THE NEW GPS DATA PROCESSING SOFTWARE BAMBA

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ABSTRACT

This paper provides the state of art of the new software BAMBA for GPS static data processing together with some results. The program is written in FORTRAN 77 and follows 3 basic steps: preprocessing, first processing, final processing.

Solution is provided by a mix of already existing strategies and completely original techniques, mostly for the first and the third step, such as a rigorous Bayesian approach for the final estimation of geometrical parameters. Currently BAMBA is able to work out a single-base processing with a very simple mathematical model of double difference observation equation, but further developments are already planned to overcome these limits and enhance the overall performance.

However, first results on real data related both to static and rapid-static surveys are quite satisfying, as regards both the comparison with a scientific software and the consistency of Bayesian solution in rapid-static applications.

1 - INTRODUCTION

BAMBA is a new software for static GPS data processing, it's written in FORTRAN 77 and follows a modular structure which consists of three sections:

1. preprocessing - detection and repair of cycle slips and computation of approximate values for the geometrical parameters (WGS84 coordinates) and the raw initial phase ambiguities;
2. first processing step - preliminary estimation of geometrical parameters and floating double difference initial phase ambiguities;
3. final processing step - final estimation of geometrical parameters with their covariance matrix.

Solution is provided by a mix of already existing strategies, such as least squares applied to phase double-differences, and completely original techniques, mostly for the first and the third step, such as a rigorous Bayesian approach for the final estimation of geometrical parameters. This approach doesn't try to fix a set of integers for double initial ambiguity, but it aims to estimate the geometrical parameters and their precision taking all possible integer sets into account according to their own probabilities, derived from the floating estimates covariance matrix computed by the first processing step: in other words, the Bayesian estimates are computed through a sort of weighed average.

It is necessary to underline that in theory we have to consider an infinite number of set of integers; on the other side, practically it is enough to consider only those sets whose probabilities are higher than a fixed value. By now the adopted strategy is very simple and it consists in analyzing all the integers falling in 3σ-confidence intervals of the floating initial double difference ambiguity estimates.

By now the program works only for a single-base analysis adopting a very simple model of phase double difference observation equation, which doesn't account for residual biases: this model holds only the geometrical parameters of the unknown receivers and the double difference initial phase ambiguities. The program needs as input pseudorange and phase observations and broadcast ephemerides following RINEX v. 2 format and SP3 format for precise ephemerides.

2 - SOME EXAMPLES

This paragraph is devoted to a description of some numerical examples based on real data, which provide a first look at the merits and limits of program BAMBA in static and fast-static applications. These examples are referred to an about 7 km long baseline inside the town of Rome between sites ING2 e DITS . The analyzed observations belong to the same session with 30^s sampling interval and with an unique 5 satellites constellation. In all the examples only the L1 carrier is used, with precise IGS ephemerides and satellite PRN3 and station ING2 as references; the unknown parameters are always 7: 3 geometrical (station DITS coordinates) and 4 initial double difference phase ambiguities. All the example were carried out by program BERNESE too to allow some comparisons; note that program BERNESE settings were selected so to not account for the residual biases and to use a very simple model as close as possible to that implemented in BAMBA.

2.1 - STATIC APPLICATION

This first example regards a static application 21 epochs long. It is possible to see that floating estimates agree very well as regards rms estimate and for coordinates: there is a maximum difference of 25 mm for Y coordinate, which is compatible with the respective standard confidence intervals (tab. 1). After this step, program BERNESE is able to find the set of integers to fix ambiguities by FARA technique; this set can be compared to the corresponding Bayesian estimates (tab. 2), which show to be integers too: this is due to the fact that the number of epochs and the quality of observations allow to find just one set of integers which has probability practically equal to one, while all the other sets have null probability.

