Merging Different Data Sets Based on Matching and Adjustment Techniques

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Lay out

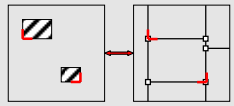
Geometry und Harmonisation?
What are the properties of Geo-Data?
How to model identical objects?
What is a topological object?
How to parameterize geometrical objects?
What is the role of the datum in the matching process?
How to find Matching-candidates?
How to test Matching-candidates?
How to avoid Missmatches?
Procedures diagram?
Matching? Searching?
Project experiences

GDI - Reality…

"Matching" and "Searching"

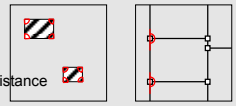
Matching: Finding of identical objects in **different** data sets

- corners
- distances
- straight lines
- points
- …



Searching: Finding of geometrical conditions within **one** data set

- right angles
- straight lines
- parallel lines
- parallel lines with given distance
- …



Geometrical harmony?

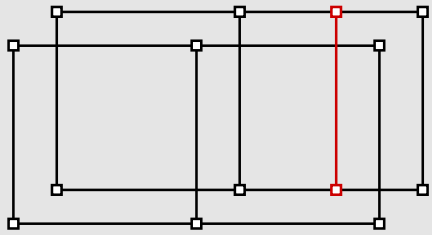
greek: *harmonia* = (bringing into agreement)

Unification of contradictable facts to a common entirety

contradictable facts → inconsistency
remove inconsistencies → adjustment

→ harmonization = adjustment

Subdivision of a plot



Preserve local neighborhood

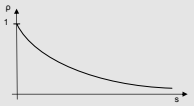
Distance depending correlations

$$\Delta x = x_E - x_A$$

$$\sigma_{\Delta x} = \sqrt{\sigma^2_{\Delta xE} + \sigma^2_{\Delta xA} - 2 \cdot \mathrm{cov}(x_A, x_E)}$$

$\mathrm{cov}(x_A, x_E) \neq 0$!

$$\mathrm{cov}(x_A, x_E) = \rho_{x_A, xE} \cdot \sigma_{\Delta xA} \cdot \sigma_{\Delta xE} = \mathrm{f}(s_{AE})$$



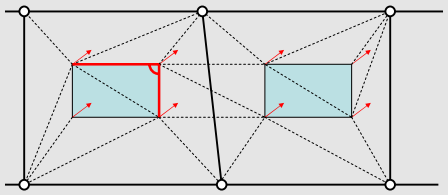
reasoning:

1. Measurement following the principle of neighborhood
2. Mapping following the principle of neighborhood

Integration of relative geometry

Case 1: Original observations are unknown

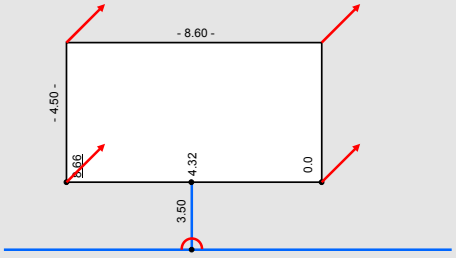
solution: Adjustment based on pseuobservables, i.e. simulating a rubber membrane, geometrical conditions



Integration of relative Geometry

Case 2: original observations given

solution: adjustment of original (and pseudo) observations



Integration of relative geometry

General Case

Membrane elements

Straight lines

Right angles

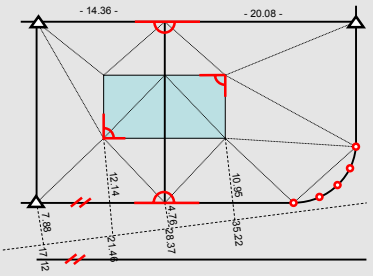
Parallel lines

Circularity conditions

Global coordinates

Locale coordinates

Distances



Lay out

Identical points

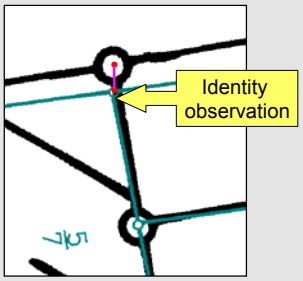
Approach: Identity observations

Functional model

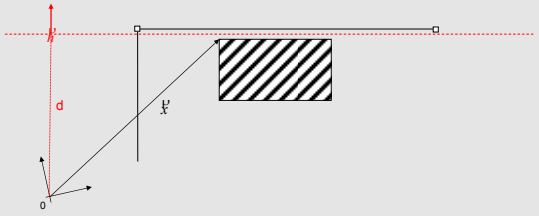
$$v_{\Delta X} = X_k - X_i$$
$$v_{\Delta Y} = Y_k - Y_i$$

