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a

- (DEM) - (TPS) :

[] []
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[]

[]

1:10000

TPS

ERDAS

TPS

PCI Gematica-OrthoEngine

MicroStation []

TPS ,Descartes 7.0

TPS

[] Rubbersheeting

- TPS []

[] []

TPS TPS

$$\sum_j a_j \phi(r_j(x_j, y_j)) + b_0 + b_1 x_j + b_2 y_j = z_j;$$

$$\sum_j a_j = 0; \sum_j a_j x_j = 0; \sum_j a_j y_j = 0;$$

$$(j = 1, \dots, n);$$

()

$$\frac{8\pi a_j}{\mu_j} + \sum_i a_i \phi(r_i(x_j, y_j)) + b_0 + b_1 x_j + b_2 y_j = z_j;$$

$$(j = 1, \dots, n)$$

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$$\phi(x, x_j) = \phi(r_j) = r_j^{2m} \log(r_j)$$

TPS

$$C^{2m-1}$$

m []

DTM

$$\phi$$

TPS

$$C^1$$

m

$$r \quad \phi(x, x_i) = \phi(r_i) = r_i^2 \log(r_i)$$

$$r_i(x_j, y_j) = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2}$$

n+3

$$\begin{pmatrix} 8\pi/\mu_1 & c_{21} & \dots & c_{n1} & | & 1 & x_1 & y_1 & a_1 \\ c_{21} & 8\pi/\mu_2 & \dots & c_{n2} & | & 1 & x_2 & y_2 & a_2 \\ \vdots & \vdots & \ddots & \vdots & | & \vdots & \vdots & \vdots & \vdots \\ c_{1n} & c_{2n} & \dots & 8\pi/\mu_n & | & 1 & x_n & y_n & a_n \\ \hline 1 & 1 & \dots & 1 & | & 0 & 0 & 0 & b_0 \\ x_1 & x_2 & \dots & x_n & | & 0 & 0 & 0 & b_1 \\ y_1 & y_2 & \dots & y_n & | & 0 & 0 & 0 & b_2 \end{pmatrix} = \begin{pmatrix} z_1 \\ z_2 \\ \vdots \\ z_n \\ 0 \\ 0 \\ 0 \end{pmatrix};$$

$$c_{ij} = \phi(r_i(x_j, y_j))$$

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$$\begin{pmatrix} C & F \\ F^T & 0 \end{pmatrix} \begin{pmatrix} a \\ b \end{pmatrix} = \begin{pmatrix} Z \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} C & F \\ F^T & 0 \end{pmatrix}$$

QR

(n,n) Q []

$$I[f(x, y)] = \iint_{\mathfrak{R}^2} f_{xx}^2 + 2f_{xy}^2 + f_{yy}^2$$

[] \mathfrak{R}^2

()

f ()

()

[]

n

$$f_i$$

$$f(x, y)$$

$$f(x_i, y_i) = f_i(x_i, y_i, f_i; i = 1, 2, \dots, n)$$

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f(x, y)

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[] (L2)

$$E_{TPS} = \sum_{i=1}^n \mu_i (f(x_i, y_i) - z_i)^2 + \iint_{\mathfrak{R}^2} f_{xx}^2 + 2f_{xy}^2 + f_{yy}^2$$

()

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P

P

f_P

r_i

i

$$\mu_i = \begin{cases} r_i = \frac{A_i}{\sum_{j=1}^n A_j}; & \text{if } (i=1,2,3,\dots,n \text{ \& } A_i \neq \infty) \\ 1; & \text{if } (A_i = \infty) \end{cases}$$

$$r_i = 1/n$$

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P

$r_i = 1$

A

[]

P=100

(b)

P

()

\mathfrak{R}^2

P

P

[]

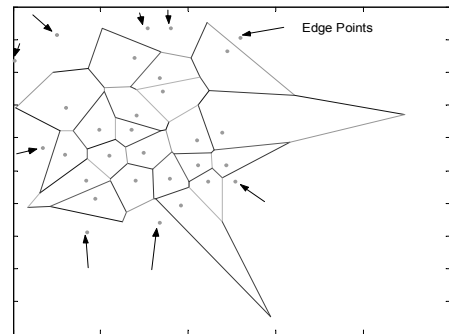
P

$$\mu_i = 100 \times \frac{A_i}{\sum_{j=1}^n A_j}; i=1,2,3,\dots,n$$

()

