MOVING POLYNOMIAL IN FILTERING OF AIRBORNE LASER SCANNING DATA

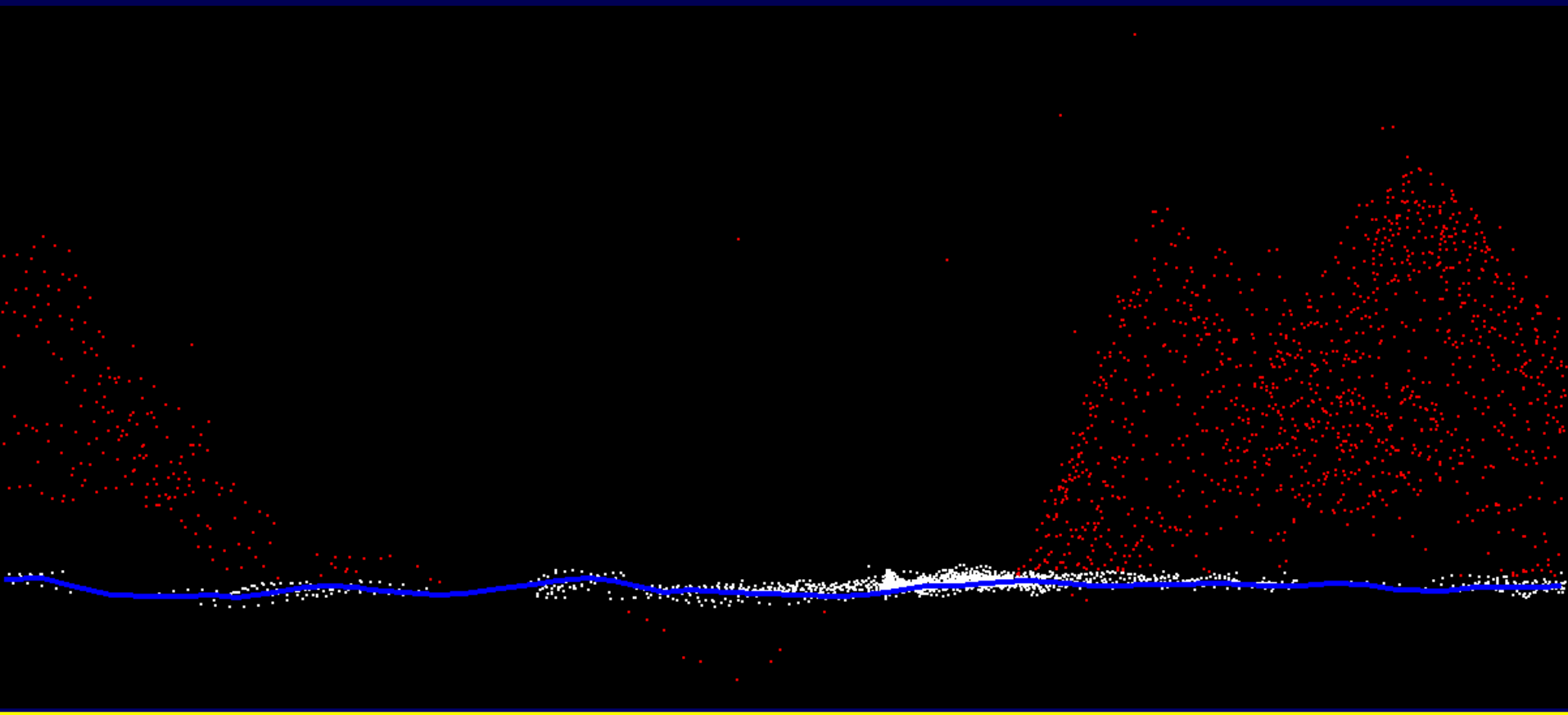
Grzegorz Jóźków

Wroclaw University of Environmental and Life Sciences

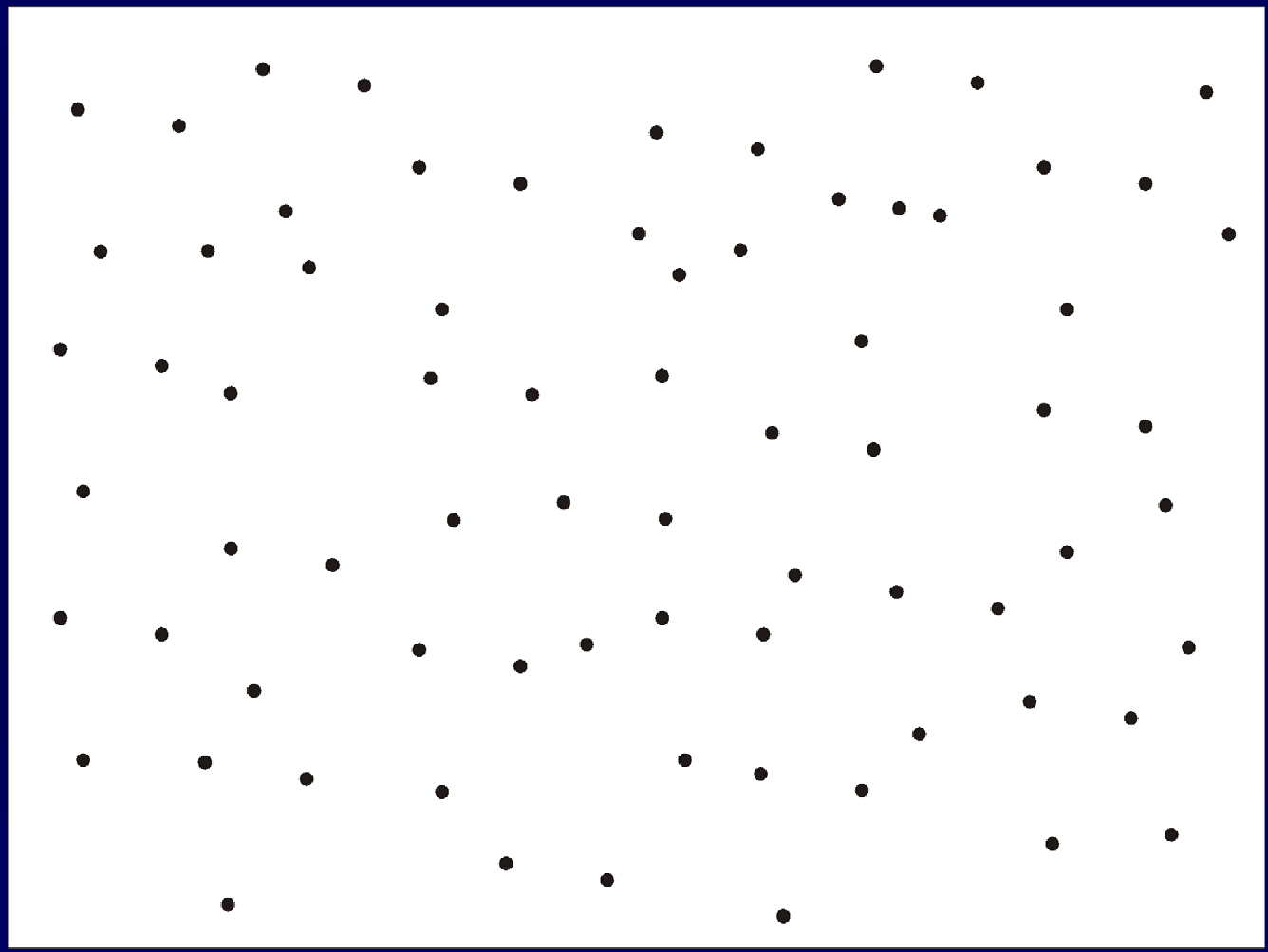
Institute of Geodesy and Geoinformatics

INTRODUCTION

