GeMMA inputs and expectations to/from the Symmetry project

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Role of GeMMA in Symmetry

- Objective O3: Integration of symmetry detection into the methodology of semantic segmentation and object recognition in EO data in order to improve accuracy and enlarge the set of recognized classes, validated in a dedicated set of applications.

Role of GeMMA in Symmetry

- O3 will be achieved through study and realization of possible use of symmetries in:
  - EO data preprocessing
  - Feature engineering – WP11
  - Data classification – WP12
  - Data segmentation – WP12
  - Applications – WP13
- To provide data for testing some other WPs

Methodology

- **Preprocessing:** filtering, resampling, interpolation, coord. systems transformations, alignment (registration)
- **Classification:** primitives (points, pixels…) inserted into classes (e.g. terrain, building, vegetation…)
- **Segmentation:** into regions or higher semantic objects
- **Applications:**
  - **Situation assessment:*** establishing relations (structuring) among entities from previous two levels.
  - **Impact assessment:*** simulations, predictive analytics…
- **Feature engineering (extraction):** feature definition, detection, and selection at different levels.

(*) Regarding the JDL/DFIG data fusion/information exploitation model

Role of GeMMA in Symmetry

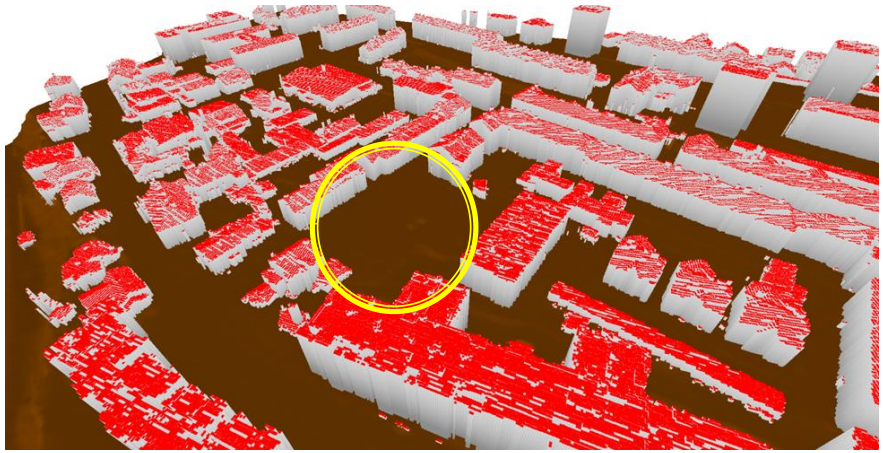
- WP10: Initial study of reflectional symmetry detection on EO data.
- WP11: Symmetry-aware feature extraction in EO data fusion.
- WP12: Integration of symmetries into semantic segmentation and object recognition in EO data fusion.
- WP13: Validation of symmetry utilization in EO data applications.

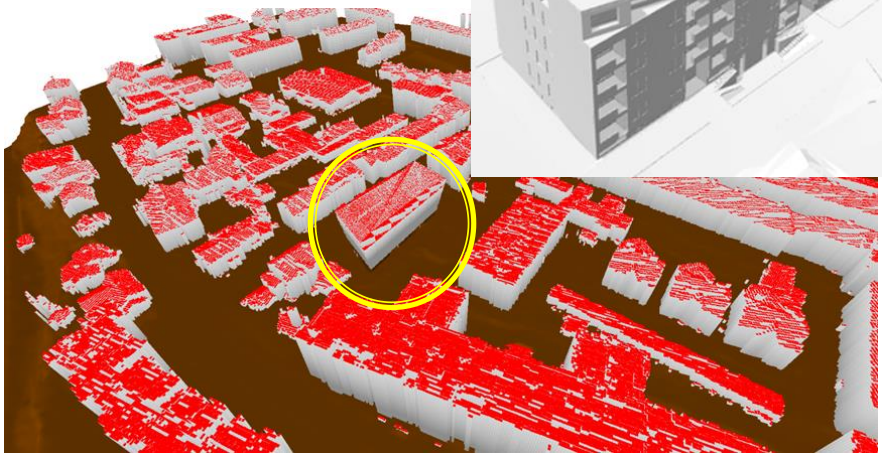
EO data in Symmetry

- 3D LiDAR points
  - mostly airborne (1-2 points per m^2)
    - Periodically acquired at national level and publicly available
  - Few scans from terrestrial/mobile scanners with higher resolution also available.
    - Acquired within specialized private/public projects.
- Satellite data
  - **Radar (SAR)** images from **Sentinel-1**
    - Till now, the data was read and differences between two consecutive images in time series calculated …
  - **Multispectral** images from **Sentinel-2**
    - More…
- Fusion with other GIS layers. Extensions within 3 years!!!

Symmetries in preprocessing

- Data registration
  - Fuse spatial datasets A and B by transforming e.g. A from its local coordinate system into the coordinate system of B.
  - Straightforward alignment if A and B are both geo-referenced.
  - Complex when A or B is not georeferenced.
    - Manual (interactive) registration error-sensitive.



