Conference and Plenary Meeting of the Permanent Committee on Cadastre in the European Union (PCC)

“Role of National Mapping, Cadastre and Land Registry Authorities in Resilience and Recovery program “

Dr. Marjan Čeh

Methodology used in the positional improvement of geometric data of the land cadastre

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JOINT PCC AND EUROGEOGRAPHICS CLRKEN WEBINAR
SLOVENIA, 10. AND 11. NOVEMBER 2021

Motivation

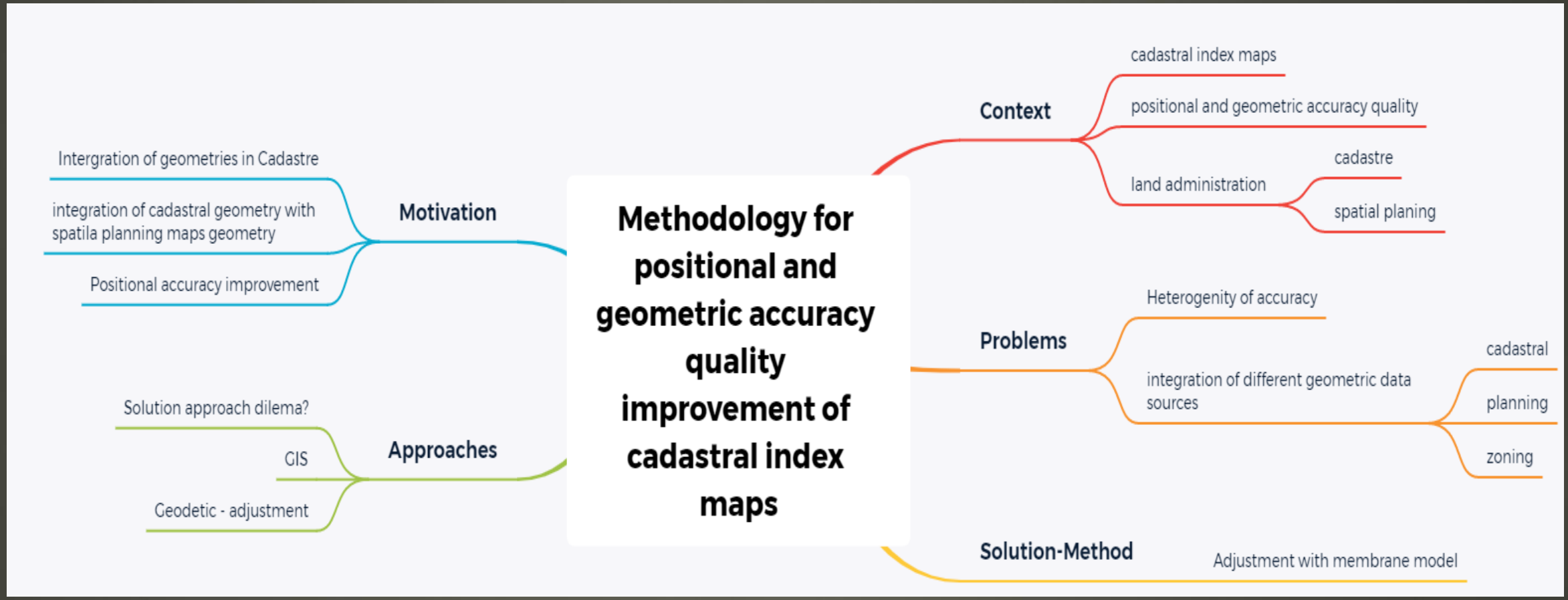
Sustainable, resilient
infrastructure for geospatial data

Digital connectivity
of public administration

Interoperability and **integration**
of fundamental datasets

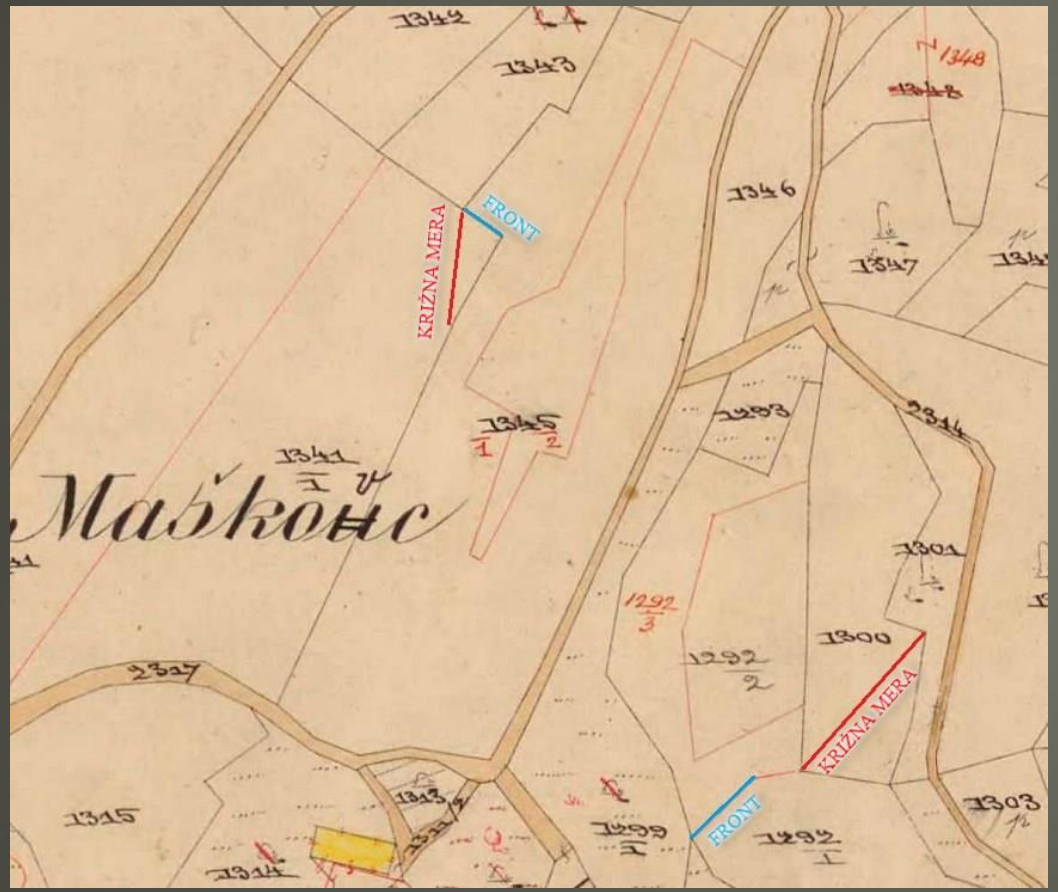
"Role of National Mapping, Cadastre and Land Registry Authorities in Resilience and Recovery program "

