Local, partial and global reflection symmetry detection in Earth observation data

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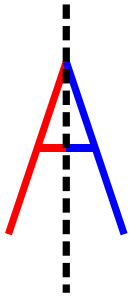
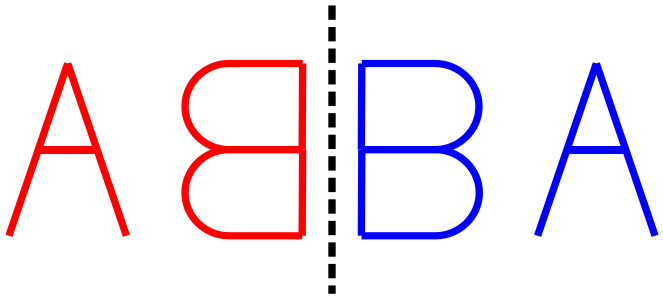
Introduction

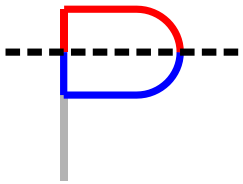
- Reflection (reflectional, mirror) symmetry
  - Connected (bilateral) or disconnected.
- Global symmetry
  - Whole input involved (no points outside the symmetry).
  - Plane/axis often runs through the centroid.
  - (Dis-)connected iff input is (dis-)connected.

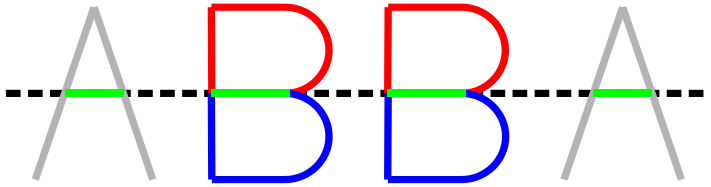




Introduction

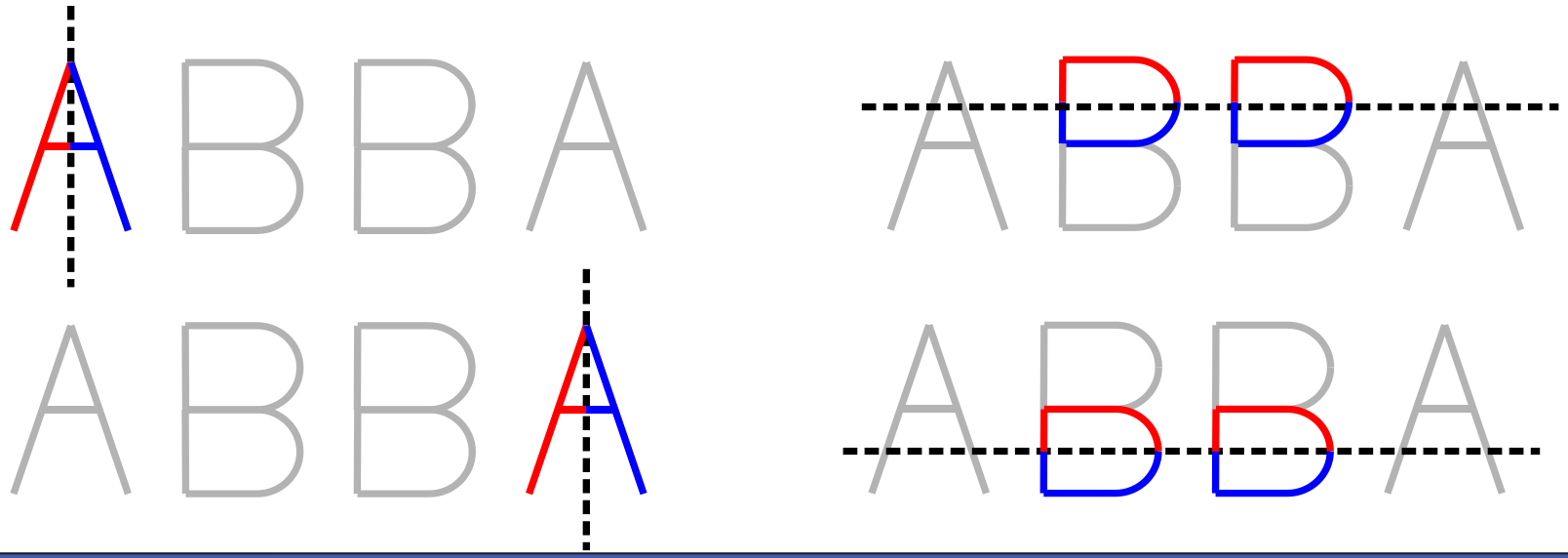
- Local symmetry
  - Subset of the input involved in the symmetry.
  - Much more complex detection. Not just symmetry test for different axes/planes, but performing such a test for a huge number of subsets of the input scene.
  - Connected (bilateral, partial) or disconnected.





