Integrating GPS and Conventional Survey Observations Using GNU Gama Least Square Adjustment Program

The use of autonomous GPS positioning for geo-referencing certain legal surveys in BC has been permitted under regulation since the year 2000. Derived coordinates must be noted at one point on the survey plan. The estimated horizontal accuracy is not stated and the following notation is appended to the plan "Coordinates are derived by autonomous GPS methods."

Typically, a land surveyor would initially validate a particular GPS receiver by comparing derived coordinates to MASCOT published coordinates of control survey monuments prior to using it for geo-referencing a legal survey. Ideally, the validation would be made under various observation conditions in order to obtain a good perspective of the performance and a feel for the expected positioning accuracy that may be attained.

In order to provide some measure of reliability in autonomous geo-referencing a legal survey plan, I assume that land surveyors are deriving averaged autonomous positions for two or more points within the legal survey where possible. This allows the autonomous GPS join to be compared to the same join from the conventional survey observations. The joins should compare within the expected accuracy otherwise additional observations should be made.

The land surveyor must then choose one of the derived autonomous positions to show on the survey plan. It seems prudent that the surveyor would select one of the points that showed the smallest discrepancy in the inverse/join comparison.

This article explores the use of Gama least square program for assessing the accuracy and reliability of integrating autonomous or CDGPS (Canada Wide Differential GPS) derived coordinates with legal or resource grade directions and distance observations.

What is GNU Gama?

GNU (Free General Public License) Gama is a program for performing a least square adjustment of 1D, 2D and 3D survey observations. The project was initiated by Jan Pytel and Ales Cepek at the Department of Mapping and Cartography, Faculty of Civil Engineering, Czech Technical University in Prague in 1998. The program name Gama is derived as an acronym from Geodesy and Mapping. Gama has been presented at FIG conferences and received status of GNU license software in 2001. The accompanying user documentation is very well presented.

Gama adjusts observed coordinates, distances, angles/directions, height differences and 3D vectors in a local coordinate system. The observation data is formatted as an XML (Extensible Markup Language) input file. This makes it easy to read and edit the data. Gama is run simply as a command line program or via the companion GUI Rocinante (written by Jan Pytel) which is very well structured and easy to use.

Gama/Rocinante are excellent programs for land surveyors to adjust and assess their conventional legal survey and GPS observations. For example, as a new user of Gama I joined the user digest and posed a question to the list asking what would be the best way to integrate conventional directions/distances and autonomous GPS observations. Ales Cepek replied very quickly and suggested a "classical free network adjustment". Ales actually amended the program and adjustment parameters to update the constrained coordinates with each iteration of the program to accommodate this type of adjustment. The less accurate autonomous GPS coordinates end up being adjusted to best fit and not distort the conventional survey network. As Ales said this "leads to minimal sum of coordinate standard deviations (rigorously: minimal trace/subtrace of cofactor matrix)".

As Gama was developed in the Czech Republic, angles/directions were formatted in the grad system. Ales recently made another change to the development version of Gama to provide an option of using degree input for angles and directions.

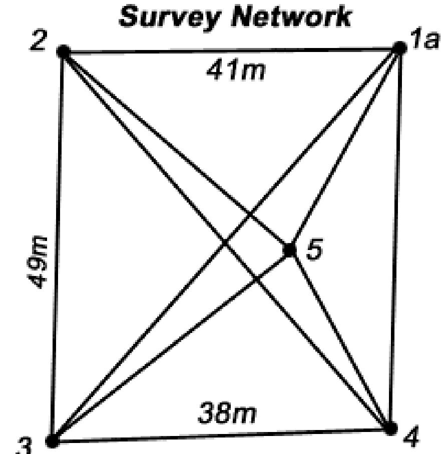
I am most grateful to Jan, Ales and the Gama project development team for making such a robust adjustment program accessible to the global survey community. Extraordinary efforts were made by this team to take that extra step in moving to GNU program status. I would also like to personally thank Ales for his help on my survey adjustment project testing.