Stochastic model (FFG)

$$\sigma^2_{\Delta X} = \sigma^2_{X_i} + \sigma^2_{X_k}$$
$$\sigma^2_{\Delta Y} = \sigma^2_{Y_i} + \sigma^2_{Y_k}$$
$$\sigma_{X_i} \ldots \sigma_{Y_k} \approx 0$$



Identical straight lines



Functional model

$v = \underset{\sim}{h}' \cdot \underset{\sim}{x}' - d$

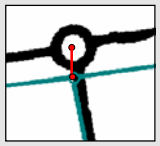
Stochastic model

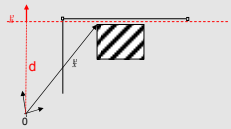
FFG: $\sigma_{xyi} \rightarrow \sigma_o$

Result of matching procedure

Observed identities for the analysis however no topological constraints!

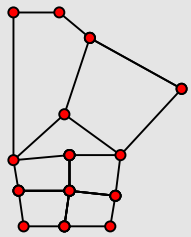
Identity is modelled geometrically not topologically.





Lay out

Graphs



Nodes

Links

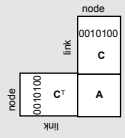
Corners

Extraction of partial graphs

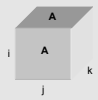
example: corner

Node-branch-matrix → Incidence-matrix **C**

Node-node-matrix → Adjacence-matrix $\mathbf{A} = \mathbf{C}^T\mathbf{C}$



Dyadic product → Adjacence-tensor $\mathbf{A} \otimes \mathbf{A}$



I, j, k are indices of corner points

Geometrical parameterization

Node	Point	X, Y	
Link	Straight line	n_x, n_y, d	
	Point-direction	X, Y, r_x, r_y	
	Point-Point	X_A, Y_A, X_E, Y_E	
Corner	Point-directions	X, Y, r_A, r_A, r_E, r_E	
	3 Points	$X_A, Y_A, X_M, Y_M, X_E, Y_E$	

Stochastic model

example: straight line

given: Point-Point

$$\mathbf{x}_K = \begin{pmatrix} x_A \\ y_A \\ x_E \\ y_E \end{pmatrix} \quad \text{mit} \quad \mathbf{C}_{KK} = \begin{pmatrix} \sigma^2_{xA} & & & 0 \\ & \sigma^2_{yA} & & \\ & & \sigma^2_{xE} & \\ 0 & & & \sigma^2_{yE} \end{pmatrix}$$

Searched for: Point-Direction

$$\mathbf{x}_R = \begin{pmatrix} x_A \\ y_A \\ r_x \\ r_y \end{pmatrix} \quad \text{mit} \quad \mathbf{C}_{RR} = \begin{pmatrix} \sigma^2_{xA} & \Lambda & \Lambda & \text{cov}(x_A, r_y) \\ & \sigma^2_{yA} & & \text{M} \\ & & \sigma^2_{rx} & \text{M} \\ & & & \sigma^2_{ry} \end{pmatrix}$$

Applying error propagation to solve for the transition

$$\mathbf{x}_R = \text{f}(\mathbf{x}_K) \quad \Rightarrow \quad \text{d}\,\mathbf{x}_R = \mathbf{F} \cdot \text{d}\,\mathbf{x}_K \quad \Rightarrow \quad \mathbf{C}_{RR} = \mathbf{F} \cdot \mathbf{C}_{KK} \cdot \mathbf{F}^{\text{T}}$$

Role of the datum

Datum dependent matching

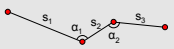
Corner Point-Directions

$\underbrace{X, Y, r_A, r_A, r_E, r_E}$

Datum dependent parameters

Datum invariant matching

traverse



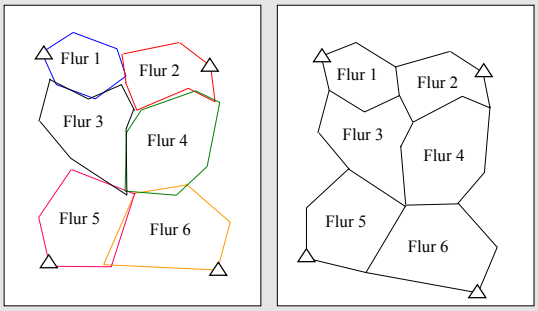
$\underbrace{s_1, s_2, s_3, \alpha_1, \alpha_2}$

Datum invariant parameters

resp.

$(s_2/s_1), (s_3/s_1), \alpha_1, \alpha_2$

Principle of interconnected transformation



How to find matching candidates?

example: two data sets with 100.000 corners each

1. possibility: to compare every corner with every corner

n*m Operations of comparison

2 * 10.000 corners ➡ 100.000.000 comparisons ➡

2 * 100.000 corners ➡ 10.000.000.000 comparisons ➡

How to find matching candidates?