	BAMBA		BERNESE	
	COORD.	RMS	COORD.	RMS
X	4642372.001	0.027	4642371.997	0.026
Y	1028724.087	0.041	1028724.112	0.041
Z	4236881.270	0.011	4236881.277	0.011

Tab. 1 - Floating estimates for station DITS (m)

SAT	BAMBA	BERNESE
6	6169973	6169973
17	-1344294	-1344294
20	7321342	7321342
22	-6238620	-6238620

	BAMBA		BERNESE	
	COORD.	RMS	COORD.	RMS
X	4642371.964	.0014	4642371.953	.0017
Y	1028723.942	.0004	1028723.965	.0005
Z	4236881.221	.0016	4236881.224	.0019

Tab. 2 - Double difference ambiguities (cycles) and final estimates for station DITS (m)

The final estimates of geometrical parameters computed by BAMBA according to the Bayesian approach and by the program BERNESE with integer ambiguities fixed, show a good agreement, again at the level of about 2 cm, even if in this case the difference is not compatible with the very low estimated rms (tab. 2). Altogether, our results seems to be highly satisfying according to the very simple model adopted, even if this example can't fully point out the weighed average estimate proper to the Bayesian methodology. On the other side it is reasonable to think that it should work when the choice among sets of integers is uncertain enough, that is when the available information is further reduced.

2.2 - FAST-STATIC APPLICATIONS

These examples aimed to evaluate the way to work and the stability of the Bayesian method in fast-static applications; therefore we perform various processing's with lower and lower number of epochs (15, 10, 8, 7, 6, 5, 4 and 3) and we compare the results to the ones derived in the static application.

Three main comments are allowed when the final solutions are analyzed:

- the estimates (figs. 1, 2, tab. 4) provided by BAMBA in fast-static applications are more consistent and closer to the solution with 21 epochs than those derived by program BERNESE;
- the drop of estimated rms is software with BAMBA than with BERNESE; may be this fact become more evident if data with a lower sampling interval (e.g. 1^s) are used: in this case we think that BAMBA rms' increase regularly while the number of epochs diminishes, whilst BERNESE rms' show again a remarkable drop at a certain epoch, when FARA is able to select a unique set of integer ambiguities (figs. 1, 2, tab. 4);
- the number of set of integers which have to be exploited to obtain Bayesian estimate (according the search strategy mentioned above) tends to increase very rapidly when the number of epochs is reduced, what implies a remarkable computation time; moreover, very few sets have significant probabilities (tab. 3); therefore, it is crucial to define an efficient search strategy of these sets.

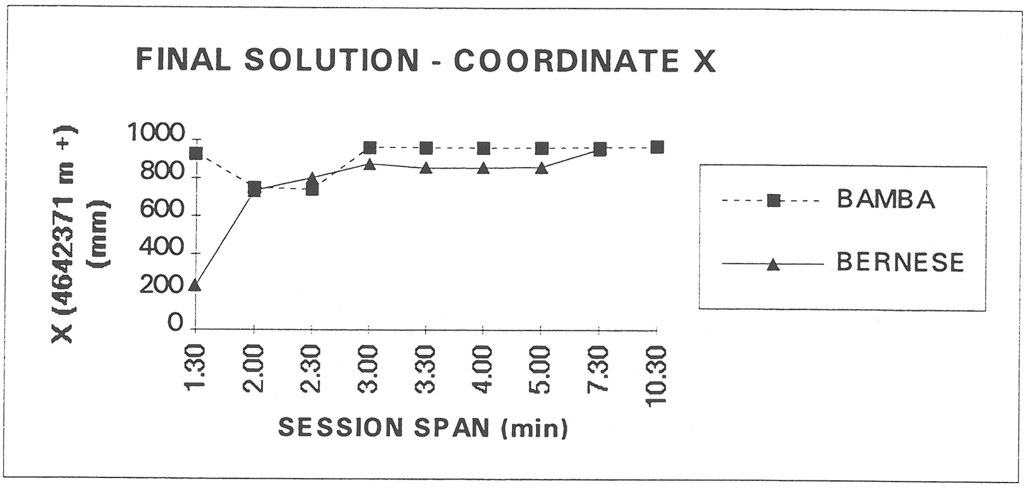
EPOCHS	# INTEGER SETS	# USEFUL INTEGER SETS
21	1	1
15	2	1
10	24	1
8	240	1
7	288	1
6	800	1
5	600	2
4	1890	2
3	10080	2