Non terrain points are regarded as gross errors



MOVING POLYNOMIAL



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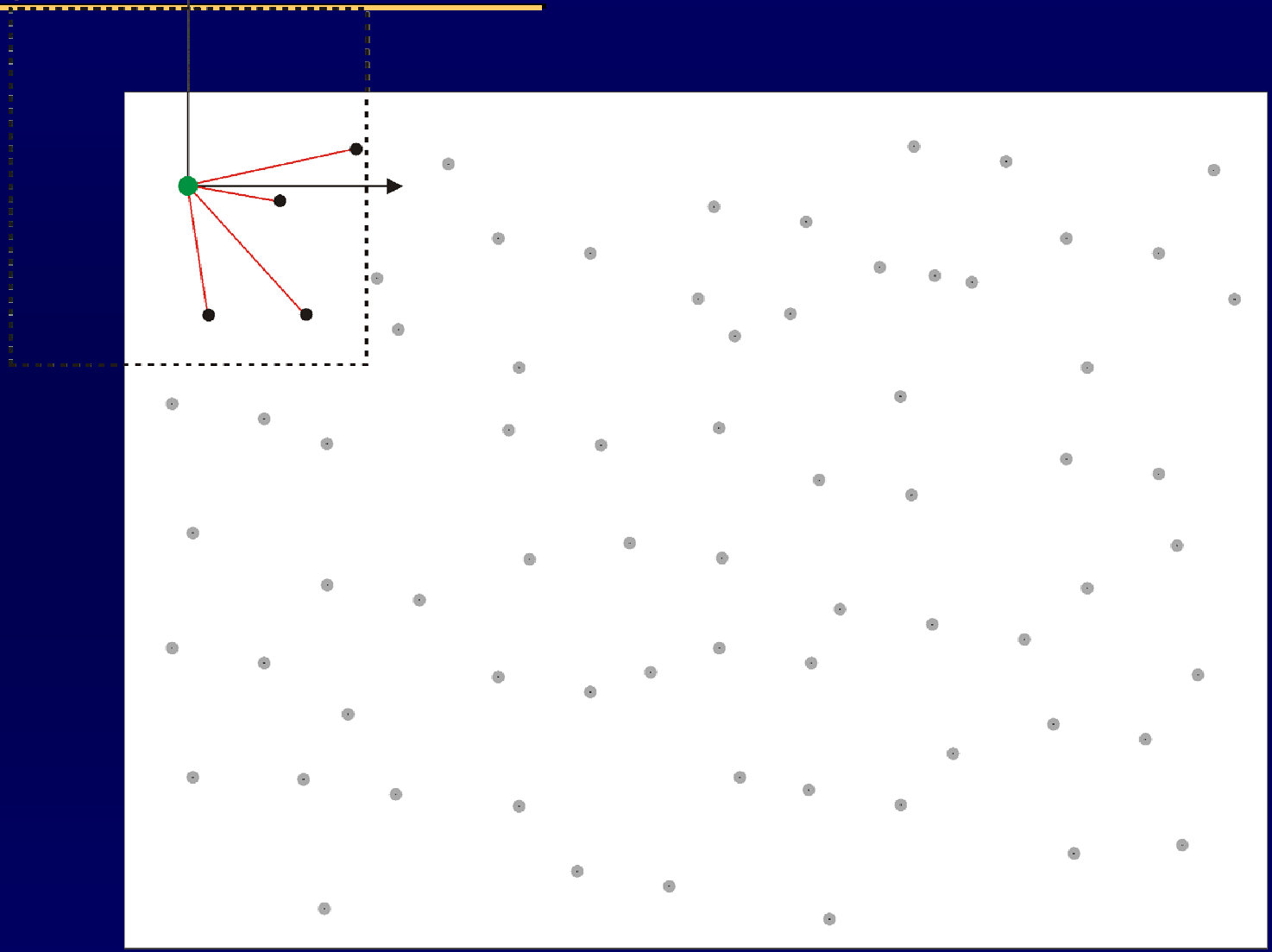

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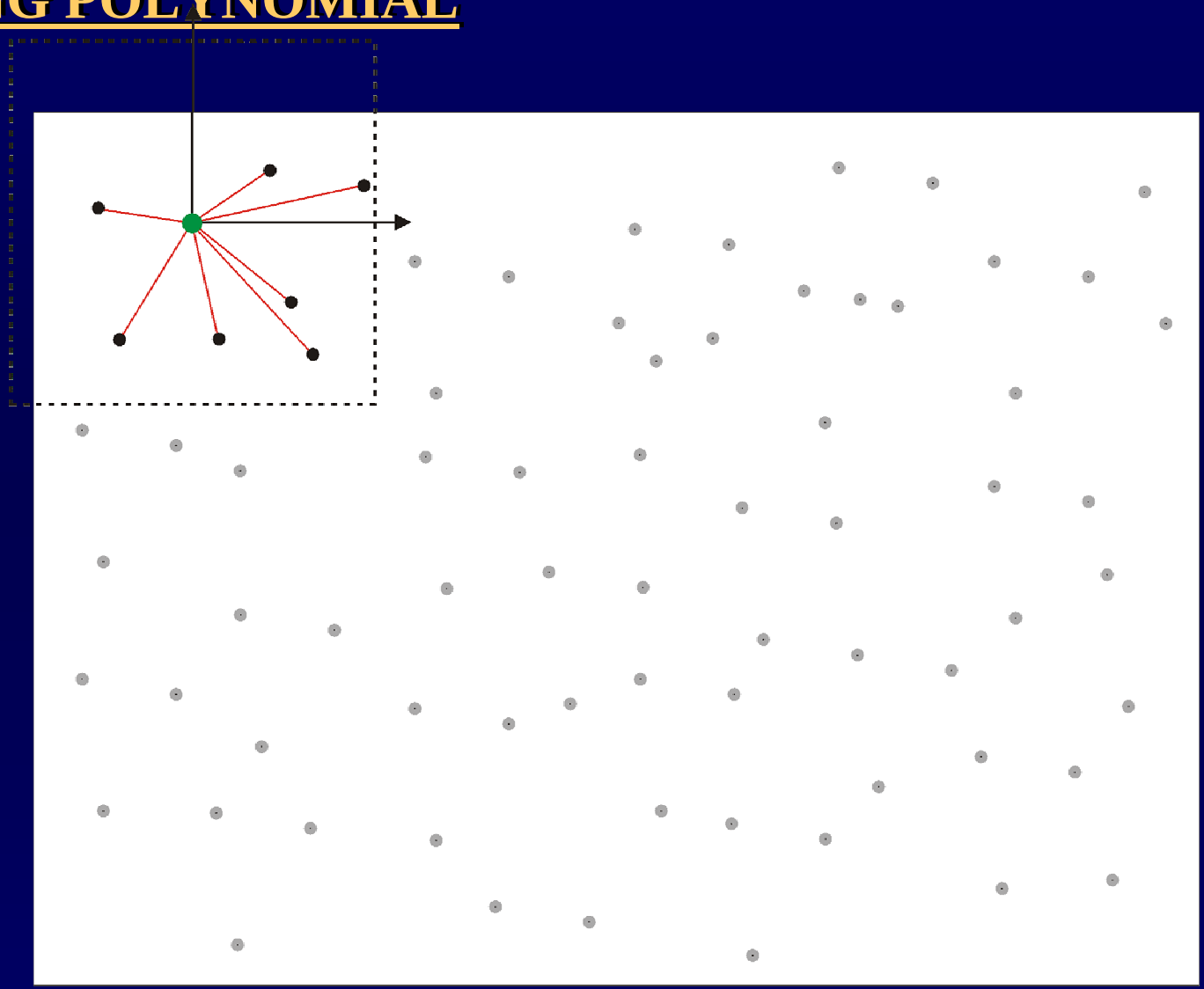

