TRAVERSE NETWORK ADJUSTMENT PROGRAM

HAVOC

Horizontal **A**djustment by **V**ariation **O**f **C**oordinates

These notes describe the operation of a MATLAB[1] program *Havoc* that can be used to adjust traverse networks using the least squares method known as Variation of Coordinates. The theory relating to this topic (and a worked example) can be found in the paper *A Review of Least Squares Theory Applied to Traverse Adjustment*[2] that is attached for your information.

The MATLAB program *Havoc* consists of the following ten *m*-files:

decdeg.m	*deg2dms.m*	*ellipse.m*
Havoc.m	*HavocPlot.m*	*join.m*
readdata.m	*results.m*	*solve.m*
status.m		

Havoc.m is the "main" program that calls the other functions listed above in the sequence:

Havoc
- *readdata*
  - *decdeg*
- *status*
- *solve*
  - *join*
- *results*
  - *deg2dms*
  - *join*
- *HavocPlot*
  - *ellipse*

i.e., *Havoc* calls *readdata* (which calls *decdeg*) then *status* then *solve* (which calls *join*) then *results* (which calls *deg2dms* and *join*) then *HavocPlot* (which calls *ellipse*).

You should copy all the programs to their own directory before running *Havoc.m* from the MATLAB command window

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[1] MATLAB is an interactive, matrix-based system for scientific and engineering computation and visualisation. The name MATLAB is derived for MATrix LABoratory and is licensed by The MathWorks, Inc.

[2] Deakin, R.E., 1991, 'A review of least squares theory applied to traverse adjustment', *The Australian Surveyor,* Vol. 36, No. 3, September 1991, pp. 245-53 and Vol. 36, No. 4, December 1991, pp. 281-90

Program *Havoc* requires an ASCII[3] text data file that can be created in the MATLAB editor, *Microsoft* Notepad or *Microsoft* Word. The data file should be saved with a `.txt` extension, e.g., `mydata.txt`

The data file is in three parts, (i) coordinates of the fixed and floating stations, (ii) observations (directions followed by distances) and (iii) constraints. Comment lines, beginning with the % symbol can be included in the data file. The program will ignore these lines.

A line of data in the data file refers to either a station in the network (the first part of the data file), an observation (the second part of the data file) or a constraint (the last part of the data file). Each line of data can be considered as having five fields and each field must be separated by whitespace (or blanks). The first field of every line of data must contain a code that identifies the type of data that follows on the line. The codes are:

1 Fixed station
2 Floating station
3 Observed Direction
4 Observed Distance
5 Constrained Bearing
6 Constrained Distance
7 Constrained Angle

Subsequent fields on the line contain data depending on the code type

All stations in the network (and in the data file) must have a serial number (an integer) and no two stations can have the same number. Every observation (and constraint) in the network is defined by serial numbers of the stations involved in the observation (or constraint).

The following data file `Survad.txt` contains the data for the example traverse adjustment in Appendix B of *A Review of Least Squares Theory Applied to Traverse Adjustment.* Comments on the right-hand-side explain the layout of the data.

```
% Data file "SURVAD.TXT" for traverse adjustment program.
%
% Data is example in Appendix B of paper titled A REVIEW OF LEAST
% SQUARES THEORY APPLIED TO TRAVERSE ADJUSTMENT.
%
% Station Information
%
% Code  serial        East         North
    1     1           500.000      500.000          1        Note that in this section of the data
    2     2           724.36       417.20           1        file the 1st field is the code, the 2nd
    2     3           637.47       329.16           1        field is the serial number, the 3rd
    2     4           640.13       211.62           1        and 4th fields are coordinates and
    2     5           492.70       229.26           1        the 5th field is a "dummy" field
    2     6           500.46       379.85           1        containing the number 1
```

