability

volume estimation

navigation

scene understanding

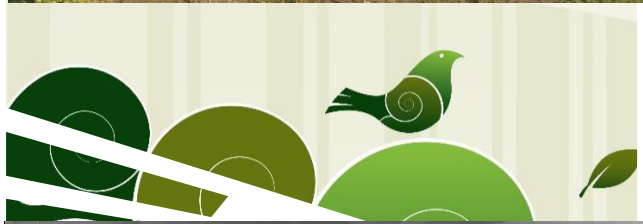
- Effects and users' requirements

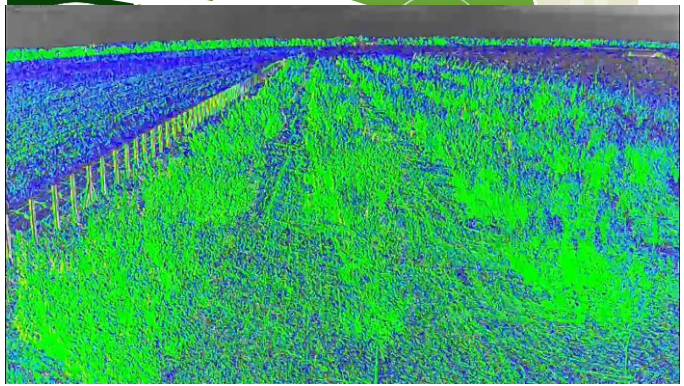
timely management

reduction of costs

yield improvement

planning and documenting





Ambientura – FTN's internal PAE

- Pathfinding experiment
- Implementation of depth perception and 3D reconstruction
- Spatial AI in peri-urban agriculture
- Agricultural production over small land areas and farms, much smaller than the ones captured with satellite imagery
- Service for discovering landowners involved in agricultural production at the outskirts of cities
- Semantic segmentation, 3D reconstruction and thematic mapping in the agricultural context
- Cooperation with the drone operating company

Spatial AI

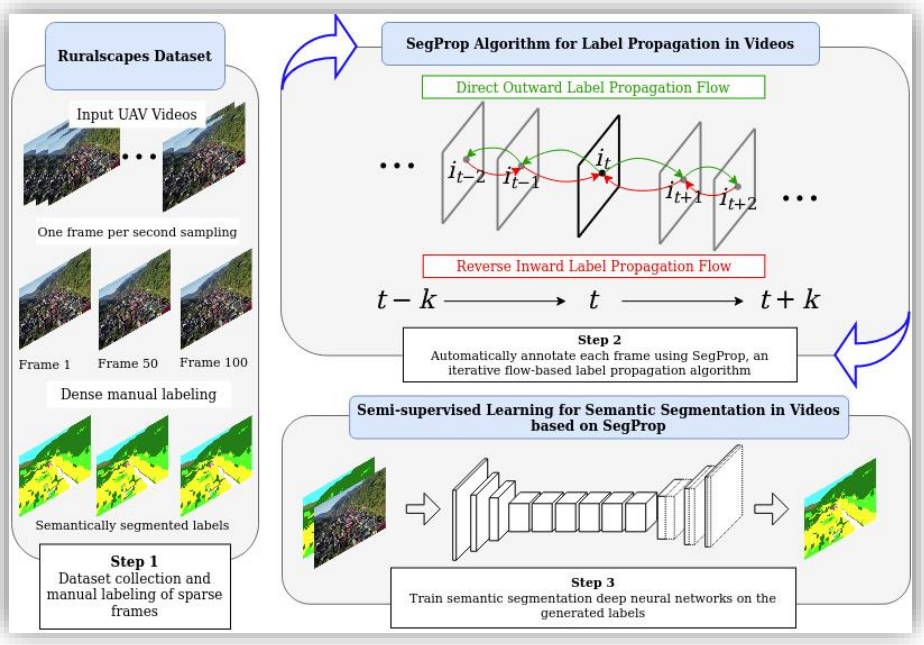
- learning of optimal signal representations
- continuous capturing of right information
- real time interpretation and action

FutureMapping: The Computational Structure of Spatial AI Systems

Andrew J. Davison
a.davison@imperial.ac.uk
Department of Computing, Imperial College London, UK

Semantics through Time: Semi-supervised Segmentation of Aerial Videos with Iterative Label Propagation