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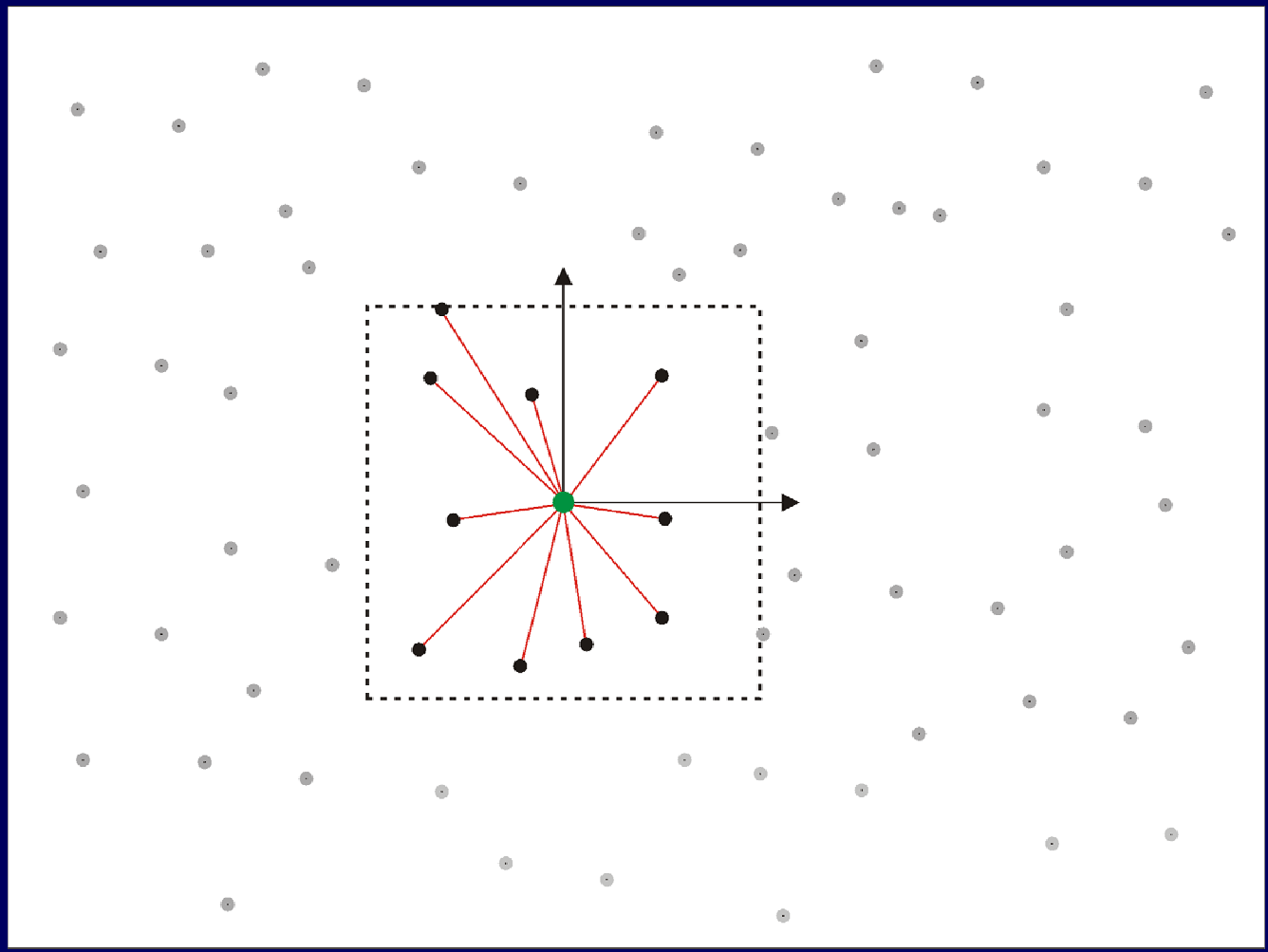

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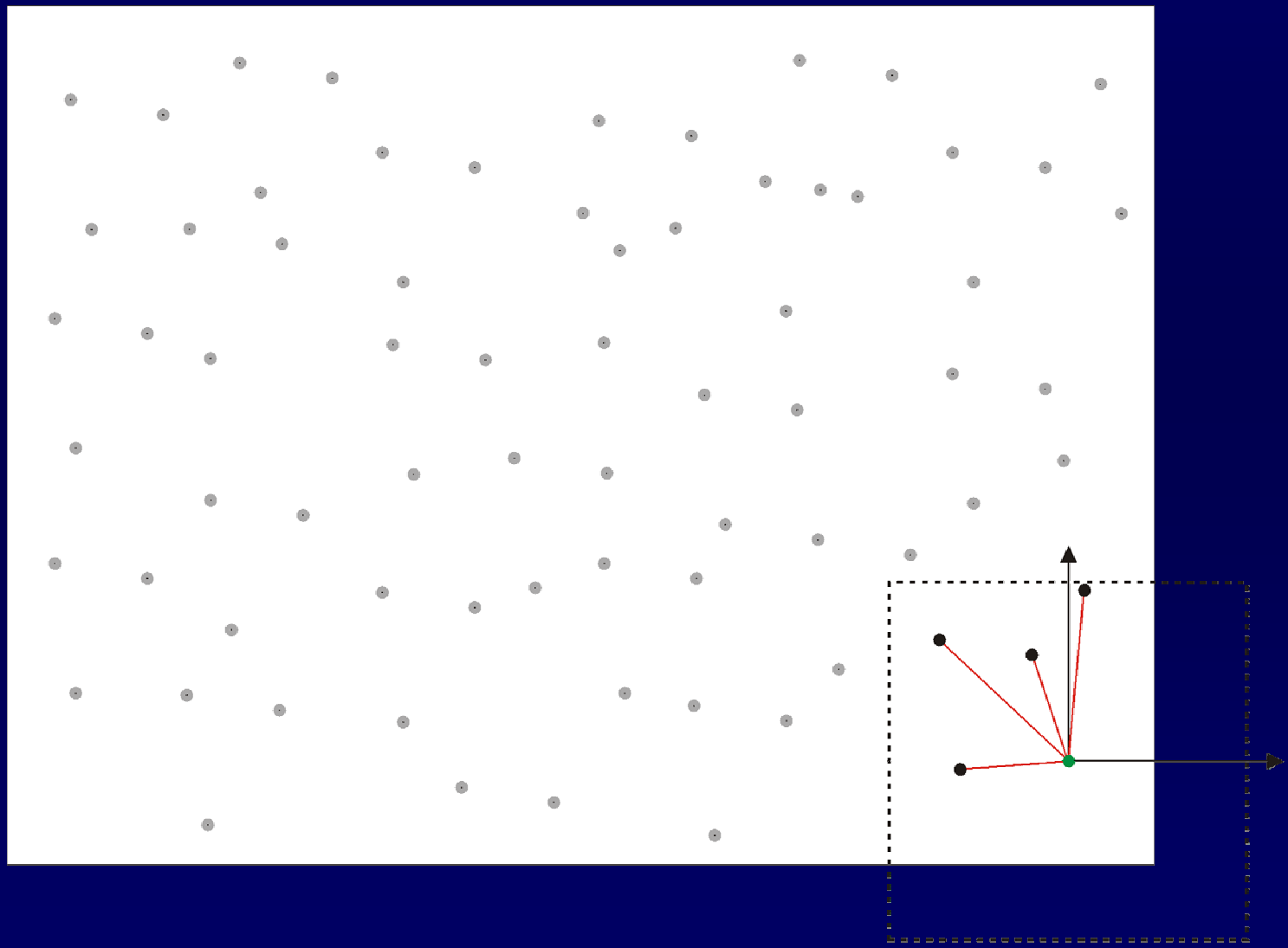