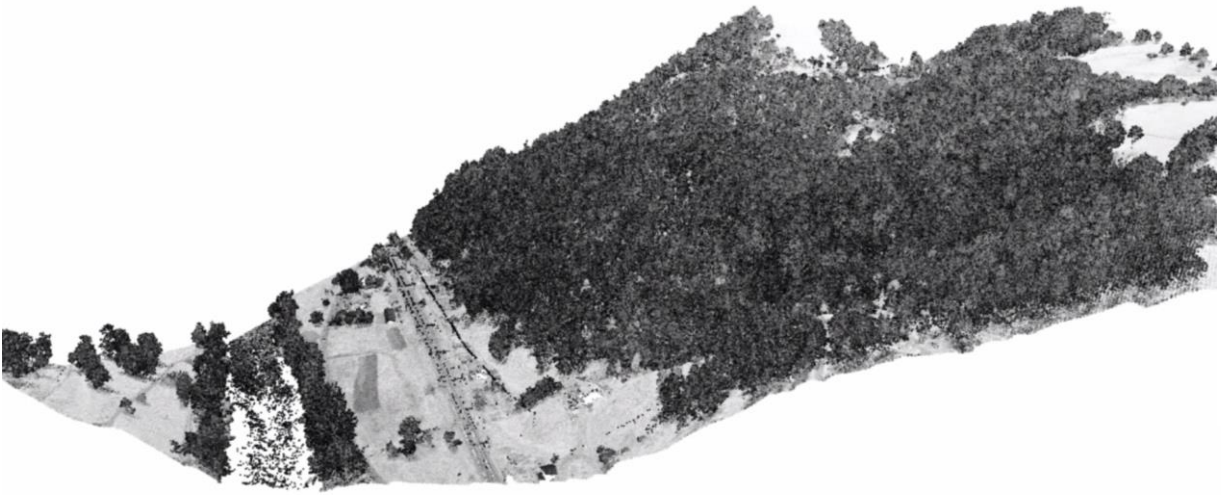


Symmetries in preprocessing

- Automatic spatial data registration
  - Still active research challenge.
  - Symmetries might be helpful?
  - Experiment:
    - Two datasets A and B representing the same scene.
    - Might be in different resolutions, with different LoD…
    - Detect symmetries in A and B and align symmetry axes?
    - Test of robustness of symmetry detection to scalling!
    - First experiment with global symmety, later with local, partial and approximate!

LiDAR data classification

- DTM construction and ground extraction



LiDAR data classification

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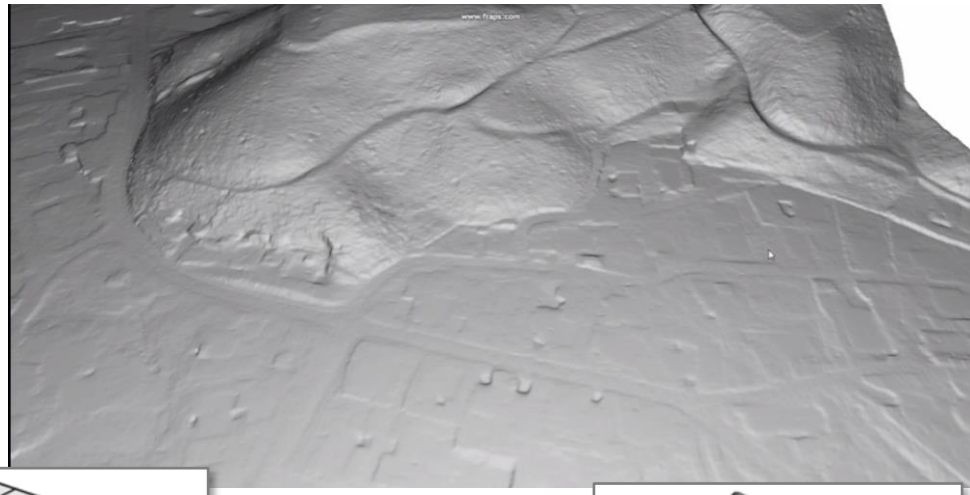
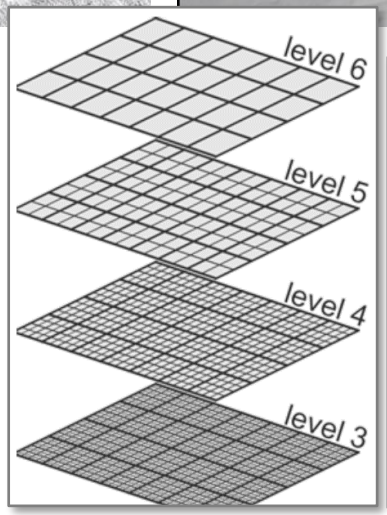
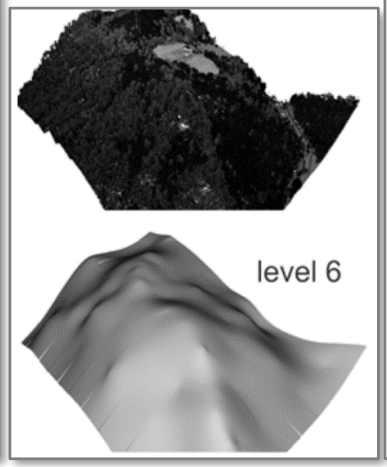
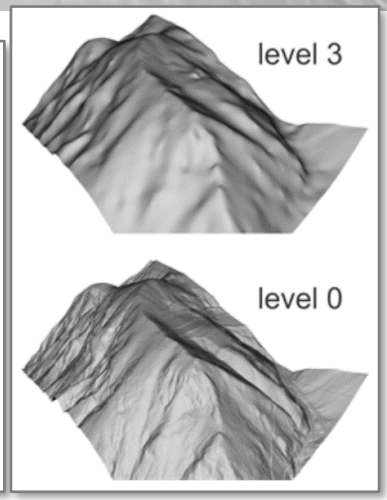


- Multiscale data decomposition using differential morphological profiles.