The Test Network

The test network consists of five points (see diagram 1). Distances were derived by cloth tape and have an average accuracy of about five centimetres. Directions were derived at each node from a 360 degree field of view photographic image compiled from multiple overlapping photographs. The images were controlled and stitched together to produce an equirectangular image map which is conformal and therefore preserves angles. The average derived angular accuracy is about eight minutes. The survey network is strong - good level of redundancy. Although the conventional survey observations are not legal survey quality, a minimally constrained Gama least square adjustment yields an average standard deviation for the northings and eastings of three centimetres. This was verified by comparisons to true. Accurate coordinates of the photographic survey network points were derived via ties to nearby integrated survey area monuments.

Diagram 1

Survey Network



directions & distances measured from each node

Test 1 – Autonomous GPS and Conventional Observations

A recreational grade receiver was used to collect autonomous GPS positions for each node of the five point network. The receiver was set to average mode and data was collected continuously for about one minute at each point and stored as a waypoint. Universal Transverse Mercator coordinate mode was selected for recording purposes and the receiver displayed coordinates to the metre – no decimals.

In order to obtain a reasonable sample of data, coordinates were observed/recorded for each node of the network eleven times. Session 1, 1a & 1b were captured on April 9, 2004 at 7:30pm. Sessions 2, 2a & 2b were captured on April 10 – 2:00pm. Sessions 3, 3a & 3b were captured on April 10 – 5:30pm. Sessions 4 & 4a were captured on April 11 – 2:00pm. Although this provides a sample of sixty coordinates to assess the repeatability when observing at different times this is still a small sample data set. It should be noted that the observing conditions were unobstructed.

Table 1 shows the actual autonomous observed GPS coordinates (UTM truncated) and their differences compared to true. The mean of the absolute value of the differences between northing and eastings for all the points is 1.5m. Therefore the average positioning error vector is the square root of the sum of $(1.5^2 + 1.5^2) = 2.1$m. The range of the differences in northing and eastings was also quite small (from -3.6m to +4.6m).

Table 1

Autonomous GPS Raw Observation Data Coordinates

	point No. 1a		**point No. 2**		**point No. 3**		**point No. 4**		**point No. 5**	
Sess#	**North**	**East**	**North**	**East**	**North**	**East**	**North**	**East**	**North**	**East**
1	8178	6686	8154	6654	8117	6679	8129	6713	8144	6688
1a	8178	6687	8157	6652	8117	6680	8130	6714	8149	6686
1b	8178	6687	8156	6653	8115	6679	8129	6715	8147	6686
2	8180	6685	8157	6651	8117	6679	8130	6713	8148	6687
2a	8178	6685	8157	6650	8117	6677	8131	6712	8148	6684
2b	8180	6685	8159	6649	8117	6677	8130	6712	8148	6683
3	8179	6686	8160	6650	8119	6678	8131	6713	8147	6685
3a	8181	6686	8158	6651	8116	6678	8131	6713	8148	6686
3b	8179	6686	8157	6650	8116	6678	8132	6713	8147	6687
4	8179	6687	8159	6652	8118	6680	8133	6714	8147	6687
4a	8181	6686	8157	6653	8120	6679	8132	6713	8148	6686
Mean	8179.2	6686.0	8157.4	6651.4	8117.2	6678.5	8130.7	6713.2	8147.4	6685.9
True	8180.0	6685.0	8155.7	6651.3	8115.4	6678.8	8128.8	6713.8	8145.0	6686.6
Diff.	-0.8	1.0	1.7	0.1	1.8	-0.3	1.9	-0.6	2.4	-0.7

	Diff. N	Diff. E	Diff. N	Diff. E	Diff. N	Diff. E	Diff. N	Diff. E	Diff. N	Diff. E
1	-2.0	1.0	-1.7	2.7	1.6	0.2	0.2	-0.8	-1.0	1.4
1a	-2.0	2.0	1.3	0.7	1.6	1.2	1.2	0.2	4.0	-0.6
1b	-2.0	2.0	0.3	1.7	-0.4	0.2	0.2	1.2	2.0	-0.6
2	0.0	0.0	1.3	-0.3	1.6	0.2	1.2	-0.8	3.0	0.4
2a	-2.0	0.0	1.3	-1.3	1.6	-1.8	2.2	-1.8	3.0	-2.6

