

# An Integrated Semantically Correct 2.5D Object Oriented TIN

Andreas Koch



# Contents

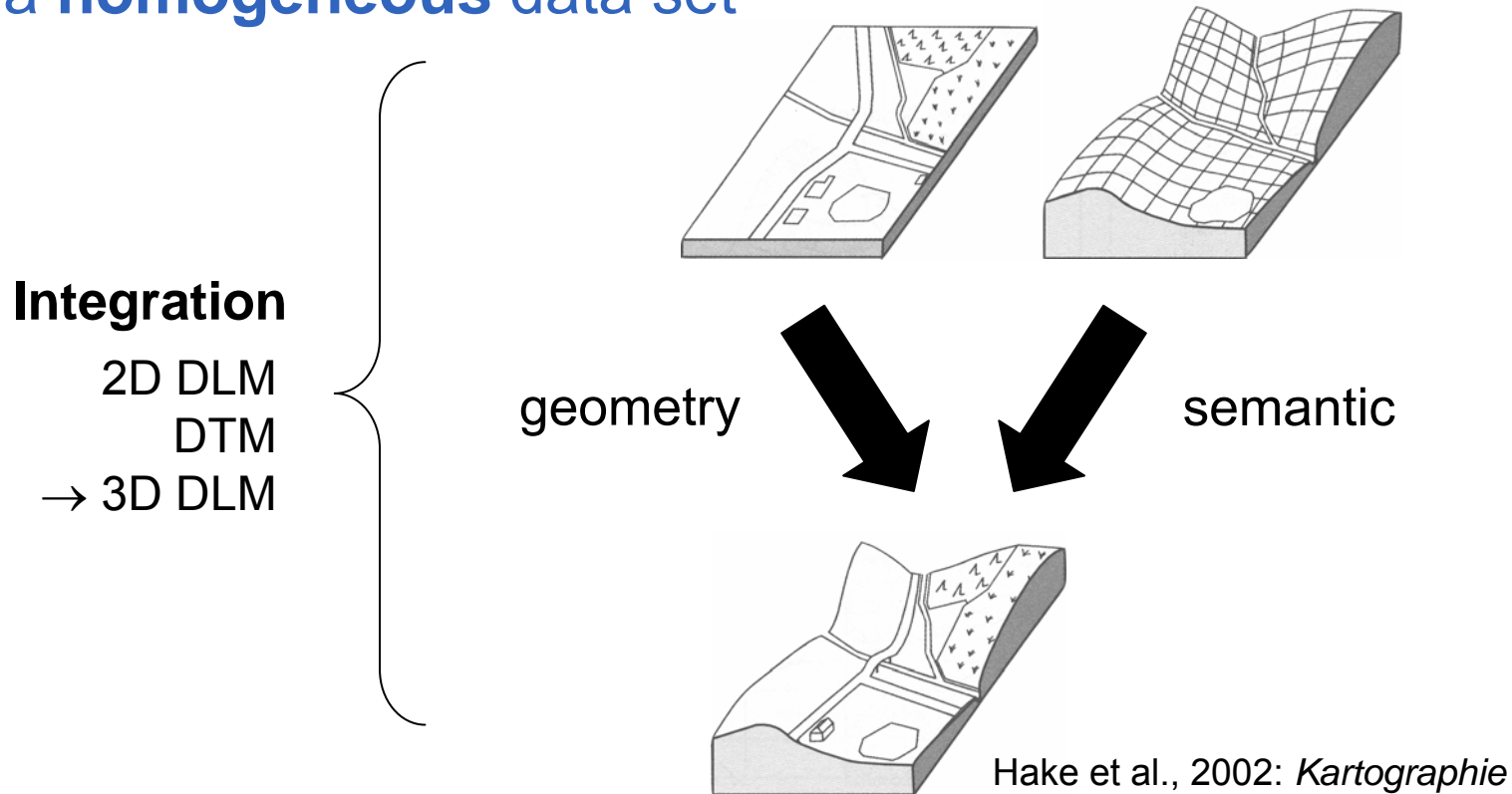
- Introduction
- Integration of a DTM and 2D GIS data
- Semantics in the context of terrain modelling
- The approach
- Examples
- Conclusions



# Introduction

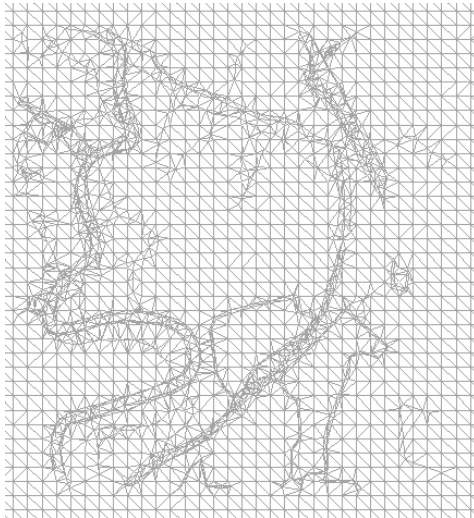
## Data Integration

- Aggregation of data from **different data sources** to obtain a **homogeneous data set**



# Integration of DTM and 2D GIS data

Example data  
ATKIS Basis-DLM  
ATKIS DGM 5



- River
- Lake
- Road
- Path

## Digital Terrain Model

2.5D

Points with coordinates XYZ

Structure elements (break lines, single heights, ...)

## GIS vector data

2D

Points, lines, areas

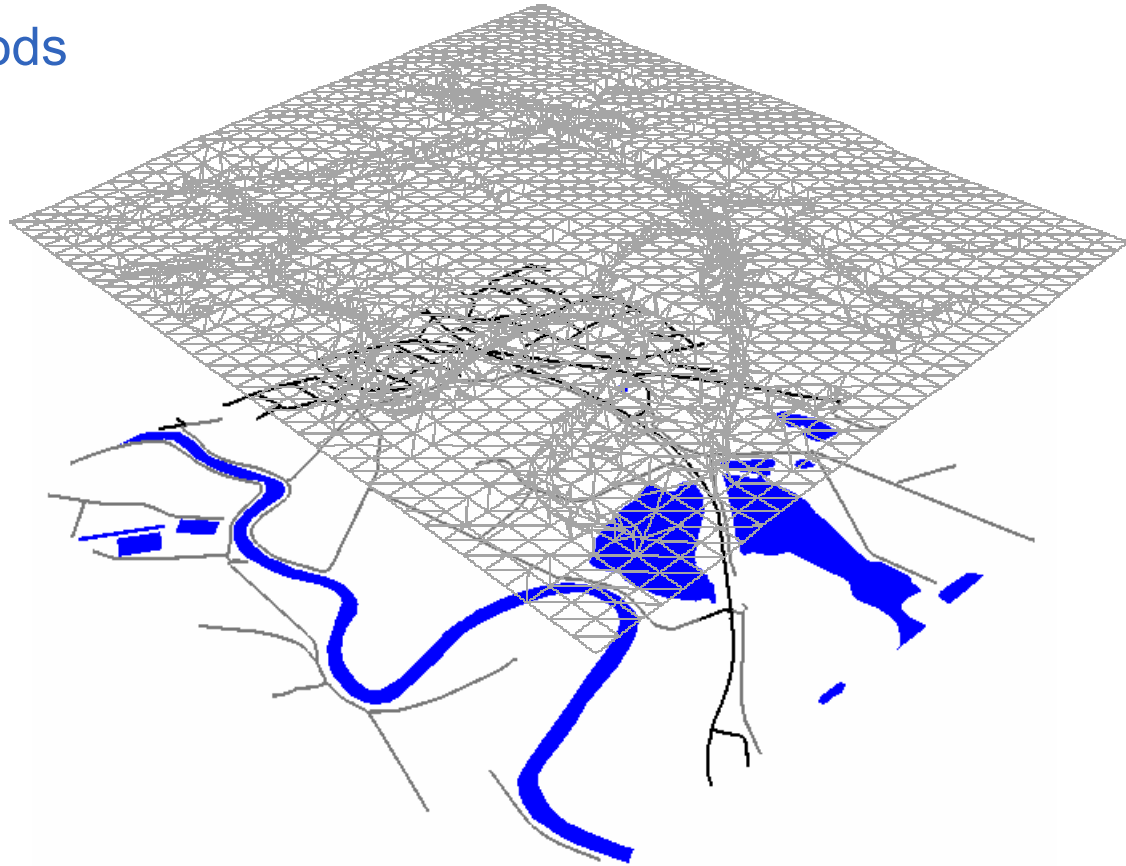
Attributes on function and dimension of the objects