[3] ASCII is an acronym for American Standard Code for Information Interchange. ASCII codes represent alphabetic and numeric characters.

```
%
% Direction Observations
%
% Code    At     To        Direction (D.MMSS)     St.Dev.(secs)
    3      1      2         0.0000                   10
    3      1      6         69.3050                  10
    3      2      1         0.0000                   10
    3      2      4         272.0050                 10
    3      2      3         294.2200                 10
    3      3      2         0.0000                   10
    3      3      4         134.0455                 10
    3      3      6         245.4045                 10
    3      4      2         0.0000                   10
    3      4      5         254.3325                 10
    3      4      3         336.2555                 10
    3      5      4         0.0000                   10
    3      5      6         266.0740                 10
    3      6      5         0.0000                   10
    3      6      1         176.4915                 10
    3      6      3         287.2110                 10
%
% Distance Observations
%
% Code    At     To        Distance (metres)     St.Dev.(metres)
    4      1      2         239.150                  0.010
    4      1      6         120.140                  0.010
    4      3      2         123.760                  0.010
    4      3      4         117.570                  0.010
    4      3      6         146.085                  0.010
    4      4      2         222.190                  0.010
    4      5      4         148.420                  0.010
    4      5      6         150.760                  0.010
%
% Constrained Bearings
%
% Code    At     To        Bearing (D.MMSS)
    5      1      2         110.1520                 1
    5      4      5         276.4935                 1
%
% Constrained Distances
%
% Code    At     To        Distance (metres)
    6      3      6         146.050                  1
%
Constrained Angles
%
% Code    At     Left   Right    Angle (D.MMSS)
    7      6      3       5      72.3900
%
% End of Data.
```

Note that in this section of the data the 1st field contains the code for directions (3), the 2nd field holds the serial number of the station "at" the 3rd field the serial number of the station "to", the 4th field the observed direction (D.MMSS) and the 5th field holds the st. deviation of the observation (in seconds)

This section of the data is similar to the direction observations, the 1st field is the code for distances (4), followed by station serial numbers for "at" and "to", the observed distance and the 5th field is again the st. deviation (in metres)

This section of the data contains the constraints, bearings (code = 5), distances (code = 6) and angles (code = 7). For bearings and distances the 5th field is a dummy field containing 1

For constrained angles, the 2nd, 3rd 4th fields define the clockwise angle by station "at", "left" and "right" serial numbers. The 5th field contains angle (D.MMSS)

Program *Havoc* is run from the MATLAB command window by typing `Havoc` after the command prompt `">>"`. The program executes and the results are placed in an ASCII text file with the same path name as the data file but with the extension `".out"`. For the example in Appendix B of *A Review of Least Squares Theory Applied to Traverse Adjustment* the data file is `Survad.txt` and the results are contained in the file `Survad.out` The output file contains the adjusted coordinates of the floating stations and the adjusted observations (with residuals) as well as the estimate of the variance factor and the upper-triangular elements of the cofactor matrix (for precision estimation and computation of error ellipses). The program also displays a "Figure window" that shows a plot of the network with error ellipses drawn at the floating stations.
The output file for `Survad.txt` is shown below

Program HAVOC: Horizontal Adjustment by Variation Of Coordinates

This file is D:\Projects\Adjust\HAVOC\MatlabProgram\Survad.out
generated from D:\Projects\Adjust\HAVOC\MatlabProgram\Survad.txt

Fixed Stations:

Serial	East	North
1	500.000	500.000

Adjusted Stations:

Serial	East	North
2	724.356	417.206
3	637.455	329.152
4	640.114	211.607
5	492.713	229.253
6	500.479	379.827

Observed Directions:

station at	station to	observation deg min sec	st.dev sec	resid sec	orient const deg min sec	plane brg deg min sec	plane dist
1	2	0 0 0.00	10.00	-4.13	110 15 24.13	110 15 20.00	239.145
1	6	69 30 50.00	10.00	4.13		179 46 18.27	120.174
2	1	0 0 0.00	10.00	-13.49	290 15 33.49	290 15 20.00	239.145
2	4	272 0 50.00	10.00	27.54		202 16 51.02	222.188
2	3	294 22 0.00	10.00	-14.06		224 37 19.43	123.714
3	2	0 0 0.00	10.00	-1.60	44 37 21.03	44 37 19.43	123.714
3	4	134 4 55.00	10.00	-0.30		178 42 15.73	117.574
3	6	245 40 45.00	10.00	1.90		290 18 7.93	146.050
4	2	0 0 0.00	10.00	23.77	22 16 27.25	22 16 51.02	222.188
4	5	254 33 25.00	10.00	-17.25		276 49 35.00	148.453
4	3	336 25 55.00	10.00	-6.52		358 42 15.73	117.574
5	4	0 0 0.00	10.00	3.53	96 49 31.47	96 49 35.00	148.453
5	6	266 7 40.00	10.00	-3.53		2 57 7.93	150.774
6	5	0 0 0.00	10.00	4.89	182 57 3.04	182 57 7.93	150.774
6	1	176 49 15.00	10.00	0.22		359 46 18.27	120.174
6	3	287 21 10.00	10.00	-5.11		110 18 7.93	146.050