POLYNOMIAL MODEL

Second rank polynomial:

$$Z(X,Y) = a_{00} + a_{10} \cdot X + a_{01} \cdot Y + a_{11} \cdot X \cdot Y + a_{20} \cdot X^2 + a_{02} \cdot Y^2$$

Z - interpolated height of measured point $\{X,Y\}$ - coordinates of interpolated point

$a_{i,j}$ - unknown parameters of local polynomial calculated from matrix equation:

$$A = (B^T \cdot P \cdot B)^{-1} \cdot B^T \cdot P \cdot H$$

$A = [a_{00} \quad a_{10} \quad a_{01} \quad a_{11} \quad a_{20} \quad a_{02}]^T$ - polynomial parameters matrix

$P = diag\{p_1 \quad p_2 \quad \dots \quad p_n\}$ - weight matrix, where weight p_i is calculated based upon distance between measured and interpolated point

$\{x_i, y_i, h_i\}$ - coordinates and height of measured point

$$B = \begin{bmatrix} 1 & x_1 & y_1 & x_1 \cdot y_1 & x_1^2 & y_1^2 \\ 1 & x_2 & y_2 & x_2 \cdot y_2 & x_2^2 & y_2^2 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & x_n & y_n & x_n \cdot y_n & x_n^2 & y_n^2 \end{bmatrix} \qquad H = [h_1 \quad h_2 \quad \dots \quad h_n]^T$$

ROBUST ESTIMATION

Polynomial parameters are calculated in iteration process:

$$A^{(K)} = (B^T \cdot P^{(K-1)} \cdot B)^{-1} \cdot B^T \cdot P^{(K-1)} \cdot H$$

$A^{(K)}$ - polynomial parameters determined in step K of iteration

$P^{(K-1)}$ - weight determined in step K-1 of iteration

New weights are calculated using damping function:

$$p_i^{(K)} = p_i \cdot q(v_i^{(K-1)})$$

$v_i^{(K-1)}$ - residues between measured and calculated in step K-1 heights

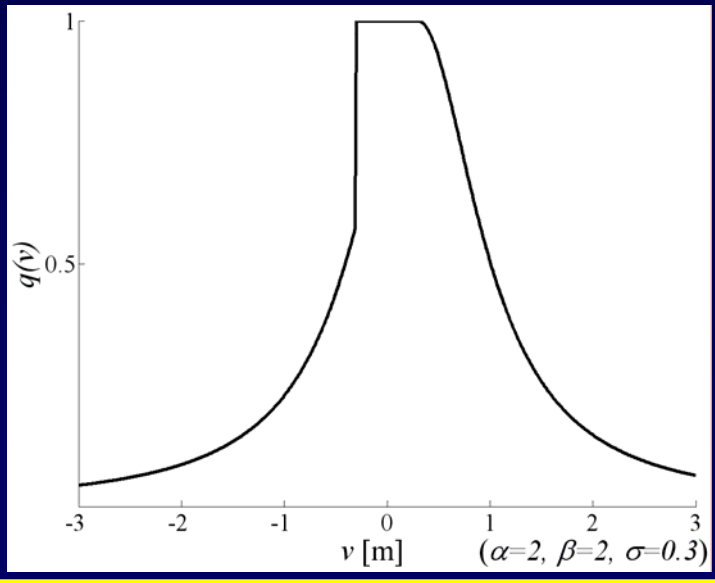
p_i - not modiefied (original) weights

$q(v)$ - damping function

Damping function:

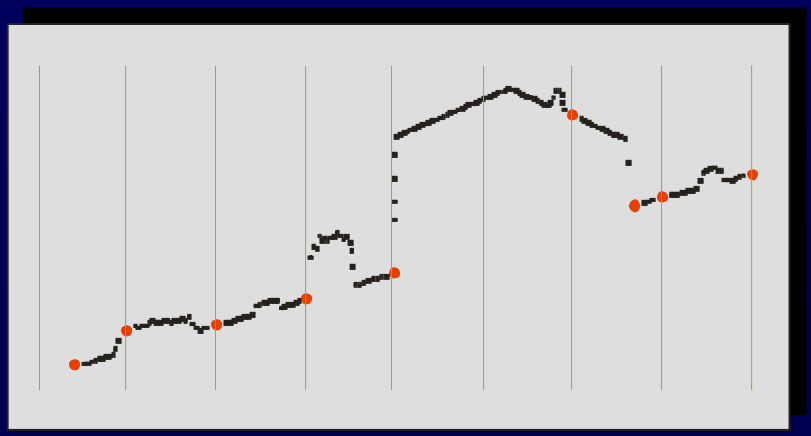
$$q(v) = \begin{cases} 1, & |v| \le \sigma \\ \dfrac{1}{1+(\alpha \cdot |v-\sigma|)^{\beta}}, & |v| > \sigma \end{cases}$$

α, β, σ - empirical chosen parameters



HIERARCHICAL MODEL (Briese et al., 2002)

- partition area and choice for each sub-area one representative point



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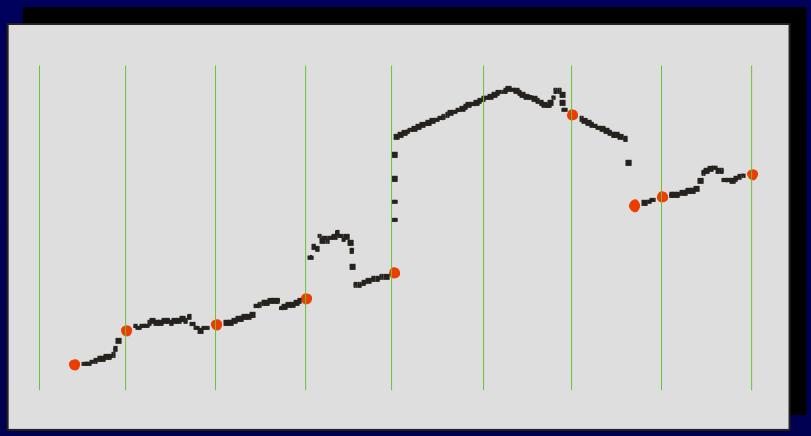
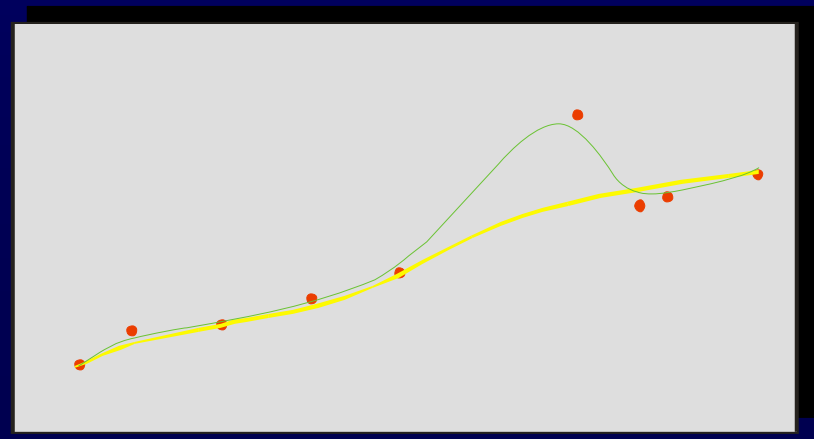


