DEVELOPMENT OF A SOFTWARE SYSTEM FOR LEAST SQUARES ESTIMATION, DEFORMATION DETECTION AND VISUALIZATION ANALYSIS

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Abstract

The measurement techniques for deformation detection usually employed by surveyors are based on the geodetic approach (such as total station and GPS). The data processing is usually consists of three separate modules: least squares estimation, deformation detection and graphical presentation. This paper describes a software system for 3-D deformation detection via geodetic methods, called GPSAD2000, currently being developed at CIMES. The main components of GPSAD2000 are: least squares estimation (LSE) of GPS baseline vectors, 3-D deformation detection (via congruency testing) and graphical visualization. All these components are integrated in one environment using Visual Basic. GPSAD2000 runs under Windows operating system, is user friendly and has many on-screen facilities for presenting the results of deformation detection, both numerically and graphically. For graphic presentation, output from GPSAD2000 may be exported to formats such as *.dxf, *.jpg and *.bmp. Test results with known data are also included.

1. Introduction

The measurement techniques for deformation detection usually employed by surveyors are based on the geodetic method (using total stations, precise levels, Global Positioning System (GPS), or combinations). Detection of deformation via geodetic method requires rigorous data processing, typically via two step analysis. The data processing is usually consists of three separate modules: least squares estimation (LSE) of each epoch, deformation detection between any two epochs and graphical presentation of the results. To date, several softwares were developed for such processing (Chen, 1983; Milev and Gruendig, 1994; Halim, 1995; Halim and Heng, 1997; Crespi and Riguzzi, 1998; Halim and Cham, 1998; Halim and Ranjit, 1998).

A windows-based software system for 3-D deformation detection via geodetic methods, called GPSAD2000, is currently being developed at CIMES. The main components of GPSAD2000 are: least squares estimation (LSE) or adjustment of GPS baseline vectors, 3-D deformation detection (via congruency testing) and graphical visualization. All these components are integrated in one environment using Visual Basic.

This paper describes the main features of GPSAD2000 and highlights the test results of GPSAD2000 using a known data.

2. Methods

GPSAD2000 is a windows-based software system specially developed for GPS baseline adjustment via LSE, deformation detection and visualization analysis. In GPSAD2000, the module of LSE processing adopted the concept of observation equation (Halim, 1995).

GPSAD2000 employs 3 types of LSE solutions, based on the selected datum, i.e. minimum constraint, minimum trace (free network) and partial minimum trace. For the deformation detection module, GPSAD2000 uses the method of congruency testing, S-transformation and single point test. Finally, a module for graphical visualization was developed for presenting the results of LSE and deformation detection. Figure 1 and 2 show the flow chart and main menu for GPSAD2000.