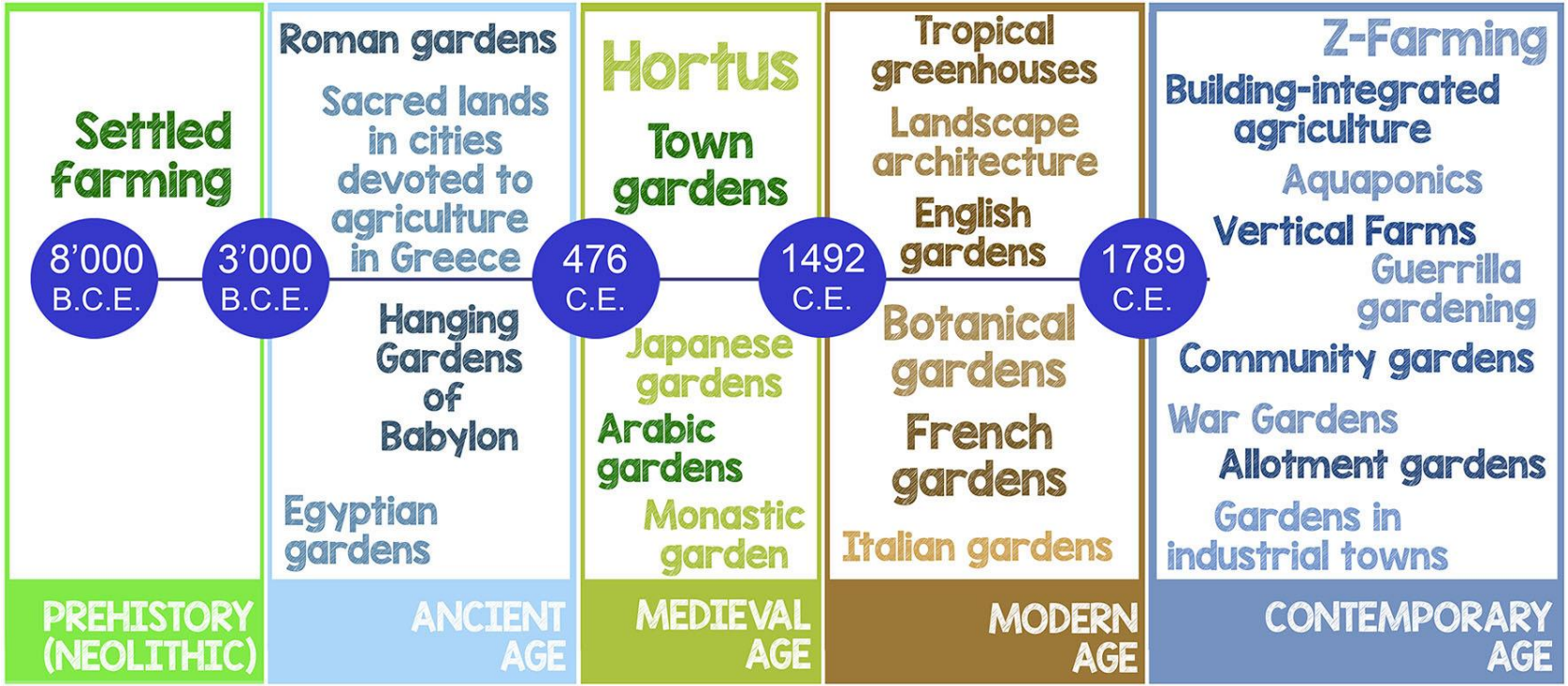
Alina Marcu[1,2], Vlad Licaret[1], Dragos Costea[1,2], and Marius Leordeanu[1,2]



Spatial AI


Original input image
Automatic semantic scene segmentation
Person
Forest
Land
Hill
Sky
Residential
Church
Haystack
Road
Fence
Car
River