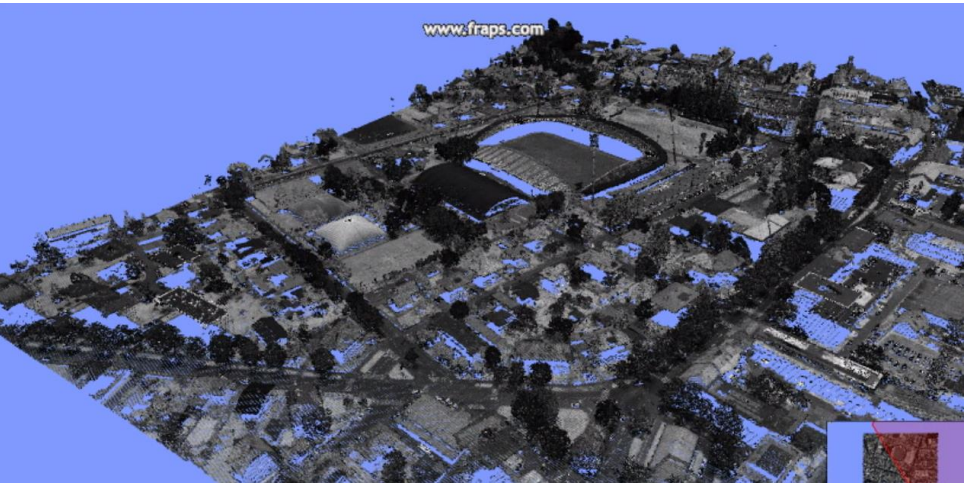




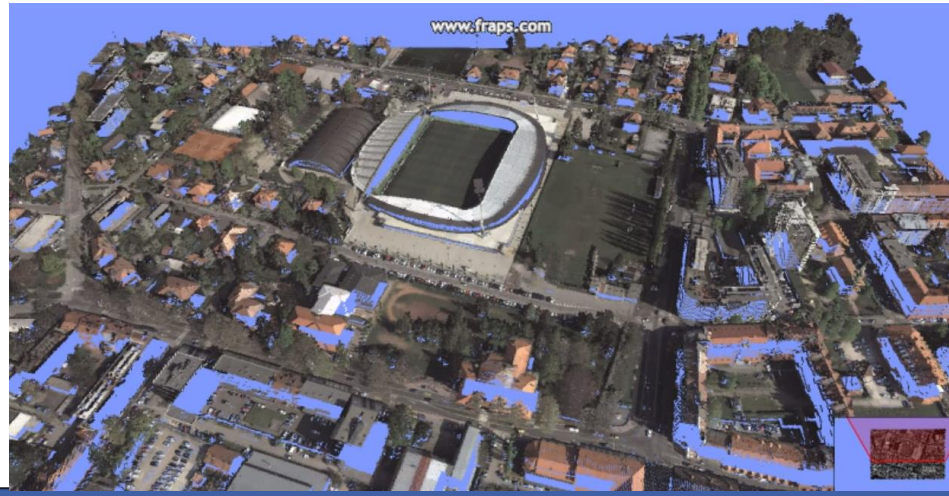


LiDAR data classification

- Non-ground points are buildings and vegetation.



- Based on locally fitted surfaces (LoFS). Points of vegetation are more perturbed around a smooth surface.



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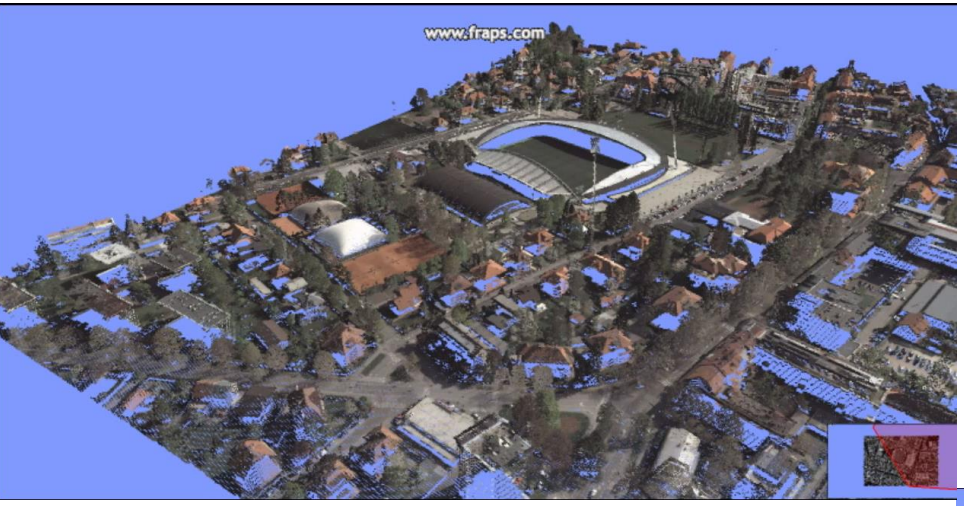
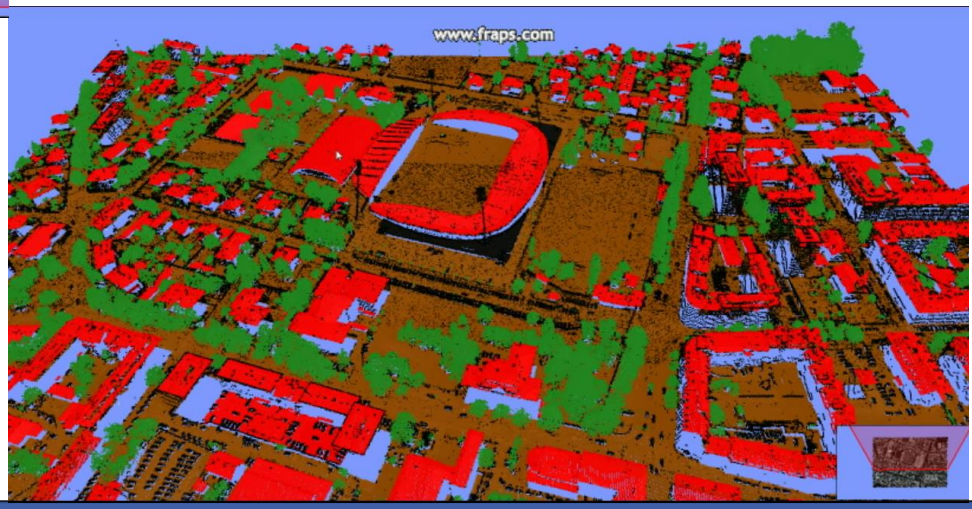
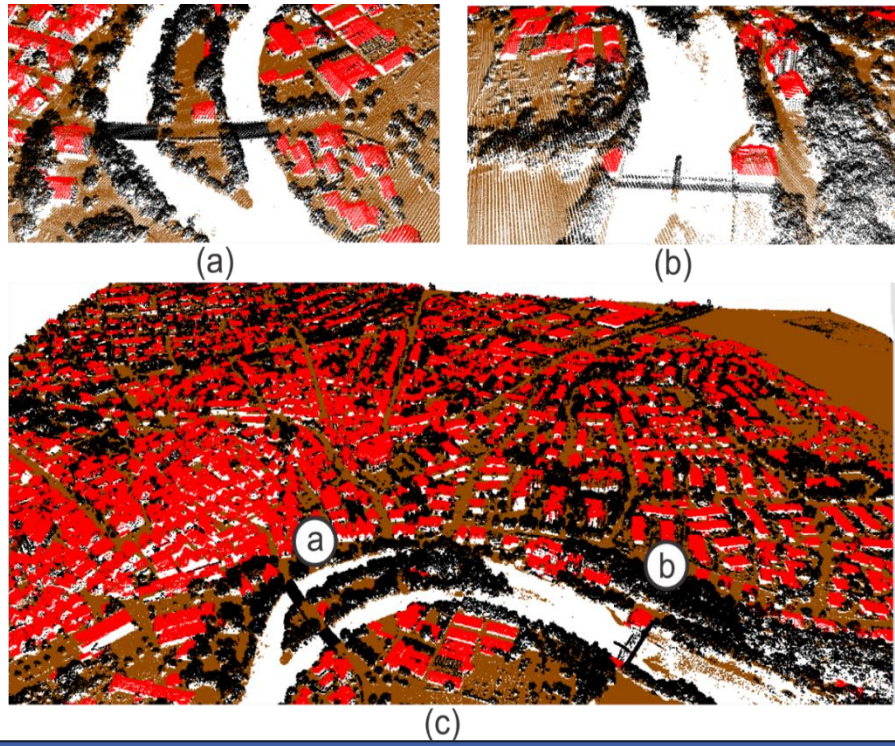