Observed Distances:

station at	station to	observation metres	st.dev metres	resid metres	plane brg deg min sec	plane dist
1	2	239.150	0.010	-0.005	110 15 20.00	239.145
1	6	120.140	0.010	0.034	179 46 18.27	120.174
3	2	123.760	0.010	-0.046	44 37 19.43	123.714
3	4	117.570	0.010	0.004	178 42 15.73	117.574
3	6	146.085	0.010	-0.035	290 18 7.93	146.050
4	2	222.190	0.010	-0.002	22 16 51.02	222.188
5	4	148.420	0.010	0.033	96 49 35.00	148.453
5	6	150.760	0.010	0.014	2 57 7.93	150.774

Constrained Bearings:

station at	station to	bearing deg	min	sec
1	2	110	15	20.00
4	5	276	49	35.00

Constrained Distances:

station at	station to	distance metres
3	6	146.050

Constrained Angles:

stations at	stations left	stations right	angle deg	min	sec
6	3	5	72	39	0.00

Standard Deviations and Standard Error Ellipse:

Serial	East	North	St. Devs E	St. Devs N	Standard Error Ellipse semi-major	semi-minor	bearing d	m	s
2	724.356	417.206	0.016	0.006	0.017	0.000	110	15	20
3	637.455	329.152	0.015	0.015	0.015	0.015	7	36	8
4	640.114	211.607	0.021	0.019	0.022	0.017	124	59	58
5	492.713	229.253	0.021	0.019	0.022	0.018	119	50	7
6	500.479	379.827	0.013	0.018	0.018	0.012	161	40	14

Adjusted Bearings and Distances:

station at	station to	plane bearing deg	min	sec	st.dev sec	plane distance m	st.dev m
1	2	110	15	20.00	0.00	239.145	0.017
1	6	179	46	18.27	22.56	120.174	0.018
2	1	290	15	20.00	0.00	239.145	0.017
2	4	202	16	51.02	19.53	222.188	0.018
2	3	224	37	19.43	21.25	123.714	0.016
3	2	44	37	19.43	21.25	123.714	0.016
3	4	178	42	15.73	21.28	117.574	0.016
3	6	290	18	7.93	17.27	146.050	0.000
4	2	22	16	51.02	19.53	222.188	0.018
4	5	276	49	35.00	0.00	148.453	0.013
4	3	358	42	15.73	21.28	117.574	0.016
5	4	96	49	35.00	0.00	148.453	0.013
5	6	2	57	7.93	17.27	150.774	0.017
6	5	182	57	7.93	17.27	150.774	0.017
6	1	359	46	18.27	22.56	120.174	0.018
6	3	110	18	7.93	17.27	146.050	0.000
1	2	110	15	20.00	0.00	239.145	0.017
1	6	179	46	18.27	22.56	120.174	0.018
3	2	44	37	19.43	21.25	123.714	0.016
3	4	178	42	15.73	21.28	117.574	0.016
3	6	290	18	7.93	17.27	146.050	0.000
4	2	22	16	51.02	19.53	222.188	0.018
5	4	96	49	35.00	0.00	148.453	0.013
5	6	2	57	7.93	17.27	150.774	0.017