2b	0.0	0.0	3.3	-2.3	1.6	-1.8	1.2	-1.8	3.0	-3.6
3	-1.0	1.0	4.3	-1.3	3.6	-0.8	2.2	-0.8	2.0	-1.6
3a	1.0	1.0	2.3	-0.3	0.6	-0.8	2.2	-0.8	3.0	-0.6
3b	-1.0	1.0	1.3	-1.3	0.6	-0.8	3.2	-0.8	2.0	0.4
4	-1.0	2.0	3.3	0.7	2.6	1.2	4.2	0.2	2.0	0.4
4a	1.0	1.0	1.3	1.7	4.6	0.2	3.2	-0.8	3.0	-0.6
Avg	1.2	1.0	2.2	1.3	1.9	0.9	1.9	0.9	2.5	1.2

Mean of the absolute value of the differences between raw N&E and true N&E is 1.5m

A Gama least square adjustment was performed to integrate the autonomous GPS and distance/direction observations. Table 2 shows Gama adjusted coordinates and their differences compared to true. The accuracy parameter for the autonomous GPS was set to 10 metres. This enables the adjustment to leverage the strength of the distance/direction observations and therefore make the GPS coordinates fit the conventional survey shape. The Gama adjustment output makes it easy to see the corrections applied to the GPS coordinates and the conventional observations. Table 3 shows a list of the Gama adjusted coordinates having the least correction applied to northing and easting from each session (also highlighted in Table 2). The mean of the absolute value of all the differences between adjusted northings/eastings and true northings /eastings is 1.2 metres. This is twenty percent better than the raw GPS coordinates. Now if we select the coordinate from each adjustment session with the least correction applied to northings/eastings, then the average compared to true is thirteen percent better than the raw GPS coordinates.

Section E (Autonomous GPS Guidelines) – of the *BC Standards Specifications and Guidelines for Resource GPS Surveys* states that the "**instantaneous** horizontal position accuracies for *recreational GPS receivers varied between 7m and 12m (95%)*". The tests were done by Greg Keel of Parallel Geo-Services in 2000 and were conducted under similar ideal observing conditions. Positioning accuracy obtainable with a recreational grade receiver in autonomous averaging mode under excellent conditions would typically range from 4 to 10 metres at 95% confidence level. Readers may want to refer to the US Forest service web-site link at the end of this article to review a summary of accuracy testing for various recreational grade receivers under open, medium and heavy canopy conditions.

It should be noted that recreational grade receivers do not have the control settings that are available on higher end models and are therefore much less reliable in difficult observing conditions. The Autonomous GPS Guidelines detail the inherent integrity risks of using single point positioning. Deriving coordinates for multiple points within the local survey and using Gama least square adjustment program will greatly assist in detecting erroneous coordinates and therefore deliver a higher level of confidence in the positioning solution. This does not preclude the possibility that a similar bias inherent at each GPS point may mask a less accurate result than what is apparent from the adjustment, however, it should largely mitigate the risk.

Members may want to consider adding a statement to their plan that describes their autonomous

GPS positioning method used in a little more detail. This is not a rigorous statement of accuracy of the positioning results. It is intended to simply provide additional information to the end user. Something similar to the following statement may be appropriate: *"Coordinates for ____ points within the local survey network were derived by autonomous GPS methods. The coordinates were integrated with the conventional survey network by least square adjustment. The GPS point with the least correction to northings and eastings is shown on the plan. The average correction to the northings and eastings was ____ metres."*