Timeline of urban agriculture

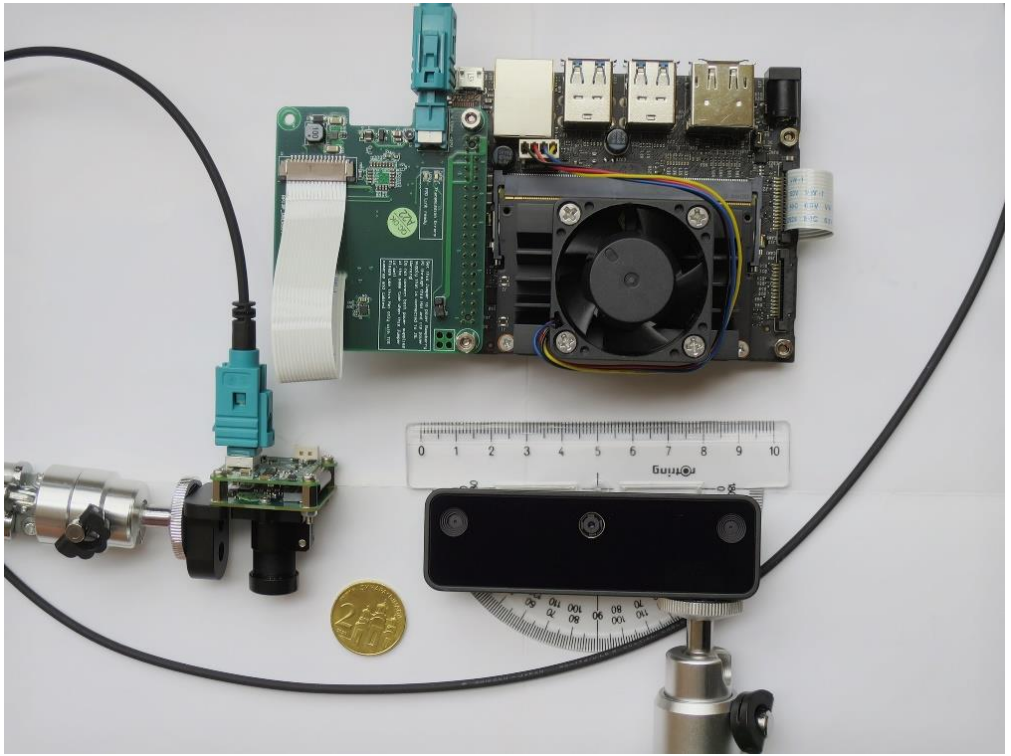


Solution choices

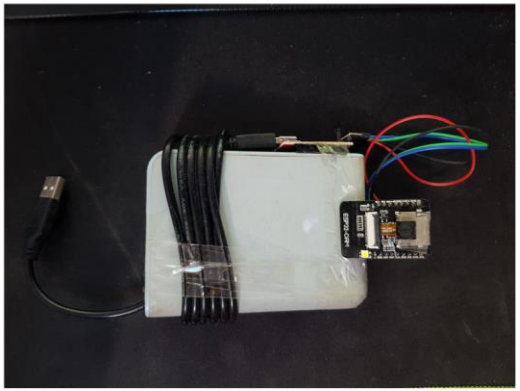
- **Visual perception (active and passive)**
- **Embedded vision platforms (Jetson Nano, OAK-D, IDS NXT, Movidius Myriad X VPU)**
- **Depth perception (native or inference based)**
- **Real time stream processing**
- **Platform choice, pros and cons of camera integration and ’on device’ processing**

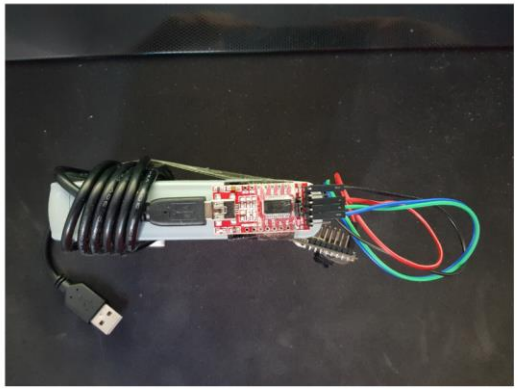
Embedded vision platforms

- General trend in the future will be towards providing CPS with multimodal information about its surrounding

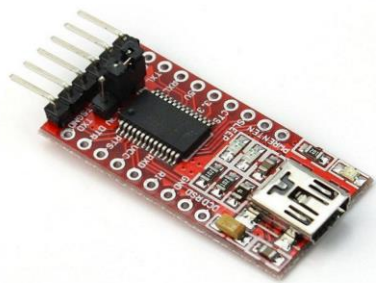


Low cost image acquisition?