Introduction

- Global and partial are special cases of local symmetry.
- Our algorithm detects multiple (all) local symmetries, including the global and partial ones.
- Only maximal symmetries considered.
- Strength of symmetry = amount of involved input.



Earth observation (EO) data

- Sampled data
  - Points of an „original“and mirrored part rarely match exactly → approximate symmetry detection (based on voxelization).
- Top view
  - 3D data, (mostly) acquired „down“ from a satellite, airplane…
  - More data collected from visible top faces than from side and bottom faces → more likely to find symmetries on top faces.
  - Usually, width and length of the considered area are much greater than the range of altitudes.
- Only vertical symmetry planes considered!!!
  - In a case of a horizontal symmetry plane candidate, much more points quite likely above it than below it.

Concept of the new method

- Bottom-up approach:
  - Basic symmetries found in each slice, followed by intra-slice and inter-slice merging of symmetries.
- Basic symmetry:
  - Between two primitives, e.g. points (voxels), line segments (LSs), …
- Non-material, material, and interesting voxels
- Line segment:
  - A pair of interesting voxels (endpoints). In the same slice.
  - Length. Threshold (80 %) interesting voxels.
- Each LS in (basic) symmetry has its symmetrical pair with the same lenght somewhere in the considered slice.

Part 1:
Local Symmetry

Method

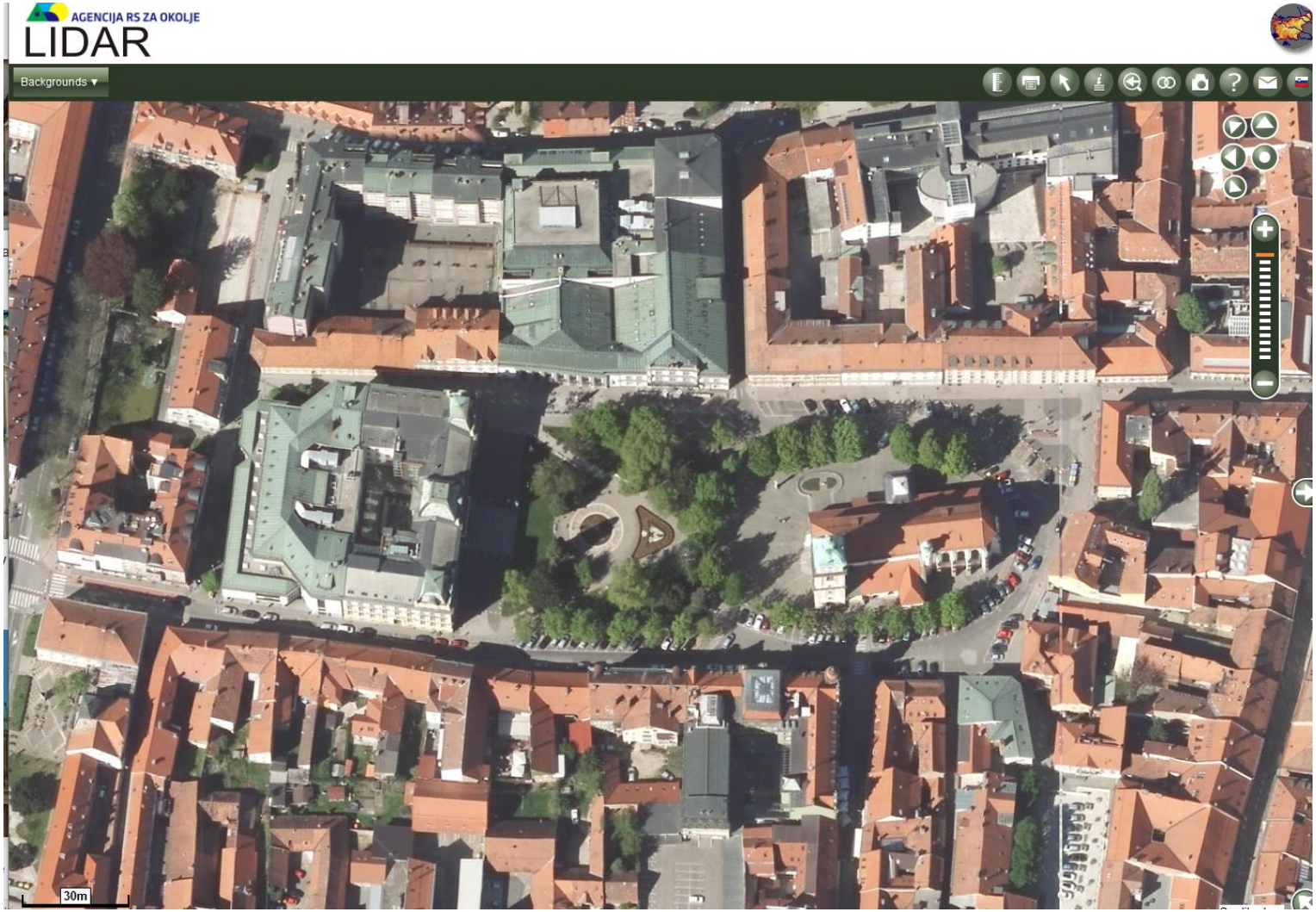
Voxelization.
Identify the material voxels (and filter them).
Identify the interesting voxels.
For each horizontal slice of the voxel grid
    Identify LSs and cluster them with respect to their lengths.
    For each cluster of LSs
        Establish basic symmetries among pairs of LSs.
        Merge symmetries.
    Merge symmetries from different clusters.
Merge symmetries from different slices.
Add „non-interesting" material voxels into symmetries.
(Postprocessing.)