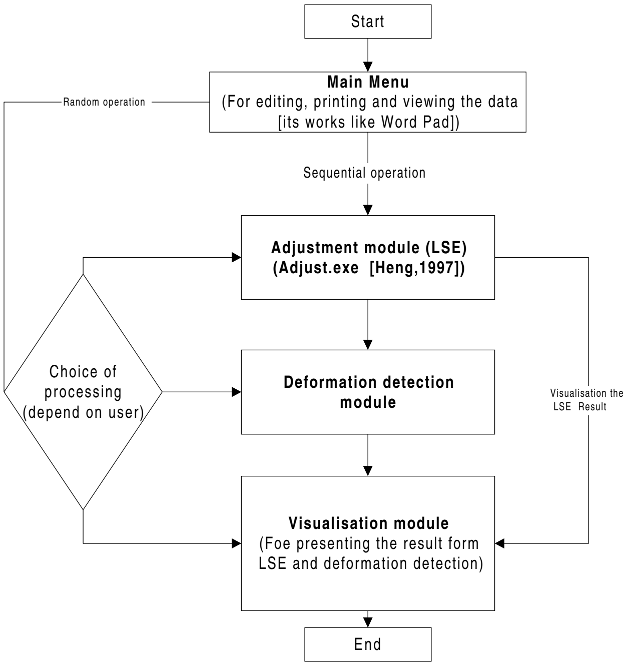

Figure 1. Flowchart for GPSAD2000

3. Adjustment module

Figure 3 shows the user interface for the LSE (adjustment) module within GPSAD2000. The LSE module offers 3 types of solutions (i.e. minimum constraint, free network and partial minimum trace), 2 modes of observations (correlated or uncorrelated) and facility for input/output files handling (similar to other windows applications). Users may select the types of adjustment and observations, and input the value of a priori variance factor (usually 1) for the LSE analysis.

The default output/answer files for this module are Deform1.def (deformation detection file), Summary1.lse (summary file) and Plotting1.plt (plotting file). Users may also save to different file's name, by simply clicking the **Save As** button. After the LSE analysis, the user may just click the **Graphical Analysis**'s button to view the graphical results such as error ellipse, network etc (Figure 3).

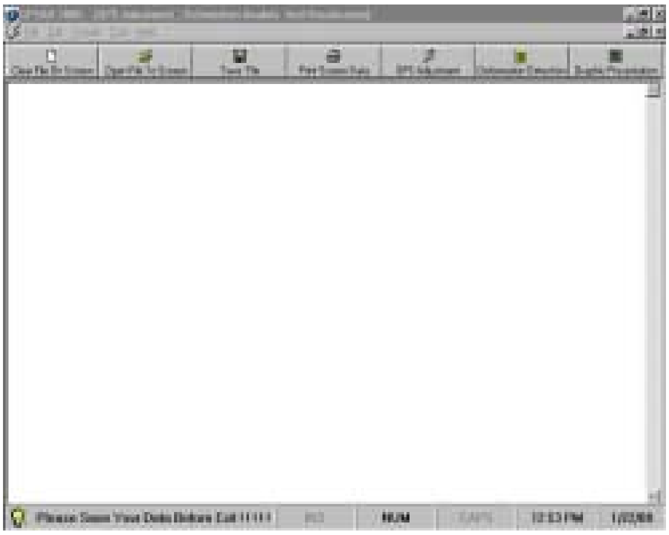

Figure 2. GPSAD2000: main menu

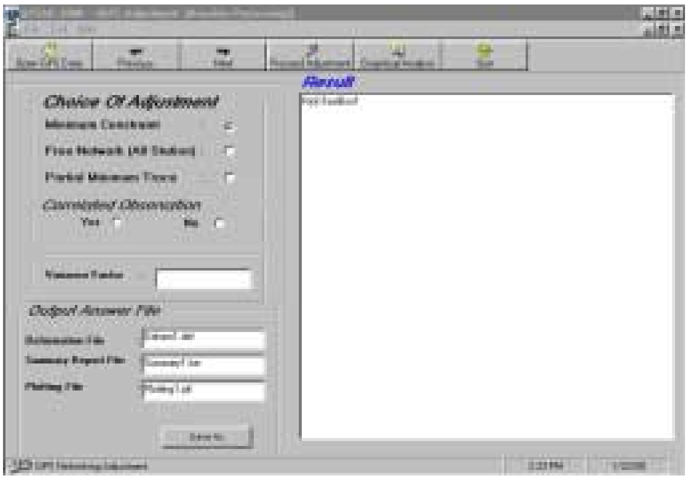

Figure 3. Adjustment module

4. Deformation detection module

Figure 4 illustrates the main user interface for the deformation detection module in GPSAD2000. The main properties of the module are (Halim, 1995): geometrical method, 2-epoch analysis via congruency testing, an absolute (reference) monitoring network, static model, coordinate differencing and no correlation between epochs. Coordinate differencing is used commonly, due to its flexibility and ability to handle different observational schemes at different epochs.