(c)

P=1000



$$\mu_i = 1000 \times \frac{A_i}{\sum_{j=1}^n A_j}; i=1,2,3,\dots,n$$

()

(d)

P=10000

$+\infty$

\mathfrak{R}^2

$-\infty$

$$\mu_i = 10000 \times \frac{A_i}{\sum_{j=1}^n A_j}; i=1,2,3,\dots,n$$

()

(e)

P=100000

(f)

P

(e) (a)

(g)

μ_i

$$\mu_i = 100000 \times \frac{A_i}{\sum_{j=1}^n A_j}; i=1,2,3,\dots,n$$

()

P=

(a)

μ_i

(f)

$$\mu_i = A_i; i = 1, 2, 3, \dots, n$$

m * m

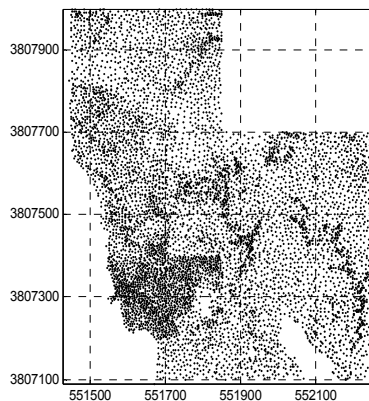
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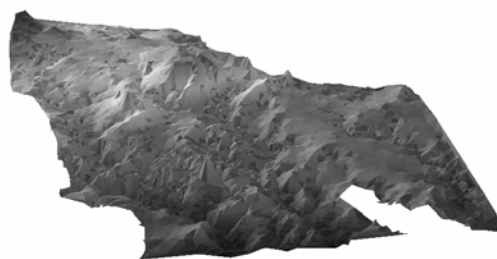
(g)

$$\mu_i = 1; i = 1, 2, 3, \dots, n$$

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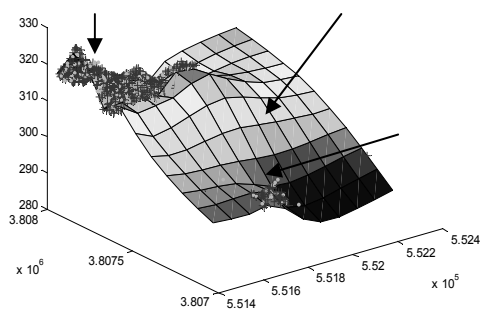
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TPS :