# Integration of DTM and 2D GIS data

## Problem

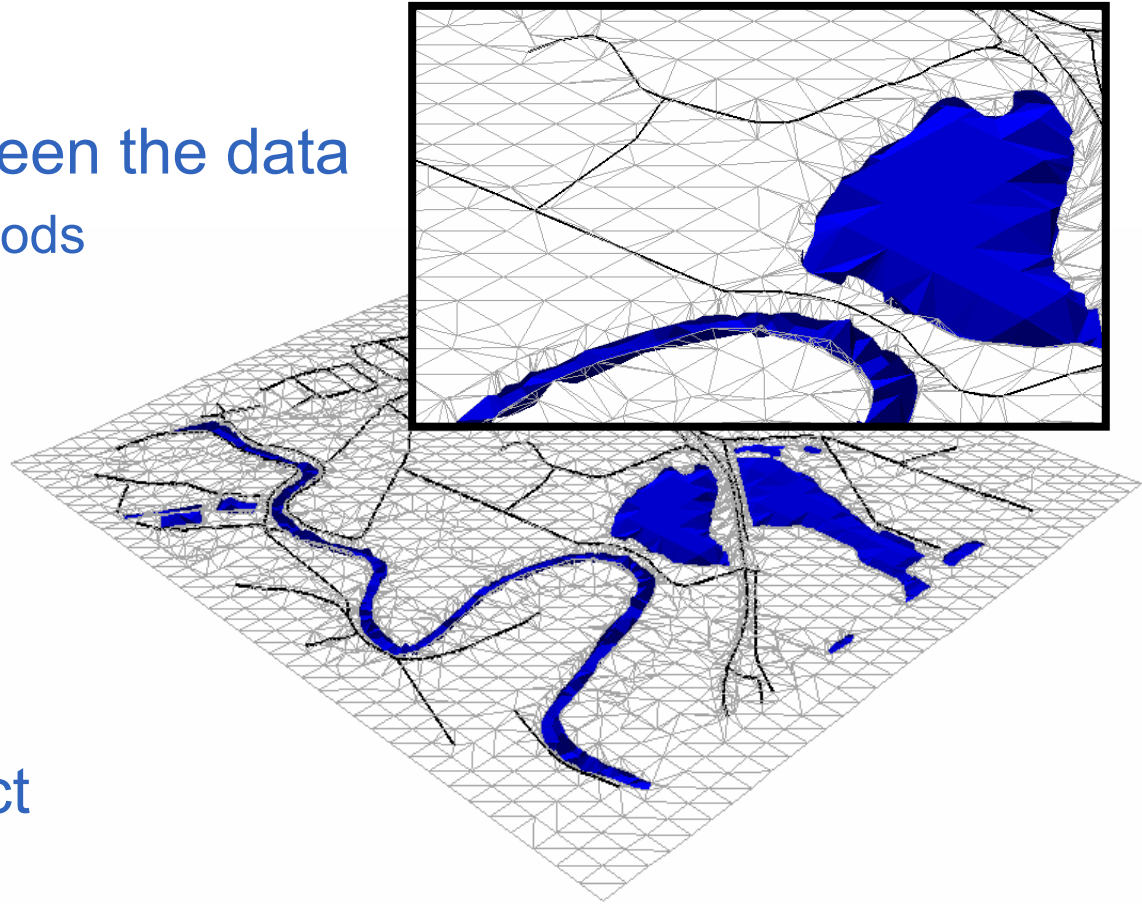
- Inconsistencies between the data
  - Data acquisition methods
  - Data modelling
  - Time shift between acquiring the data



# Integration of DTM and 2D GIS data

## Problem

- Inconsistencies between the data
  - Data acquisition methods
  - Data modelling
  - Time shift between acquiring the data



## Result

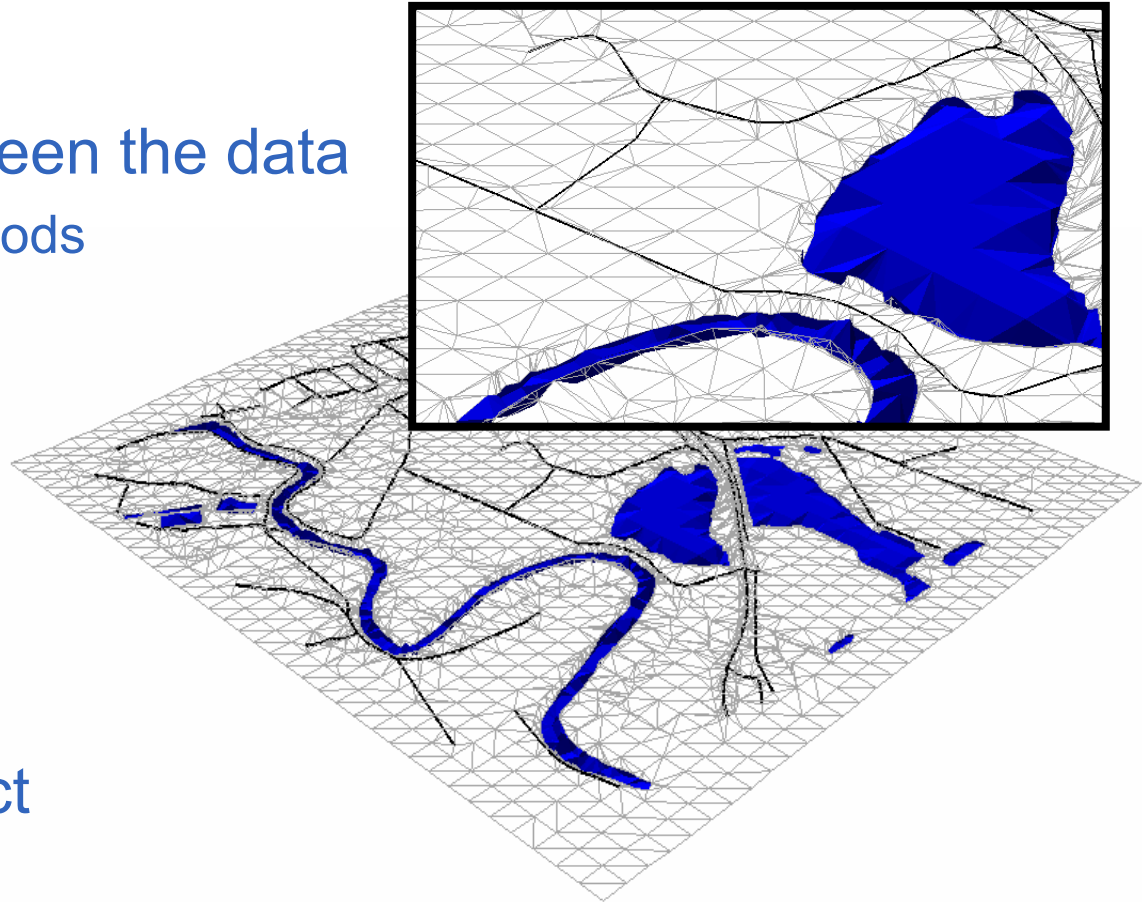
- Integrated TIN
- Semantically incorrect



# Integration of DTM and 2D GIS data

## Problem

- Inconsistencies between the data
  - Data acquisition methods
  - Data modelling
  - Time shift between acquiring the data



## Result

- Integrated TIN
- Semantically incorrect

## The aim

- Re-establishment of the semantic correctness



# Semantics in the context of terrain modelling

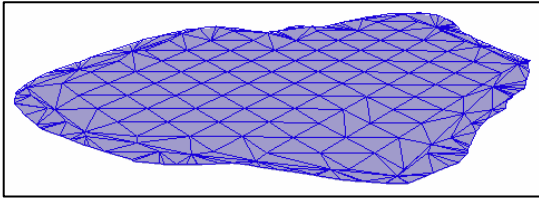


## Object characteristics

- Horizontal plane
  - Increasing terrain
- Sloped and curved areas
  - Maximum slopes and curvatures
  - Decreasing niveau and increasing terrain



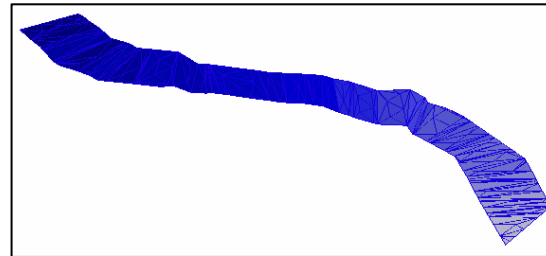
# Semantics in the context of terrain modelling