Results

- Slomšek Square with the Maribor Cathedral (Church of St John the Baptist)

PHOTO: Igor Napast, www.vecer.com

Results



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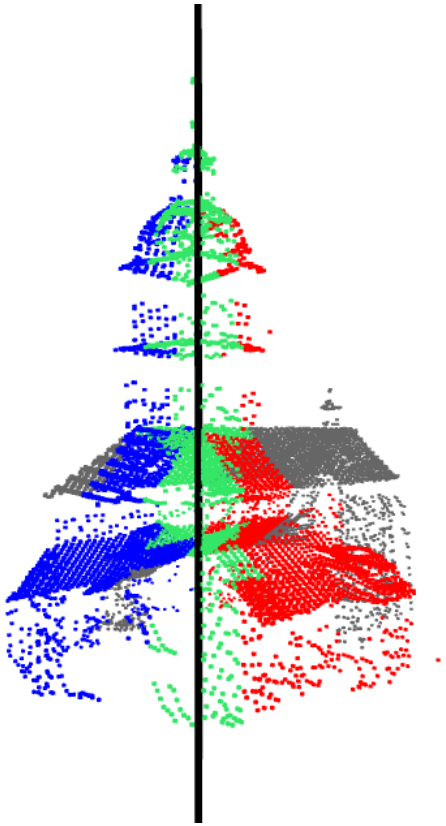
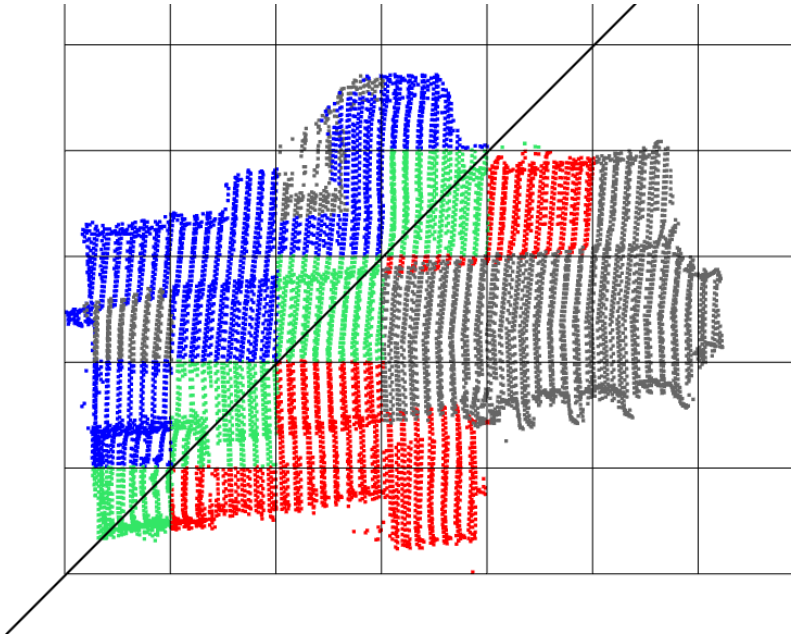
Results