TPS

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MATLAB

[a] P=1

TPS

L2

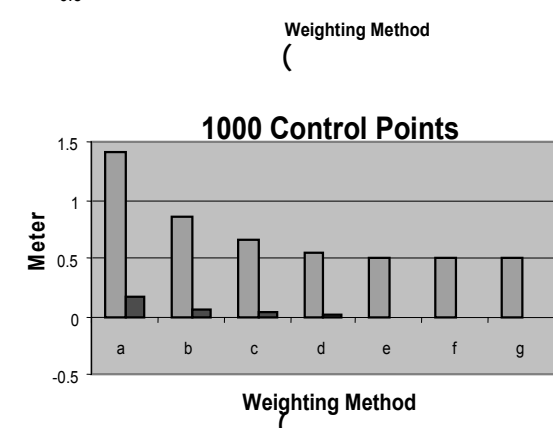
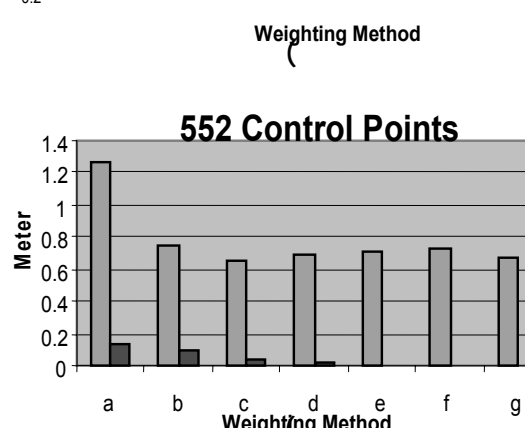
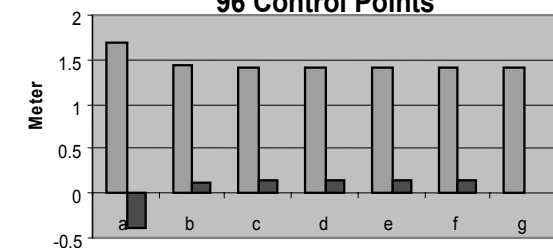
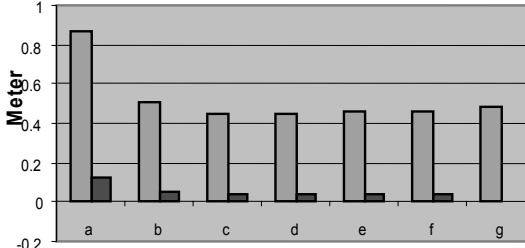
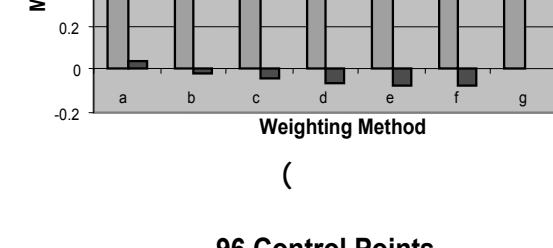
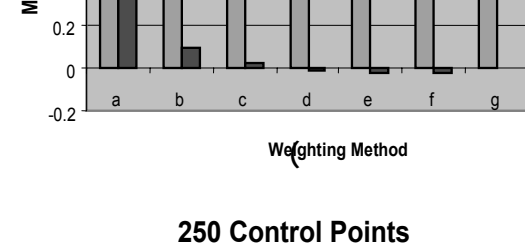
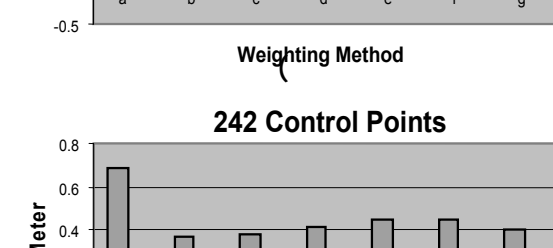
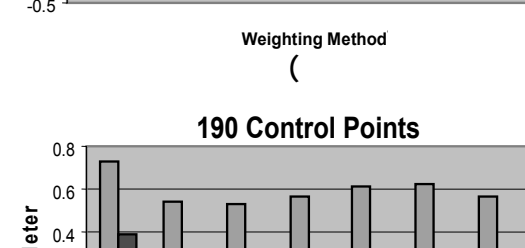
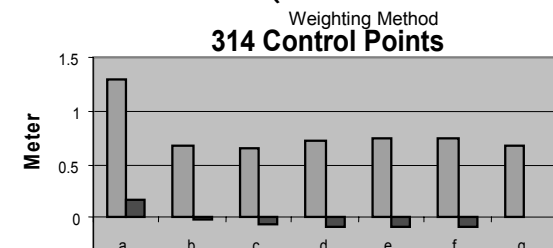
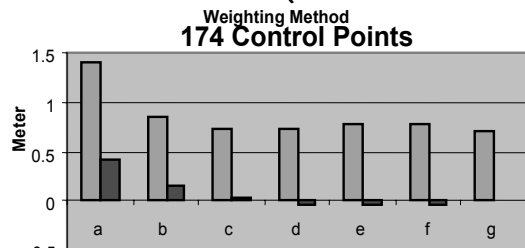
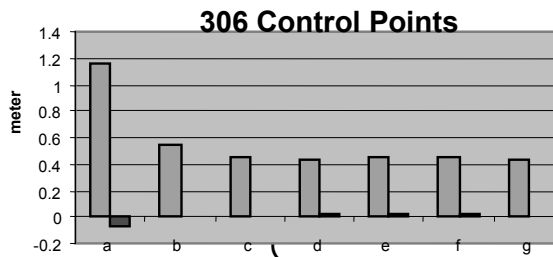
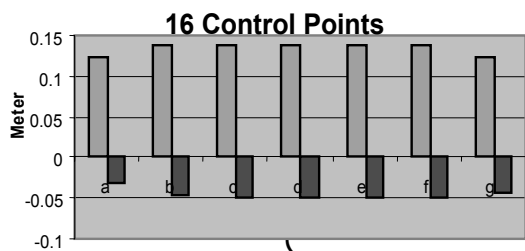
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) . (f e,d,c,b,a [P] μ_i (g) () () [P=100] b , e d c P (e d c b) P (n) () a f C_n^2 e d c b TPS