Content

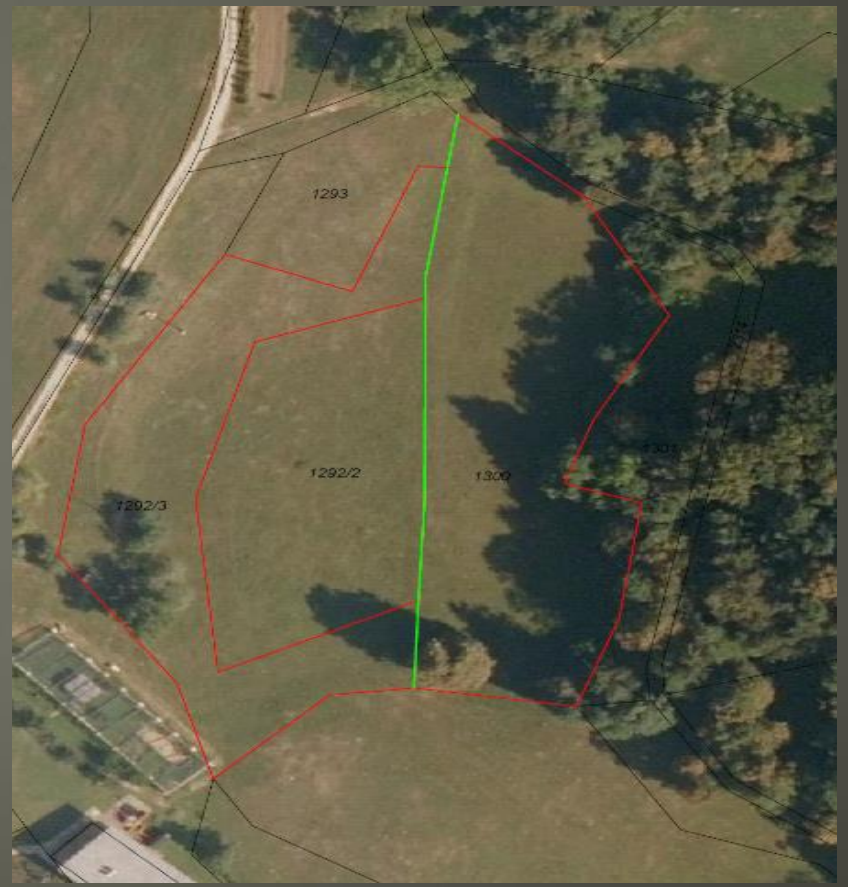

Intergration of geometries in Cadastre
integration of cadastral geometry with spatila planning maps geometry
Positional accuracy improvement
Motivation
Solution approach dilema?
GIS
Geodetic - adjustment
Approaches
Methodology for positional and geometric accuracy quality improvement of cadastral index maps
Context
cadastral index maps
positional and geometric accuracy quality
land administration
cadastre
spatial planing
Problems
Heterogenity of accuracy
integration of different geometric data sources
cadastral
planning
zoning
Solution-Method
Adjustment with membrane model

Cadastral index MAP

traditional



vectorised



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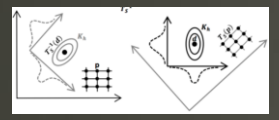
Situation and **geometric problems** of cadastre

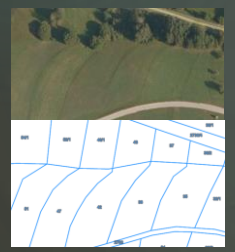
in **Slovenian rural regions**



- various **local coordinate reference** systems

- **digitised** traditional cadastral **index maps**,

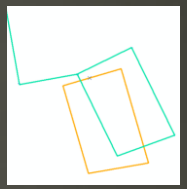
- land boundary **monuments** - **reference** points



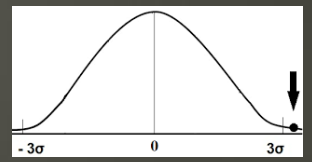
- **no monuments** - boundary points in neighbourhood of reference points.

the past **geometry maintenance**

- **outdated measurement** technologies,



- **inappropriate maintenance** of geometry - manual rigid proximity fitting (translation, rotation, reconnection)



- number of **gross geometric errors**,

- **heterogeneous accuracy** of cadastral maps

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Heterogeneity of geometric datasets in cadastre

- **Technology development**

- **Precision improvement**
  - Traditional mappings (cadastral, topographic MAP)

  - Geodetic observations (cadastral PLAN)

- **Methodology development ???**

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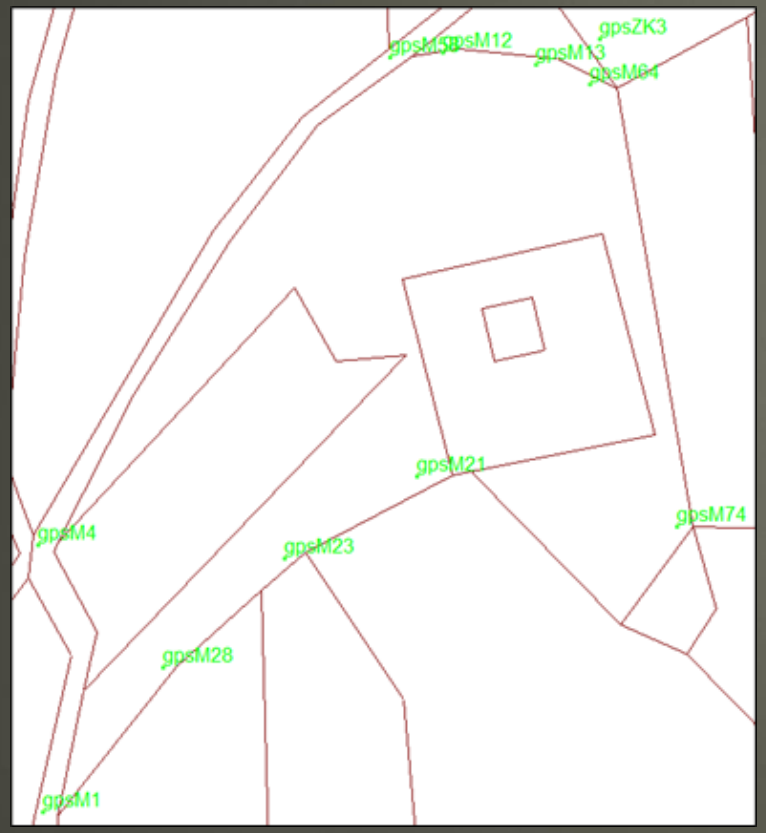
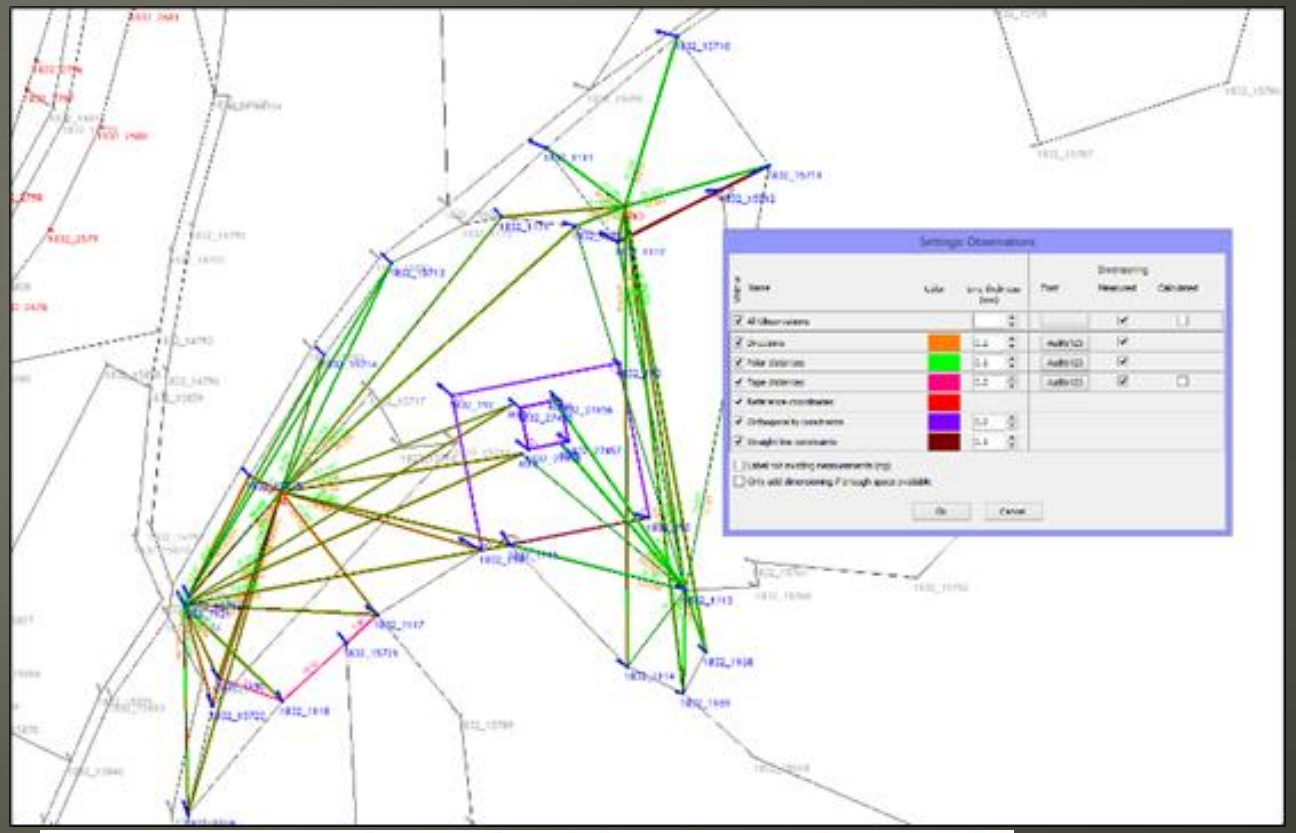
GIS versus geodetic approach