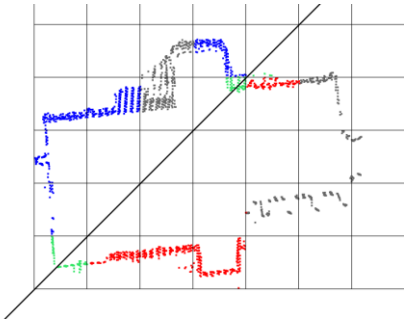
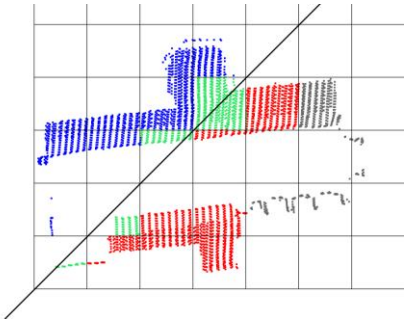
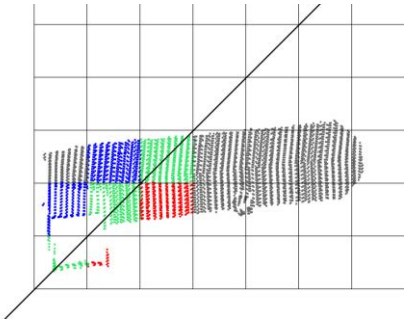
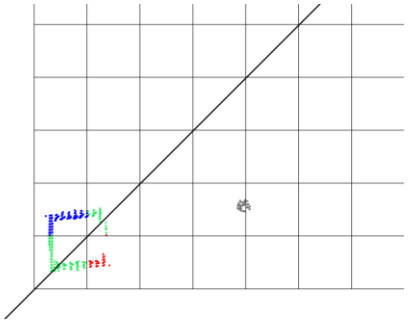
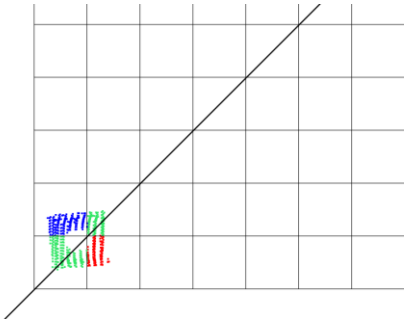
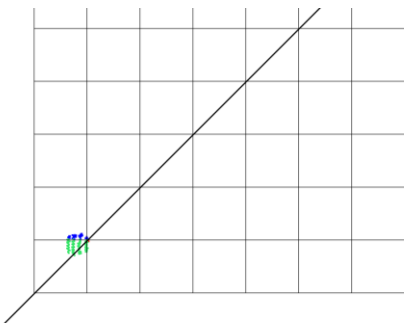
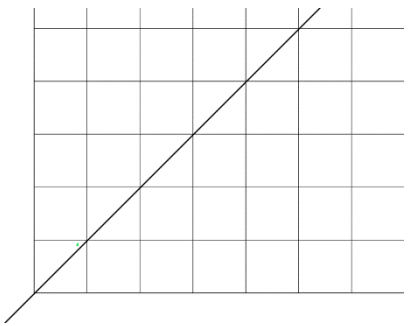
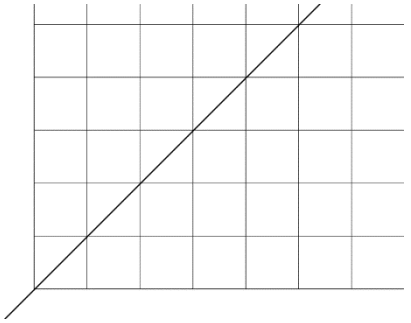
- Strongest symmetry at 500 voxels.