	a	b	c	d	e	f	g
16	0.122	0.139	0.138	0.138	0.138	0.138	0.122
174	1.414	0.861	0.717	0.740	0.779	0.783	0.710
190	0.724	0.542	0.521	0.568	0.614	0.622	0.564
250	0.872	0.505	0.453	0.454	0.458	0.457	0.483
552	1.257	0.748	0.660	0.683	0.718	0.723	0.663
306	1.152	0.547	0.452	0.437	0.458	0.460	0.432
314	1.301	0.682	0.641	0.710	0.747	0.749	0.682
242	0.692	0.373	0.382	0.417	0.444	0.447	0.398
96	1.693	1.429	1.410	1.416	1.420	1.420	1.404
1000	1.401	0.867	0.654	0.536	0.507	0.510	0.504

	a	b	c	d	e	f	g
16	-0.032	-0.045	-0.048	-0.049	-0.049	-0.049	-0.043
174	0.411	0.140	0.033	-0.034	-0.051	-0.051	-0.020
190	0.385	0.092	0.032	-0.009	-0.023	-0.025	0.001
250	0.123	0.056	0.040	0.040	0.041	0.041	0.035
552	0.140	0.088	0.042	0.021	0.008	0.006	0.016
306	-0.069	0.003	0.005	0.017	0.019	0.019	0.012
314	0.177	-0.009	-0.054	-0.082	-0.093	-0.094	0.010
242	0.040	-0.022	-0.044	-0.068	-0.079	-0.080	-0.061
96	-0.390	0.112	0.133	0.139	0.143	0.143	0.117
1000	0.156	0.049	0.029	0.005	-0.006	-0.010	-0.013



((((

((((((:

I+¼II () () ✓

¼II

II

() () I+½II

()

μ_i

TPS

(g)

(I)

(II)

()

(g)

μ_i

I

II

()

() ()

I

, P

II

II

TPS

II

() ()

I+½II

I

½ II

TPS

II

.II I

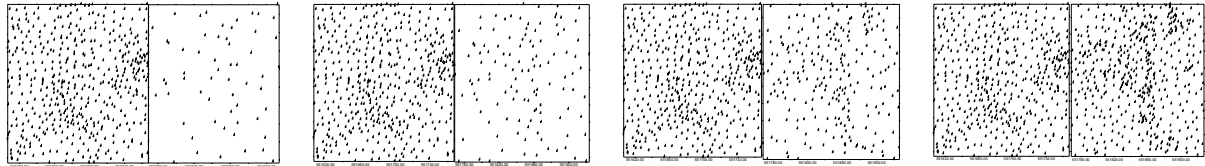
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	a	b	c	d	e	f	g
I+II	1.789	0.816	0.637	0.583	0.595	0.609	0.581
I+½II	1.308	0.685	0.623	0.634	0.634	0.635	0.615
I+¼II	2.638	1.004	0.648	0.648	0.622	0.638	0.620
I+⅛II	1.690	0.578	0.578	0.534	0.545	0.554	0.531

