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A TURBO PASCAL 7.0 PROGRAM TO FIT A POLYNOMIAL OF ANY ORDER TO POTENTIAL FIELD ANOMALIES BASED ON THE ANALYTIC LEAST SQUARES METHOD

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ABSTRACT:- *An anomaly separation program for gravity (or magnetic) data in prospecting domain is presented. It can be applied to the gravity or magnetic anomaly separation of degree up to three and allows the management of up to 1200 data. Its implementation requires a Turbo Pascal surrounding through a TP7 list on the main root of the computer. The results obtained after execution of the program can be displayed, printed or stocked in a data file. In order to test the program, we have compared our results with those obtained from a Fortran program written by Radhakrisha and Krishnamacharyulu (1990) using the least squares method. The advantage of using our program is that a great number of data can be handled even for a local study, the execution is rapid and the accuracy is greatly improved upon.*

INTRODUCTION

The Bouguer anomalies are due to the whole effect of the superficial and deeper structures, corresponding respectively to the residual and regional anomalies. Before any interpretation, the separation of main anomalies into its different components is a very important stage. Agocs (1951), Grant (1954) and other authors showed different mathematical processes among which the analytic method was discussed. For this method, the regional anomaly is represented by an analytic function of different orders, admitting a series expansion. The coefficients of this series depend on the input data and can be determined by solving a set of linear equations using the least square method. The equations can be solved using the matrix method.

In this paper, a separating program of gravity and magnetic anomalies is presented. This Turbo Pascal 7.0 program based on least square method, permits to determine the coefficients of the polynomial analytic function corresponding to the first-, second- and third-order surface. But it can be extended to a polynomial of any order. The program separates the gravity or magnetic anomalies into residual and regional anomalies for up to 1200 data. The values obtained are stocked in a data file created by the program. The data permit to have maps using in particular the Winsurf program of Golden Software (1994). In order to test the program, a comparison has been made with the results obtained using the least square method in a Fortran 77 program published by Radhakrisha Murthy and Krishnamacharyulu (1990).

THEORY OF THE METHOD

The Bouguer anomaly B(x, y) at a point M(x, y) in a arbitrary rectangular coordinate is the sum of the residual anomaly A(x, y) and the regional anomaly R(x, y), Shoeffler (1975), :

$$B(x, y) = A(x, y) + R(x, y) \qquad (1)$$

The regional is represented by an analytic function that can be expanded in a power series, Baranov (1954). For a third-order surface, the analytic regional is given by the polynomial expression :

$$R(x, y) = C_1 + C_2x + C_3y + C_4xy + C_5x^2 + C_6y^2 + C_7x^2y + C_8xy^2 + C_9x^3 + C_{10}y^3 \qquad 2$$

The second- and the first-order surfaces can be obtained respectively by giving the value 0 to the coefficients C_7, C_8, C_9 and C_{10} and to the coefficients C_4, …., C_{10}. In the least square sense, the residual is minimal and this is expressed by the relation:

$$\sum_{j=1}^{n} \frac{\partial\left[A(x_j, y_j)\right]^2}{\partial C_i} = 0 \qquad 3$$

where x_j, y_j (j =1, …, n) are the coordinates (in km) of anomaly point and the C_i (i=1,…, (m+1)(m+2)/2) are the coefficients of the m-order analytic function. The previous equation can be written in a simple form :

$$\sum_{j=1}^{n} A(x_j, y_j) \frac{\partial A(x_j, y_j)}{\partial C_i} = 0 \qquad 4$$

Equation (4) permits to obtain a linear equations system of (m+1)(m+2)/2 unknown coefficients in the form DC = E that the program solves using the matrix method. The coefficients C_i , residual A (in mgal or in gamma) and the regional R (in mgal or in gamma) values are next calculated by the program.

COMPUTER PROGRAM

The program presented in this paper permits gravity and magnetic anomalies separation for regional up to the third-order and for up to 1200 anomaly data. Its implementation requires a Turbo Pascal surrounding and a TP7 list on the main root of the hard disk. The inputs of the program for each anomaly point are (x, y, B), the rectangular coordinates and the gravity or magnetic anomaly. The data are stocked in matrix of the linear equations system that the program solves and gives values of the coefficients, regional and residual for each corresponding anomaly point. These outputs of the program are saved in a data file (Gm-sep.dat) that can be used in particular in the Winsurf program of Golden Software (1994) to represent three dimension anomaly maps.