- heights interpolation in each representative point



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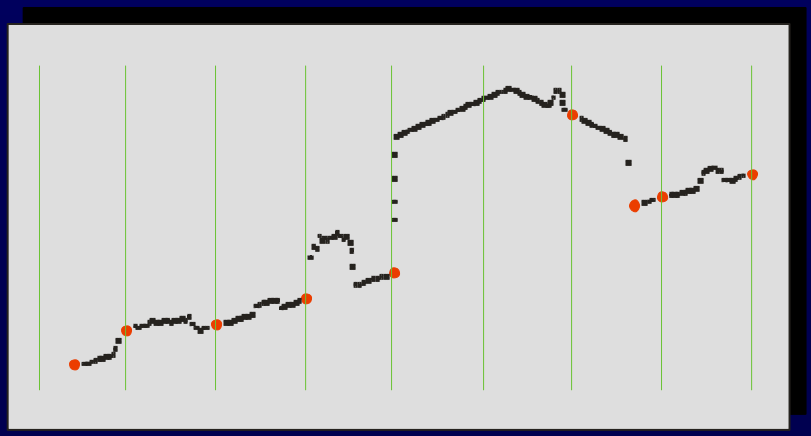

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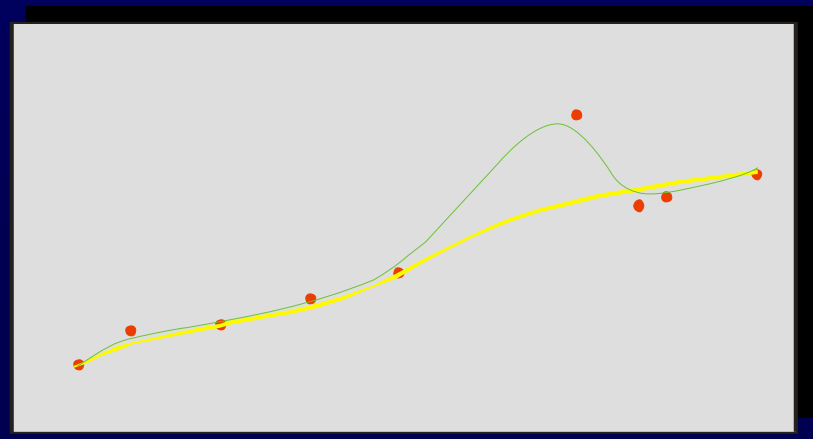
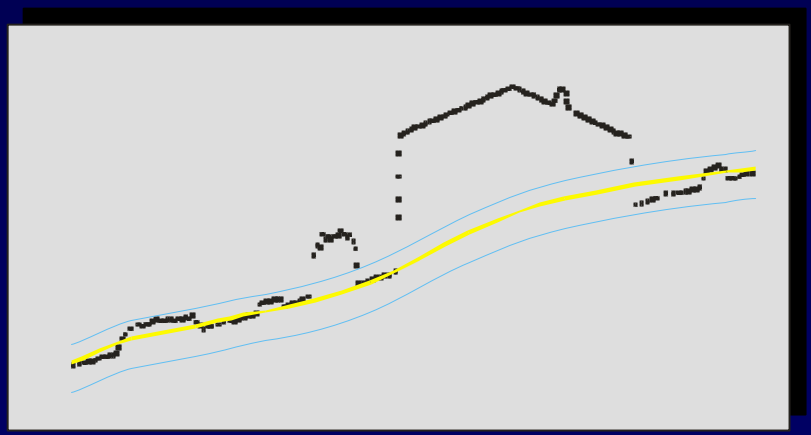


- removing all points, that were not included in the cache of terrain trend



HIERARCHICAL MODEL (Briese et al., 2002)

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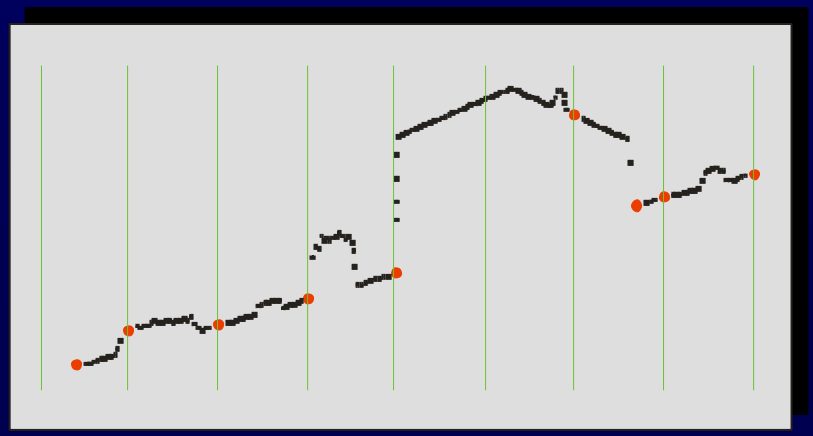
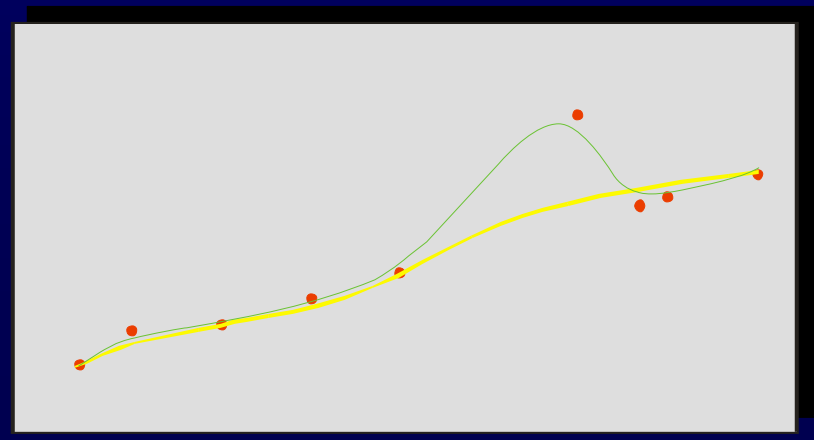