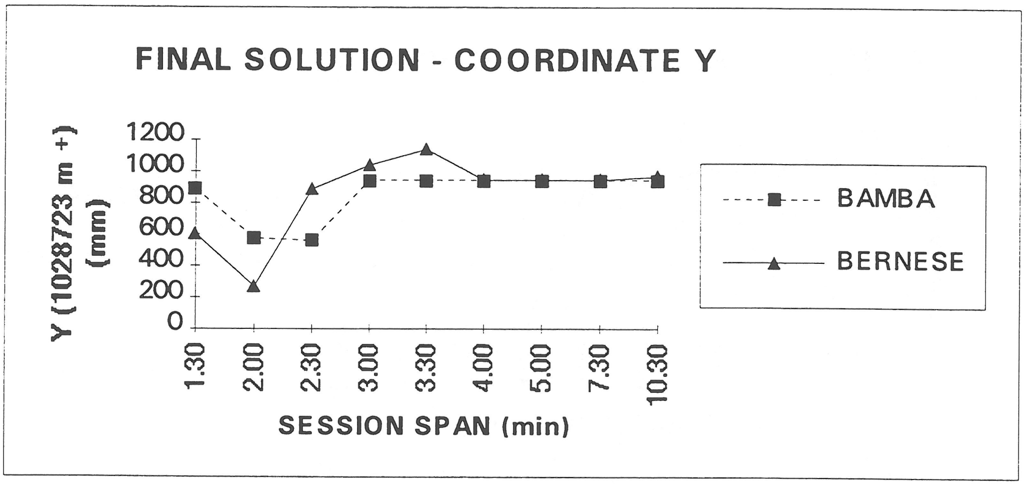
Tab. 3 - Total integer sets vs. useful integer sets (non-null probability)

BAMBA		X	RMS X	Y	RMS Y	Z	RMS Z
SESSION	SPAN	4642371 (m) +		1028723 (m) +		4236880 (m) +	
EPOCHS	MINUTES	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
3	1.30	929	76	889	133	1169	113
4	2.00	749	44	575	75	902	64
5	2.30	741	1	560	1	889	2
6	3.00	962	2	943	1	1216	2
7	3.30	961	1	943	1	1216	2
8	4.00	960	1	943	1	1215	2
10	5.00	960	1	943	1	1215	2
15	7.30	963	1	943	1	1218	2
21	10.30	964	1	942	1	1221	2
	MEAN	910		853		1140	
	RMS	94		163		140	

BERNESE		X	RMS X	Y	RMS Y	Z	RMS Z
SESSION	SPAN	4642371 (m) +		1028723 (m) +		4236880 (m) +	
EPOCHS	MINUTS	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
3	1.30	458	410	600	654	940	169
4	2.00	230	204	269	325	915	84
5	2.30	733	202	887	322	1060	84
6	3.00	801	134	1039	222	1076	58
7	3.30	876	108	1140	171	1110	45
8	4.00	854	2	946	1	1130	2
10	5.00	855	2	945	1	1131	2
15	7.30	858	2	945	1	1135	2
21	10.30	953	2	965	1	1224	2
	MEAN	750		917		1096	
	RMS	249		297		115	