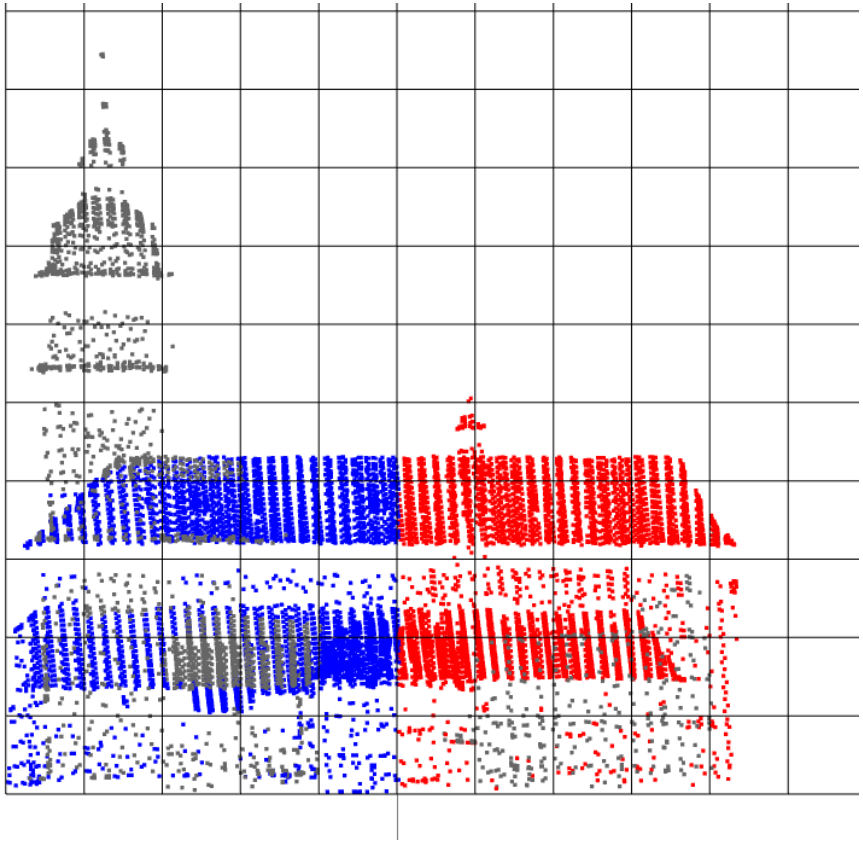
Results

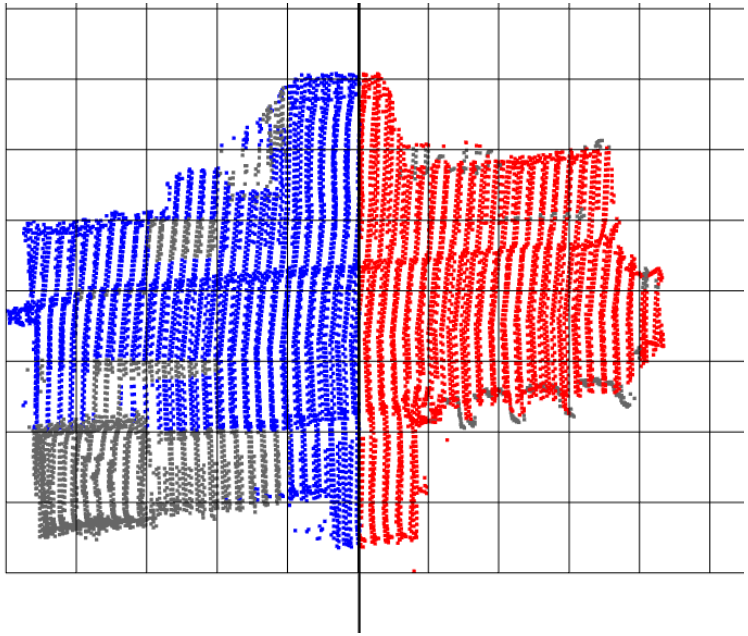
- Strongest symmetry at 500 voxels. 8 slices.

Results

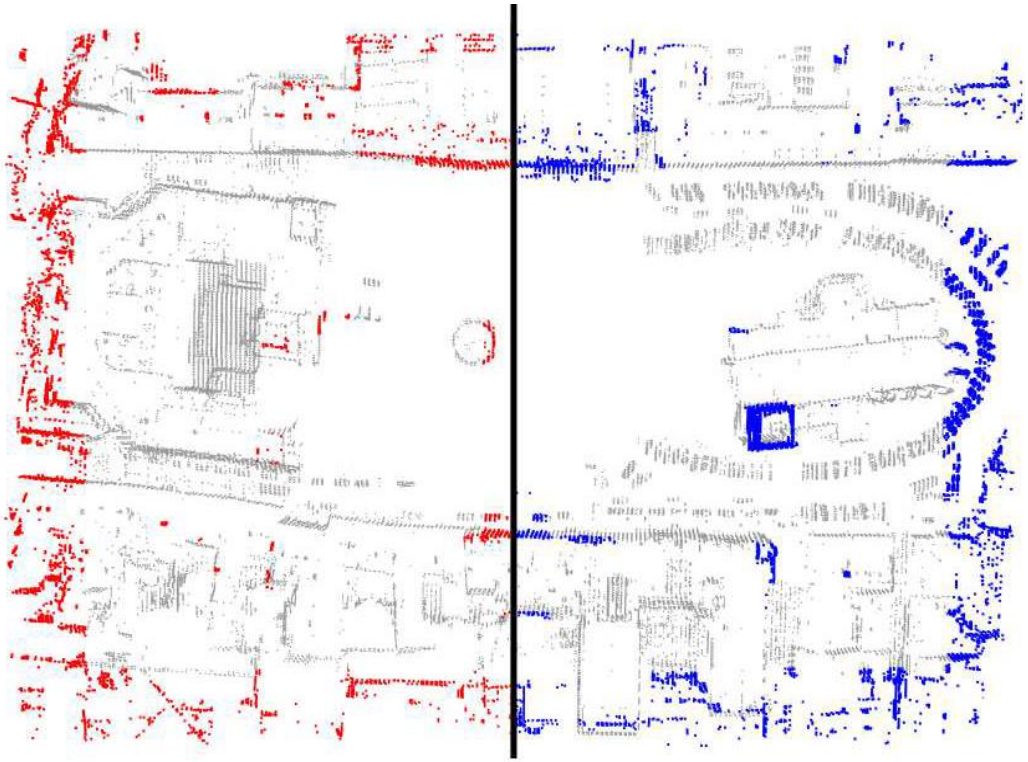
- Strongest symmetry at 1500 voxels.