coordinates



original observations



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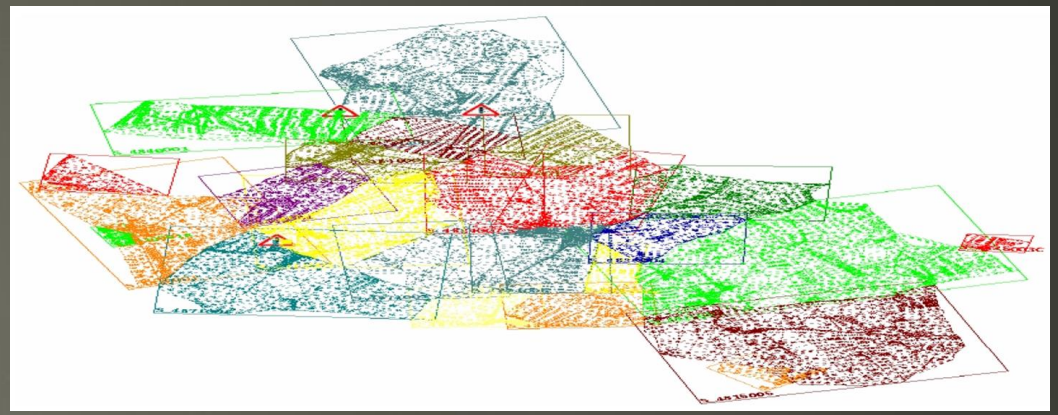
2 Aims

- **Improve positional accuracy** (PAI) of
  - cadastral index map (GIS)
  - **RMSE less than 1 m**

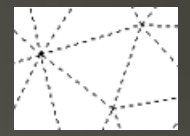
- The **positional integration** of vector LAS datasets
  - **planning** zones,
  - agriculture and forestry **land use units**

How?

- Adjustment of Geodetic Network
  - **an interconnected transformation**
  - of local systems
    - digitized **cadastral maps**,
    - **orthogonal** systems such as measurement lines,
    - **polar** systems such as angles and distances,
  - into a **national reference system** (D96/TM).



Input



- **„GIS“ points** (vectorised cadastral index map)
- **reference points** (surveyed cadastral monuments)
- **point relations** (automated identity observation)

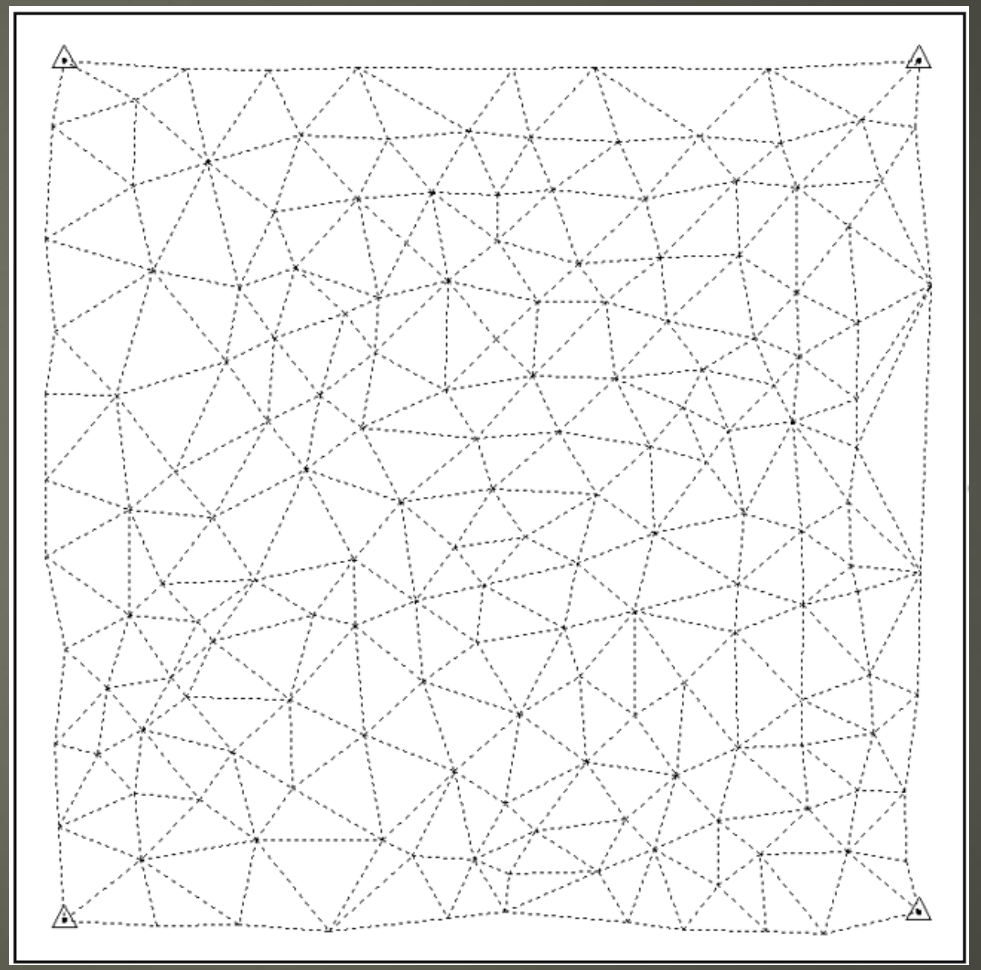
- **Functional** model (geodetic network)
  - Configuration of network – controllability – triangular – **TIN**
  - **Scales of the membrane triangles** as observations

- **Stochastic** model (**weights of a scale** observations)

Functional model: Triangular Irregular Network (TIN)

Membrane simulation - triangulation

define
topological and
proximity relations
between spatial map objects



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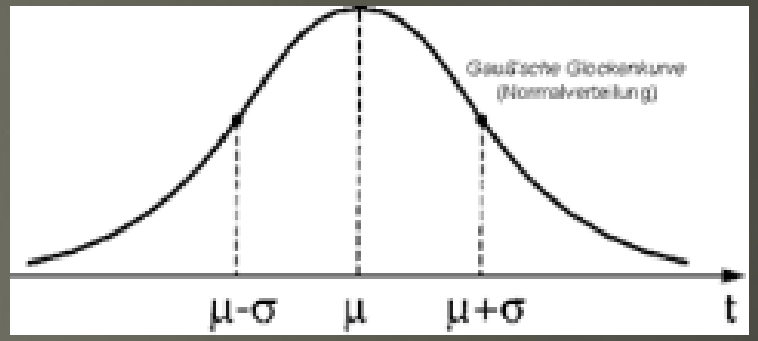
Stochastic model

- **Least squares adjustment** (Gauss-Markov model)

based on original geodetic observations in Cadastre (not on GIS coordinates)

Observations are stochastic variables – statistic

- influenced by **uncertainty**
  - to determine one pair of coordinates
  - mass of observations – **redundancy**
  - **adjustment**

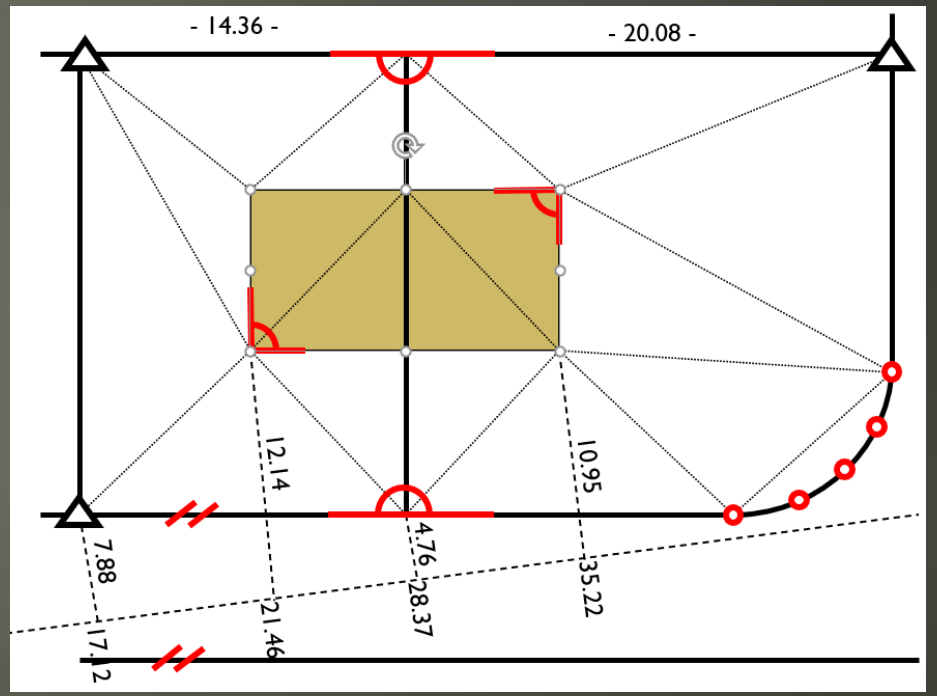


$$v^T P v \stackrel{!}{=} \min \qquad x = (A^T P A)^{-1} A^T P l$$

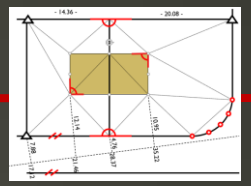
- **Results of calculations (coordinates) are not final but changeable!**