Tab.4 - Final solutions by BAMBA and BERNESE programs





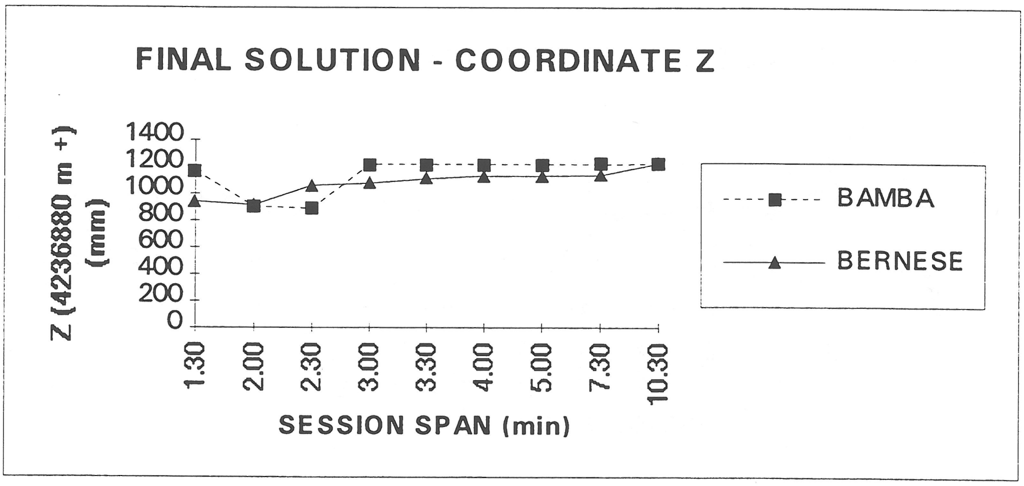
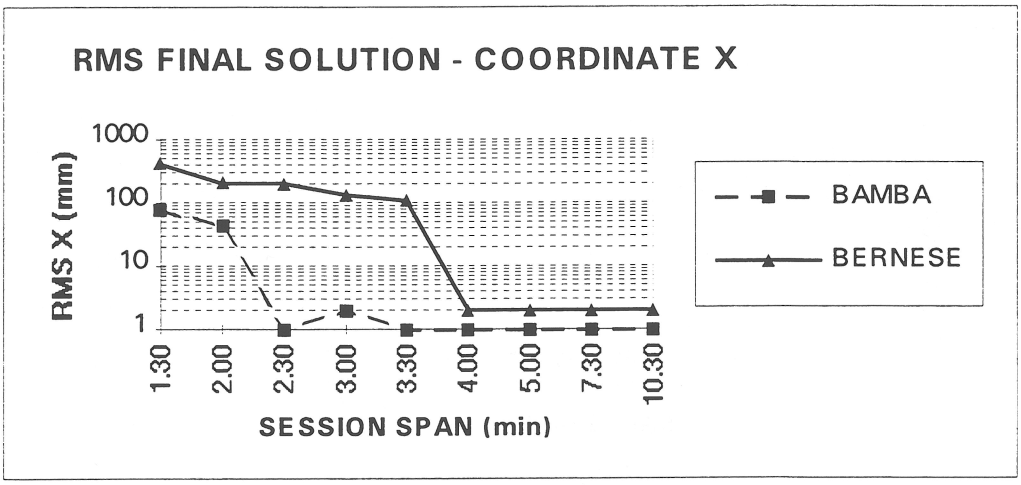
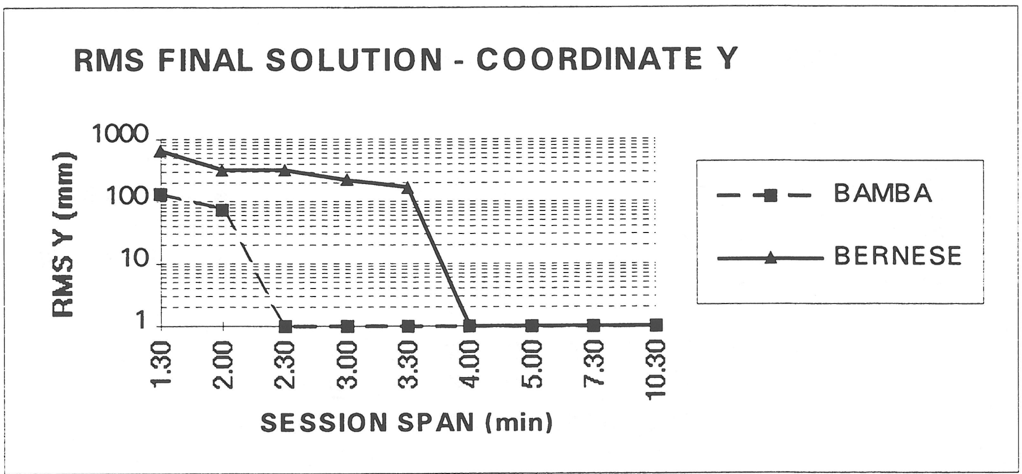