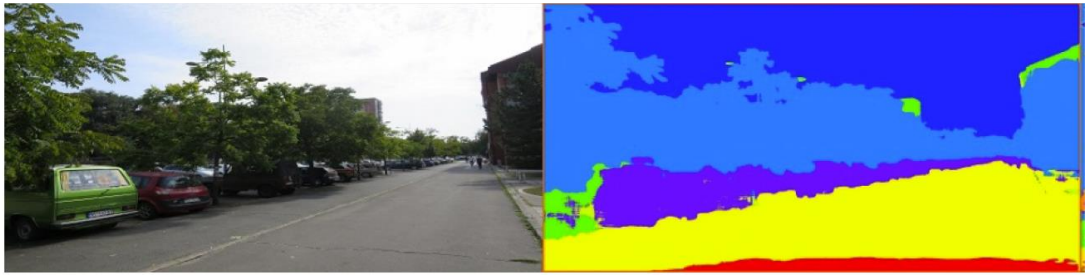




(a)

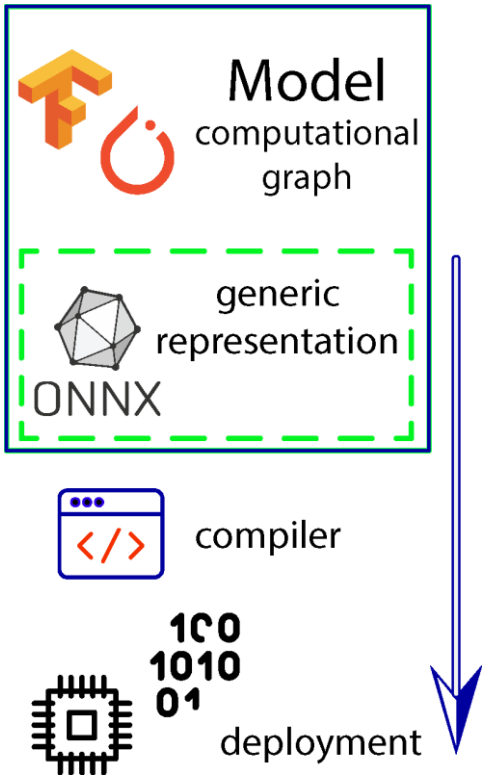


(b)



Platform – expectations

- Stream processing
- Hardware encoding
- Heterogeneous computing
- Camera integration
- User community
- Reconfigurable hardware and optimized algorithms