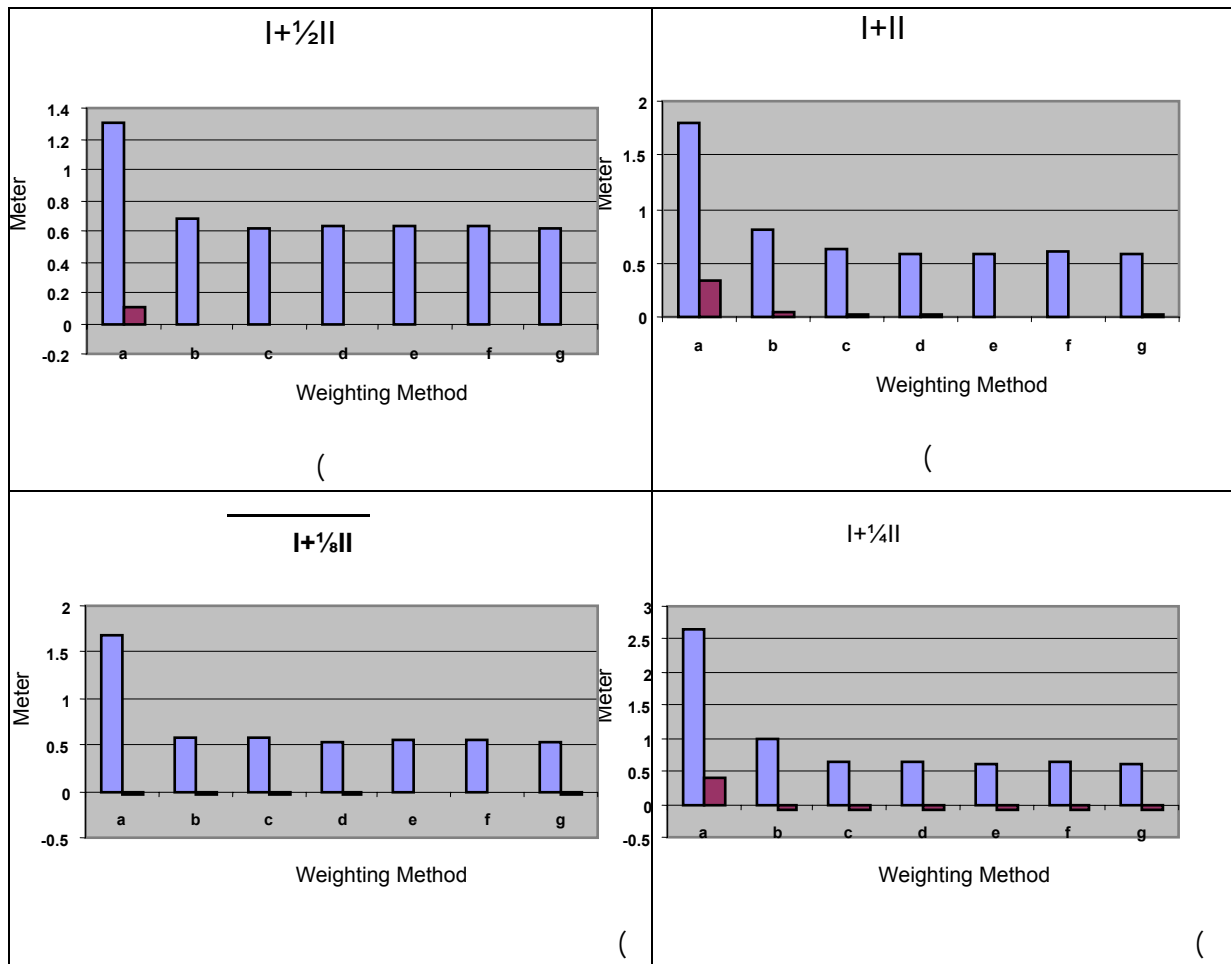
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	a	b	c	d	e	f	g
I+II	0.342	0.046	0.021	0.017	0.010	0.003	0.011
I+½II	0.110	-0.014	-0.013	-0.001	-0.001	-0.001	-0.009
I+¼II	0.412	-0.084	-0.090	-0.090	-0.081	-0.077	-0.082
I+⅛II	-0.045	-0.038	-0.038	-0.025	-0.017	-0.017	-0.026



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TPS

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- 14 - <http://www.bentley.com/products/descartes>

1 - Thin plate splines

2 - J. Duchon

3 - Radial Bases Functions

4 - J. Meinguet

5 - Sjowall

6 - IKONOS

7 - Digital Elevation Model

8 - Boztosun

9 - Interpolation

10 - Approximation

11 - Digital Terrain Model (DTM)

12 - C. Carasso

13 - Orthogonal-triangular decomposition

14 - Rank

15 - Voronoi Polygons

16 - Check Point

17 - ExtraPolation

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