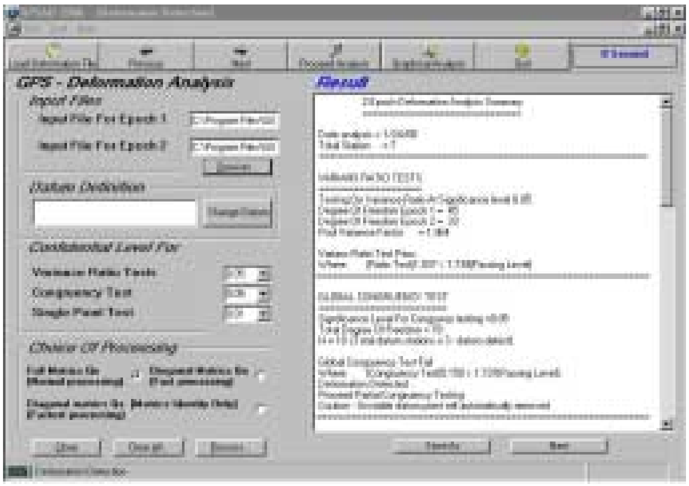

Figure 4. Deformation detection module

As shown in Figure 4, two input files are required (one from each epoch). User may freely choose the significance level for variance ratio, congruency and single point tests (typical values of 0.05, 0.05 and 0.01 respectively). It is also possible to change the datum definition just by typing the required datum points (must not less than 2 stations). Moreover, this module also provided the facility to speed up the analysis via choice of processing mode for covariance matrix Qx (full matrix, sub-diagonal or full-diagonal). After the deformation analysis, the user may click the **Graphical Analysis**'s button to view the graphical results such as error ellipse, network, displacement vector, station numbers etc.

5. Visualization module

GPSAD2000 runs under Windows operating system, is user friendly and has many on-screen facilities for presenting the results. The basic user interface for the visualization module is shown in Figure 5. This module is specially designed for the graphic presentation (in XY, YZ and XZ axes) of the results from LSE and deformation detection.

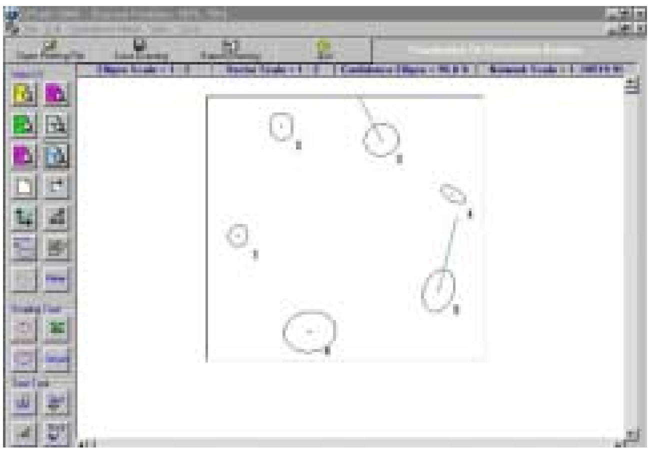

Figure 5. Visualization module

The graphics shown in this module include error ellipses, displacement vectors, networks, station numbers, network scales, the scales of displacement vectors and error ellipses, as well as the viewing axes.

The visualization module also offers a variety of toolbar menu (i.e. main toolbar, general graphic toolbar, toolbar for changing scale, and toolbar to modify and enter new text). The toolbar simplifies the graphical analysis as user only need to click the appropriate toolbar (Figure 5). For data exchange, the graphics can be exported to other formats, such as *.dxf, *.jpg and *.bmp. In addition, the visualization module also incorporated the Geographical Information System (GIS) concept, which enables the user to query the information for the particular station. The user simply moves the mouse cursor to the selected station and double clicks it. The relevant information for the selected station will be displayed (Figure 6).