- Or anything else (black) still waiting to be classified (maybe with help of symmetries?).



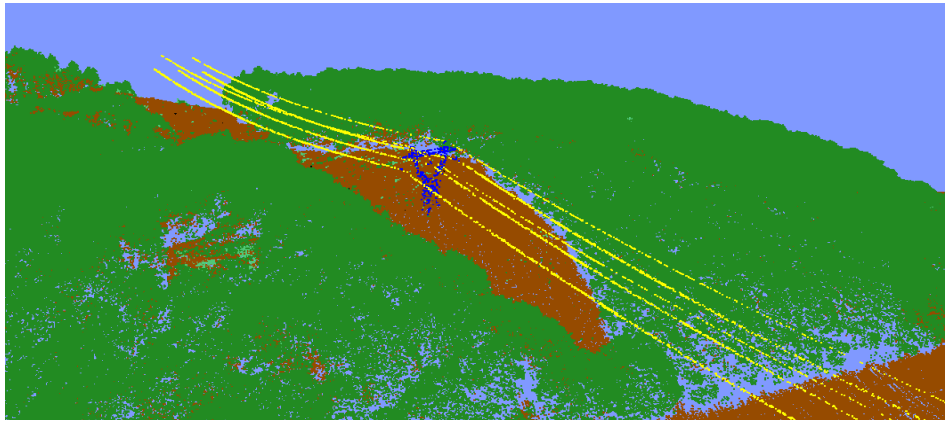
LiDAR data classification

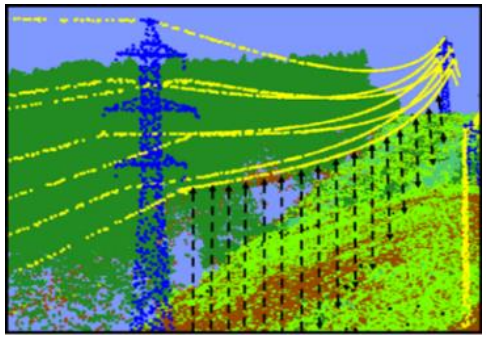
- Black objects below are vegetation or something else.
- Additional morphological profiles (contextual filters) for
- Low, middle and high vegetation.
- Overgrowing vegetation.
- Small objects attached onto flat surfaces (balconies, chimneys, noise on buildings).
- Small standalone objects (fances, vehicles, statues…).