Table 2

Gama Least Square Adjustment Results

Autonomous GPS Coordinates with Direction and Distance Observations

	point No. 1a		**point No. 2**		**point No. 3**		**point No. 4**		**point No. 5**	
Sess#	**North**	**East**	**North**	**East**	**North**	**East**	**North**	**East**	**North**	**East**
1	8181.0	6686.0	8158.4	6651.3	8118.4	6679.1	8132.1	6714.0	8148.1	6686.6
1a	8177.7	6686.8	8155.4	6651.9	8115.2	6679.6	8128.8	6714.6	8144.9	6687.2
1b	8179.5	6686.7	8157.3	6651.7	8117.0	6679.3	8130.5	6714.3	8146.6	6687.0
2	8178.3	6687.0	8156.2	6652.0	8115.8	6679.3	8129.2	6714.4	8145.4	6687.2
2a	8179.8	6685.6	8157.2	6650.9	8117.2	6678.7	8131.0	6713.6	8146.9	6686.2
2b	8179.5	6684.5	8157.3	6649.5	8117.0	6677.0	8130.5	6712.1	8146.6	6684.8
3	8180.1	6684.7	8158.5	6649.3	8117.7	6676.1	8130.6	6711.4	8147.2	6684.4
3a	8180.5	6686.0	8159.0	6650.6	8118.1	6677.2	8130.8	6712.6	8147.6	6685.6
3b	8180.1	6685.8	8158.0	6650.8	8117.6	6678.1	8131.0	6713.2	8147.2	6686.0
4	8179.6	6685.3	8157.0	6650.6	8117.0	6678.6	8130.8	6713.5	8146.7	6686.0
4a	8180.6	6686.7	8158.1	6651.9	8118.0	6679.6	8131.6	6714.6	8147.7	6687.2
Mean	8179.7	6685.9	8157.5	6651	8117.2	6678.4	8130.6	6713.5	8146.8	6686.2
TRUE	8180.0	6685.0	8155.7	6651.3	8115.4	6678.8	8128.8	6713.8	8145.0	6686.6
Diff.	-0.3	0.9	1.8	-0.3	1.8	-0.4	1.8	-0.3	1.8	-0.4
	Diff. N	Diff. E	Diff. N	Diff. E	Diff. N	Diff. E	Diff. N	Diff. E	Diff. N	Diff. E
1	1.0	1.0	2.7	0.0	3.0	0.3	3.3	0.2	3.1	0.0
1a	-2.3	1.8	-0.3	0.6	-0.2	0.8	0.0	0.8	-0.1	0.6
1b	-0.5	1.7	1.6	0.4	1.6	0.5	1.7	0.5	1.6	0.4

2	-1.7	2.0	0.5	0.7	0.4	0.5	0.4	0.6	0.4	0.6
2a	-0.2	0.6	1.5	-0.4	1.8	-0.1	2.2	-0.2	1.9	-0.4
2b	-0.5	-0.5	1.6	-1.8	1.6	-1.8	1.7	-1.7	1.6	-1.8
3	0.1	-0.3	2.8	-2.0	2.3	-2.7	1.8	-2.4	2.2	-2.2
3a	0.5	1.0	3.3	-0.7	2.7	-1.6	2.0	-1.2	2.6	-1.0
3b	0.1	0.8	2.3	-0.5	2.2	-0.7	2.2	-0.6	2.2	-0.6
4	-0.4	0.3	1.3	-0.7	1.6	-0.2	2	-0.3	1.7	-0.6
4a	0.6	1.7	2.4	0.6	2.6	0.8	2.8	0.8	2.7	0.6
Avg	0.7	1.1	1.9	0.9	0.8	0.9	1.8	0.8	1.8	0.8

Mean of the absolute value of the differences between adjusted N&E and true N&E is 1.2m

Table 3 - Autonomous GPS adjustment

Gama adjusted coordinates showing the point in each session with the least correction

Sess#	Adusted N	Adjusted E	Diff. N	Diff E	Point No.
1	8181.0	6686.0	1.0	1.0	1a
1a	8177.7	6686.8	-2.3	1.8	1a
1b	8157.3	6651.7	1.6	0.4	2
2	8178.3	6687.0	-1.7	2.0	1a
2a	8157.2	6650.9	1.5	-0.4	2
2b	8117.0	6677.0	1.6	-1.8	3
3	8180.1	6684.7	0.1	-0.3	1a
3a	8130.8	6712.6	2.0	-1.2	4
3b	8158.0	6650.8	2.3	-0.5	2
4	8157.0	6650.6	1.3	-0.7	2
4a	8118.0	6679.6	2.6	0.8	3
		Avg	**1.6**	**1.0**	