- heights interpolation in each representative point



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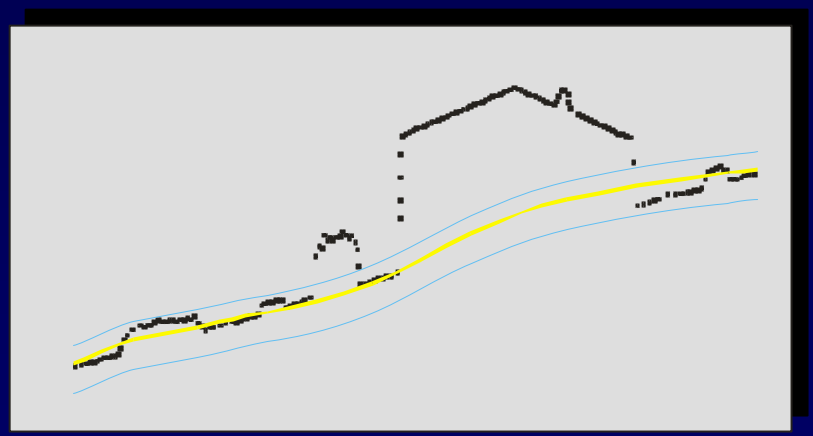
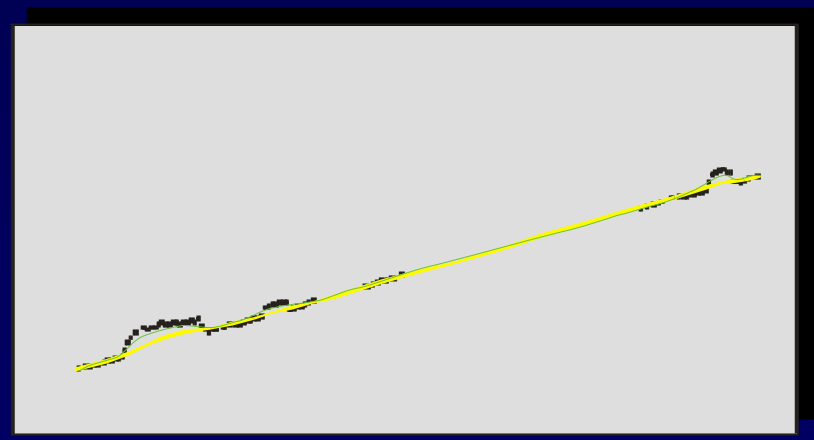


- heights interpolation in non-removed points

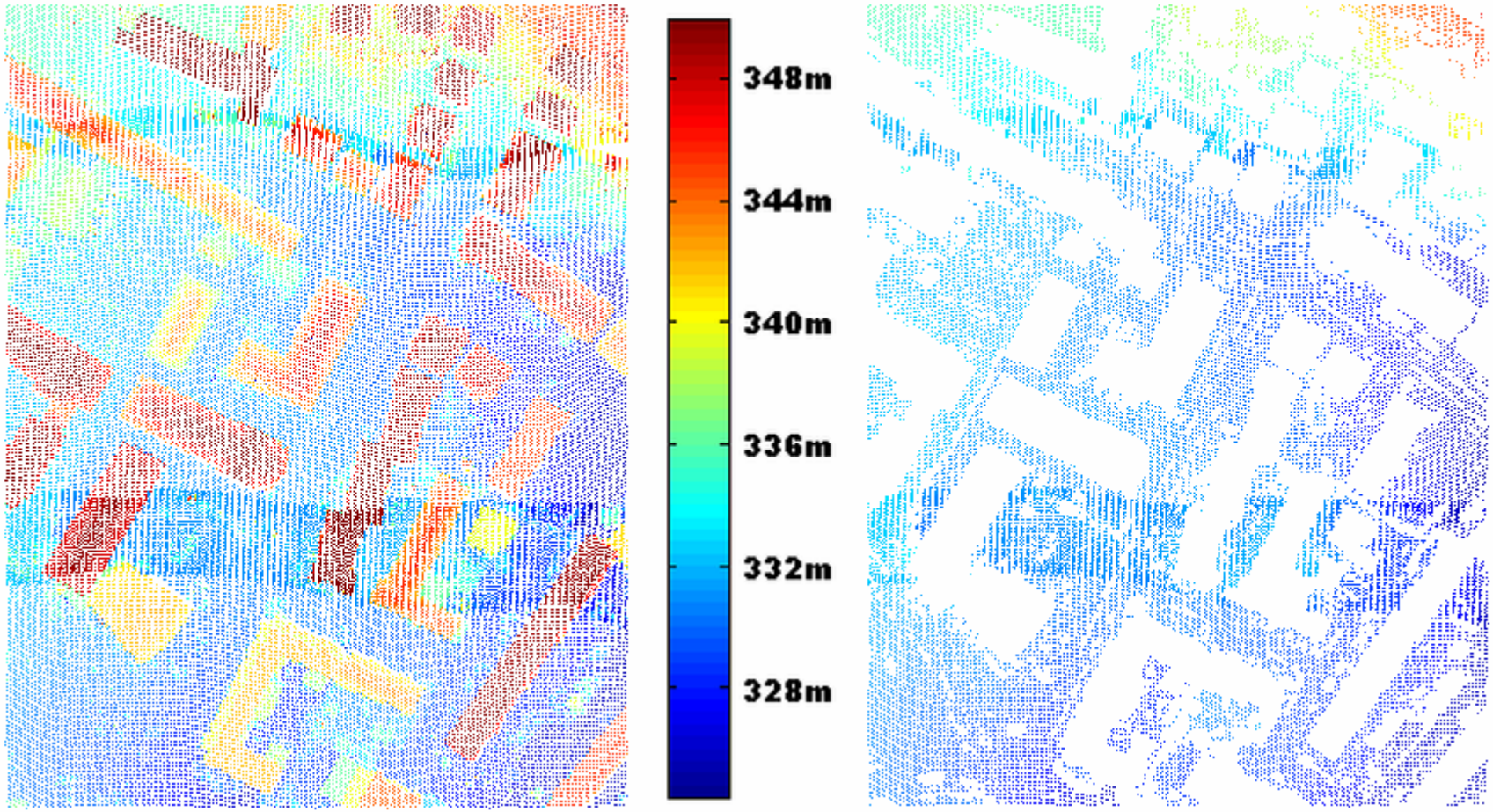


EXAMPLE 1 (samp12.txt, http://www.itc.nl/isprswgIII-3/filtertest/Reference.zip)