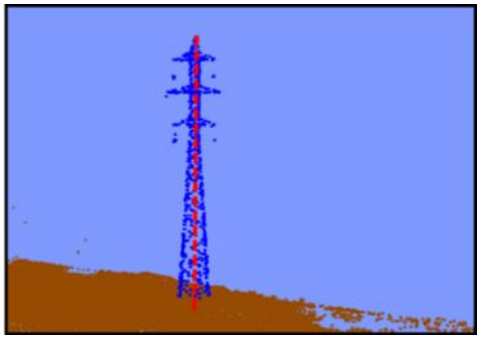


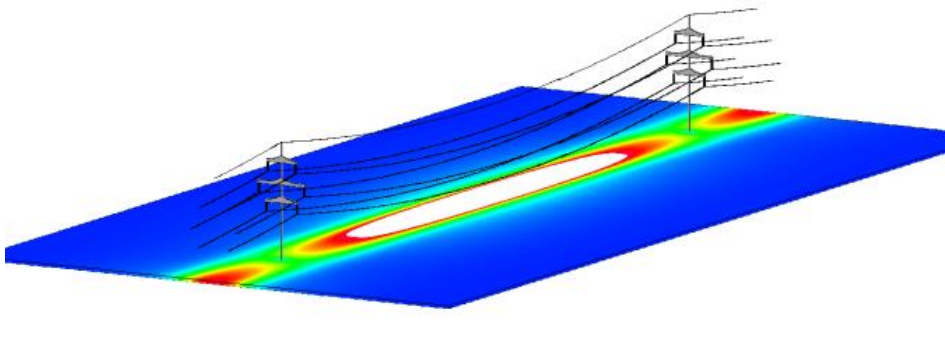
LiDAR data classification

- Contextual classification (recognition) of power lines
  - towers and conductors
  - EM field below the lines
  - Not active project, but anyway:
    Any symmetries?







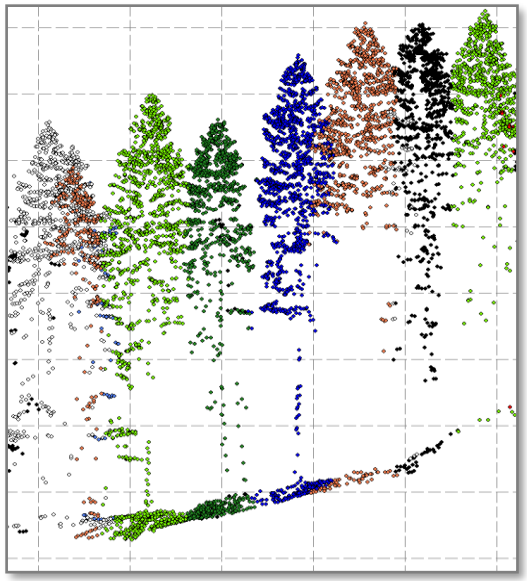


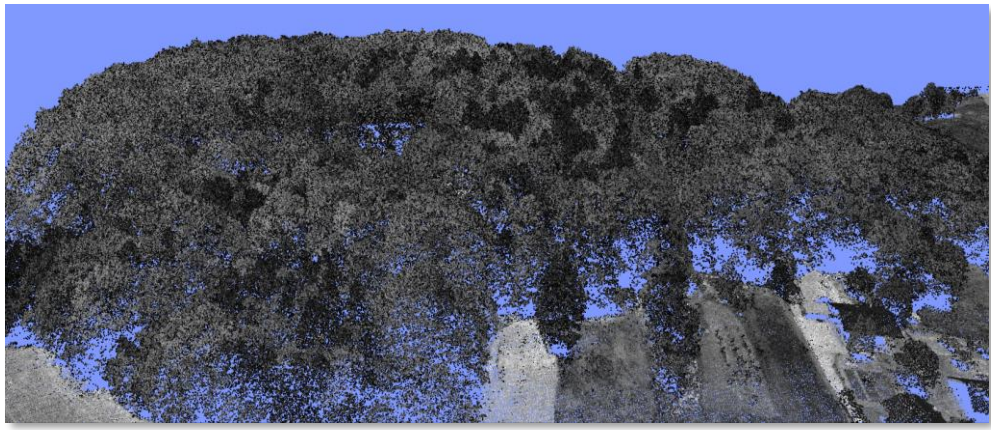
LiDAR data segmentation

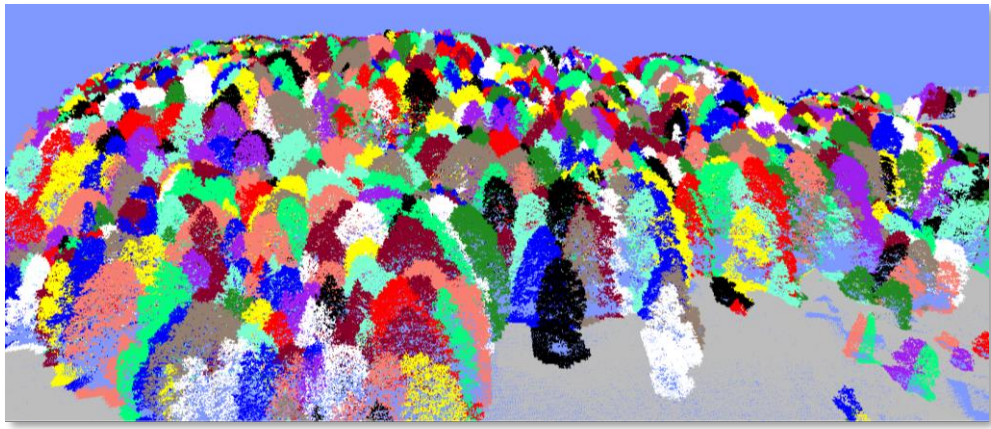
- **Segmentation:** detection of connected regions of an individual class.
- **Object extraction (recognition):** region with some higher semantic meaning.
  - Building = roof U walls
  - Not necessarily segmentation based.

LiDAR data segmentation

- Extraction of individual trees.
  - Basis for tree species recognition from tree canopy shapes.
  - Utilization of symmetries (one of pilots in WP13)?