**Lake**

Local TIN with horizontal triangles

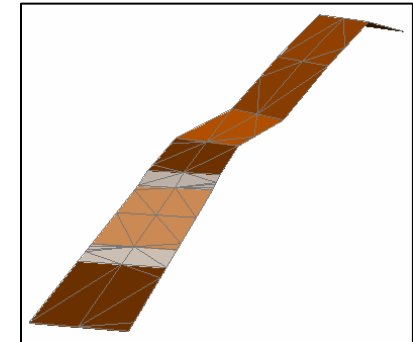
Terrain higher than lake height



**River**

Object with tilted planes; local TIN inside

Terrain higher than local river height



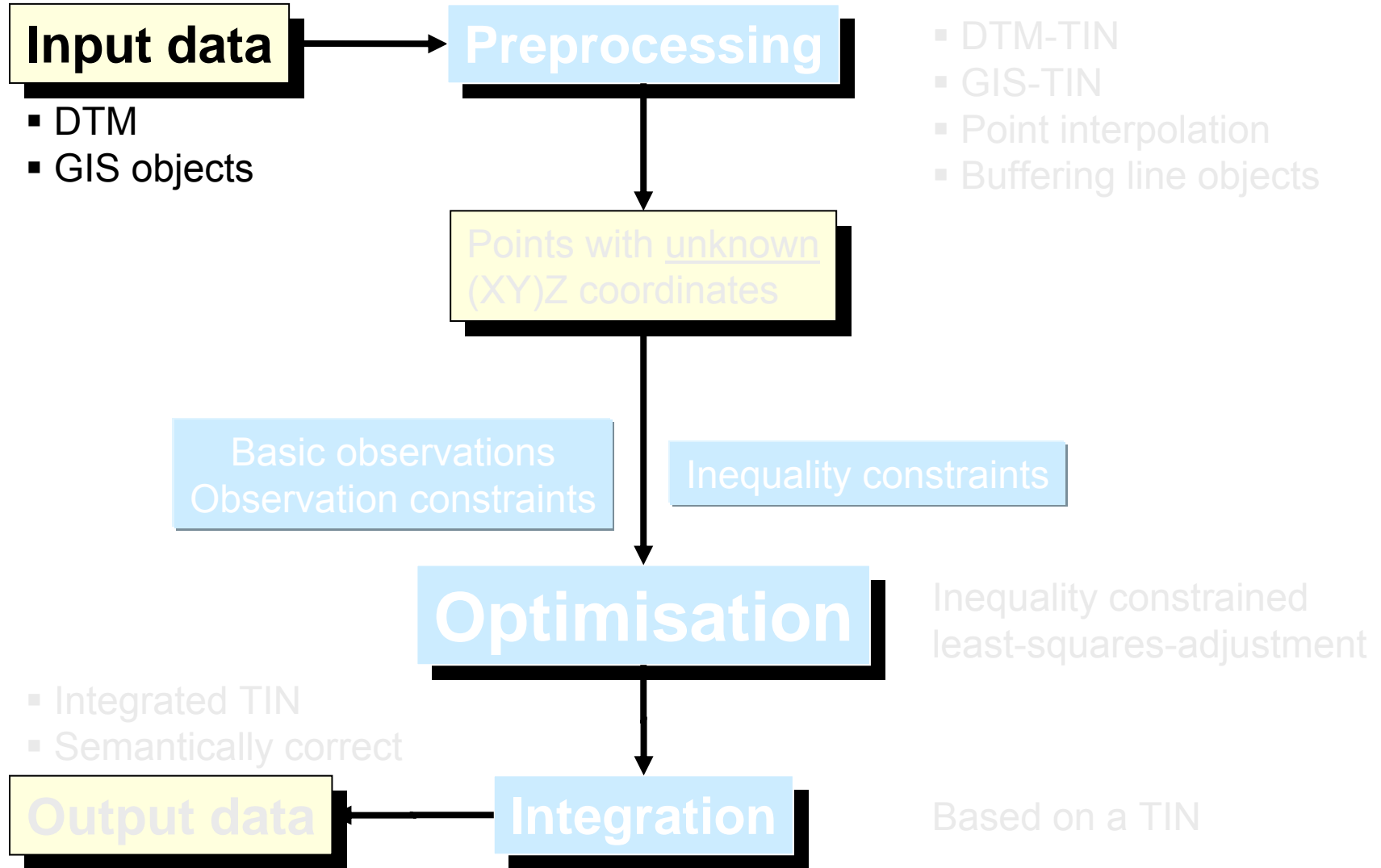
**Road / Path**

Object with tilted planes; local TIN inside

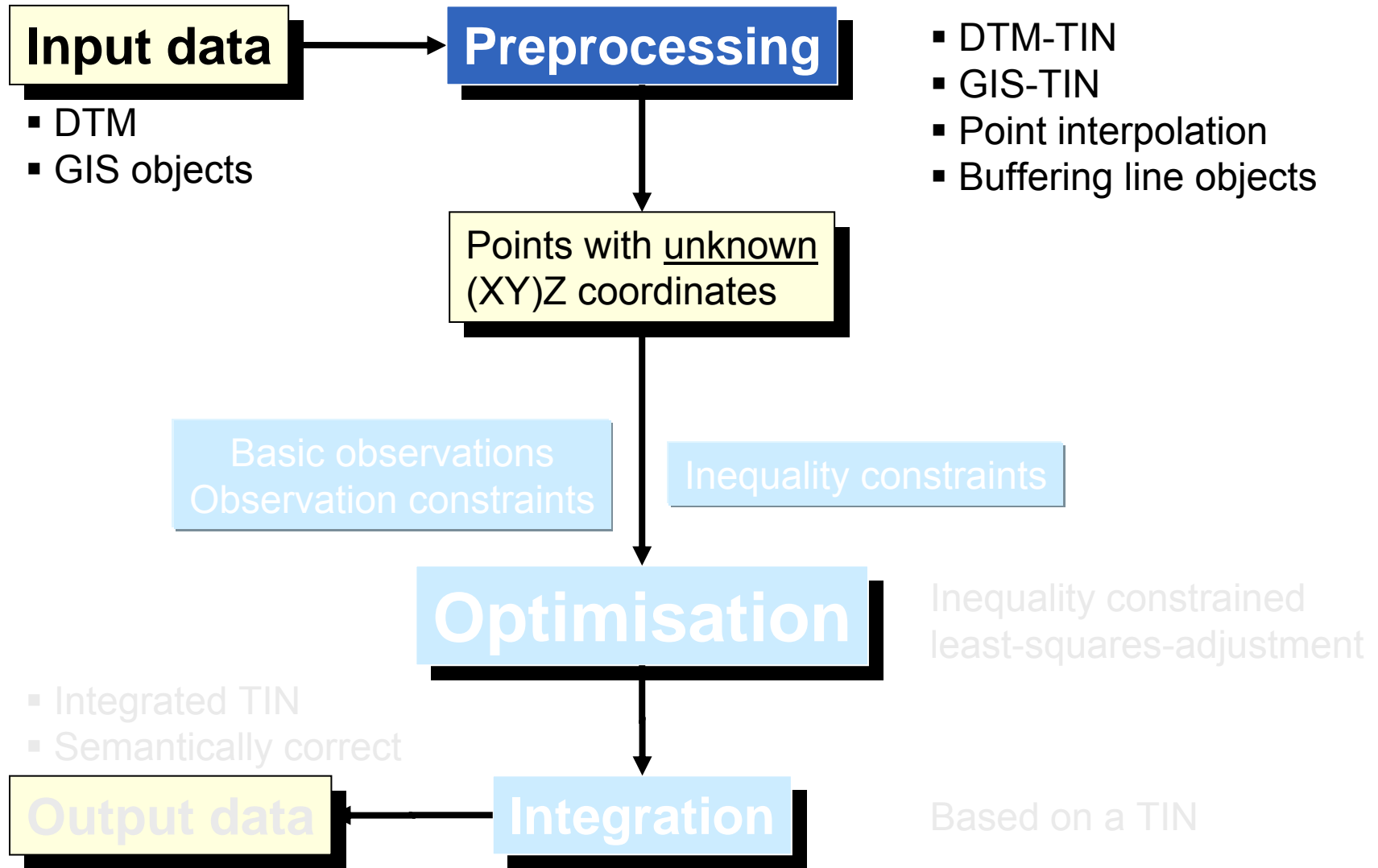
Limited slope and curvature



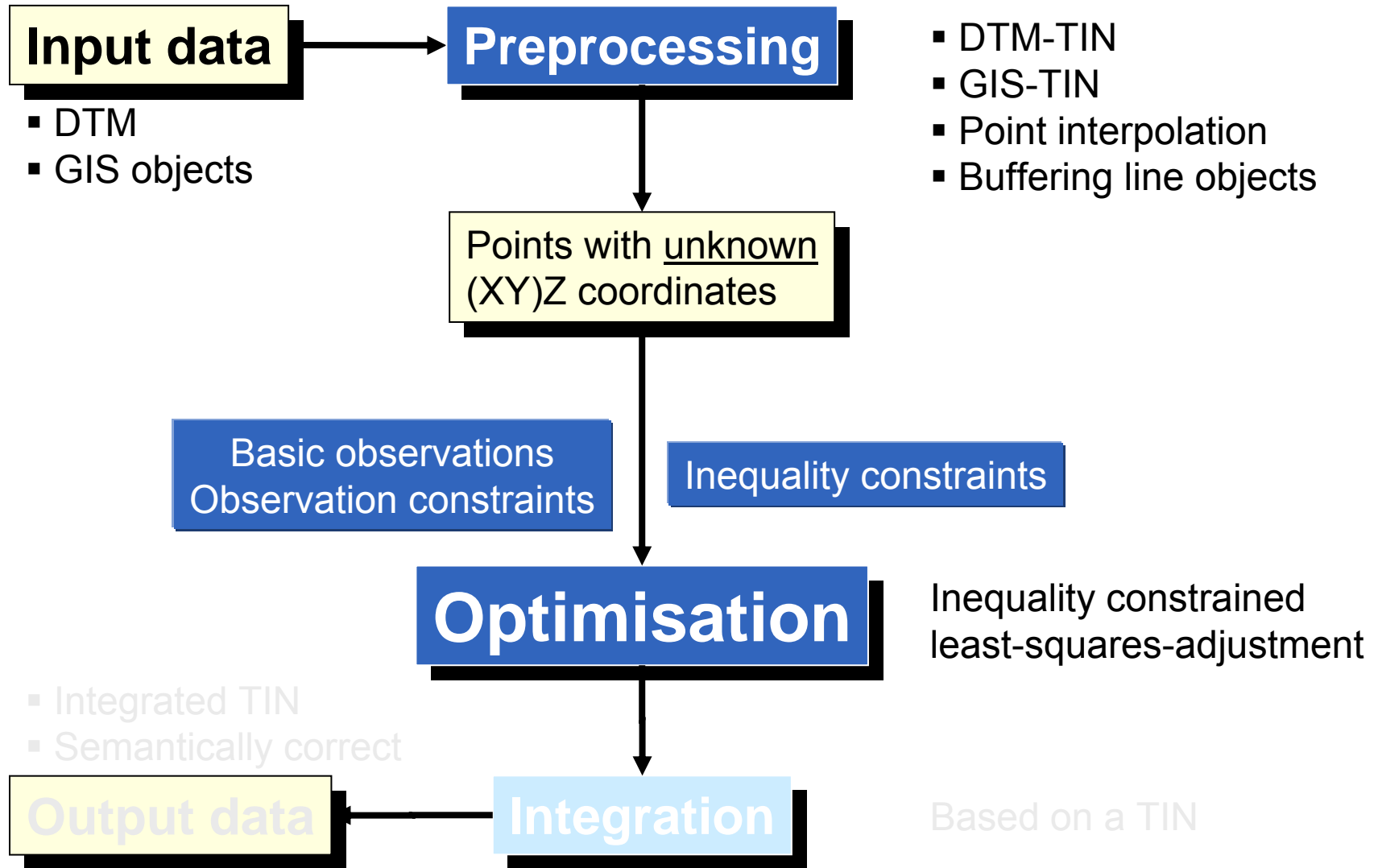
# The approach



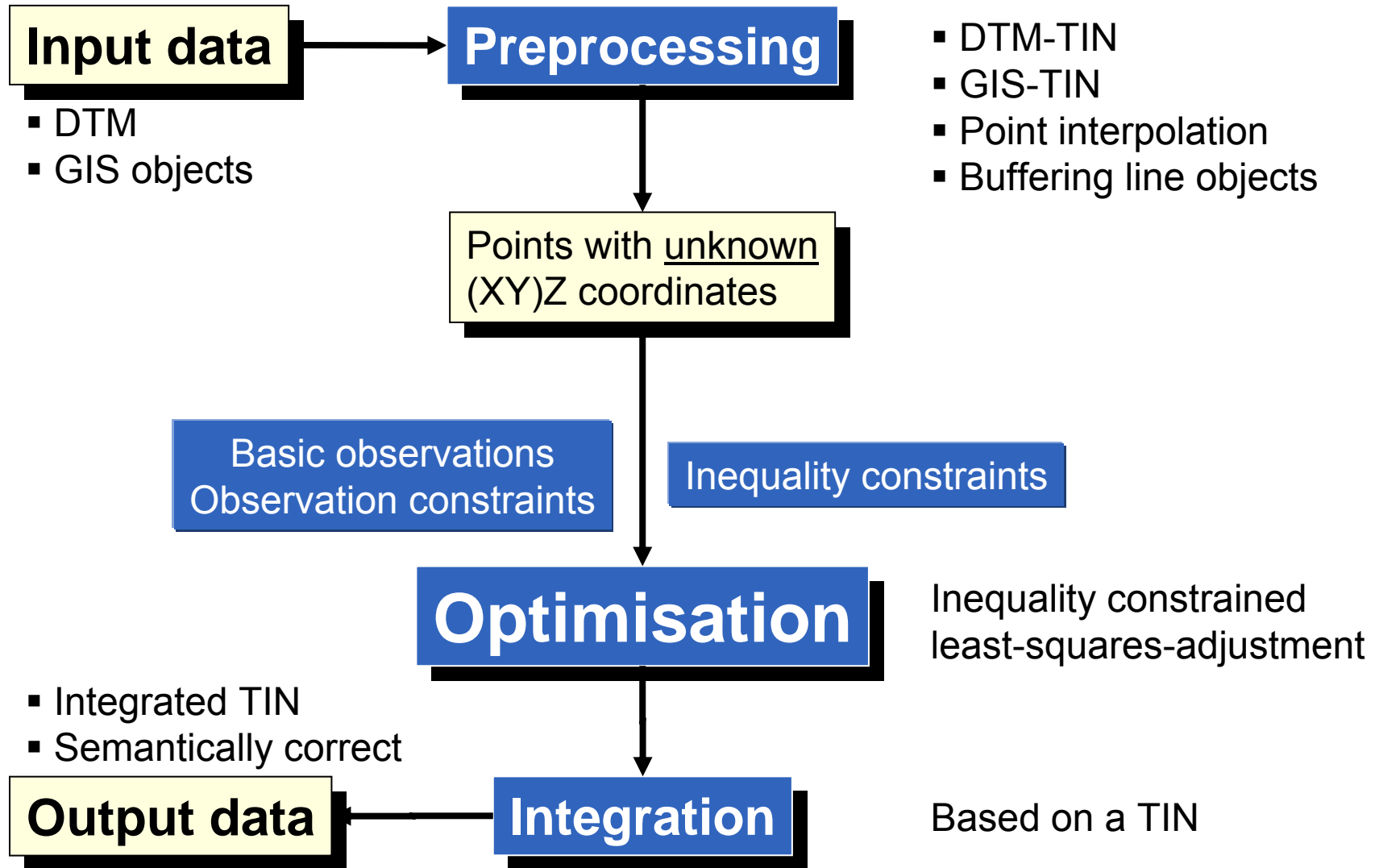
# The approach



# The approach



# The approach



# Optimisation

- Inequality constrained least-squares-adjustment

- Functional model

$$\begin{pmatrix} I \\ I_c \end{pmatrix} = \begin{pmatrix} A \\ A_c \end{pmatrix} \hat{\mathbf{x}}^* - \begin{pmatrix} \mathbf{v} \\ \mathbf{v}_c \end{pmatrix}$$

$$\mathbf{H} \hat{\mathbf{x}}^* \leq \mathbf{b}$$

$$\mathbf{H} \hat{\mathbf{x}}^* + \hat{\mathbf{z}} - \mathbf{b} = \mathbf{0}$$

$$\hat{\mathbf{z}}^T = \left( \hat{z}_1^2 \quad \hat{z}_2^2 \quad \dots \quad \hat{z}_r^2 \right)^T$$

$$\hat{\mathbf{z}} \geq \mathbf{0}$$

- Stochastic model

$$\Sigma = \begin{pmatrix} \Sigma_{//} & \mathbf{0} \\ \mathbf{0} & \Sigma_{I_c I_c} \end{pmatrix}$$

- Transformation into the Linear Complementary Problem (LCP)

- Solution using the Lemke-Algorithm (Pivoting method)