4 Requirements to the improvement method

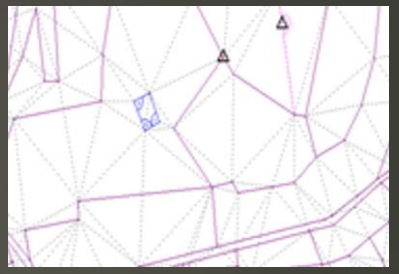
- …for **integration of relative geometry** to adjustment
- with **keeping neighbourhood relations.**



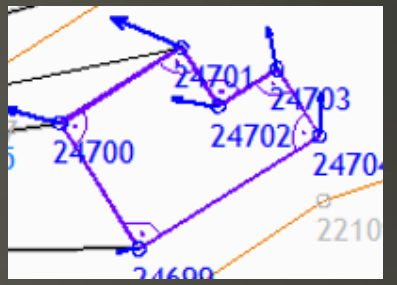
Relative geometry integration conditions (1)



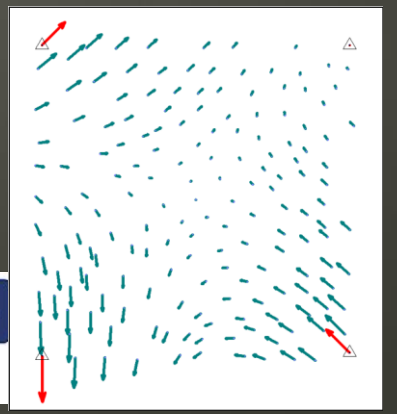
1. **Corrections of coordinates at tie points**
   must be **transferred to neighbouring** points **along lines between them** (TIN edges) - **proximity fitted**
   (larger distance – smaller influence)



2. **Influence of geometric conditions** (orthogonality, parallelism) must be transferred to neighbouring points.



Shift vectors in vicinity of tie points must **be harmonic** (similar in distance and direction) – **proximity fitted**



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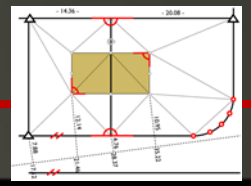
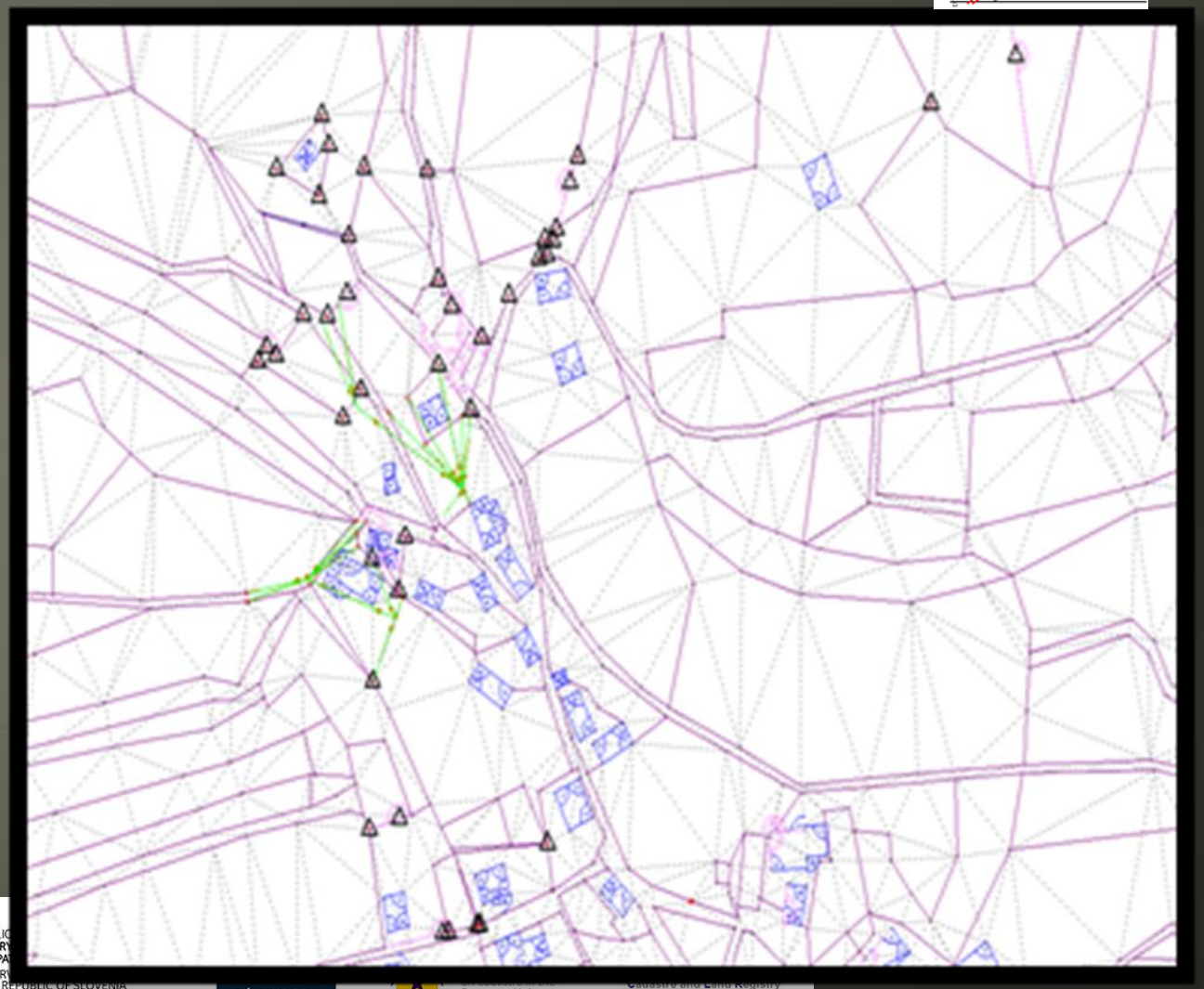
Relative geometry integration conditions (2)