In order to test the program, we used data from the paper published by Radhakrisha Murthy and Krishnamacharyulu in 1990, in a Fortran 77 program using the least square method for fitting mathematical surface. The results obtained are represented in tables 1 and 2, and those published by Radhakrisha Murthy and Krishnamacharyulu are in tables 3 and 4. The comparison of the two results shows that the integer parts of the coefficients and separated anomalies are the same. However, a small difference is observed in the decimal part of the coefficients and the separated anomalies values at stations 2, 5, 19, 20,26, 27,28 and 34.

Table 1: Coefficients obtained with the program

Coefficients	Values
c[1]	7.8706
c[2]	2.0223
c[3]	0.78
c[4]	-0.0437
c[5]	-0.3101
c[6]	-0.3029
c[7]	0.0006
c[8]	0.0043
c[9]	0.0074
c[10]	0.0084

Table 2: Values of separated anomalies obtained by the program

Stations	x(km)	y(km)	B(mGal)	A(mGal)	(mGal)
1	0.00	0.00	8.60	0.73	7.87
2	0.00	1.00	8.40	0.04	8.36
3	0.00	2.00	7.90	-0.39	8.29
4	0.00	3.00	7.30	-0.41	7.71
5	0.00	4.00	6.60	-0.08	6.68
6	0.00	5.00	5.90	0.65	5.25
7	1.00	0.00	9.60	0.01	9.59
8	1.00	1.00	9.40	-0.64	10.04
9	1.00	2.00	9.50	-0.44	9.94
10	1.00	3.00	9.20	-0.14	9.34
11	1.00	4.00	8.00	-0.30	8.30
12	1.00	5.00	6.70	-0.17	6.87
13	2.00	0.00	10.30	-0.43	10.73
14	2.00	1.00	10.60	-0.54	11.14
15	2.00	2.00	12.10	1.09	11.01
16	2.00	3.00	12.10	1.70	10.40
17	2.00	4.00	9.20	-0.15	9.35
18	2.00	5.00	7.60	-0.31	7.91
19	3.00	0.00	11.00	-0.35	11.35
20	3.00	1.00	11.70	-0.02	11.72
21	3.00	2.00	12.70	1.14	11.56
22	3.00	3.00	11.40	0.47	10.93
23	3.00	4.00	9.70	-0.17	9.87
24	3.00	5.00	8.00	-0.43	8.43
25	4.00	0.00	11.40	-0.07	11.47
26	4.00	1.00	11.74	-0.07	11.81
27	4.00	2.00	11.60	-0.03	11.63
28	4.00	3.00	10.40	-0.58	10.98
29	4.00	4.00	9.40	-0.50	9.90
30	4.00	5.00	8.40	-0.06	8.46
31	5.00	0.00	11.70	0.54	11.16
32	5.00	1.00	11.40	-0.06	11.46
33	5.00	2.00	10.80	-0.45	11.25
34	5.00	3.00	10.30	-0.28	10.58
35	5.00	4.00	9.50	-0.01	9.51
36	5.00	5.00	8.80	0.73	8.07

Table 3: coefficients obtained by Radhakrisha Murthy and Krishnamacharyulu (1990)

Coefficients	Valeurs
c[1]	7.8722
c[2]	2.0258
c[3]	0.7739
c[4]	-0.0434
c[5]	-0.3131
c[6]	-0.2997
c[7]	0.0006
c[8]	0.0044
c[9]	0.0079
c[10]	0.008

Table 4: Values of separated anomalies obtained by Radhakrisha Murthy and Krishnamacharyulu (1990)

Stations	x(km)	y(km)	B(mGal)	A(mGal)	(mGal)
1	0.00	0.00	8.60	0.73	7.87
2	0.00	1.00	8.40	0.05	8.35
3	0.00	2.00	7.90	-0.39	8.29
4	0.00	3.00	7.30	-0.41	7.71
5	0.00	4.00	6.60	-0.09	6.69
6	0.00	5.00	5.90	0.65	5.25
7	1.00	0.00	9.60	0.01	9.59
8	1.00	1.00	9.40	-0.64	10.04
9	1.00	2.00	9.50	-0.44	9.94
10	1.00	3.00	9.20	-0.14	9.34
11	1.00	4.00	8.00	-0.30	8.30
12	1.00	5.00	6.70	-0.17	6.87
13	2.00	0.00	10.30	-0.43	10.73
14	2.00	1.00	10.60	-0.54	11.14
15	2.00	2.00	12.10	1.09	11.01
16	2.00	3.00	12.10	1.70	10.40
17	2.00	4.00	9.20	-0.15	9.35
18	2.00	5.00	7.60	-0.31	7.91
19	3.00	0.00	11.00	-0.34	11.34
20	3.00	1.00	11.70	-0.01	11.71
21	3.00	2.00	12.70	1.14	11.56
22	3.00	3.00	11.40	0.47	10.93
23	3.00	4.00	9.70	-0.17	9.87
24	3.00	5.00	8.00	-0.43	8.43
25	4.00	0.00	11.40	-0.07	11.47
26	4.00	1.00	11.74	-0.10	11.80
27	4.00	2.00	11.60	-0.02	11.62
28	4.00	3.00	10.40	-0.57	10.97
29	4.00	4.00	9.40	-0.50	9.90
30	4.00	5.00	8.40	-0.06	8.46
31	5.00	0.00	11.70	0.54	11.16
32	5.00	1.00	11.40	-0.06	11.46
33	5.00	2.00	10.80	-0.45	11.25
34	5.00	3.00	10.30	-0.29	10.59
35	5.00	4.00	9.50	-0.01	9.51
36	5.00	5.00	8.80	0.73	8.07