# Equations and inequations

## ■ Lake

### - Observations

$$v_i = \hat{Z}_{lake} - Z_i$$

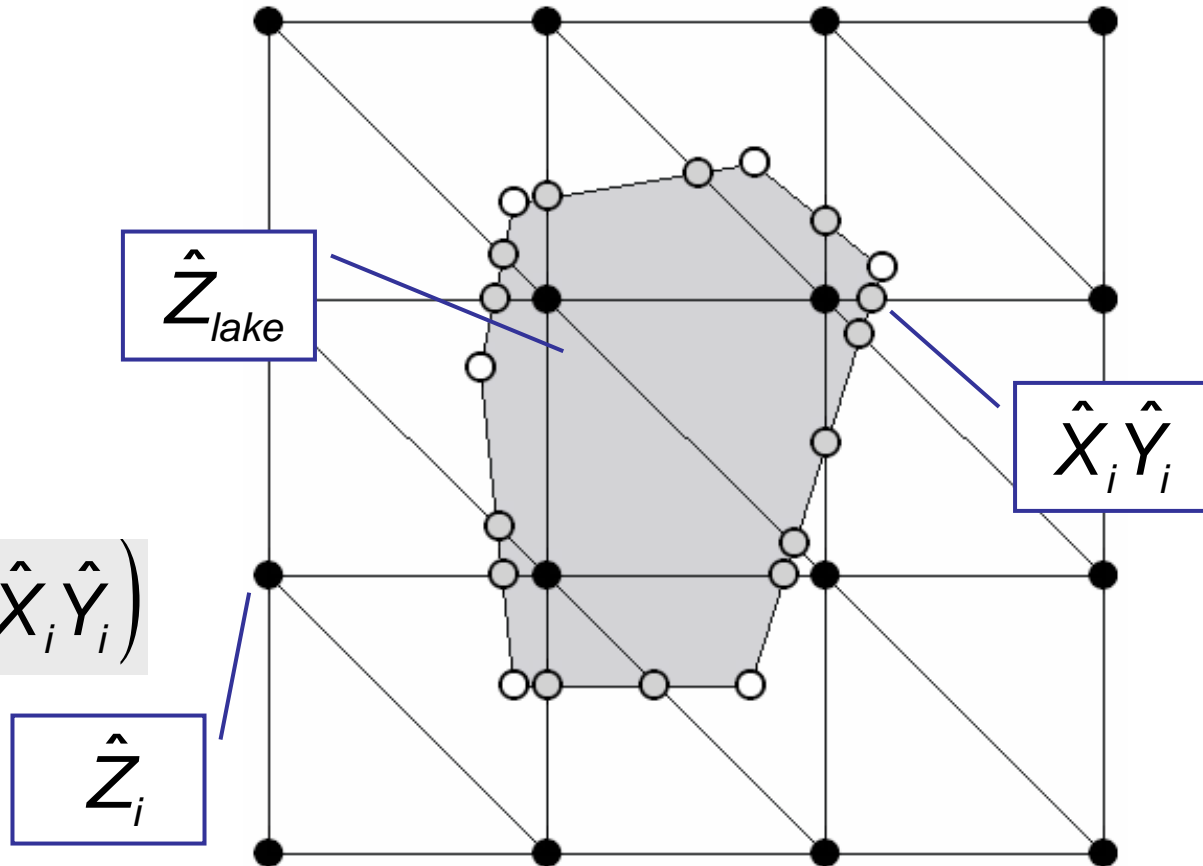
$$v_i = \hat{X}_i - X_i$$

$$v_i = \hat{Y}_i - Y_i$$

$$v_i = \hat{Z}_{lake} - Z_i(\hat{X}_i, \hat{Y}_i)$$

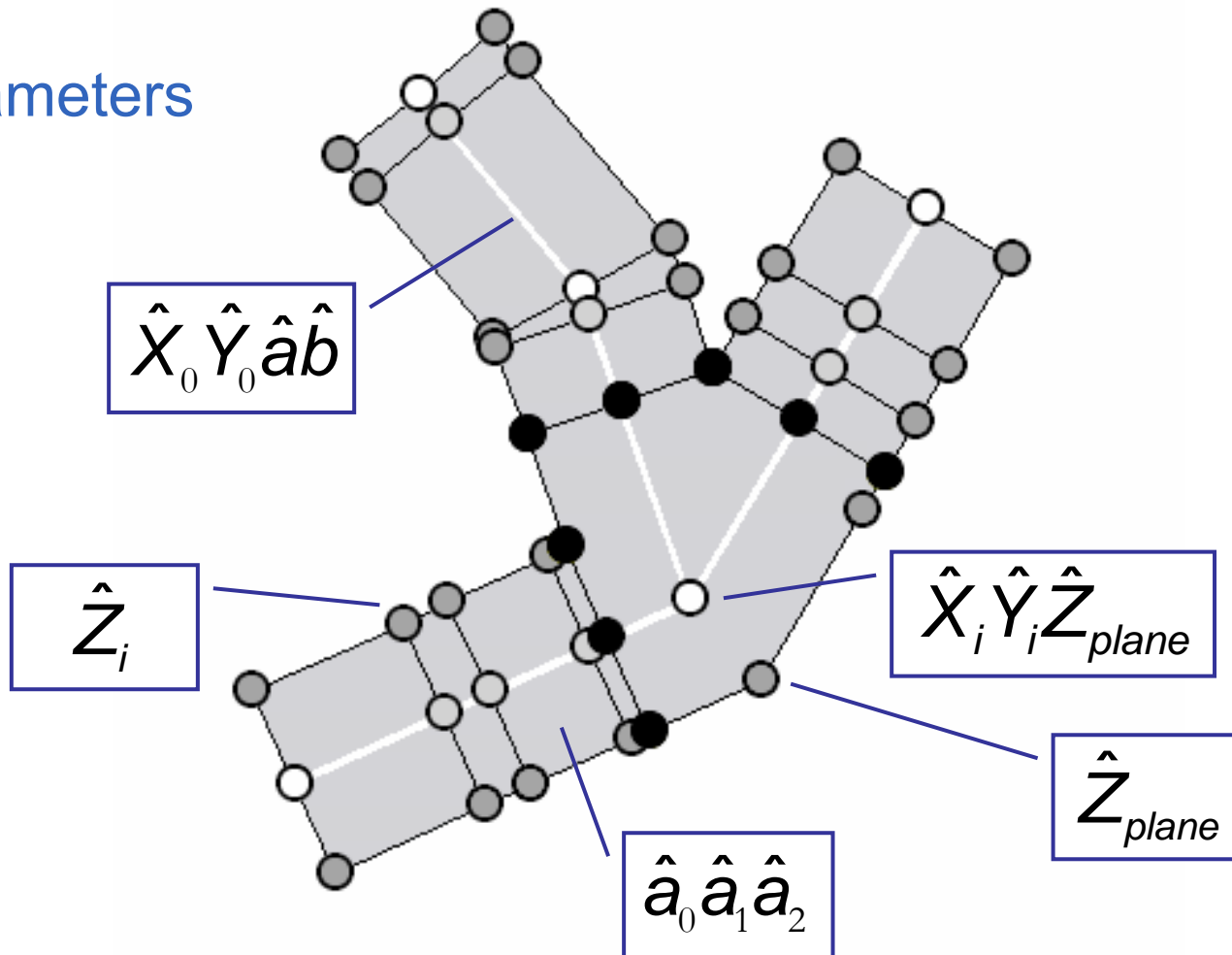
### - Inequations

$$\hat{Z}_{lake} - \hat{Z}_j < 0$$



# Equations and inequations

- Road
  - Parameters



# Equations and inequations

- Road

- Observations

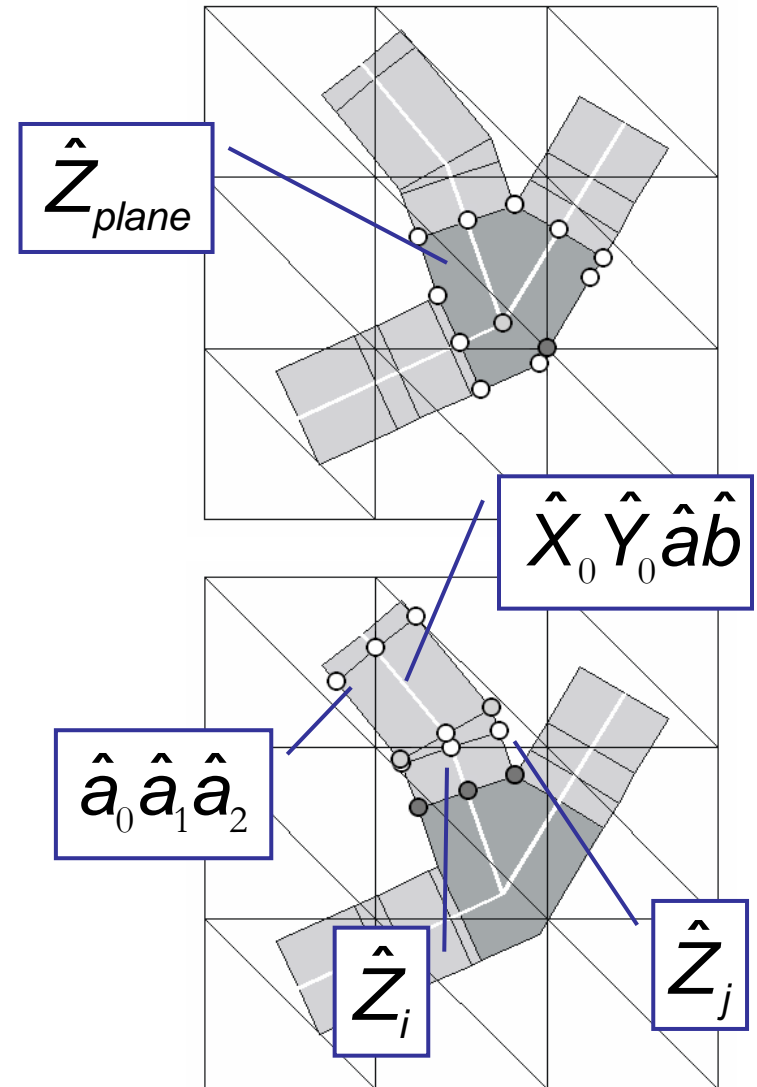
$$v_i = \hat{Z}_{plane} - Z_i$$

$$v_i = \hat{Z}_{plane} - Z_i(X_i^t Y_i^t)$$

$$X_i^t = X_i(\hat{X}_0 \hat{Y}_0 \hat{a} \hat{b}) \quad Y_i^t = Y_i(\hat{X}_0 \hat{Y}_0 \hat{a} \hat{b})$$