3. Improvement model must be **independent of spatial configuration of tie points**

4. Improvement model must be **independent of configuration of GIS points** (cadastral index map)

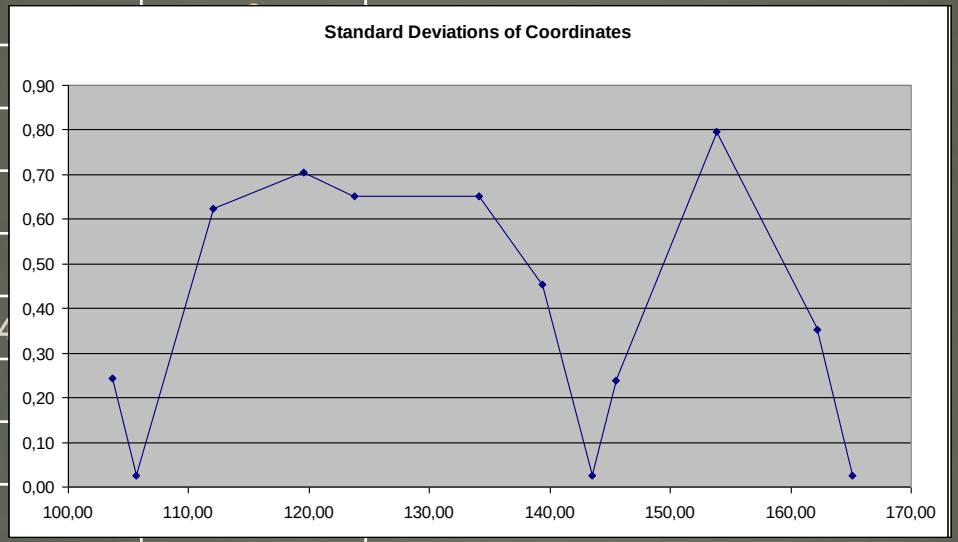


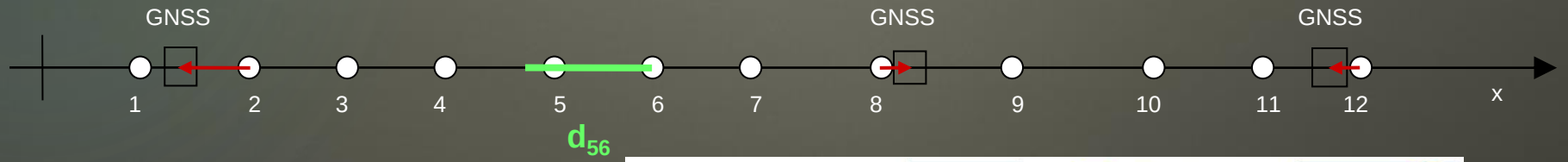
Adjustment with respecting **spatial correlations**

GIS Point	X GNSS	DX GIS
1		-
2	105,65	2
3		
4		
5		
6		
7		
8	14	
9		
10		
11		
12	165,13	3

Observations:

1. **Coordinate differences GIS (pseudo observations)**
2. **Coordinates GNSS**
3. **Distance (real relative geometry observations)**





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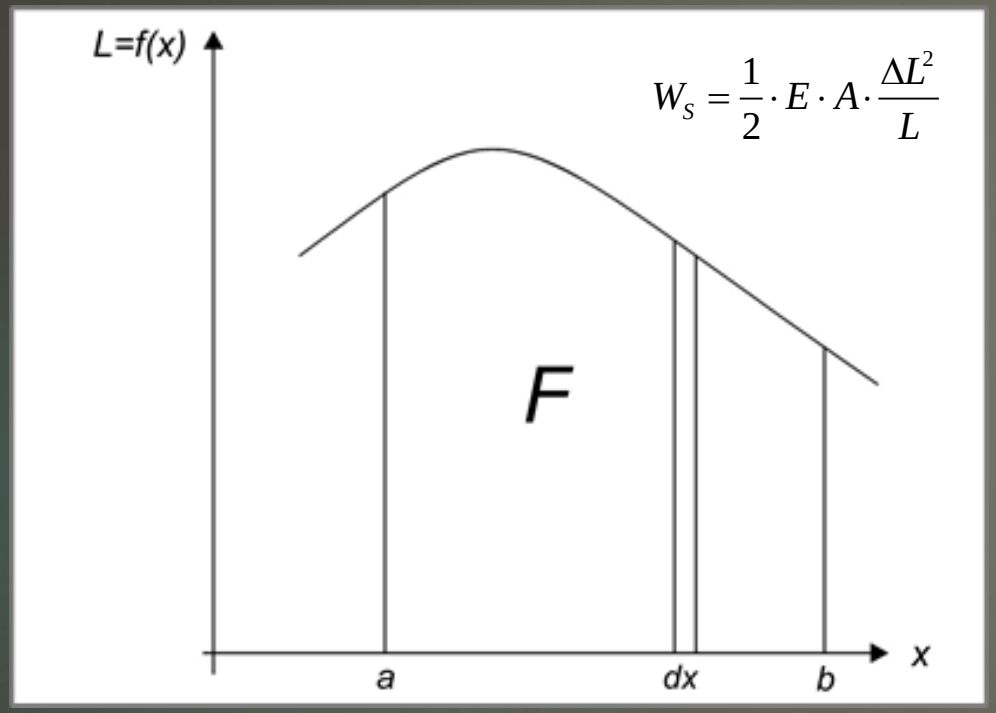
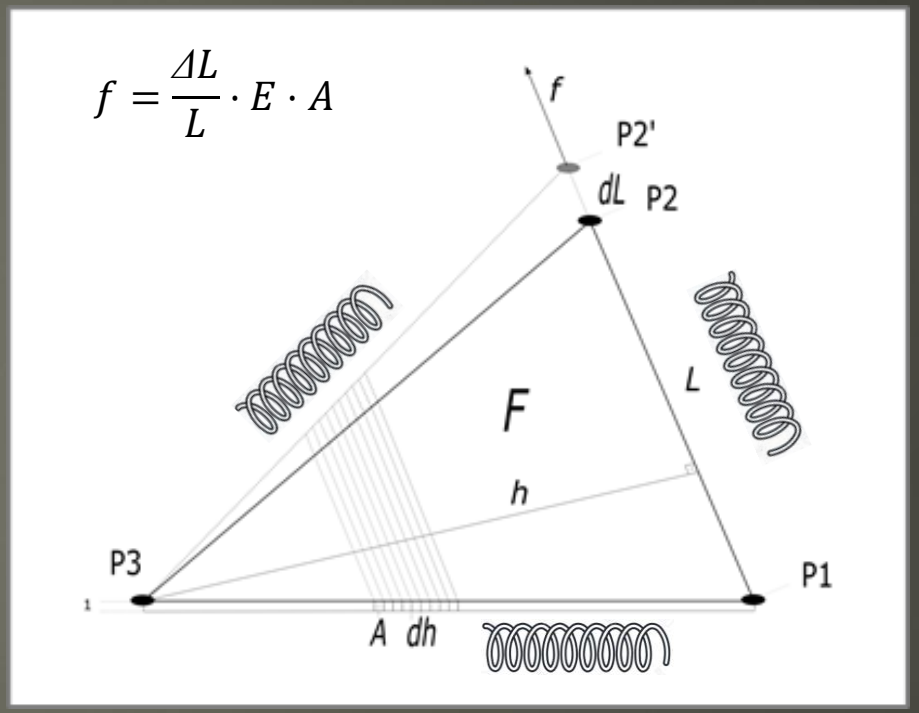
Mechanical Membrane Model Based on Hooke's Law

Deformation energy W

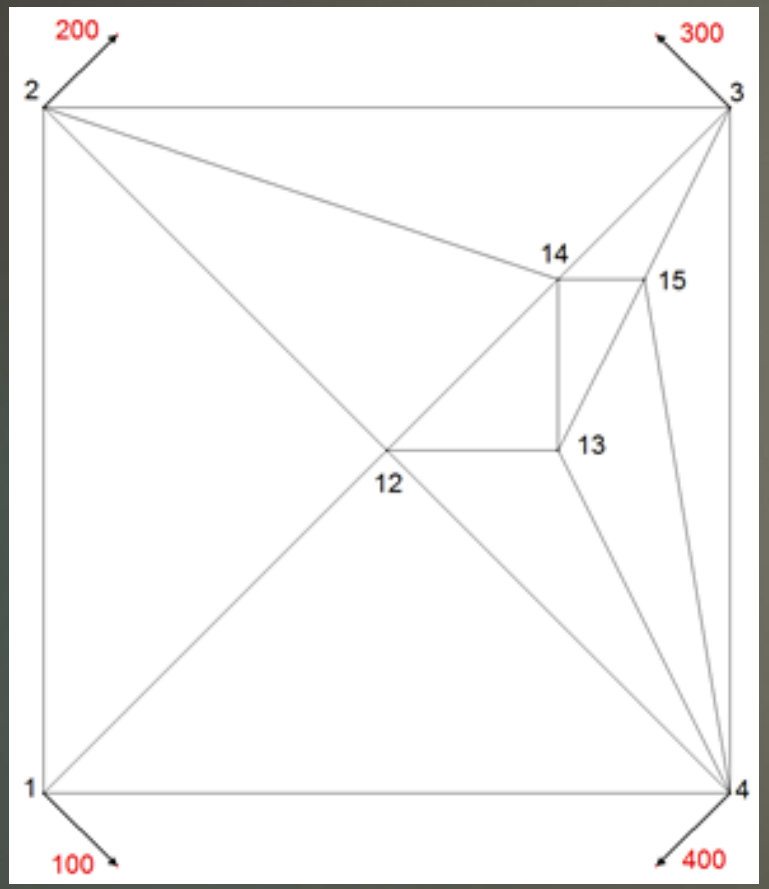
$$\frac{\Delta L}{L} = \frac{\sigma}{E}$$