The mean of the absolute value of the differences of adjusted and true N/E and true N/E is 1.3m

CDGPS Test

A recreational grade receiver was ported to a CDGPS device to receive RTCM corrections and collect coordinates for each node of the network. The receiver was set to average mode (same as autonomous GPS test). CDGPS data was collected continuously for about one minute at each point and coordinates were stored as waypoints.

In order to obtain a reasonable sample of data, coordinates were observed/recorded for each node of the network ten times. Session 1 & 1a were captured on April 2, 2004 at 2:00pm. Sessions 2, 2a & 2b were captured on April 2– 5:00pm. Sessions 3, 3a & 3b were captured on April 3 – 10:00am. Sessions 4 & 4a were captured on April 3 – 5:15pm. This provides a sample of fifty coordinates to assess the repeatability when observing at different times. Again, observing conditions were unobstructed. I'd like to thank Brad Hlasny and Vern Vogt of Base Mapping and Geomatics Services Branch for letting me borrow the CDGPS unit for testing.

Table 4 shows the actual recorded CDGPS coordinates and their differences compared to true. The mean of the absolute value of the differences between northings and eastings for all the points is 1.4m. Therefore the positioning error is the square root of the sum of $(1.4^2 + 1.4^2)$ = 2.0m. The range of the differences in northing and eastings was also quite small (from -4.7m to +5.0). It should be noted that the CDGPS positioning has a higher level of integrity than autonomous positioning with a recreational grade receiver. The system also provides redundancy at the data collection, transmission and processing stages. CDGPS also has an added advantage that the data signal is structured to perform well in difficult or foliated conditions.

A Gama least square adjustment was performed to integrate the CDGPS and distance/direction observations. Again, the accuracy parameter for the GPS was set to 10 metres. Table 5 shows the Gama adjustment and differences in northings/eastings. Table 6 shows a list of the Gama adjusted coordinates having the least correction applied to northing and easting from each session (also highlighted in Table 5). The mean of the absolute value of all the differences between adjusted northings/eastings and true northings/eastings is 1.2 metres. This is twenty percent better than the raw CDGPS coordinates. Now if we select the coordinate from each adjustment session with the least correction applied to northings/eastings, then the average compared to true is forty percent better than the raw GPS coordinates.

Table 4

CDGPS Raw Data Coordinates

	point No. 1a		**point No. 2**		**point No. 3**		**point No. 4**		**point No. 5**	
Sess#	**North**	**East**	**North**	**East**	**North**	**East**	**North**	**East**	**North**	**East**
1	8178	6686	8156	6656	8116	6679	8130	6714	8147	6686
1a	8176	6688	8157	6651	8116	6680	8129	6713	8145	6687
2			8153	6652	8117	6680	8132	6715	8150	6686
2a	8181	6687	8158	6652	8117	6680	8130	6716	8145	6686
2b	8179	6688	8158	6653	8118	6680	8130	6714	8146	6687
3	8178	6687	8157	6649	8118	6678	8129	6713	8146	6687

3a	8178	6686	8157	6653	8117	6679	8129	6713	8145	6686
3b	8180	6686	8156	6652	8117	6679	8130	6715	8146	6688
4	8177	6684	8157	6652	8119	6677	8130	6713	8146	6685
4a	8178	6684	8151	6649	8114	6678	8128	6713	8141	6686
Mean	8178.3	6686.2	8156.0	6651.9	8116.9	6679	8129.7	6713.9	8145.7	6686.4
TRUE	8180.0	6685.0	8155.7	6651.3	8115.4	6678.8	8128.8	6713.8	8145.0	6686.6
Diff.	-1.7	1.2	0.3	0.6	1.5	0.2	0.9	0.1	0.7	-0.2