DISCUSSION

There are many programs for fitting mathematical surfaces applied to the separation of gravity or magnetic anomalies. The main problem in using some of those programs is the limited number of anomaly data accepted. For local studies, the program presented in this paper can bring solutions to these problems and can permit a fast exploitation of results in particular using the Winsurf mapping program through the data output file created. The comparison of the two results shows that the present program permits to have almost the same results. The small difference observed in the two results can be considered as improvement of published results for a better accuracy.

CONCLUSION

The implementation of the program presented in this paper has permitted to solve the problem of anomaly separation before any interpretation for a local study. The programming language and its structure make easier the understanding and the using of the program. It is a guide for users who want to extend the order of the analytic regional beyond 3 and for a wide study area for the best exploitation of the program.

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APPENDICE

```
program separation;
uses  crt,dos,printer;
const n1=1000000;p3=10;
var i,j,k,m1,m,n,o,v: integer;  b3,b33,b333,m2:real;X,Y,B,R3,R31,R32,A3:
array[1..1200]of real;
   D1,D:array[1..p3,1..p3]of real; e1,s3,E,C3: array[1..p3]of real;
fichier1,fichier2:text;
procedure openfile(var fichier1:text;nomf:string);
```

```
begin
assign(fichier1,nomf); rewrite(fichier1);
end;
Begin
    openfile(fichier1,’c:\tp7\gm-sep.dat’); writeln;
writeln(‘   Entrer n le nombre de points de mesure que vous avez!’);
readln(n) ;writeln;
                for i:=1 to n do
                begin
writeln;writeln(‘Entrer X[‘,i,’]’);readln(X[i]);writeln(‘Entrer
y[‘,i,’]’);readln(Y[i]); writeln(‘Entrer B[‘,i,’]’);readln(B[i]);
end; writeln;
Repeat
for i:=1 to n do
begin
writeln(‘X[‘,i,’]=’,x[i]);writeln(‘y[‘,i,’]=’,y[i]);writeln(‘B[‘,i,’]=’,B[i]);
writeln; writeln(‘   Si les valeurs sont bonnes appuyer sur 1 sinon sur
0’); writeln; readln(o);
if o=0 then
begin
writeln(‘Entrer X[‘,i,’]’);readln(X[i]);writeln(‘Entrer y[‘,i,’]’);readln(y[i]);
writeln(‘Entrer B[‘,i,’]’);readln(B[i]);
end; end; writeln; writeln(‘   Controler les valeurs introduites’);writeln;
                for i:=1 to n do
                begin
writeln(‘X[‘,i,’]=’,X[i]); writeln(‘Y[‘,i,’]=’,Y[i]); writeln(‘B[‘,i,’]=’,B[i]);