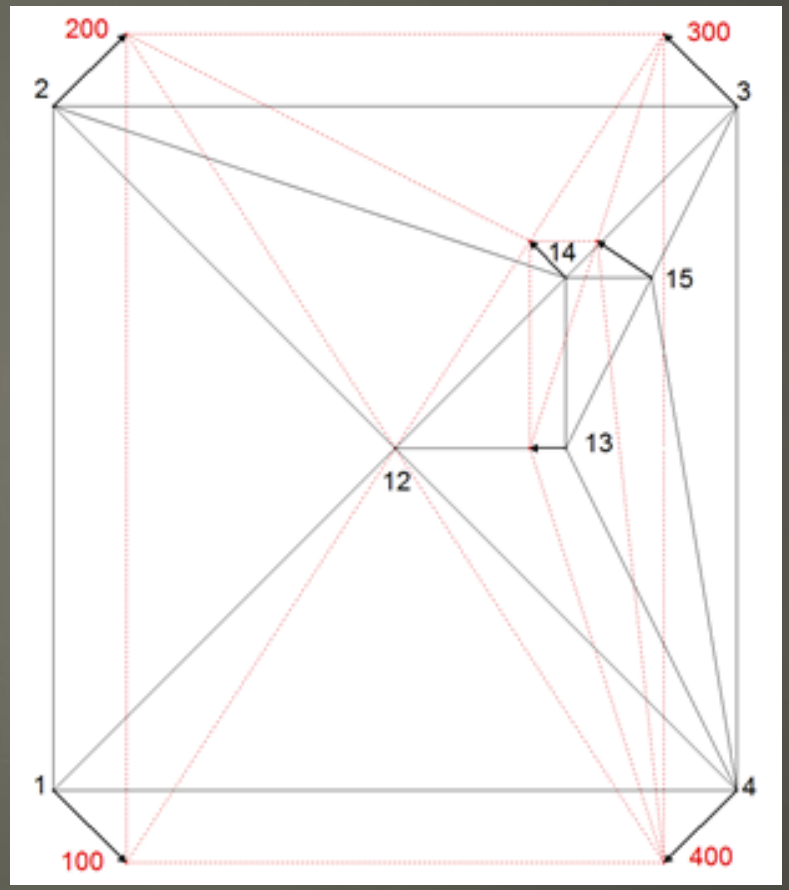


E – module of elasticity
A – thickness of membrane

Effect of the proximity fitting with membrane



Symmetric deformation



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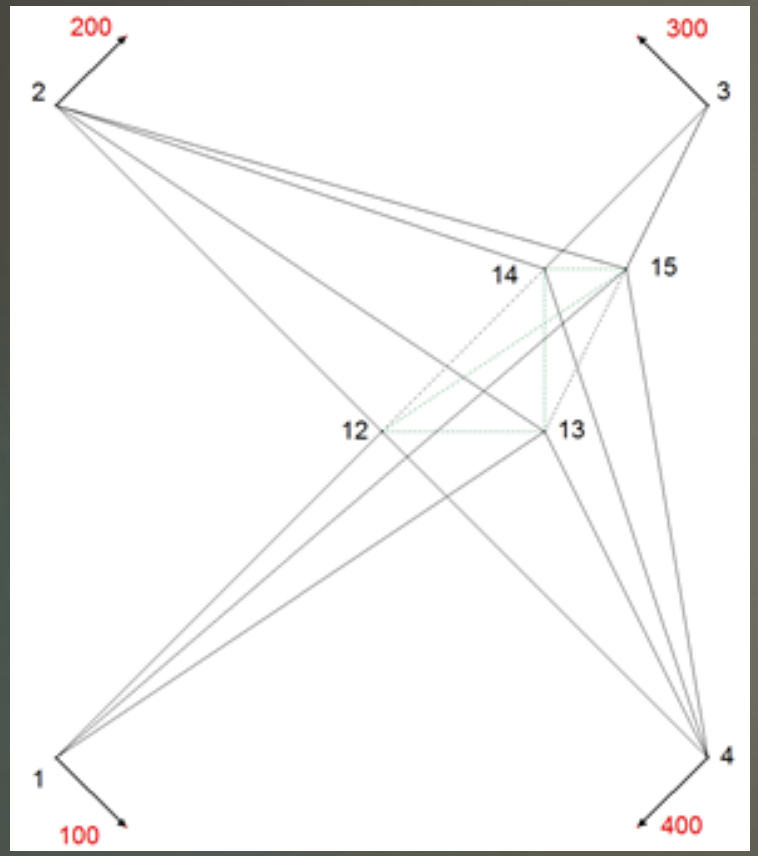
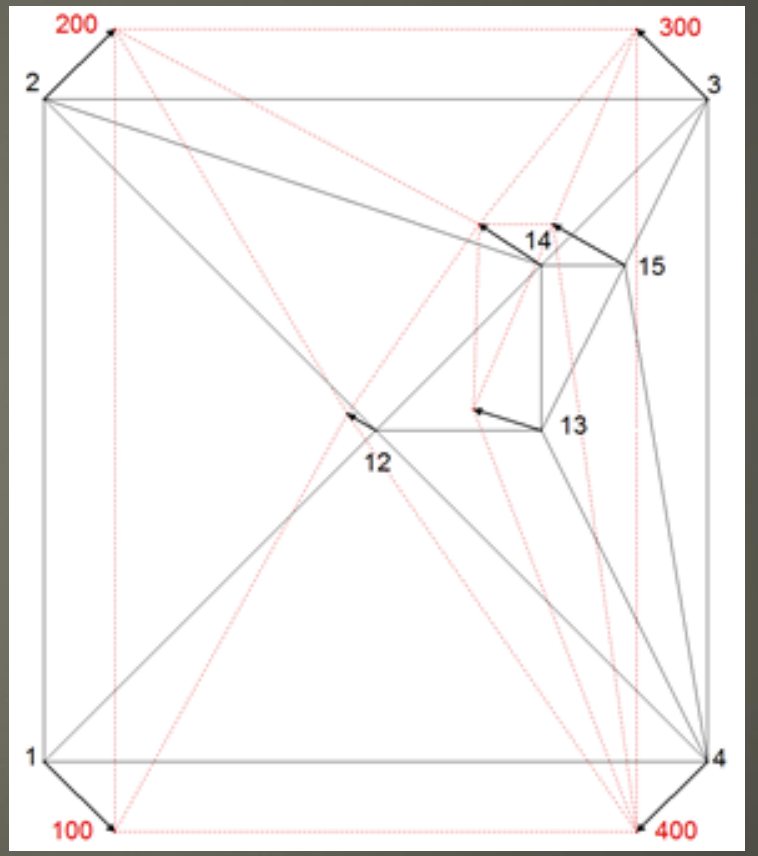
Effect of the proximity fitting without TIN model



Non - symmetric deformation !