$$v_i = \hat{Z}_i - \hat{Z}_j$$

$$v_i = \hat{a}_0 + \hat{a}_1 X_i^t + \hat{a}_2 Y_i^t - \hat{Z}_i$$



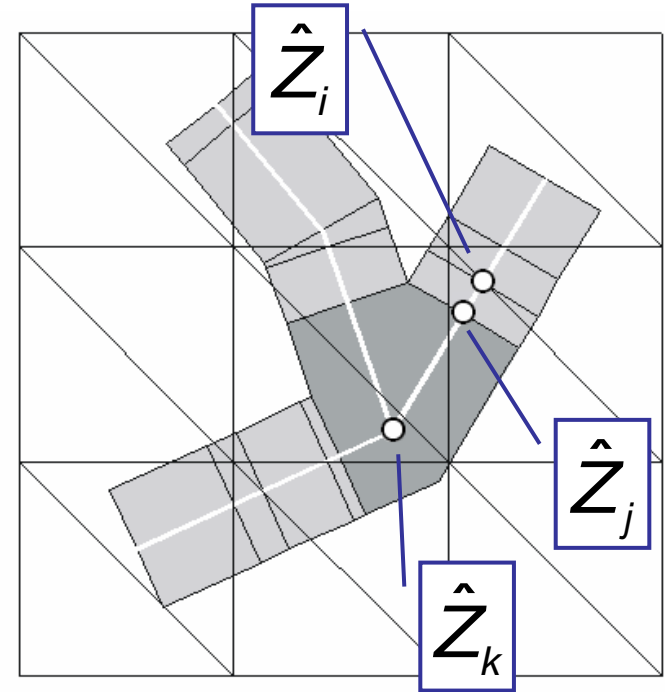
# Equations and inequations

- Road
  - Inequations

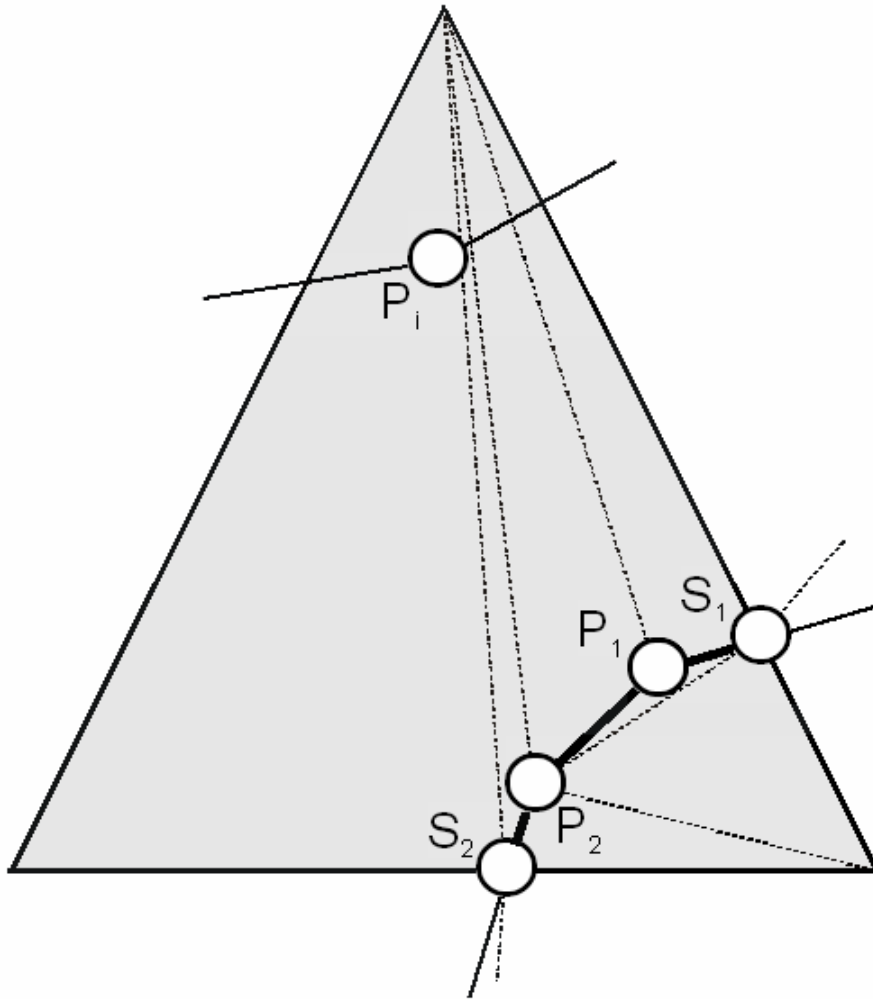
$$s_{\max} \geq \left| \frac{\hat{Z}_i - \hat{Z}_j}{S_{ij}} \right|$$

$$ds_{\max} \geq \left| \frac{\hat{Z}_i - \hat{Z}_j}{S_{ij}} - \frac{\hat{Z}_j - \hat{Z}_k}{S_{jk}} \right|$$

$$S_{ij} = S_{ij}(X_i^t Y_i^t X_j^t Y_j^t)$$



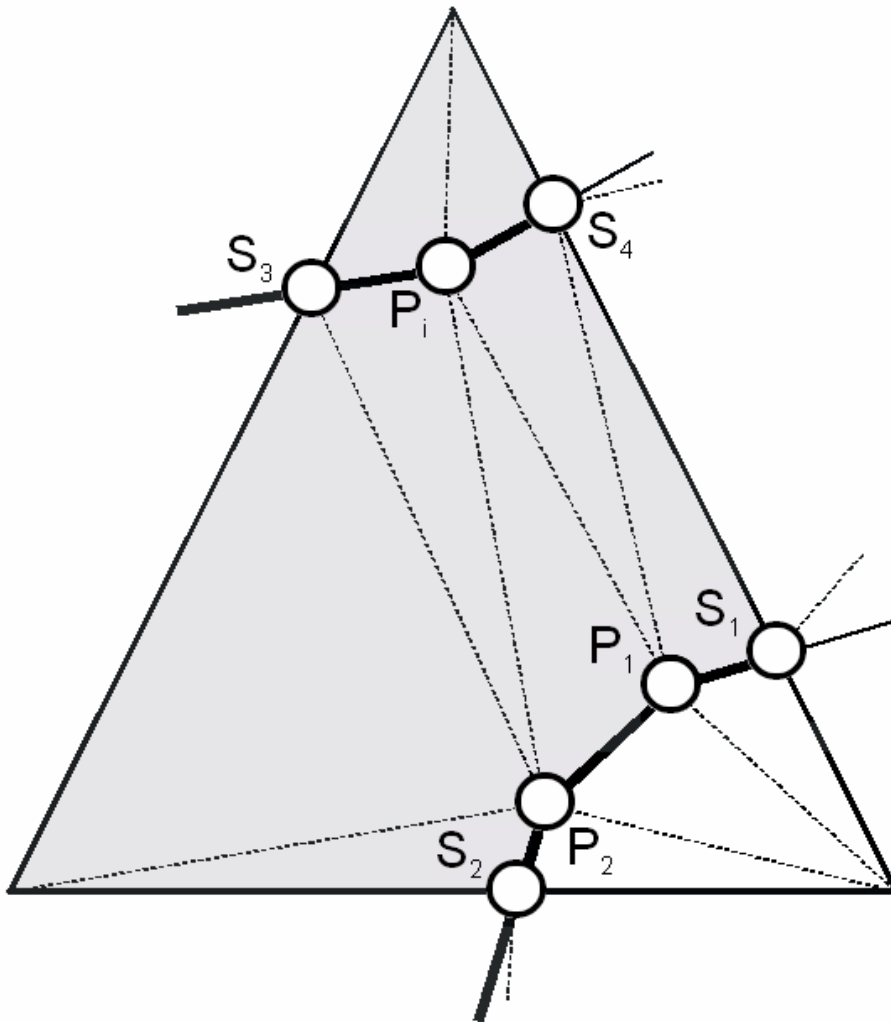
# Integration



- Startpoint  $P_1$
- Area of consideration
- Points of intersection  $S_1$  and  $S_2$
- Integration of object geometry between  $S_1$  and  $S_2$
- Height interpolation
- Polygon triangulation



# Integration

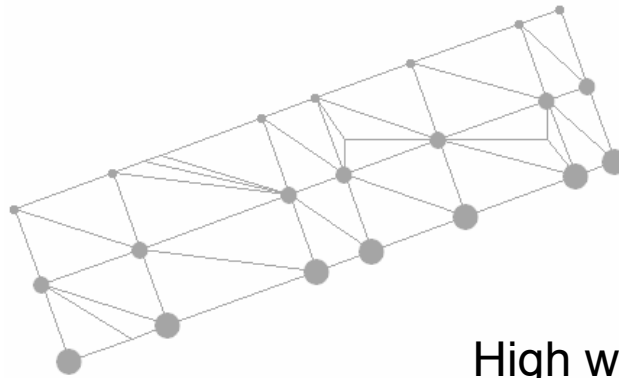


- Optimisation of the shape of the triangle
  - Edge flip
- $S_2$  is next startpoint
- Crossing the same triangle a second time
  - Different area of consideration



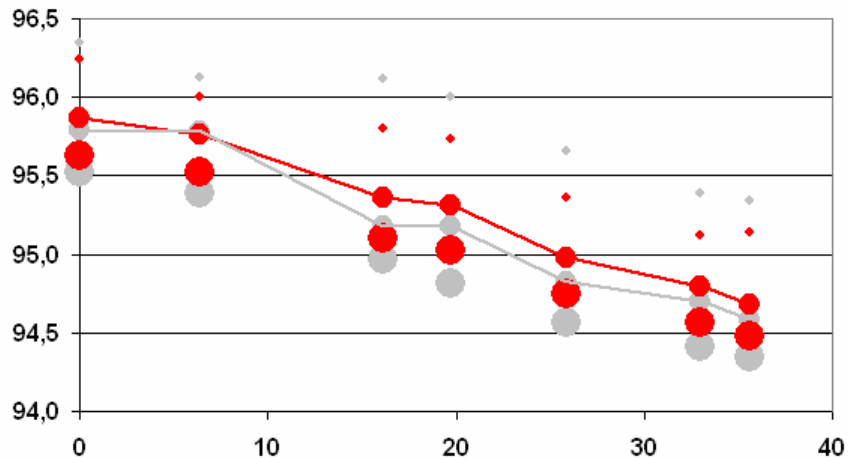
# Examples

- Synthetic data  
**Road**



Identical weights

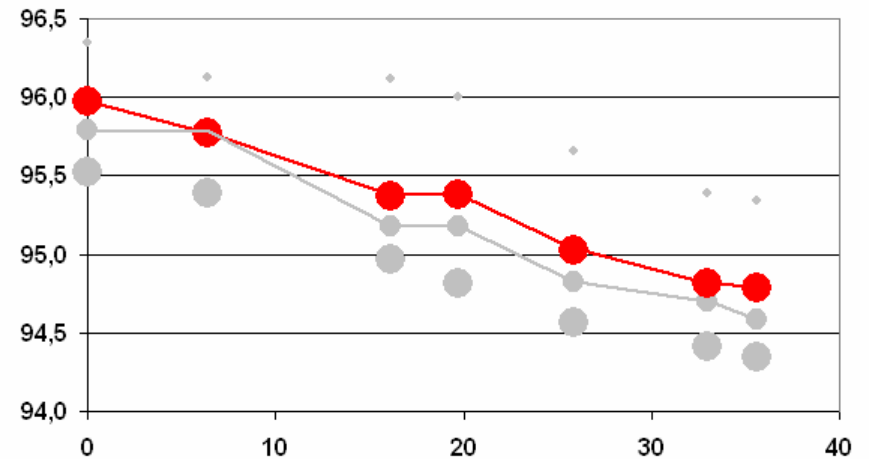
$s_{Max}$  0,1  
 $ds_{Max}$  0,2



High weights:

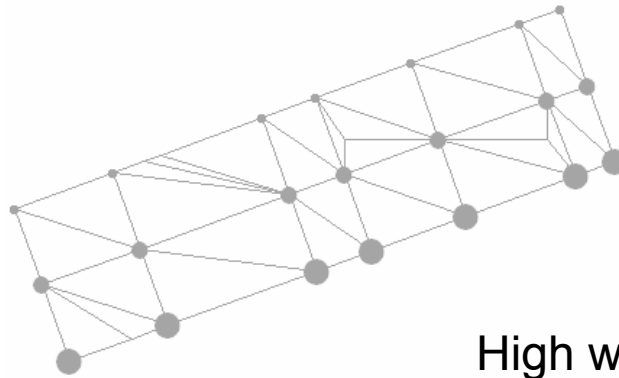
Horizontal cross profiles & planes

$s_{Max}$  0,1  
 $ds_{Max}$  0,2



# Examples

- Synthetic data  
**Road**



Identical weights

$s_{Max}$  0,03

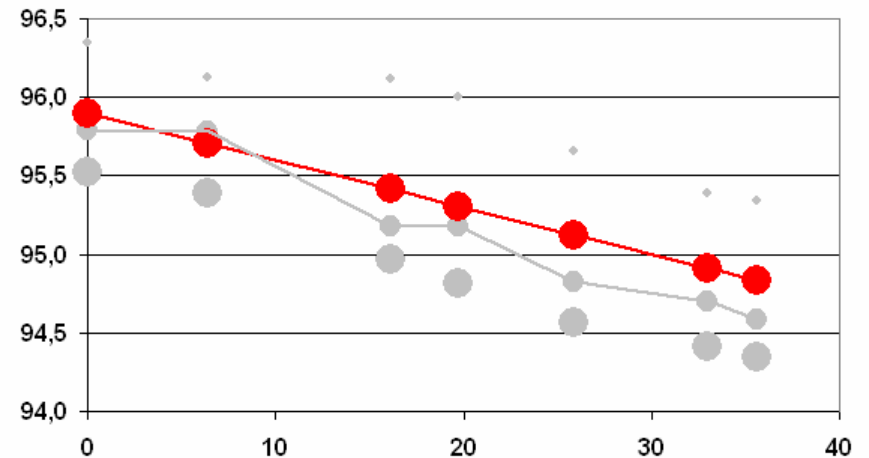
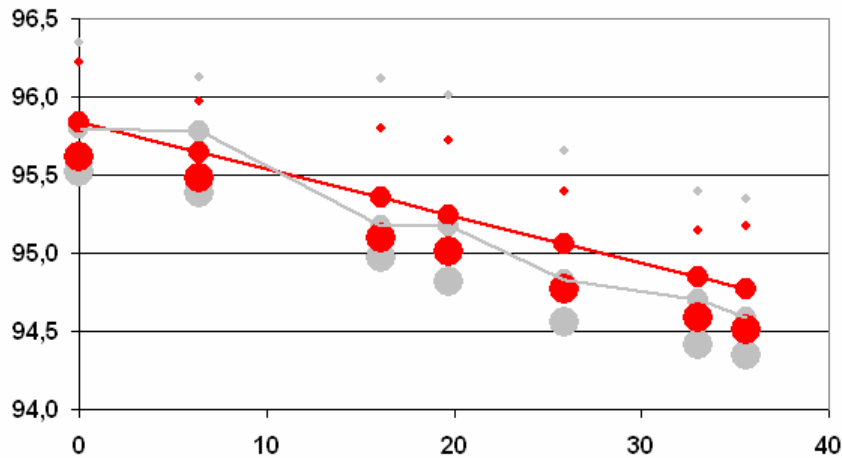
$ds_{Max}$  0,06

High weights:

Horizontal cross profiles & planes

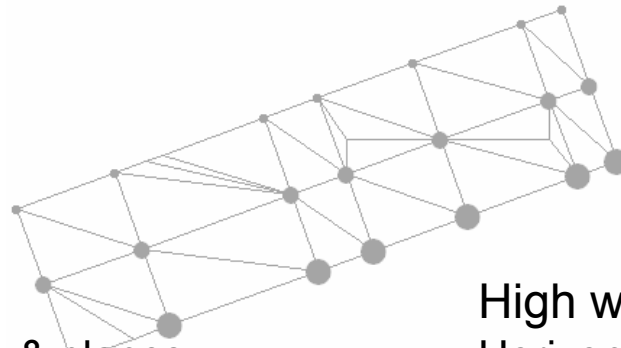
$s_{Max}$  0,03

$ds_{Max}$  0,06



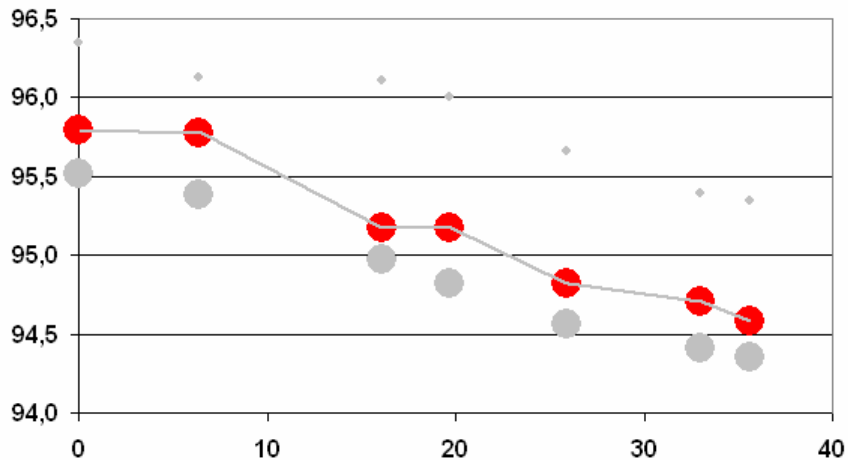
# Examples

## ■ Synthetic data Road



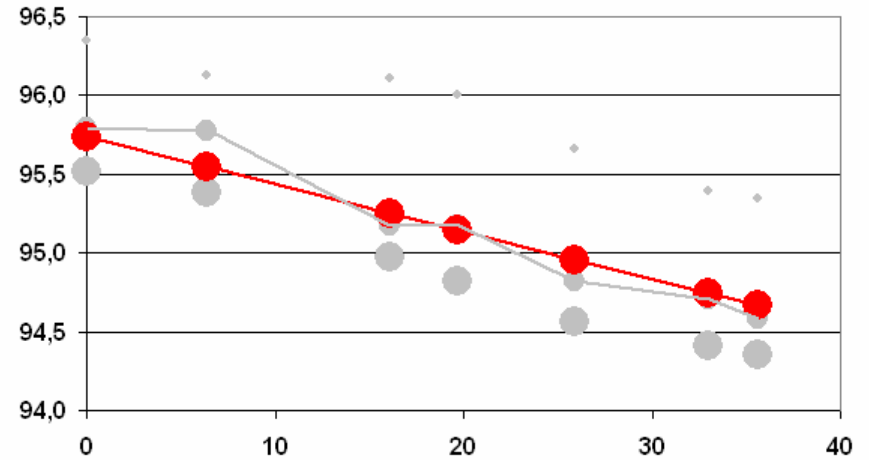
High weights:  
Horizontal cross profiles & planes  
Points of center axis