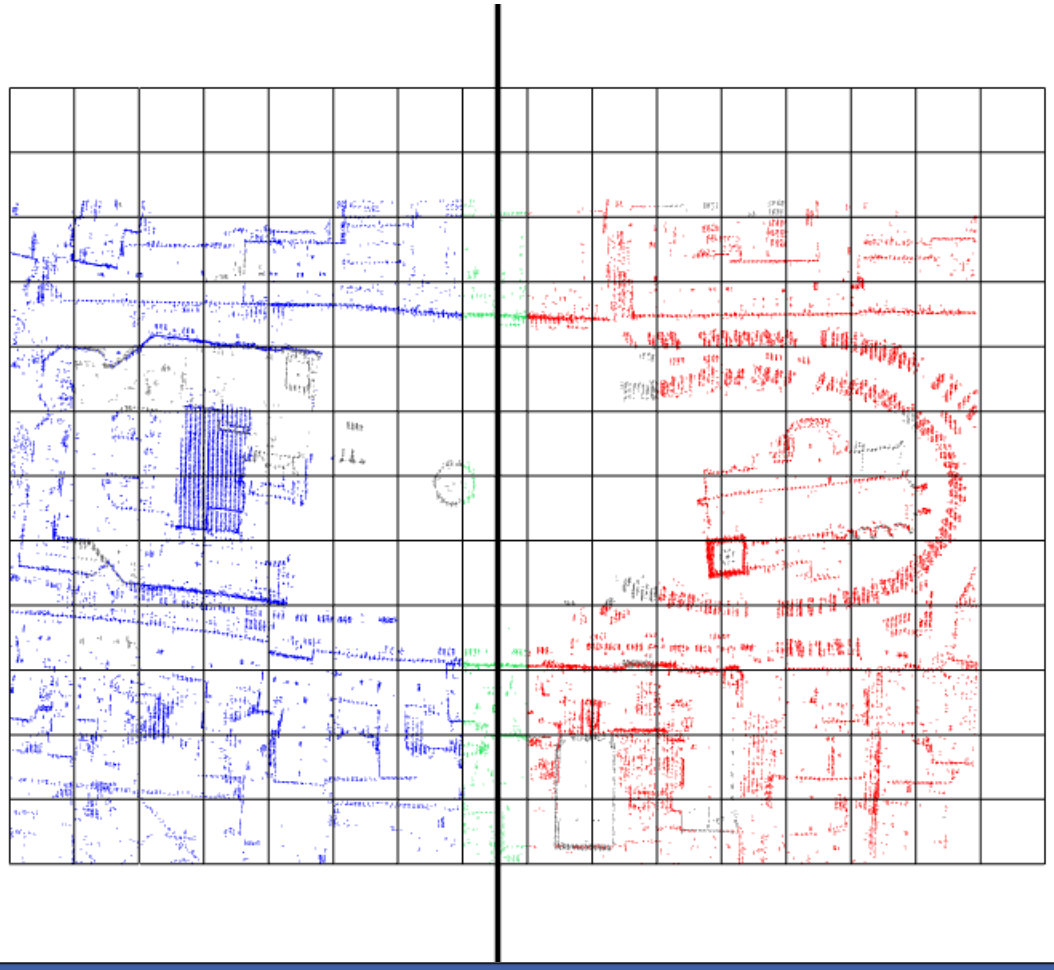
Results

- Strongest symmetry at 1000 voxels.