writeln; writeln(‘       Taper sur Entrer pour continuer’);readln; end;
writeln(‘                Si les valeurs sont toutes bonnes, appuyer sur 1
sinon 0’); writeln; readln(v); until v=1; writeln;
for i:= 1 to n do
begin
D[1,1]:=D[1,1]+1;D[1,2]:=D[1,2]+x[i];D[1,3]:=D[1,3]+y[i];
D[1,4]:=D[1,4]+x[i]*y[i];D[1,5]:=D[1,5]+x[i]*x[i];
D[1,6]:=D[1,6]+y[i]*y[i];D[1,7]:=D[1,7]+x[i]*x[i]*y[i];
D[1,8]:=D[1,8]+x[i]*y[i]*y[i];D[1,9]:=D[1,9]+x[i]*x[i]*x[i];
D[1,10]:=D[1,10]+y[i]*y[i]*y[i];D[2,1]:=D[1,2];D[2,2]:=D[2,2]+x[i]*x[i];
D[2,3]:=D[2,3]+x[i]*y[i];
D[2,4]:=D[2,4]+x[i]*x[i]*y[i];D[2,5]:=D[2,5]+x[i]*x[i]*x[i];
[2,6]:=D[2,6]+x[i]*y[i]*y[i];D[2,7]:=D[2,7]+x[i]*x[i]*x[i]*y[i];
D[2,8]:=D[2,8]+x[i]*x[i]*y[i]*y[i];D[2,9]:=D[2,9]+x[i]*x[i]*x[i]*x[i];
D[2,10]:=D[2,10]+x[i]*y[i]*y[i]*y[i];D[3,1]:=D[1,3];
D[3,2]:=D[2,3];D[3,3]:=D[3,3]+y[i]*y[i];D[3,4]:=D[3,4]+x[i]*y[i]*y[i];
D[3,5]:=D[3,5]+x[i]*y[i]*x[i];D[3,6]:=D[3,6]+y[i]*y[i]*y[i];
D[3,7]:=D[3,7]+x[i]*x[i]*y[i]*y[i];D[3,8]:=D[3,8]+x[i]*y[i]*y[i]*y[i];
D[3,9]:=D[3,9]+x[i]*x[i]*x[i]*y[i];D[3,10]:=D[3,10]+y[i]*y[i]*y[i]*y[i];
D[4,1]:=D[1,4];D[4,2]:=D[2,4];D[4,3]:=D[3,4];D[4,4]:=D[4,4]+x[i]*y[i]*x[i]*y[i];
D[4,5]:=D[4,5]+x[i]*x[i]*x[i]*y[i];D[4,6]:=D[4,6]+x[i]*y[i]*y[i]*y[i];
D[4,7]:=D[4,7]+x[i]*x[i]*x[i]*y[i]*y[i];D[4,8]:=D[4,8]+x[i]*x[i]*y[i]*y[i]*y[i];
D[4,9]:=D[4,9]+x[i]*x[i]*x[i]*x[i]*y[i];
D[4,10]:=D[4,10]+x[i]*y[i]*y[i]*y[i]*y[i];D[5,1]:=D[1,5];D[5,2]:=D[2,5];
D[5,3]:=D[3,5];D[5,4]:=D[4,5];D[5,5]:=D[5,5]+x[i]*x[i]*x[i]*x[i];
D[5,6]:=D[5,6]+x[i]*y[i]*x[i]*y[i];D[5,7]:=D[5,7]+x[i]*x[i]*x[i]*x[i]*y[i];
D[5,8]:=D[5,8]+x[i]*x[i]*x[i]*y[i]*y[i];D[5,9]:=D[5,9]+x[i]*x[i]*x[i]*x[i]*x[i];
D[5,10]:=D[5,10]+x[i]*x[i]*y[i]*y[i]*y[i];D[6,1]:=D[1,6];D[6,2]:=D[2,6];
D[6,3]:=D[3,6];D[6,4]:=D[4,6];D[6,5]:=D[5,6];D[6,6]:=D[6,6]+y[i]*y[i]*y[i]*y[i];
D[6,7]:=D[6,7]+x[i]*x[i]*y[i]*y[i]*y[i];D[6,8]:=D[6,8]+x[i]*y[i]*y[i]*y[i]*y[i];
D[6,9]:=D[6,9]+x[i]*x[i]*x[i]*y[i]*y[i];D[6,10]:=D[6,10]+y[i]*y[i]*y[i]*y[i]*y[i];
D[7,1]:=D[1,7];D[7,2]:=D[2,7];D[7,3]:=D[3,7];D[7,4]:=D[4,7];D[7,5]:=D[5,7];
D[7,6]:=D[6,7];D[7,7]:=D[7,7]+x[i]*x[i]*x[i]*x[i]*y[i]*y[i];
D[7,8]:=D[7,8]+x[i]*x[i]*x[i]*y[i]*y[i]*y[i];
D[7,9]:=D[7,9]+x[i]*x[i]*x[i]*x[i]*x[i]*y[i];
D[7,10]:=D[7,10]+x[i]*x[i]*y[i]*y[i]*y[i]*y[i];D[8,1]:=D[1,8];D[8,2]:=D[2,8];
D[8,3]:=D[3,8];D[8,4]:=D[4,8];D[8,5]:=D[5,8];D[8,6]:=D[6,8];D[8,7]:=D[7,8];
D[8,8]:=D[8,8]+x[i]*x[i]*y[i]*y[i]*y[i]*y[i];