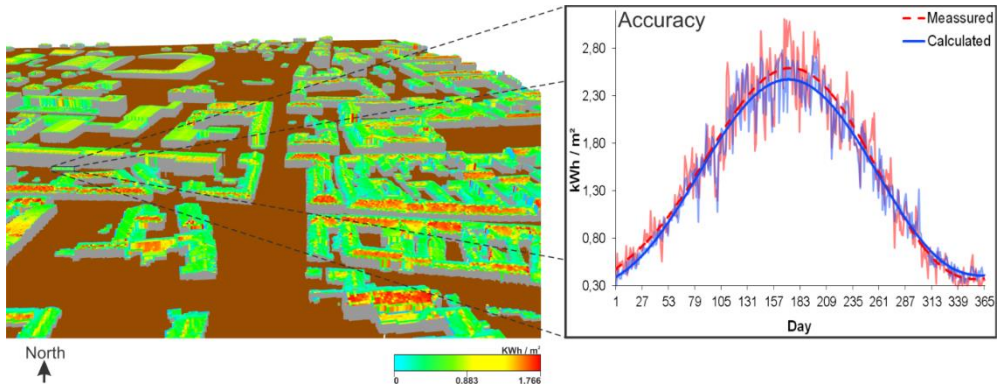


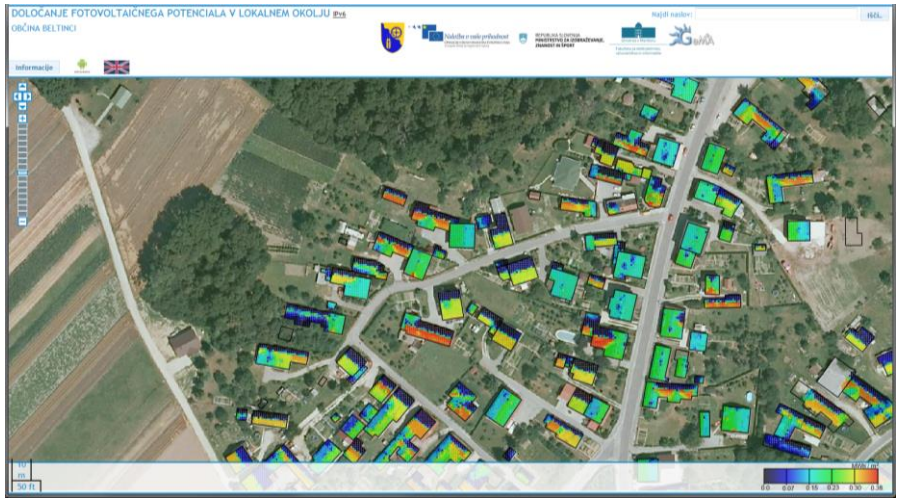




Applications

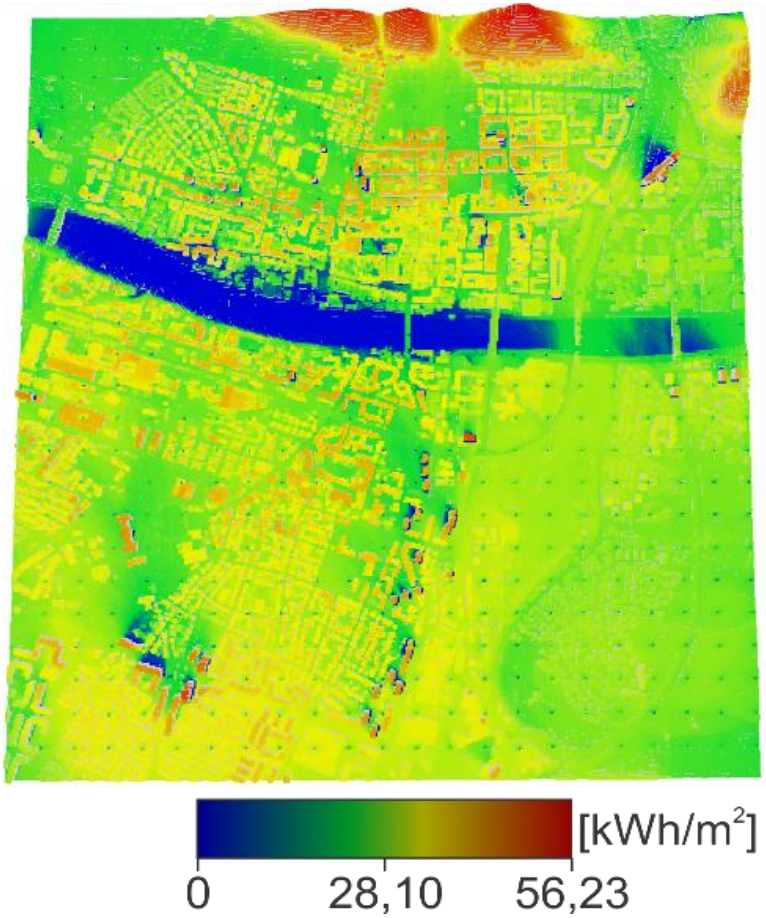
- Photovoltaic potential estimation.
- LiDAR + other data used. New data produced.
  - Relations between symmetries in different layers could be studied (similarly as with the power lines and EM field).





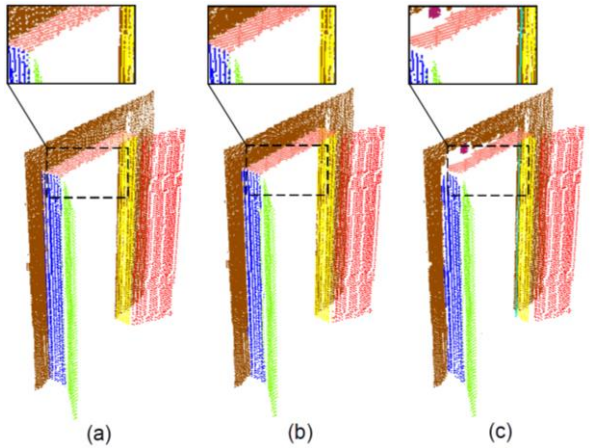
Applications

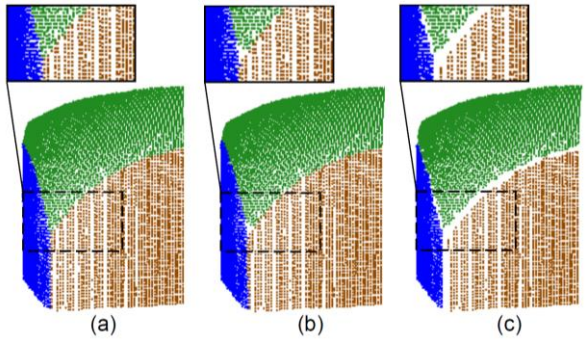
- Wind potential estimation.