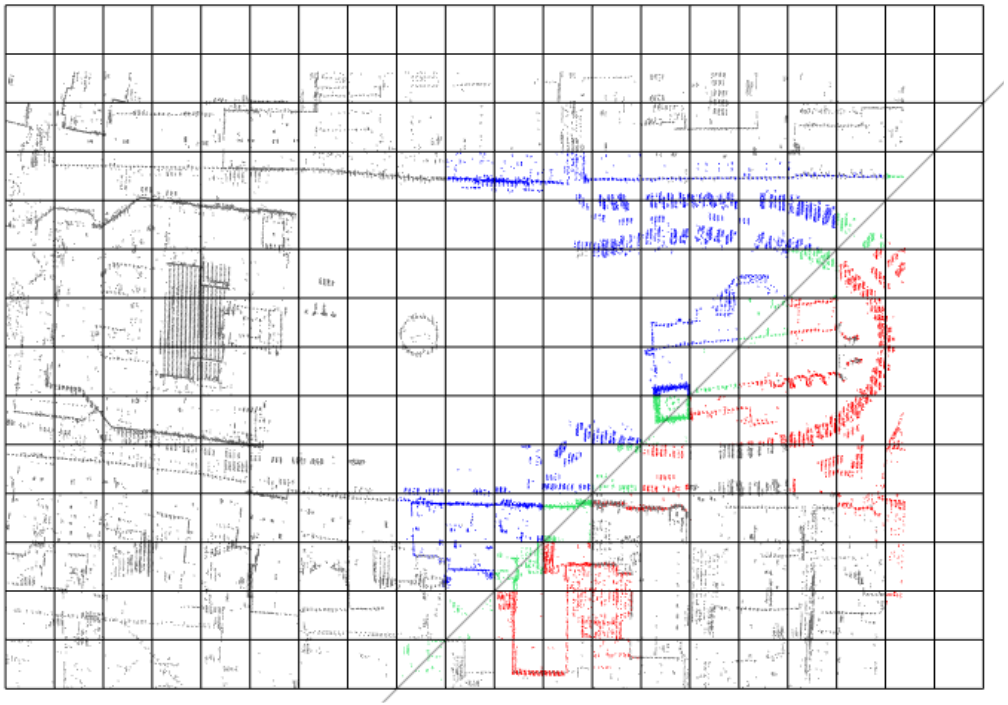
Results

- Strongest symmetry at 1000 voxels.



Results

- One of the (average) symmetries at 2000 voxels.
  - Nearly the same plane as with the strongest symmetry of Cathedral at 500 voxels.



Results

Measure	Cathedral	Cathedral	Square	Square
Points	11779	11779	35985	35985
Voxel size [m]	9	6	16	13
Input voxels	500	1500	1000	2000
Voxels	384	1089	960	1680
Material voxels	78	193	64	428
Interesting voxels	37	64	129	132
Symmetries	37	66	345	432
Time [s]	0.026	0.060	0.519	1.452

- Cathedral: 25,000 voxels with 2 m side, 0.954 s.
- Square: 25,000 voxels with 5 m side, 186.125 s.

Results

	The Cathedral			Slomšek Square		
	Points	Voxels	%	Points	Voxels	%
Best	2493	26	33.33	7489	133	31.07
2nd	2129	18	23.08	5715	116	27.10
3rd	779	10	12.82	7428	106	24.77
Last	174	4	5.13	131	4	0.93

- Number of points and voxels included in individual symmetries and % of the latter among the material voxels.

Part 2:
Global Symmetry

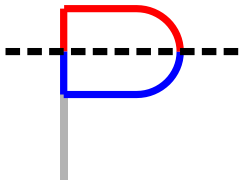
Global symmetry

- Special case of local symmetry with 100% amount of the input data involved in the symmetry.
- Automatically detected by the algorithm
  - Common symmetry plane in all slices
  - 100% involvement of input data in all slices
- More global symmetries may be detected (with different planes of symmetry).
- Local symmetries may be detected besides the global one, but not with the same symmetry plane.