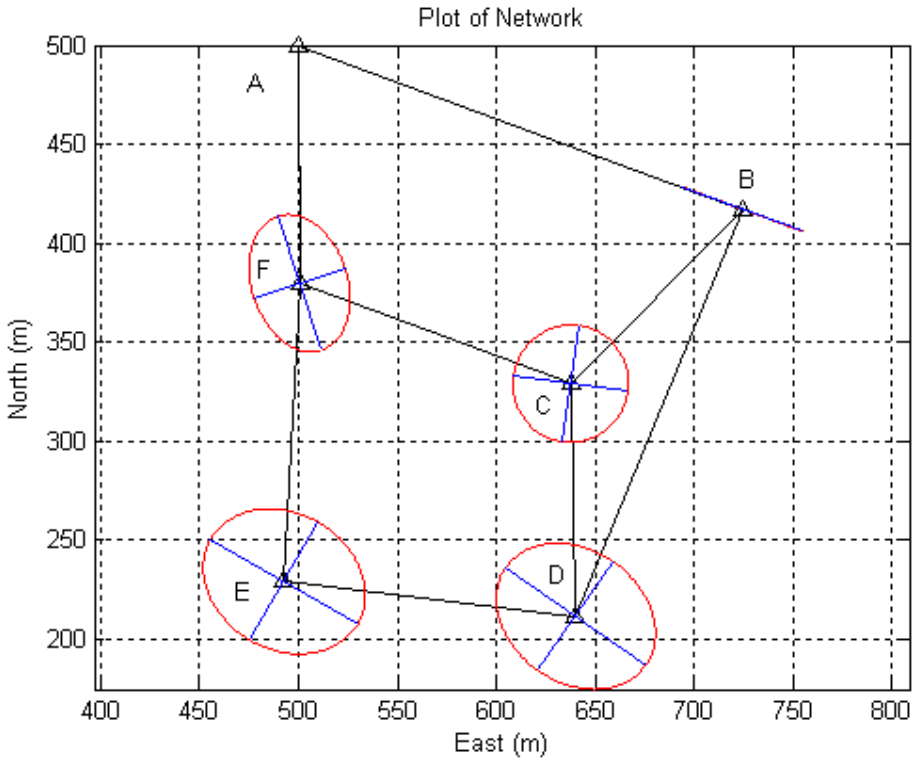
Variance Factor = 6.6353e+000

```
Cofactor matrix Qxx (upper triangular portion)
Units of metre squared, printed in same order as adjusted stations.
The * symbol indicates new row of cofactor matrix beginning at
diagonal element, east variance followed by covariances
then north variance followed by covariances.
*  3.6381e-005 -1.3426e-005  1.8552e-005 -1.3627e-005  1.8367e-005 -1.4420e-005
   2.1449e-005 -1.4789e-005  1.7156e-005 -1.7400e-005
*  4.9545e-006 -6.8462e-006  5.0287e-006 -6.7780e-006  5.3213e-006 -7.9153e-006
   5.4575e-006 -6.3311e-006  6.4210e-006
*  3.3970e-005  1.6930e-007  3.8229e-005 -7.2631e-006  4.4761e-005 -8.0451e-006
   2.8677e-005 -1.4138e-005
*  3.5216e-005 -3.9278e-006  2.5148e-005  2.3953e-006  2.4391e-005 -1.1449e-006
   3.1664e-005
*  6.4783e-005 -1.4217e-005  5.3712e-005 -1.2892e-005  3.0702e-005 -2.4272e-005
*  5.4433e-005 -9.7877e-006  5.3903e-005 -5.3716e-006  3.0261e-005
*  6.7042e-005 -1.1383e-005  3.3908e-005 -2.6938e-005
*  5.3723e-005 -5.7554e-006  3.0580e-005
*  2.6095e-005 -8.1228e-006
*  4.7923e-005


Adjustment Data:

 1 fixed stations
 5 floating stations
16 observed directions
 8 observed distances
 2 constrained bearings
 1 constrained distances
 1 constrained angles
 6 orientation constants

degrees of freedom = observations
                   - unknowns
                   + constraints
                   = 12
 2 iterations required for solution
```


Plot of Network
A
B
C
D
E
F
North (m)
East (m)
500
450
400
350
300
250
200
400
450
500
550
600
650
700
750
800