2. possibility: Multi dimensional search trees

Every corner has 6 geometrical parameters (x, y, rx_A, ry_A, rx_E, ry_E)…
…and therefore can be seen as point in a 6D space.

Setting up a 64-Tree (2^6 = 64 „Quadrants“)

Search in 6D-window n*$\log_d$m Operations of comparison

2 * 100.000 corners ➡ ≈ 500.000 comparisons ➡

result: 0…n matching-candidates

Test referring to identity

given.: two random vectors

$$\mathbf{x}_1 = \begin{pmatrix} x_1 \\ y_1 \\ r_{xA1} \\ r_{yA1} \\ r_{xE1} \\ r_{yE1} \end{pmatrix} \quad \text{und} \quad \mathbf{x}_2 = \begin{pmatrix} x_2 \\ y_2 \\ r_{xA2} \\ r_{yA2} \\ r_{xE2} \\ r_{yE2} \end{pmatrix}$$

and the corresponding covariance matrices
(singular with rang defect of 2)

$$\mathbf{C}_{xx1} = \begin{pmatrix} \sigma^2_{x1} & \Lambda & \Lambda & \text{cov}(x, ryE) \\ & \text{O} & & \text{M} \\ & & \text{O} & \text{M} \\ & & & \sigma^2_{ryE1} \end{pmatrix} \quad \text{and} \quad \mathbf{C}_{xx2} = \begin{pmatrix} \sigma^2_{x2} & \Lambda & \Lambda & \text{cov}(x, ryE) \\ & \text{O} & & \text{M} \\ & & \text{O} & \text{M} \\ & & & \sigma^2_{ryE2} \end{pmatrix}$$

Test referring to identity

Hypothesis: $\mathbf{x}_1 = \mathbf{x}_2 \rightarrow \mathbf{x}_1 - \mathbf{x}_2 = \mathbf{d} = \mathbf{0}$

FFG to **d**: $\mathbf{C}_{dd} = \mathbf{C}_{xx1} + \mathbf{C}_{xx2}$

check: $\mathbf{d}^T\mathbf{C}_{dd}\mathbf{d} \sim \chi^2_{(f=4)}$

Boundary value: $\chi^2_s = \chi^2_s(f,\alpha)$ for $f = 4$ and $\alpha = 5\%$ $\rightarrow \chi^2_s \approx 9{,}5$

Test decision:

$\chi^2 < \chi^2_s \rightarrow$ corners are identical

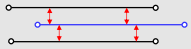
$\chi^2 > \chi^2_s \rightarrow$ corners are not identical

Lay out

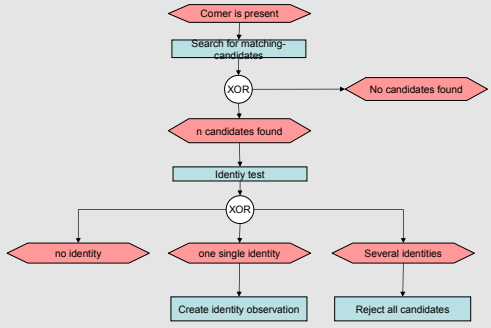
Treatment of multiple choice possibilities

Corner-operator

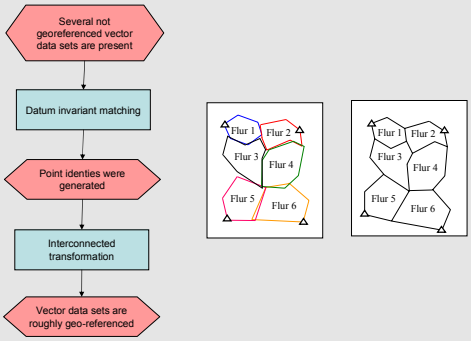
Straight line-operator



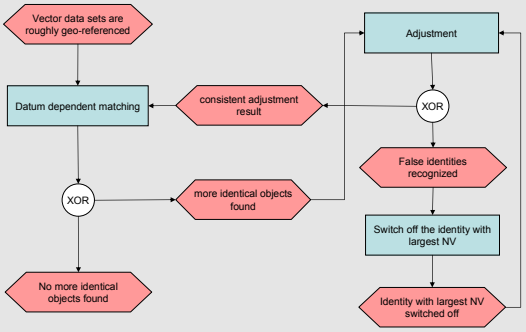
Treatment of multiple choice possibilities