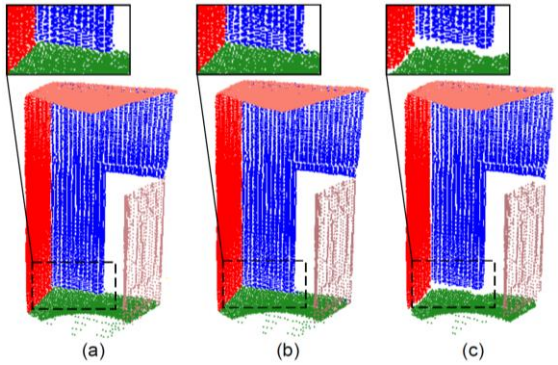


Other

- LoFS-based segmentation
  - Just and example of using non-airborne LiDAR data
  - Not ideas on using symmetries yet.







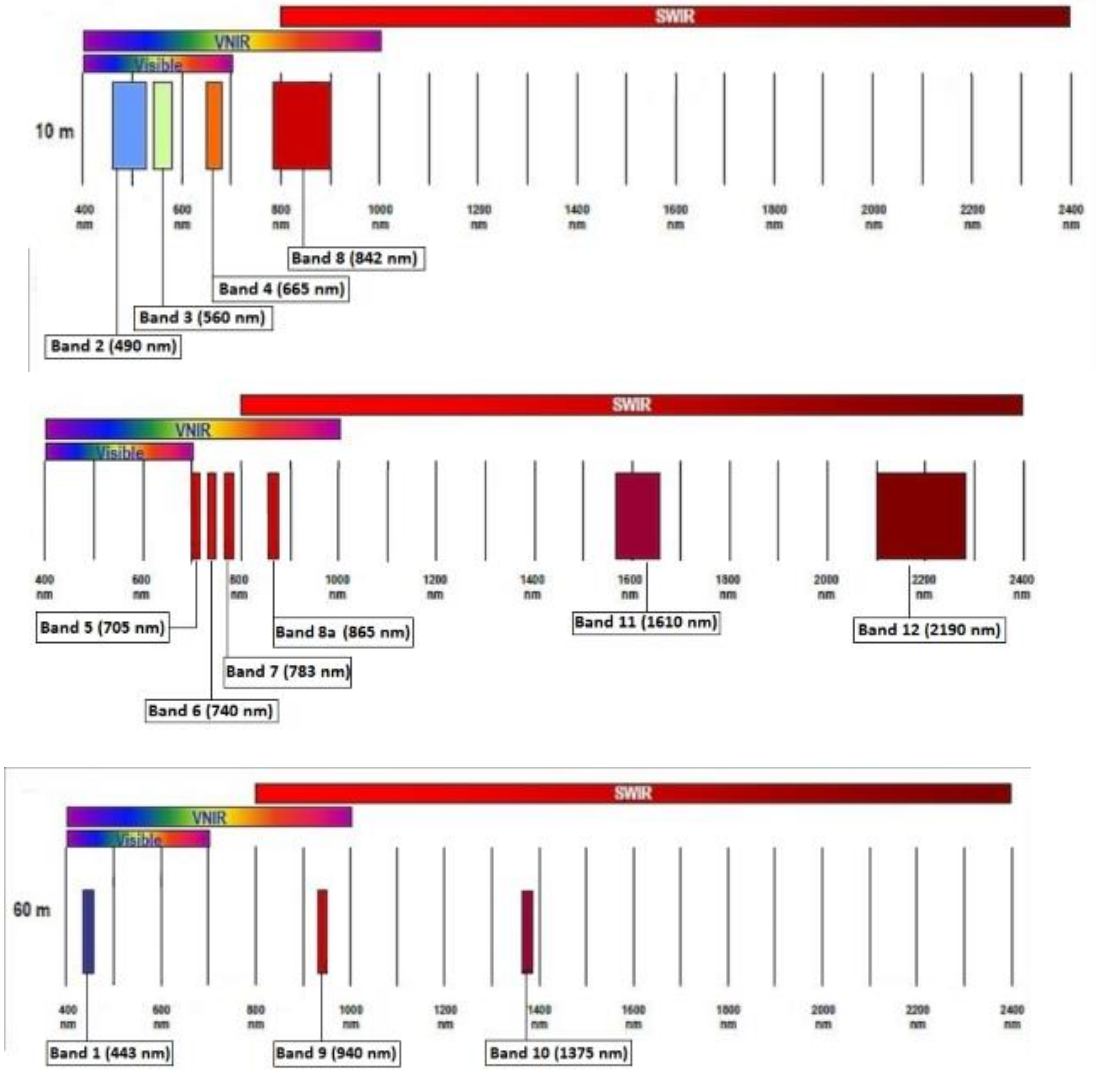
Conclusion (LiDAR)

- The classification and segmentation with high accuracy of above 90% on all ISPRS benchmarks (exact numbers in our publications).
- Can we further improve any of the results by utilization of symmetries?

- VIDEOS!
- https://gemma.feri.um.si/presentations/

Sentinel-2 data

- Sentinel info on ESA, Copernicus and Sentinel pages.
- Multispectral images
  - 13 spectral bands
  - 4 with spatial resolution 10 m, 6 with 20 m, and 3 with 60 m.