	Diff. N	Diff. E	Diff. N	Diff. E	Diff. N	Diff. E	Diff. N	Diff. E	Diff. N	Diff. E
1	-2.0	1.0	0.3	4.7	0.6	0.2	1.2	0.2	2.0	-0.6
1a	-4.0	3.0	1.3	-0.3	0.6	1.2	0.2	-0.8	0.0	0.4
2			-2.7	0.7	1.6	1.2	3.2	1.2	5.0	-0.6
2a	1.0	2.0	2.3	0.7	1.6	1.2	1.2	2.2	0.0	-0.6
2b	-1.0	3.0	2.3	1.7	2.6	1.2	1.2	0.2	1.0	0.4
3	-2.0	2.0	1.3	-2.3	2.6	-0.8	0.2	-0.8	1.0	0.4
3a	-2.0	1.0	1.3	1.7	1.6	0.2	0.2	-0.8	0.0	-0.6
3b	0.0	1.0	0.3	0.7	1.6	0.2	1.2	1.2	1.0	1.4
4	-3.0	-1.0	1.3	0.7	3.6	-1.8	1.2	-0.8	1.0	-1.6
4a	-2.0	-1.0	-4.7	-2.3	-1.4	-0.8	-0.8	-0.8	-4.0	-0.6
Avg	1.9	1.6	1.8	1.6	1.8	0.9	1.1	0.9	1.5	0.7

Mean of the absolute value of the differences between raw N&E and true N&E is 1.4m

Table 5

Gama Least Square Adjustment Results

CDGPS coordinates with Direction and Distance Observations

	Point No. 1a		**point No. 2**		**point No. 3**		**point No. 4**		**point No. 5**	
Sess#	**North**	**East**	**North**	**East**	**North**	**East**	**North**	**East**	**North**	**East**
1	8178.7	6687.2	8156.6	6652	8116.2	6679.6	8129.6	6714.9	8145.8	6687.4
1a	8177.9	6687.3	8156.3	6650.5	8115.5	6678.7	8128.3	6714	8145	6687

2	8179.9	6683.7	8155	6652.2	8117	6679.6	8133.1	6715	8147.1	6686.5
2a	8179.5	6687.1	8157.3	6652.6	8117	6679.6	8130.5	6714.7	8146.7	6687.4
2b	8179.5	6688	8157.9	6651	8117.1	6679.3	8129.9	6714.6	8146.6	6687.6
3	8178.9	6686.4	8157.3	6651.5	8116.5	6677.7	8129.3	6713	8146	6686
3a	8178.5	6686.8	8156.8	6651.8	8116.1	6678.4	8129	6713.7	8145.6	6686.6
3b	8179.2	6686.5	8156.5	6650.2	8116.6	6679.8	8130.4	6714.7	8146.3	6687.2
4	8179.1	6685.3	8157.1	6649.5	8116.7	6677.5	8129.9	6712.6	8146.2	6685.4
4a	8175.8	6683.5	8152.2	6651.3	8113.1	6678.7	8128	6713.1	8143	6685.2
Mean	8178.7	6686.2	8156.3	6651.3	8116.2	6678.9	8129.8	6714	8145.8	6686.6
TRUE	8180.0	6685.0	8155.7	6651.3	8115.4	6678.8	8128.8	6713.8	8145.0	6686.6
Diff.	-1.3	1.2	0.6	0.0	0.8	0.1	1.0	0.2	0.8	0.0