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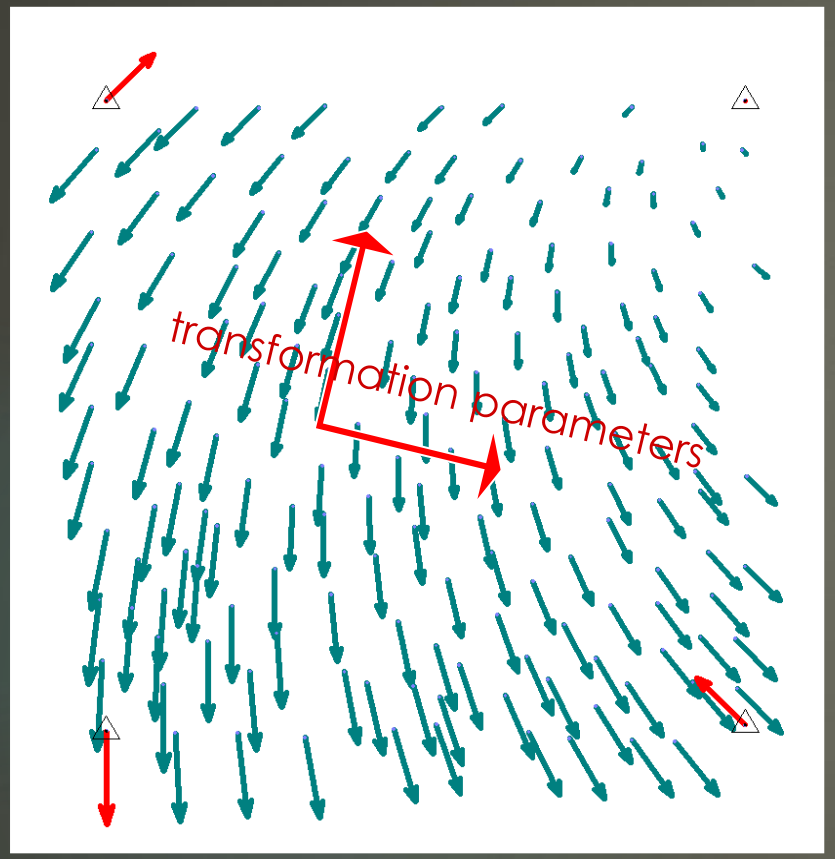
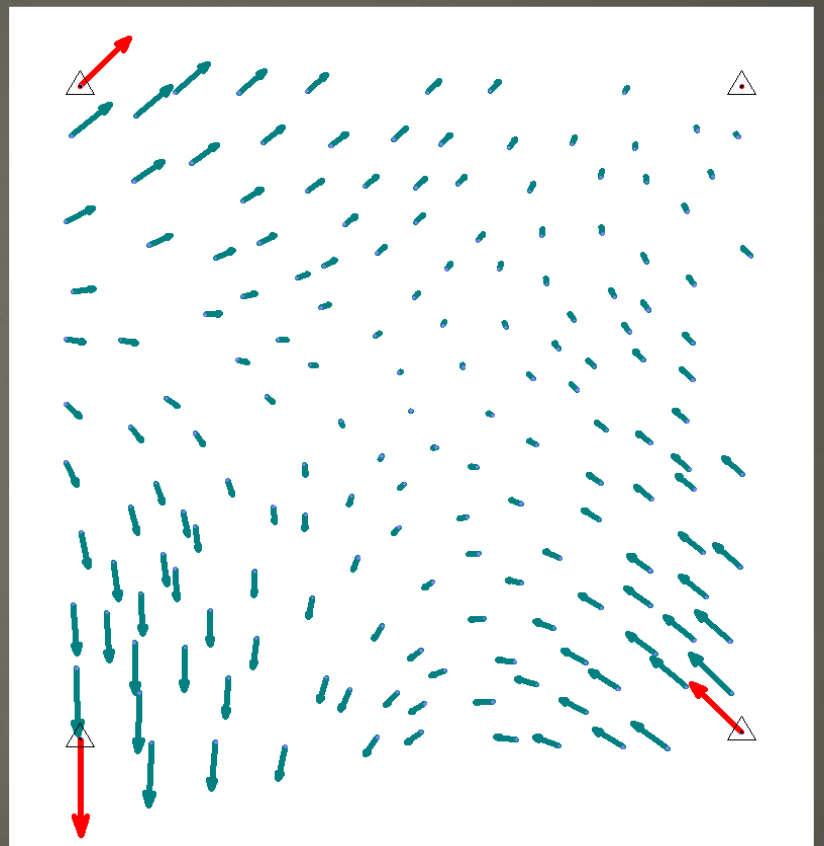
Transformation : Adjustment of transformation



Transformed; **not improved**



Adjusted TIN Transformation; **improved global coordinates !**

Considered GIS points dependence of distance to tie points !

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METHOD: Proximity Fitting with a Mechanical Membrane Model Based on Hooke's Law

- Preparation Phase 1: Topological **Net Construction**
- Adjustment Phase 1: Adjustment with Conjugate Gradient
  - Step 1: Calculation of the **Initial** Approximate Values for Unknowns
  - Step 2: Calculation of **Improved** Approximate Values for Unknowns
- Preparation Phase 2: Introduction of the **Pseudo-Observations** for Linearization of Residual Equations
- Preparation Phase 3 **Elimination** of Incorrect Observations
- Adjustment Phase 2: **Indirect Adjustment** by the Gaussian Algorithm
- Adjustment Phase 3: Distribution of the Residuals with Neighbourhood Adjustment - **Homogenization**

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PAI results

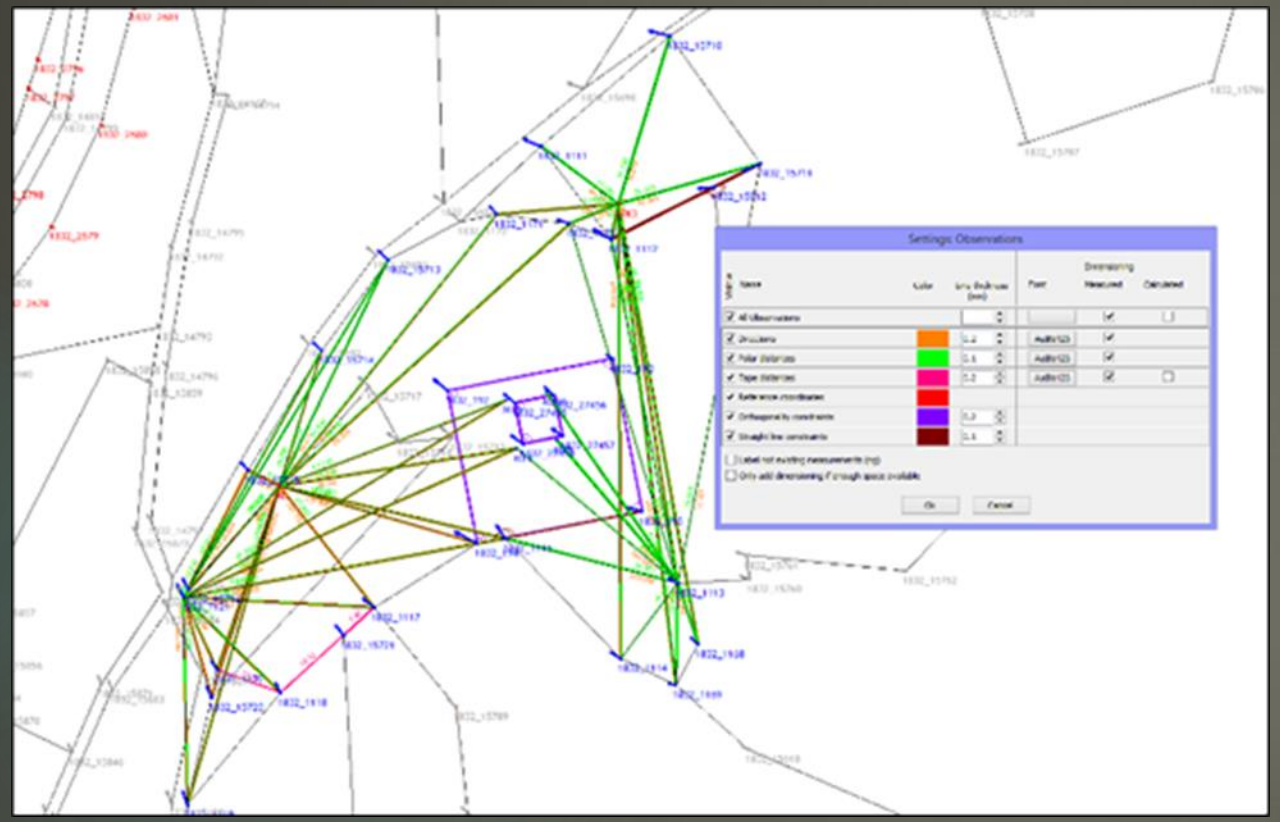
- Previous: triangle-based piecewise affine plane transformation (**RMSE = 2.4 m**)