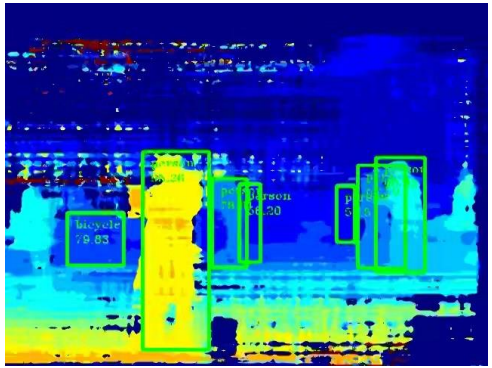
Neural inference

Methods/Approach

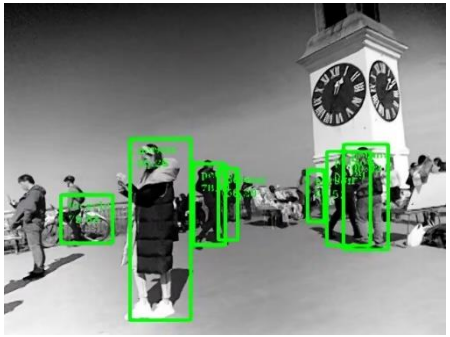
Mono LEFT Global shutter

Mono RIGHT Global shutter

4K rolling shutter

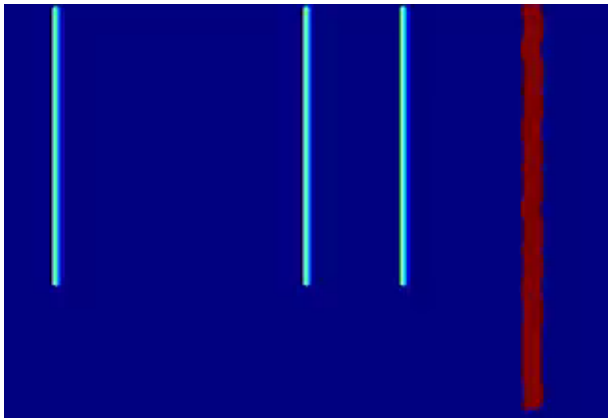


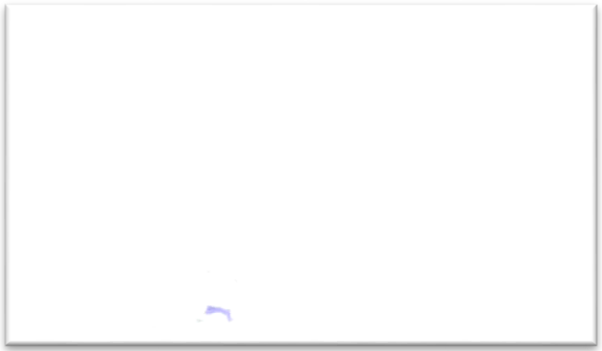
Disparity map (depth perception)

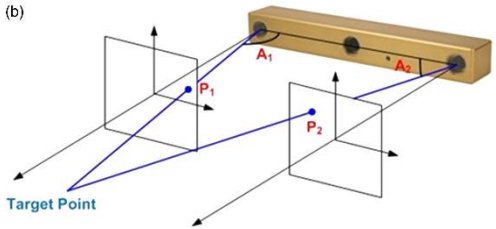


Detections (scene understanding)

Stream processing







At what precision?

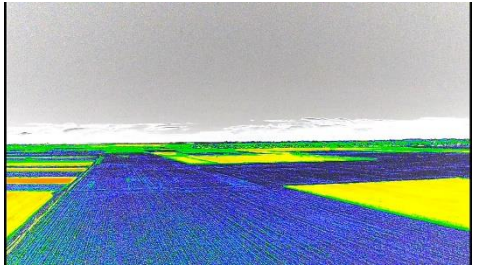
single platform
(resource constrained)

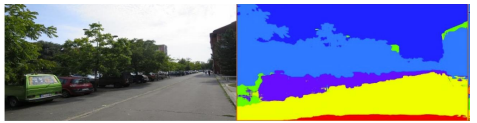
’on device’ solution (native depth perception without neural inference)

combined platforms
(host + acquisition device)

’on host’ solution (neural inference based on stereo pair)

Internal PAE – current results





- CPSs benefit from improved perception
- Market for embedded vision platforms is growing
- Depth perception is only one of necessary functionalities for spatial AI
- Out of the box solutions have certain limitations
- Advantages of combining different devices/platforms
- Need for platform-agnostic algorithm development and model deployment (’users in mind’)
- Energy consumption – should be important
- Future steps – distributed 3D SfM service and semantic segmentation

Related activities

SENSECO: Optical synergies for spatiotemporal sensing of scalable ecophysiological traits (COST Action CA17134)

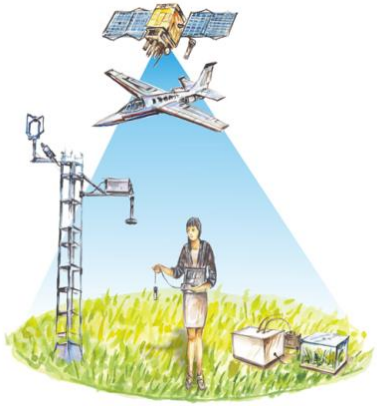
http://www.senseco.eu/

WG 1 Closing the scaling gap: from leaf measurements to satellite images

WG 2 Closing the temporal gap: from daily observations to seasonal trends

WG 3 Realizing synergy between passive EO spectral domains

WG 4 Establishing data quality through traceability and uncertainty



The main objectives:

- To tackle the scaling gap between leaf and satellite measurements in order to link driving mechanisms at the leaf scale to photosynthesis at the global scale.
- To improve the time-series processing of satellite sensor data for modelling vegetation processes related to seasonal productivity.
- To improve synergies between passive optical EO domains.
- To ensure measurements comparability across different scales, space and time.

Recent events …

Remote Sensing of Environment 280 (2022) 113198

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Review

Multi-sensor spectral synergies for crop stress detection and monitoring in the optical domain: A review

SENSECO

http://www.senseco.eu/

Thank you for your attention

https://smart4all-project.eu/

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