	Diff. N	Diff. E	Diff. N	Diff. E	Diff. N	Diff. E	Diff. N	Diff. E	Diff. N	Diff. E
1	-1.3	2.2	0.9	0.7	0.8	0.8	0.8	1.1	0.8	0.8
1a	-2.1	2.3	0.6	-0.8	0.1	-0.1	-0.5	0.2	0.0	0.4
2	-0.1	-1.3	-0.7	0.9	1.6	0.8	4.3	1.2	2.1	-0.1
2a	-0.5	2.1	1.6	1.3	1.6	0.8	1.7	0.9	1.7	0.8
2b	-0.5	3.0	2.2	-0.3	1.7	0.5	1.1	0.8	1.6	1
3	-1.1	1.4	1.6	0.2	1.1	-1.1	0.5	-0.8	1.0	-0.6
3a	-1.5	1.8	1.1	0.5	0.7	-0.4	0.2	-0.1	0.6	0
3b	-0.8	1.5	0.8	-1.1	1.2	1	1.6	0.9	1.3	0.6
4	-0.9	0.3	1.4	-1.8	1.3	-1.3	1.1	-1.2	1.2	-1.2
4a	-4.2	-1.5	-3.5	0	-2.3	-0.1	-0.8	-0.7	-2.0	-1.4
Avg	1.3	1.7	1.5	0.9	1.2	0.5	1.3	0.8	1.2	0.7

Mean of the absolute value of the differences between adjusted N&E and true N&E is 1.1m

Table 6 - CDGPS adjusted coordinates

Gama adjusted coordinates showing the point in each session with the least correction

Sess#	Adjusted N	Adjusted E	Diff. N	Diff E	Point No.

1	8116.2	6679.6	0.8	0.8	3
1a	8145.0	6687.0	0.0	0.4	5
2	8155	6652.2	-0.7	0.9	2
2a	8117.0	6679.6	1.6	0.8	3
2b	8157.9	6651.0	2.2	-0.3	2
3	8129.3	6713.0	0.5	-0.8	4
3a	8129	6713.7	0.2	-0.1	4
3b	8156.5	6650.2	0.8	-1.1	2
4	8129.9	6712.6	1.1	-1.2	4
4a	8128.0	6713.1	-0.8	-0.7	4
		Avg	0.9	0.7	

The mean of the absolute value of the differences of adjusted and true N/E and true N/E is 0.8m

What is Precise Point Positioning

The Geodetic Survey Division of Natural Resources Canada recently rolled out a new free on-line service for GPS users called CSRS-PPP (Precise Point Positioning). The service greatly increases positioning accuracy results obtained using one receiver (single or dual frequency) operating in static or kinematic mode. The user submits their data via an on-line internet form. Precise ephemeris and clock information is used to improve the accuracy results by a factor of 2 to 100 times. This is a tremendous new geo-referencing service for the survey community across Canada.

I am very excited about the opportunity for land surveyors to combine the use of PPP and Gama to provide a fast and inexpensive means of integrating PPP coordinate data and conventional survey observations. The Gama classical least square adjustment enables you to quickly adjust and assess the quality of both conventional and GPS derived coordinate data. Although I have not tested the PPP system yet, it appears that it may provide the accuracy required to enable derivation of bearings with a single receiver provided the separation distances between GPS nodes is adequate.

Section 21(1)(d) of the General Survey Instruction Rules states that bearings may be derived from "*GPS derived baselines of a minimum length of 150 metres*". Section 27(1) states that a survey plan must show " *the derivation of bearings*". Traditionally, a GPS baseline is derived from two receivers observing simultaneously. Deriving a GPS baseline from two PPP positions could be better described as a GPS derived pseudo-baseline. This may or may not be construed as meeting the intent of the rule. My personal interpretation of the rule is that these two sections do not appear to preclude using PPP methods for deriving bearings.

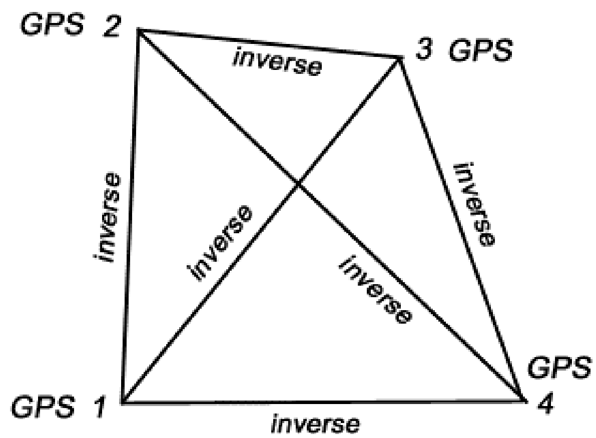
Use Gama Now

We are very fortunate to have such a robust geo-referencing infrastructure in place in BC. In order to optimize the use of this infrastructure, we should always be looking for new processes to improve efficiencies, accuracy and reliability in our survey operations. I encourage members to experiment with integrating GPS and conventional survey observations using Gama as it offers a fast and effective processing solution. The websites for Gama least square adjustment program and the companion Rocinante (GUI) are cited at the end of this article.