52119 points, area 204 m x 264 m, density about 1 point per square meter

Measured points

Identiefied terrain points



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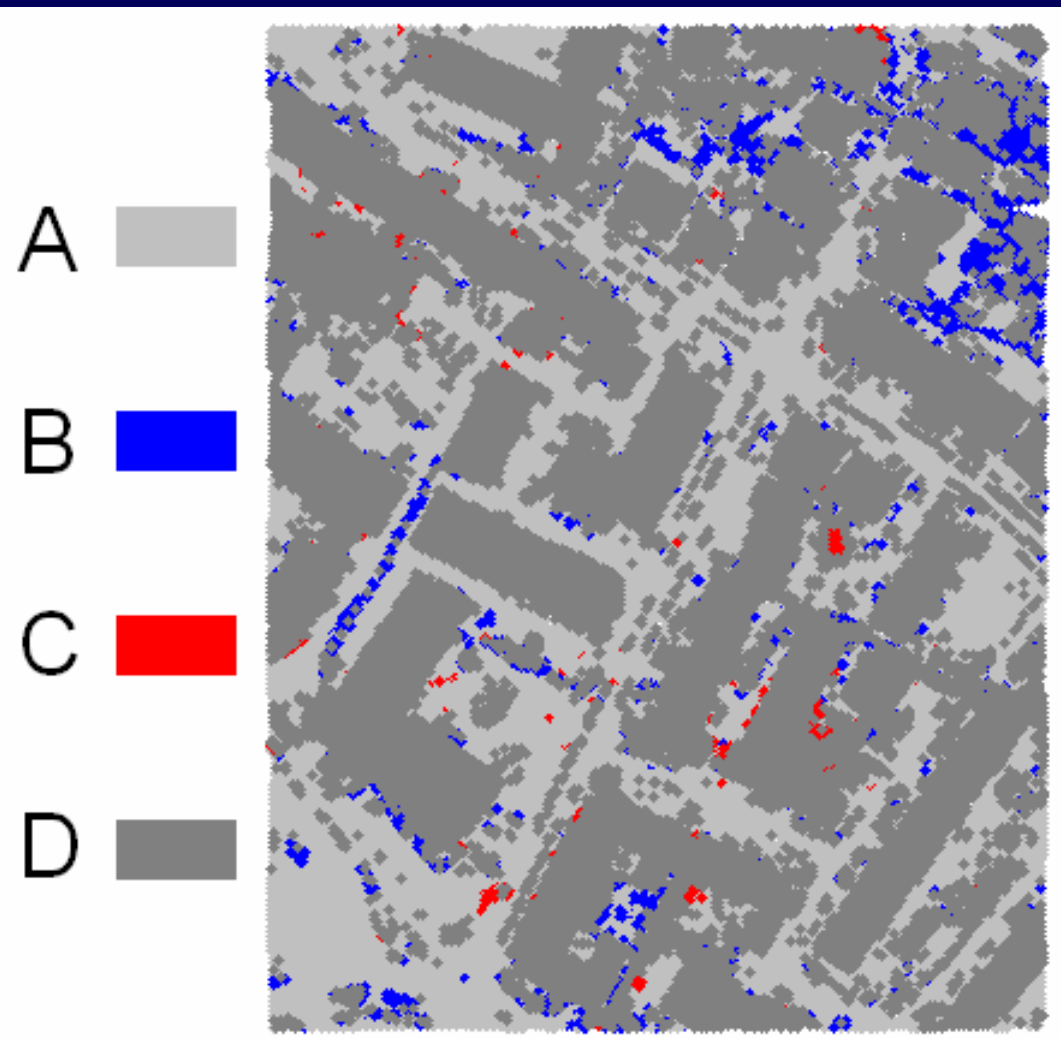
Filtering results

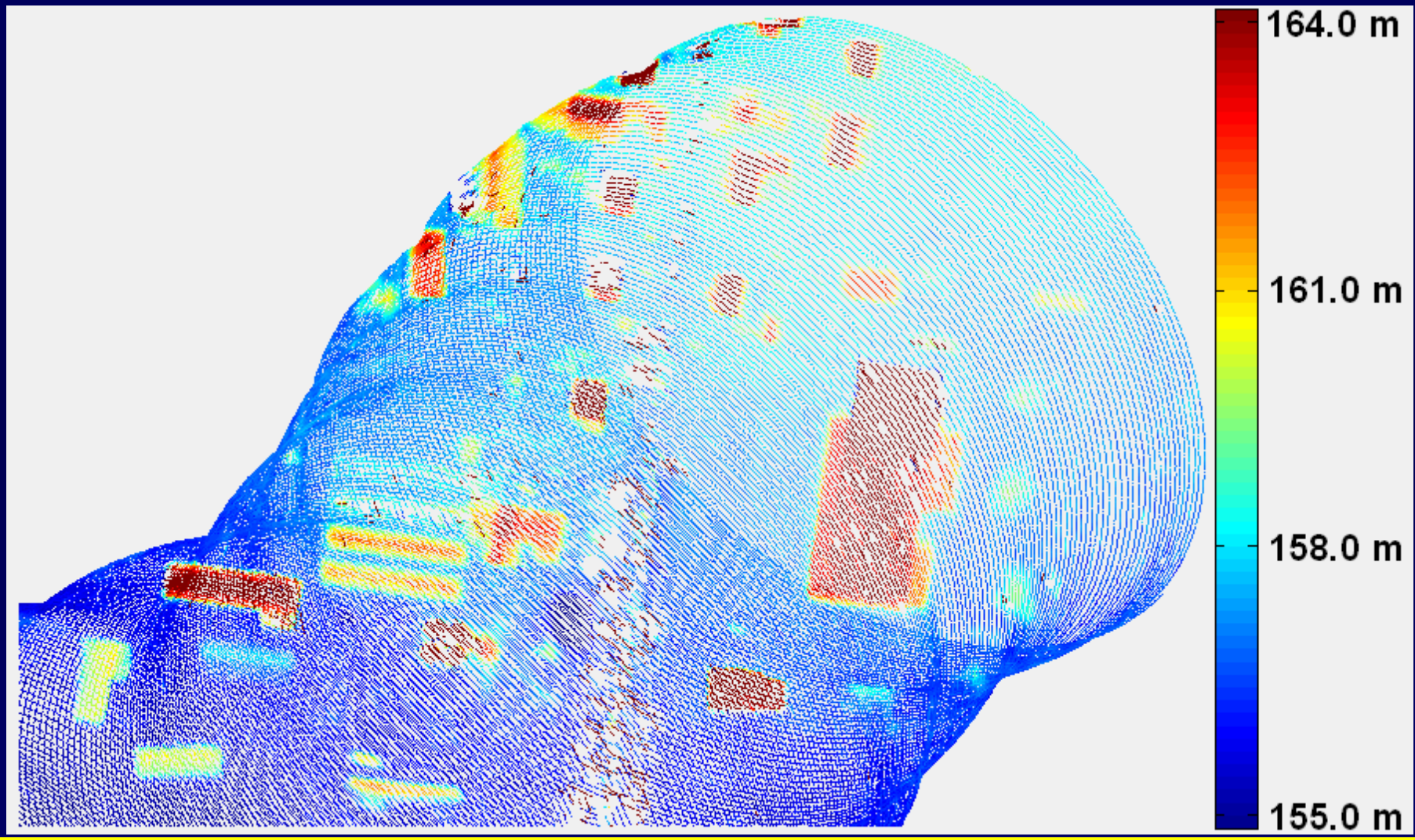
Total (points)		E	52119
Correct classified bare earth		A	24455
Type 1 errors (bare earth as object)		B	2236
Type 2 errors (object as bare earth)		C	401
Correct classified object		D	25027
Reference	Bare earth	A+B	26691
	Object	C+D	25428
Filtered	Bare earth	A+C	24856
	Object	B+D	27263
Percentage of type 1 error		B/(A+B)	8.38%
Percentage of type 2 error		C/(C+D)	1.58%
Percentage of total error		(B+C)/E	5.06%
Ratio type 1 to type 2 errors		B/C	5.58



EXAMPLE 2 (ScaLARS)