Part 3:
Partial Symmetry

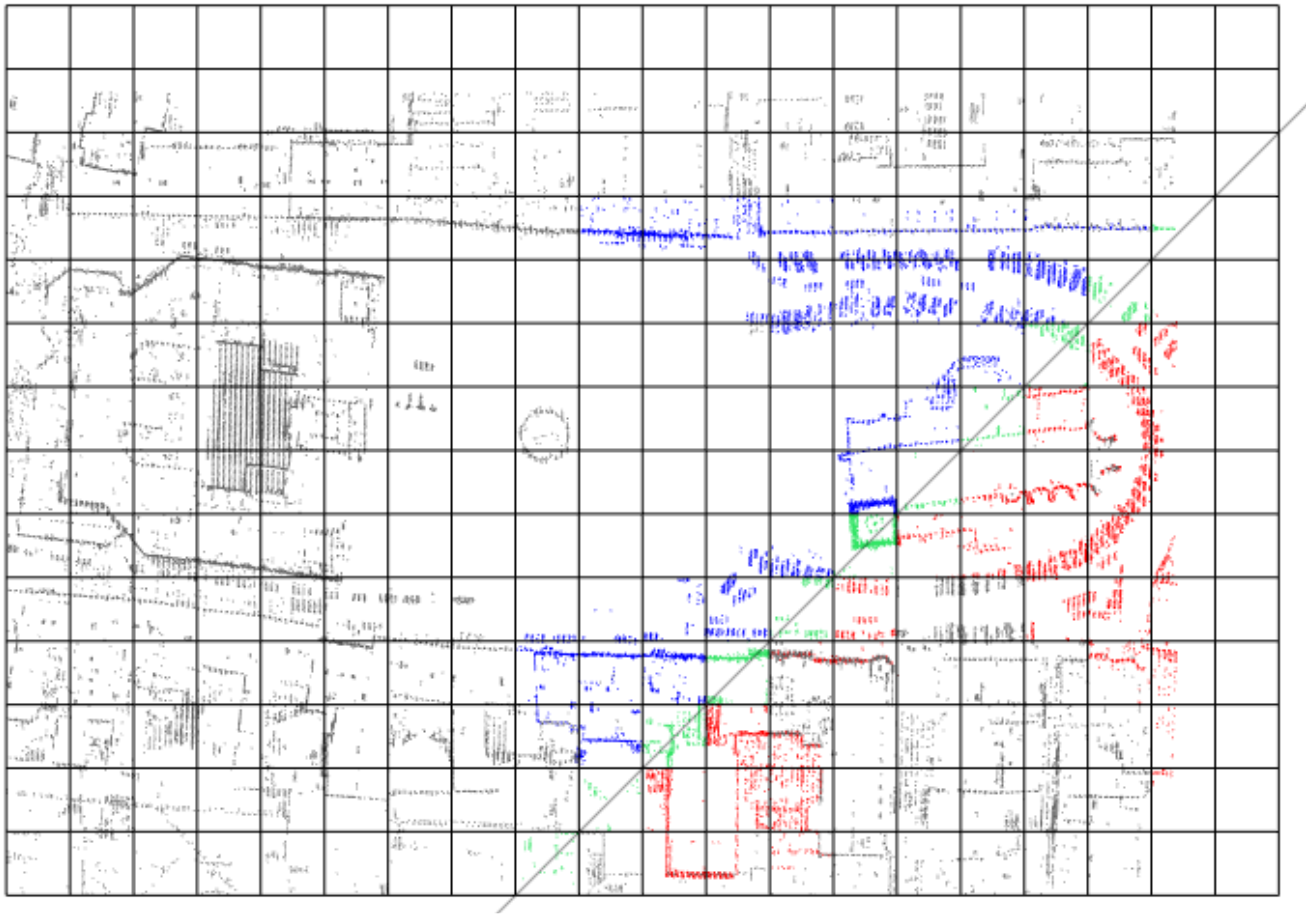
Partial symmetry

- May be automatically detected by the local symmetry detection algorithm.
- Can be obtained by the decomposition of the disconnected local/global symmetry
  - Each connected component intersected by the symmetry plane represents the partial symmetry.
  - Green voxels + adjacent red and blue voxels.



Results

- For the considered examples the same as with local symmetry.



Results

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Voxel size [m]	9	6	16	13
Input voxels	500	1500	1000	2000
Voxels	384	1089	960	1680
Material voxels	78	193	64	428
Interesting voxels	37	64	129	132
Symmetries (local)	37	66	345	432
Symmetries (partial)	34	77	522	727
Time (local) [s]	0.026	0.060	0.519	1.452
Time (partial) [s]	0.001	0.002	0.009	0.017
Time (total) [s]	0.027	0.062	0.528	1.452

Conclusion

- The local symmetry part has been presented at the international conference MATCOS-22 in Koper, Slovenia, in the first half of October 2022.
- Journal paper being prepared.
- Local rotational symmetry detection about to be implemented on mostly the same principles.