Gama will work well for adjusting all your observations, however, in some cases you may want to quickly integrate the GPS points to the local survey by just including pseudo-observations (inverses between the common GPS points and the conventional survey points). This will allow you to leverage the accurate relative shape of the conventional survey and let the lower accuracy GPS coordinates fit the conventional survey. Diagram 2 shows a typical case with four GPS nodes.

You will need to create an initial adjustment XML input template in Rocinante that suits your observation data. The following steps outline the basic process of running a Gama least square adjustment.

Diagram 2
GPS nodes and pseudo observations



1. Compile Gama & Rocinante source code (for members convenience and testing, I also expect to temporarily post compiled executables at www.vrmapper/gama/)
2. Read the documentation and select the appropriate adjustment parameters and options to suit your survey instruments/data (e.g. for distances, angles (right handed), confidence level, coordinate axes, etc.)
3. Open Rocinante and enter a project description, enter GPS coordinates and enter directions and distances from each GPS node to the other GPS nodes (derived from inverses from conventional survey data or input all survey data)
4. Run Gama adjustment and analyse output.

Once your initial template is made, it can easily be used for the next project. If you would like a sample template to test, you can contact me at jim@vrmapper.com. I would be interested to hear about any experiences and tests using Gama/Rocinante that you would like to share. There is a formal project feedback process listed on the Gama website.

Review Survey Rules & Manual of Standard Practice

Section 17 of the rules states that the minimum accuracy standard, expressed as a misclosure within the surveyors own work, shall be 1:5000. Section 22 of the rules requires surveys outside of integrated survey areas, if practical, to be geo-referenced where differential GPS is being used or where the local survey is tied to physical control monuments. The referencing must be less than 2 metres at 95% confidence level. Section 22 also provides for geo-referencing certain surveys outside of integrated survey areas via autonomous GPS methods.

Considering the existing active control infrastructure and the recent implementation of Precise Point Positioning and CDGPS, combined with Gama or other commercial processing tools, it seems like an excellent time to start discussions about modernizing the geo-referencing requirements and survey accuracy standards within the General Survey Instruction Rules. It may be best to strike a task force to conduct a thorough review of the practical accuracy capabilities and cost impact of using these tools in a more comprehensive manner. Depending on the outcome of the research, this may lead to a more rigorous approach to defining accuracy requirements and a subsequent updating of our survey rules. It would also be a good opportunity to amend Section 7 of the Manual of Standard Practice to provide enhanced guidelines for the use of new geo-referencing tools and processing methods.

Website References:

Gama Least Square Program - http://www.gnu.org/software/gama/gama.html

Rocinante GUI - http://roci.sourceforge.net/

BC Standards, Specifications and Guidelines for Resource Surveys using GPS Technology – Release 3.0 - http://srmwww.gov.bc.ca/bmgs/gsr/specifications/resource gps/bc specifications - gps resource mapping release 3.0.pdf

CDGPS - http://www.cdgps.com

CSRS – Precise Point Positioning (PPP) -
http://www.geod.nrcan.gc.ca/index_e/products_e/services_e/ppp_e.html

High-Precision Single Frequency GPS Positioning by T. Beran, D Kim and R.B. Langley, UNB -
http://gauss.gge.unb.ca/papers.pdf/iongpsgnss2003.beran.pdf

Integrating GPS and Conventional Survey Observations Using GNU Gama Least Square Adjustment Program - http://www.vrmapper/gama/

US Forest Service Receiver Performance Reports
http://www.fs.fed.us/database/gps/gps_standards/GpsAccuracyStd.pdf