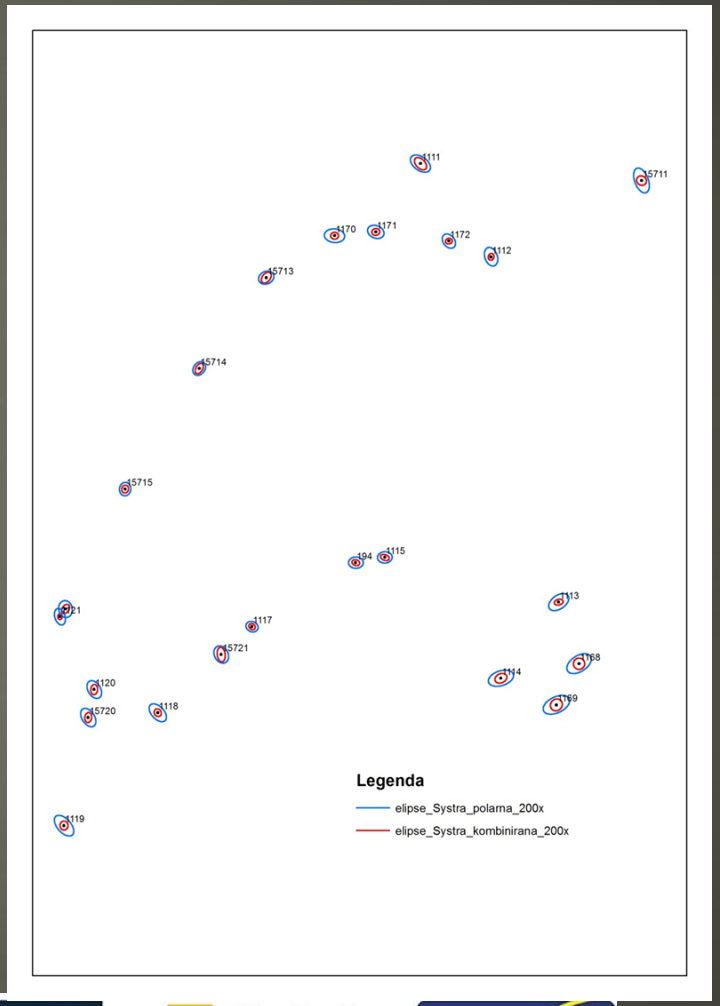
- Now: **adjustment of transformation with the membrane model included** (**RMSE < 1.0 m**)
  - Method tested at 623 control points

Shift vectors - harmonic

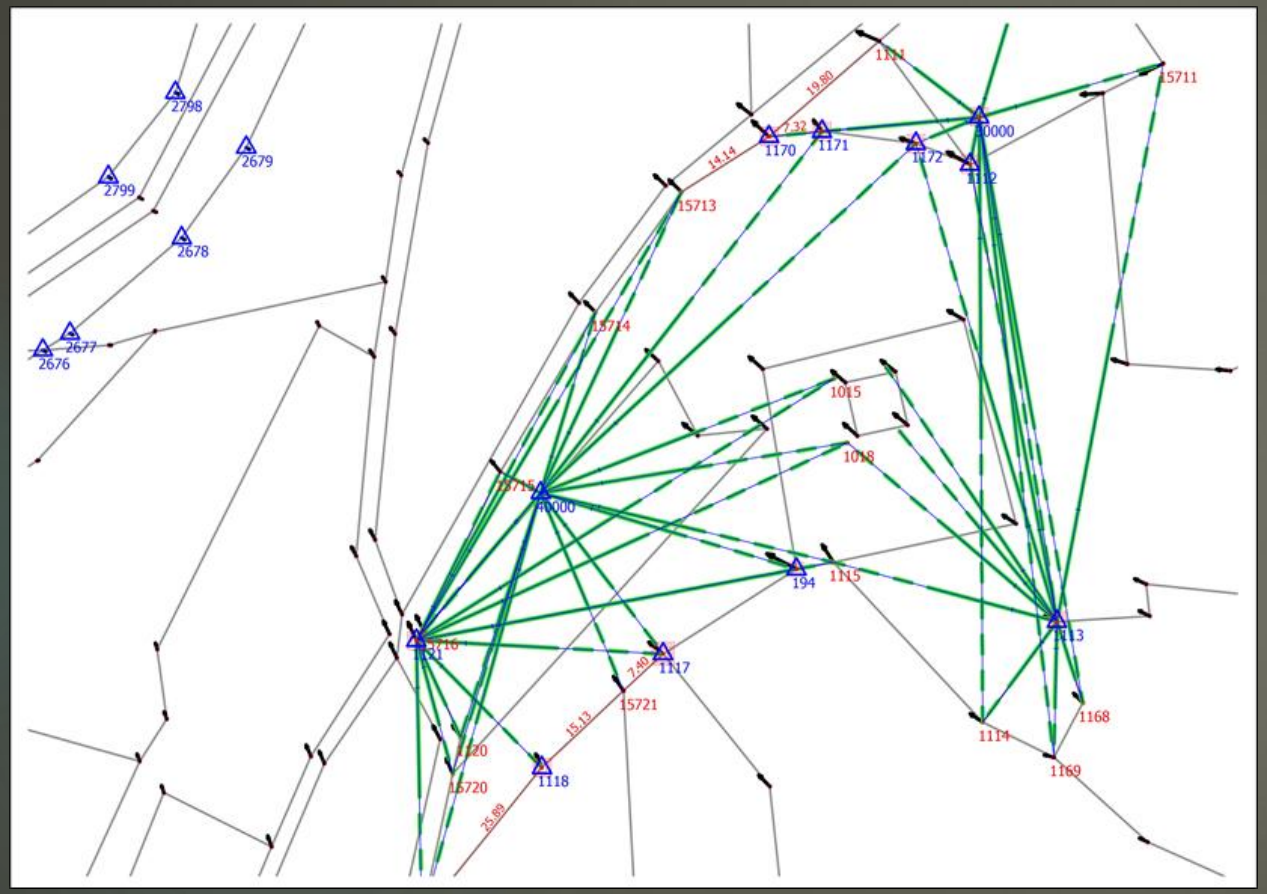
Before After

Comparison of ellipses at 68 % probability

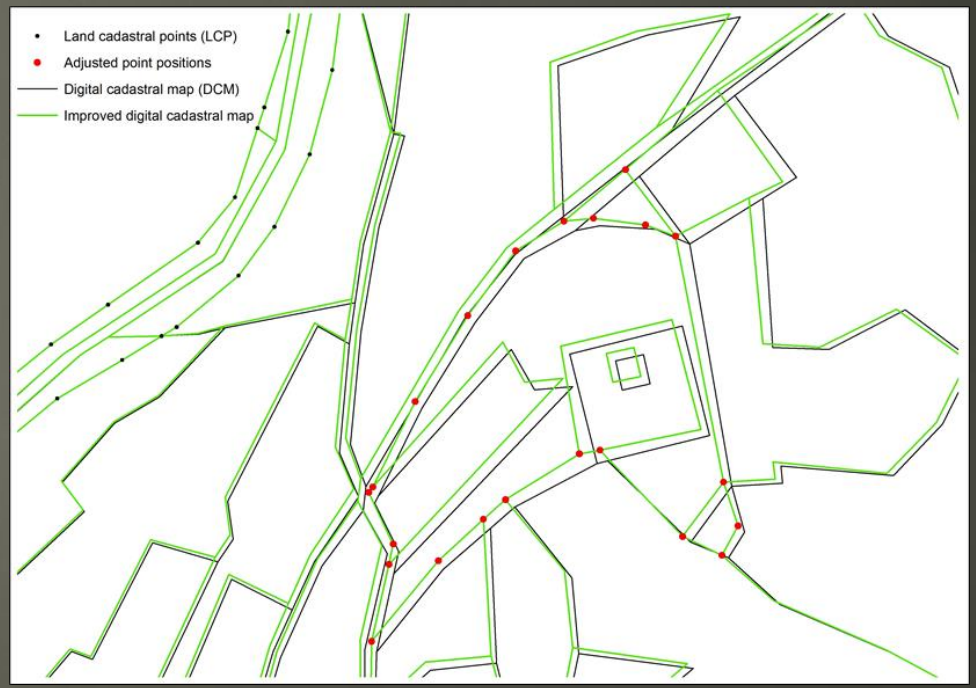




Adjusted field book observations geometric data



Homogenization of neighbourhood



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Integrated cadastral geometry

Project e-space: Location improvements of land cadastral index map

(2018-2020)

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Integrating spatial plans to improved cadastral index map

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Reference:

Čeh M, Gielsdorf F, Trobec B, Krivic M, Lisec A.

Improving the Positional Accuracy of Traditional Cadastral Index Maps with Membrane Adjustment in Slovenia

ISPRS International Journal of Geo-Information. 2019; 8(8):338.

https://doi.org/10.3390/ijgi8080338

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