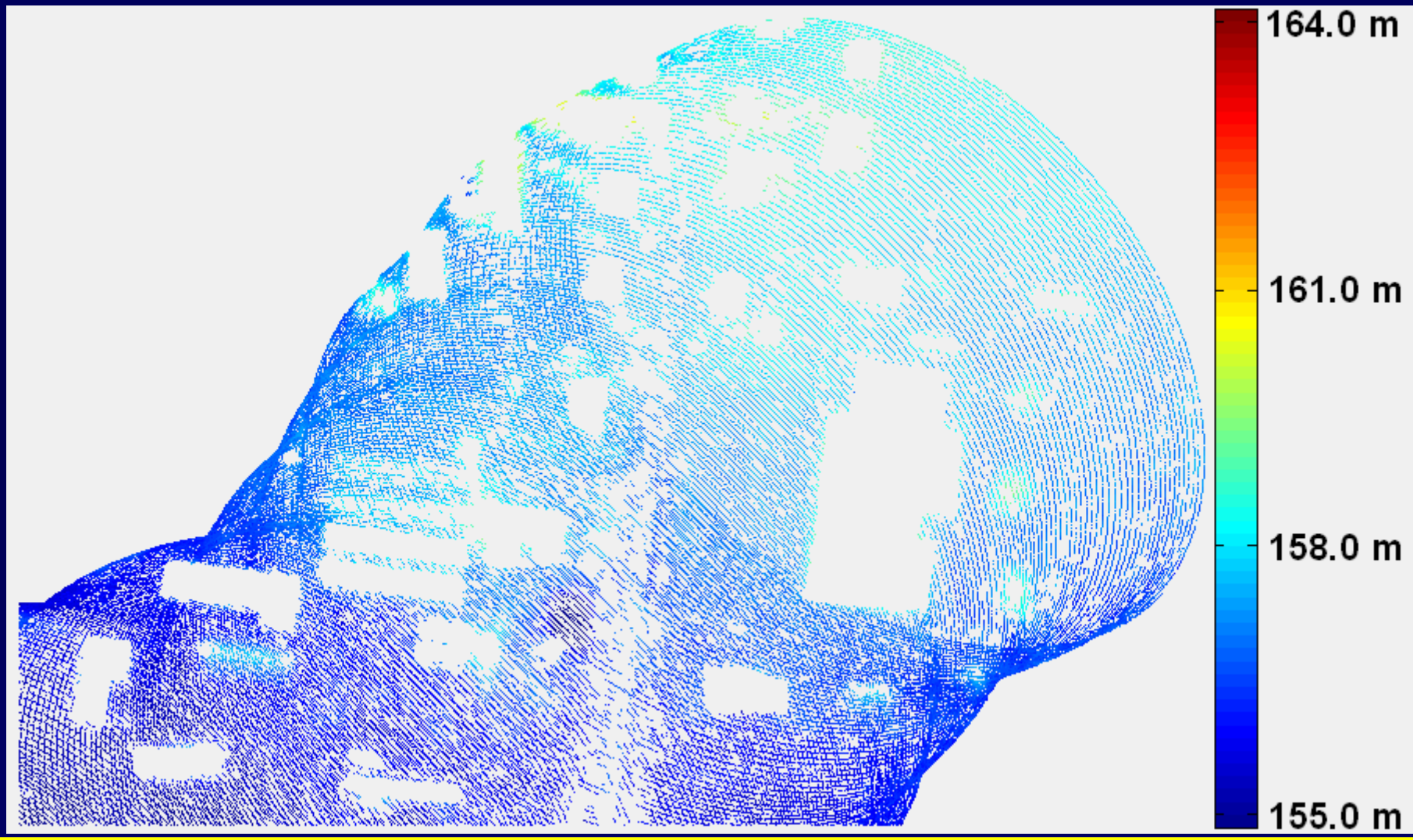
127175 points, area 85000 m^2, density about 1.5 point per square meter

Measured points



EXAMPLE 2 (ScaLARS)

Terrain points (90178 points)



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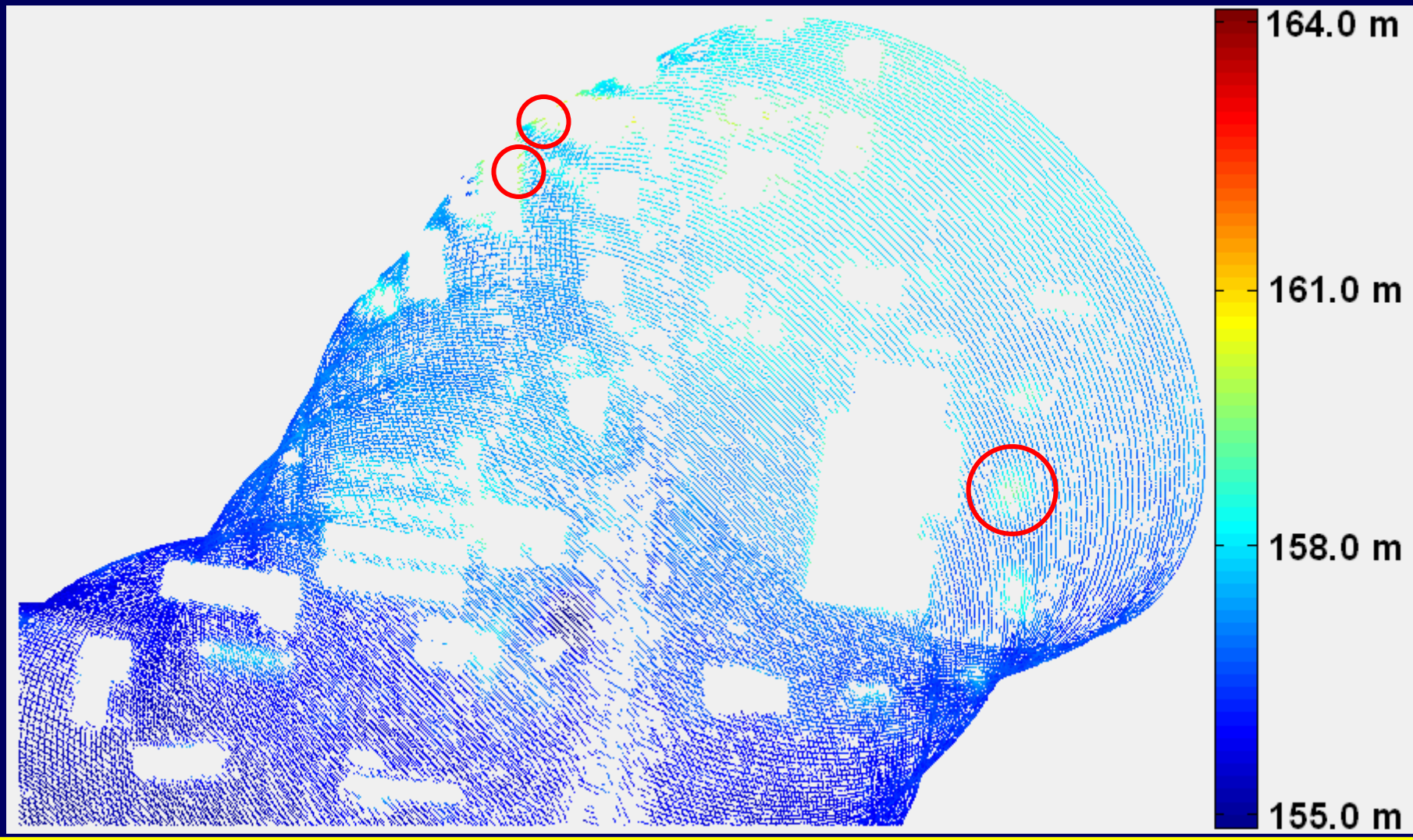

SUMMARY

- algorithm is based upon the original data (without grid computing),
- hierarchical approach is necessary in this method,
- polynomial surface fits good to the local terrain structures,
- algorithm description is simple, nevetheless determination of polynomial parameters in the iteration process for each point requests strong computing power
- filtering of airborne laser scanning data using moving polynomial surface give correct results.

THANK YOU FOR YOUR ATTENTION