D[8,9]:=D[8,9]+x[i]*x[i]*x[i]*x[i]*y[i]*y[i];
D[8,10]:=D[8,10]+x[i]*y[i]*y[i]*y[i]*y[i]*y[i];D[9,1]:=D[1,9];D[9,2]:=D[2,9];
D[9,3]:=D[3,9];D[9,4]:=D[4,9];D[9,5]:=D[5,9];D[9,6]:=D[6,9];D[9,7]:=D[7,9];
D[9,8]:=D[8,9];D[9,9]:=D[9,9]+x[i]*x[i]*x[i]*x[i]*x[i]*x[i];
D[9,10]:=D[9,10]+x[i]*x[i]*x[i]*y[i]*y[i]*y[i];D[10,1]:=D[1,10];
D[10,2]:=D[2,10];D[10,3]:=D[3,10];D[10,4]:=D[4,10];D[10,5]:=D[5,10];
D[10,6]:=D[6,10];D[10,7]:=D[7,10];D[10,8]:=D[8,10];D[10,9]:=D[9,10];
D[10,10]:=D[10,10]+y[i]*y[i]*y[i]*y[i]*y[i]*y[i];
E[1]:=E[1]+B[i];E[2]:=E[2]+B[i]*x[i];E[3]:=E[3]+B[i]*y[i];
E[4]:=E[4]+B[i]*x[i]*y[i];E[5]:=E[5]+B[i]*x[i]*x[i];E[6]:=E[6]+B[i]*y[i]*y[i];
E[7]:=E[7]+B[i]*x[i]*x[i]*y[i];E[8]:=E[8]+B[i]*x[i]*y[i]*y[i];
E[9]:=E[9]+B[i]*x[i]*x[i]*x[i];E[10]:=E[10]+B[i]*y[i]*y[i]*y[i];
      end;
repeat
writeln(‘     Entrer  m le degré du polynôme’);
readln(m); m2:=(m+1)*(m+2)/2; m1:=m;  m:=Trunc(m2);
for i:=1 to m do
begin
for j:=1 to m do
begin
d1[i,j]:=d[i,j]; end; e1[i]:=e[i];c3[i]:=0; end;
for k:=1 to (m-1) do
begin
   for i:=(k+1) to m do
 begin
if abs(d1[i,k])>abs(d1[k,k]) then
  begin
for j:=k to m do
    begin
s3[j]:=d1[k,j]; d1[k,j]:=d1[i,j]; d1[i,j]:=s3[j]; end; b3:=e1[k]; e1[k]:=e1[i];
e1[i]:=b3; end; end;
for i:=(k+1) to m do
 begin
b33:=e1[i]-(d1[i,k]*e1[k])/d1[k,k];e1[i]:=b33;
for j:=m downto k do
     begin
b333:=d1[i,j]-(d1[i,k]*d1[k,j])/d1[k,k];d1[i,j]:=b333; end; end; end;
c3[m]:=e1[m]/d1[m,m];
for k:=(m-1) downto 1 do
begin
for j:=k+1 to m do
begin
c3[k]:=c3[k]+d1[k,j]*c3[j]; end; c3[k]:=(e1[k]-c3[k])/d1[k,k]; end;
for i:=1 to m do
begin
writeln(fichier1,’c[‘,i,’]=’,c3[i]) ; end;
for i:=m+1 to p3 do
begin
c3[i]:=0; end; writeln(‘    Calcul de la résiduelle A et de la régionale R’);
writeln(‘     Pour le cas d une régionale de degré m=’,m1); writeln;
writeln(‘      Taper sur Entrer pour continuer’); readln;
              for i:=1 to n do
              begin
R31[i]:=C3[1]+C3[2]*x[i]+C3[3]*y[i]+C3[4]*x[i]*y[i]+C3[5]*x[i]*x[i];
R32[i]:=C3[6]*y[i]*y[i]+C3[7]*x[i]*x[i]*y[i]+C3[8]*x[i]*y[i]*y[i]+C3[9]*x[i]*x[i]*x[i]+C3[10]*y[i]*y[i]*y[i];
R3[i]:=R31[i]+R32[i]; A3[i]:=B[i]-R3[i];
writeln(‘A[‘,i,’]=’, A3[i]); writeln(‘R[‘,i,’]=’, R3[i]); writeln(‘B[‘,i,’]=’,
B[i]);
writeln(fichier1, i,’,’,x[i],’,’,y[i],’,’,B[i],’,’,A3[i],’,’,R3[i]); end;
writeln(fichier1,’Fin du calcul pour le cas d une régionale de degré
m=’,m1);
Until m1=3;
writeln(fichier1,’Fin du calcul’);
              end.
```