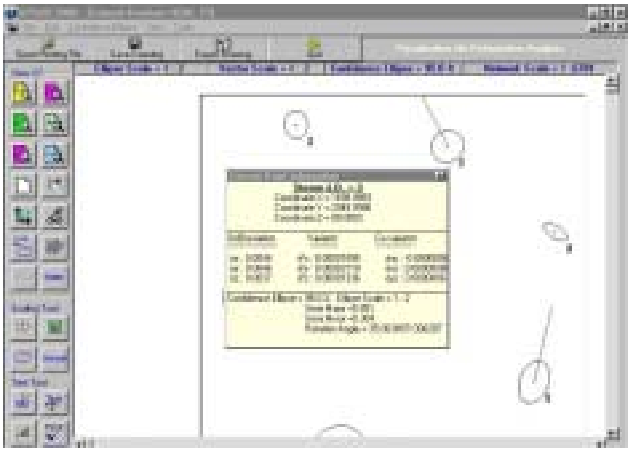

Figure 6. Information of the selected station

6. Test results

Several modules of the program system GPSAD2000 have been described in the previous sections. A known 2 epochs data sets from a GPS network with 7 stations (Crespi and Riguzzi, 1998) has been used to test the performance of GPSAD2000. For verification, results were compared with NETGPS.EXE and DENETGPS.EXE (Crespi and Riguzzi, 1998).

Table 1 shows the LSE results obtained from GPSAD2000 (LSE module) and NETGPS.EXE. The results are very close, with no significant differences. The deformation detection results (Table 2) obtained from both GPSAD2000 and DENETGPS.EXE conform stations 2 and 4 as unstable. Figure 7 shows the results for visualization analysis. All the results show that all the functions in GPSAD2000 work well.

7. Conclusions

A user friendly windows-based software system for 3-D deformation detection via geodetic methods, called GPSAD2000, has been described. GPSAD2000 offers many on-screen facilities, and comprises of three main modules: least squares estimation (LSE) of GPS baseline vectors, 3-D deformation detection (via congruency testing) and graphical visualization. The test results show the suitability of the software system for practical applications.

		GPSAD2000 ‘s Result			NETGPS.EXE ‘s result		
STN	Id	X	y	Z	x	Y	z
1		4565537.6534	1266701.6867	4255762.5381	4565537.6530	1266701.6870	4255762.5380
2		4761340.1655	1419704.9456	3986901.6445	4761340.1660	1419704.9460	3986901.6450
3		4621781.1958	1705359.9327	4037659.0318	4621781.1960	1705359.9330	4037659.0320
4		4700914.9833	1817828.3796	3895980.8469	4700914.9820	1817828.3800	3895980.8480
5		4652812.4835	1757512.5702	3979543.4007	4652812.4840	1757512.5700	3979543.4000
6		4636898.4509	1547667.2874	4083410.8370	4636898.4510	1547667.2870	4083410.8370
7	Fix	4641949.8030	1393045.1790	4133287.2390	4641949.8030	1393045.1790	4133287.2390

Table 1. The LSE results

	DENETGPS.EXE ‘s result			GPSAD2000 ‘s result		
St	Dis. Vector	Fcom	Info	Dis. Vector	fcom	info
1	0.065	1.720	Stable[1]	0.0719	2.18	stable [1]
2	**0.251**	**12.130**	**Moved[0]**	**0.255**	**11.35**	**moved [0]**
3	0.062	0.980	Stable[1]	0.0531	0.73	stable [1]
4	**0.134**	**5.300**	**Moved[0]**	**0.1301**	**4.38**	**moved [0]**
5	0.077	2.700	Stable[1]	0.0711	2.28	stable [1]
6	0.030	0.360	Stable[1]	0.039	0.56	stable [1]
7	0.037	2.060	Stable[1]	0.0459	2.1	stable [0]

Dis. Vector = Displacement vector
Fcom = Critical value from Fisher distribution
Info = Status of Station

Table 2. The Deformation Detection Results

Figure 7. The Visualization results

Reference

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