$s_{Max}$  0,1  
 $ds_{Max}$  0,2



High weights:  
Horizontal cross profiles & planes  
Points of center axis

$s_{Max}$  0,03  
 $ds_{Max}$  0,06



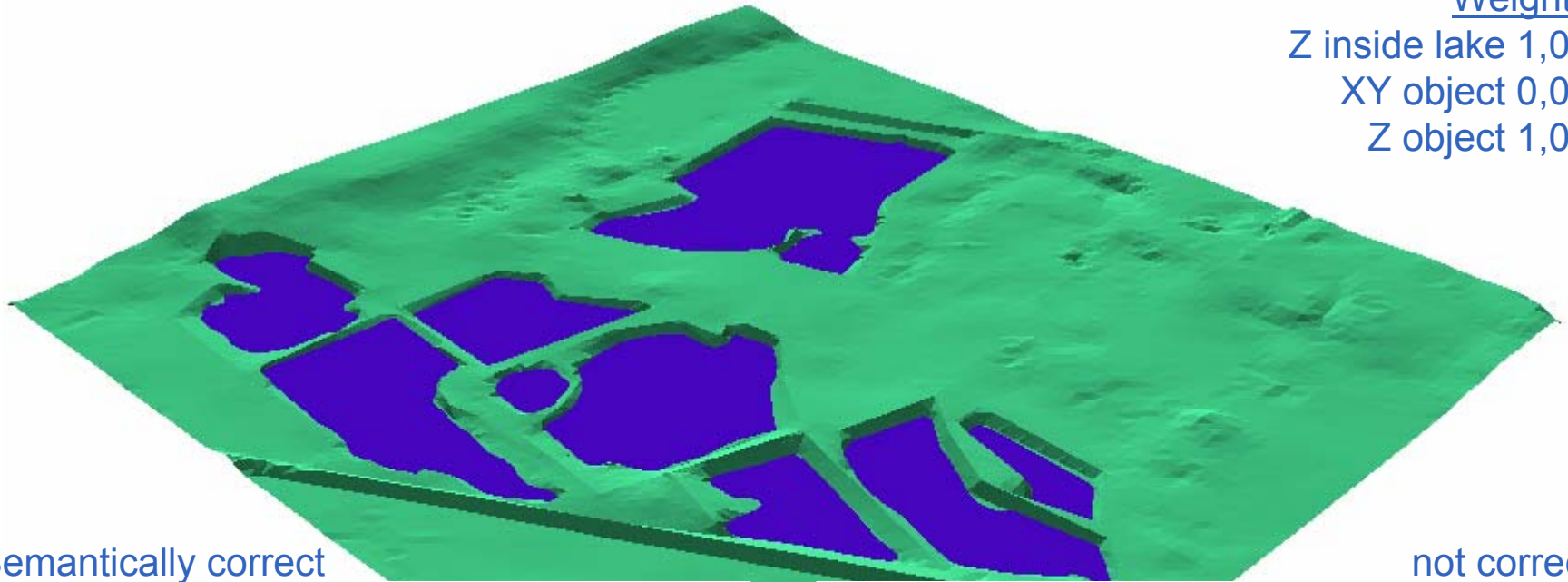
# Examples

## Weights

Z inside lake 1,00

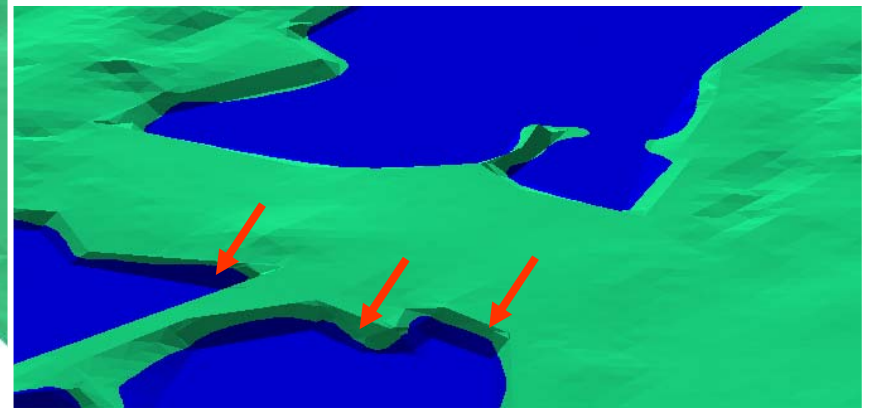
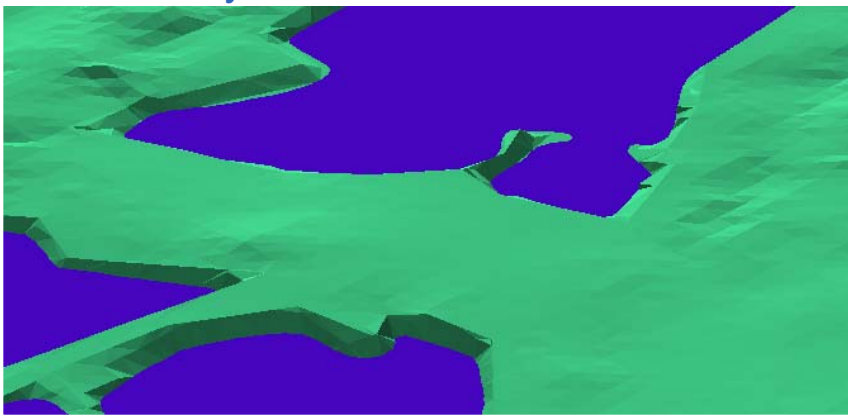
XY object 0,04

Z object 1,00

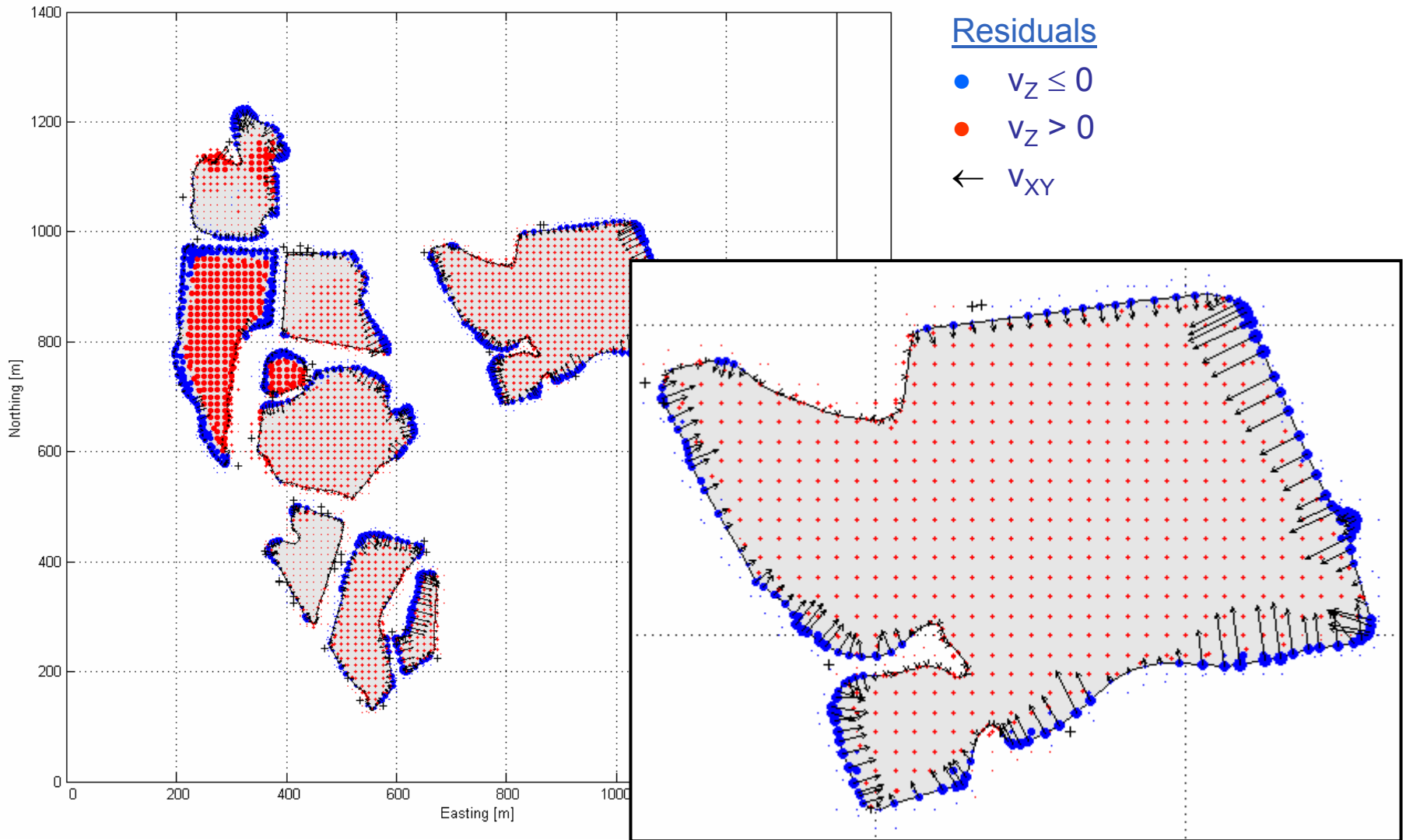


Semantically correct

not correct

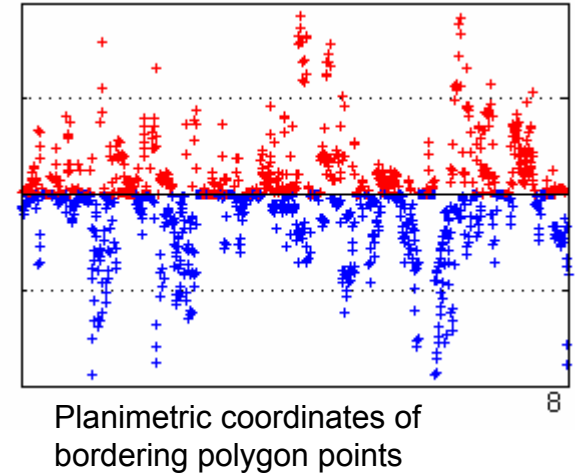
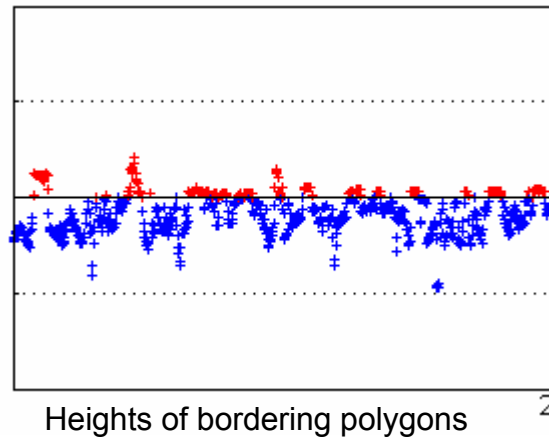
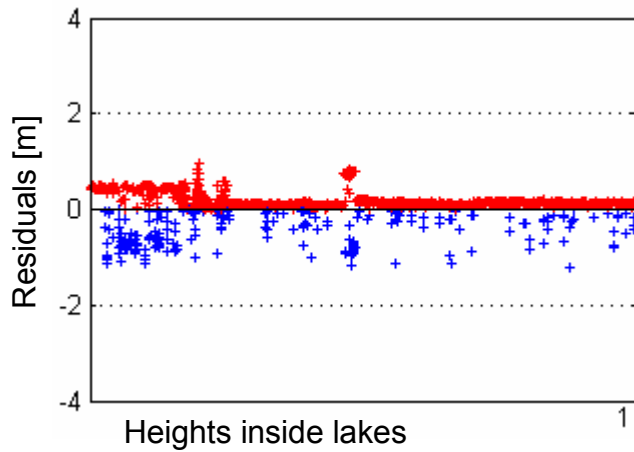


# Examples



# Examples

## Residuals



# Conclusions

- An approach was presented which produces an integrated semantically correct TIN
  - Optimisation and Integration
  - Using objects with implicit height information
  - Changing the heights and the planimetric positions of the objects
- Approach is a further development of a method changing only the heights
- The results are satisfying



# The end

Thank you for your attention!