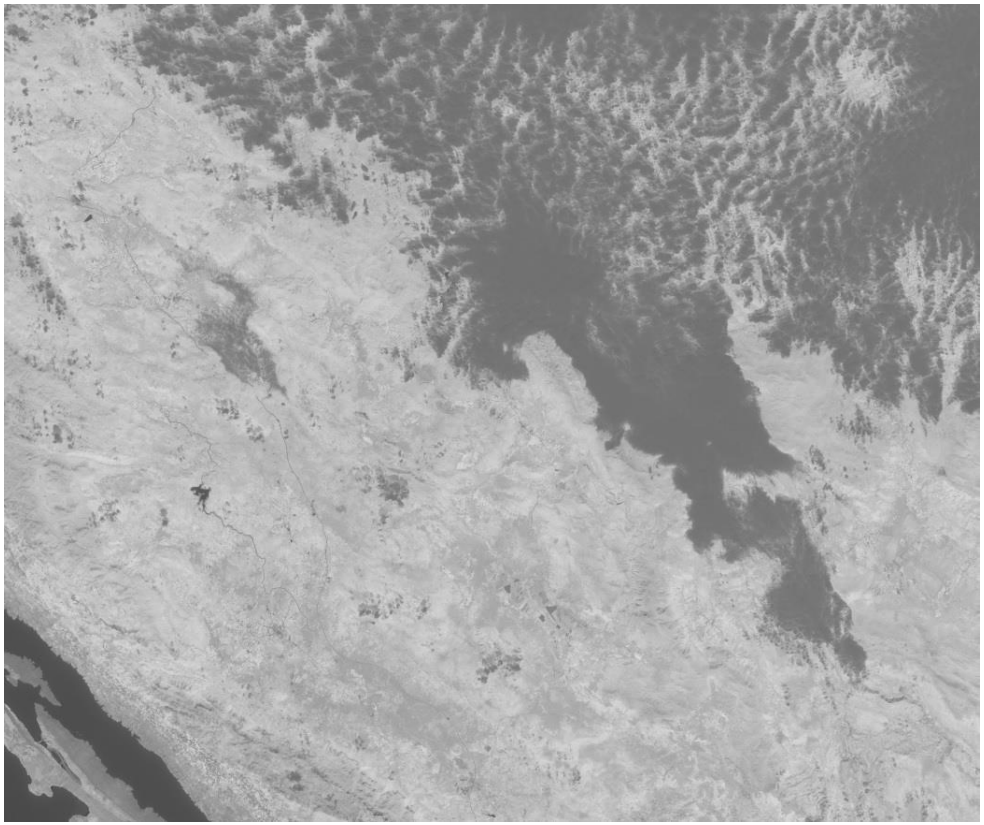


Sentinel-2 data

- Several indices computed as combinations of values from individual bands.
  - Similar idea to R, G, B → Y, Cb, Cr, but the Sentinel indices have some semantic meaning in EO analyses.
- Idea is to detect symmetries in individual indices and/or original spectral bands, and study eventual relationships.
- We have an interface for any Sentinel-2 reading and visualization. Example:
  - Normalized difference vegetation index
  - NDVI = (band8 - band4)/(band8 + band4)
  - Index replaces Z coordinate.

Sentinel-2 data

- North Dalmatia (Croatia)



Sentinel-2 data

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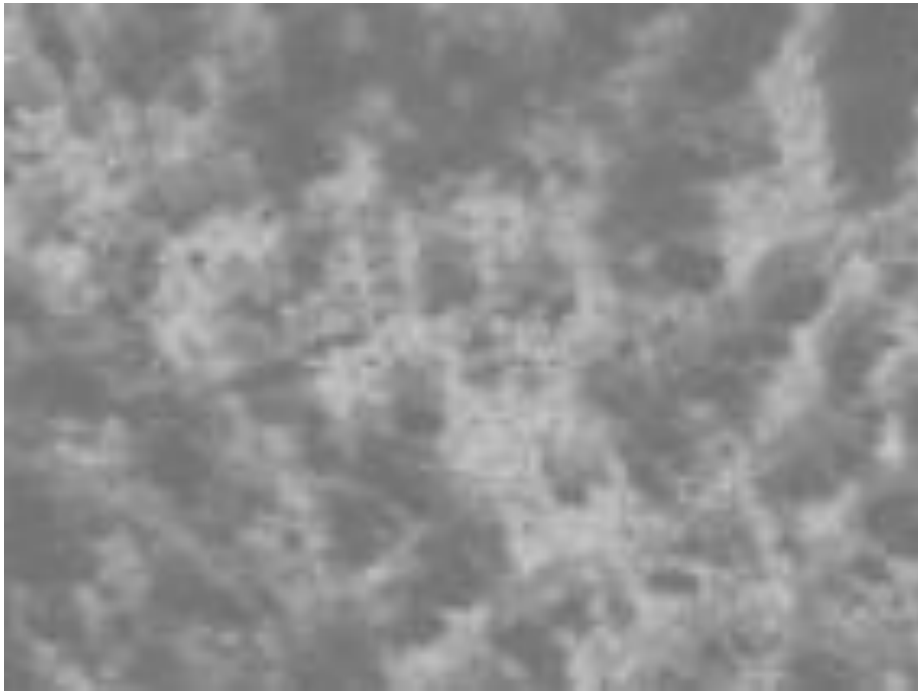

Conclusion

- Survey of some but no all our EO-related work.
  - Fusion with IoT data, AI-based feature engineering, big data…
- What do we need?
  - Local symmetries.
  - Partial symmetries.
  - Approximate symmetries.
  - Multiple symmetries-
  - Ideas!!!
  - And even more ideas based on your mathematicians' work.
- What can we participate to your work?
  - ???