Process chain Matching-Adjustment



Process chain Matching-Adjustment



Lay out

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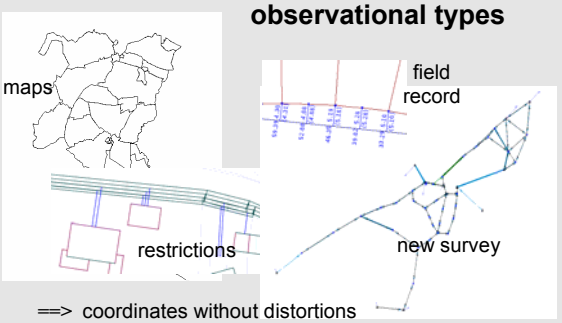
Procedures diagram?
Matching? Searching?
Experience based on real projects

SYSTRA software package

observational types

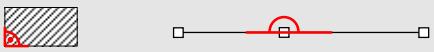


==> coordinates without distortions
==> unique result of analysis

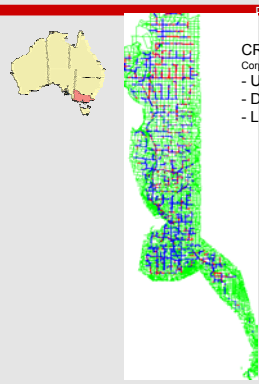
SYSMATCH routine

Matching:
- corners → point identities
- straight lines → local systems
- points → point identies

Searching:
- right angles → observed right angles
- straight lines → observed straight lines



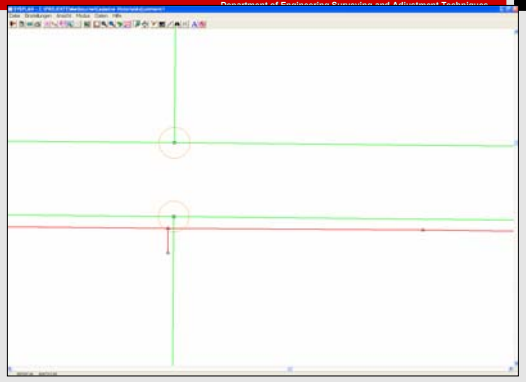
Wimmera Mallee Project



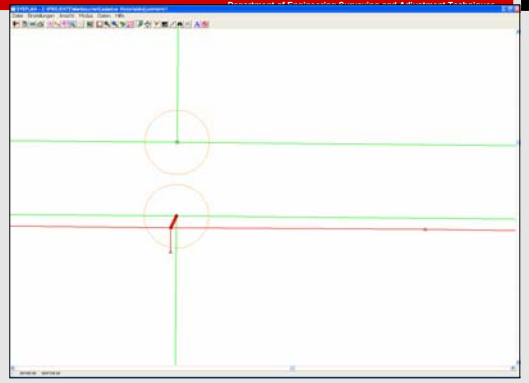
CRC-SI
Corporative Research Centre – Spatial Information
- University of Melbourne
- Department of Sustainability and Environment
- Logica CMG

extension:	
North-South	170 km
East-West	138 km
Cadastral points:	89.175
GPS points:	14.064
links:	116.873
given point identities:	25
Corners in cadastre:	155.200
Corners in GPS data:	10.276

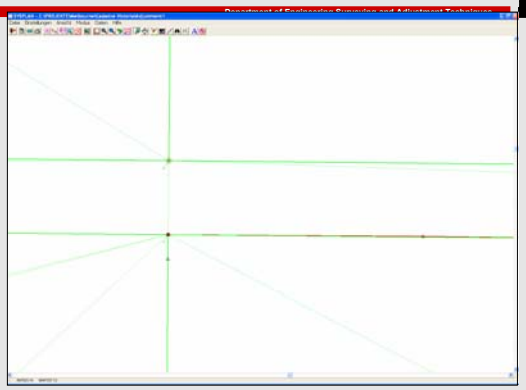
Starting situation



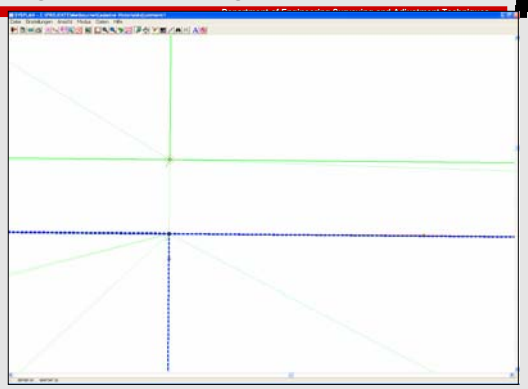
Corner- matching



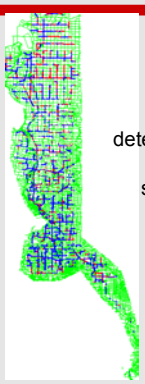
Geometrical „Harmonization“



Straight line - matching



Matching-result



detected point identities: 522

straight line identities: 8.708

Summary

Geometrical harmonization does not work without adjustment

Prerequisite for the adjustment are information with respect to identical objects

Matching-algorithms are efficient tools to find identity-information

Matching and adjustment can not be separated