Fig. 1 - Final solutions by BAMBA and BERNESE programs





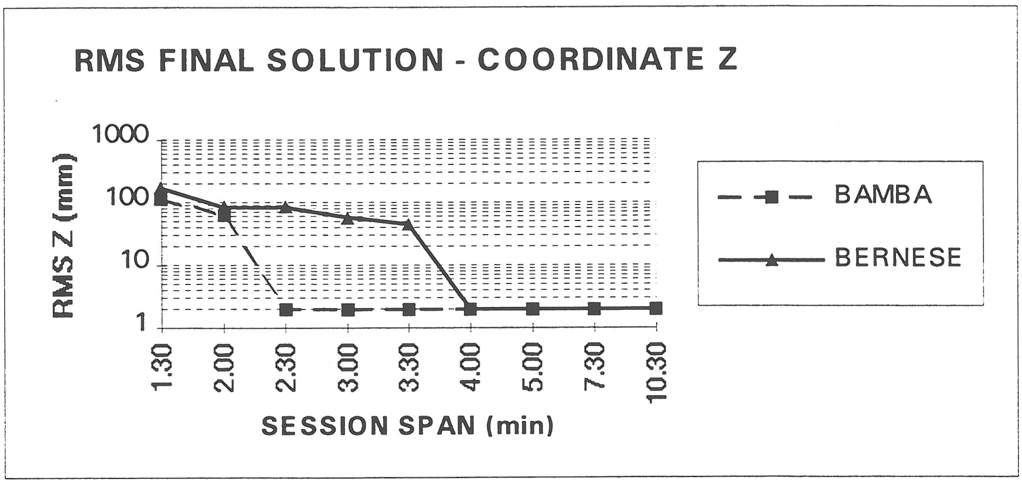


Fig. 2 - RMS final solutions by BAMBA and BERNESE programs

3 - CONCLUSIONS

These first results are highly satisfying both for the stability of the method implemented in BAMBA and for the comparisons carried out with program BERNESE, which is at present and without any doubt, one of the most refined available software product. The future work will be devoted to the implementation of a multi-baseline procedure, to the improvement of the double difference phase observation model and to define the search strategy for the *interesting* integer sets, that is those sets with non null probabilities.
We also plan to add in our program a new procedure developed by Prof. Teunissen from the University of Delft (The Netherlands) so as to look for the *interesting* integer sets efficiently. This is a new reparametrization technique and allows to reduce the size of the search space. Further, due to the stability of the Bayesian procedure and to its flexibility in comparison to the classical floating solutions, this approach seems to be quite suited for kinematic applications too. Therefore, further developments need to be done also in this direction.

REFERENCES

1. BETTI B., CRESPI M., SANSÒ F., 1993; *A geometric illustration of ambiguity resolution in GPS theory and a Bayesian approach*; Manuscipta Geodaetica, vol. # 18.
2. BETTI B., CARPINO M., CRESPI M., MARANA B., 1996; *State of art of the implementation of the new GPS data processing software BAMBA*; Reports on Surveying and Geodesy, In memory of Prof. Gubellini and Prof. Folloni.
3. CARPINO M., 1995; *Sage 02: User Manual.*
4. CRESPI M., 1991; *Il trattamento di dati GPS: vantaggi e limiti degli approcci tradizionali*; Phd. Thesis.
5. de JONGE P., TIBERIUS C., 1996; *The LAMBDA method for integer ambiguity estimation: implementation aspects*; LGR-Series, Publications of the Delft Geodetic Computing Centre # 12.
6. EULER H. J., GOAD C. C., 1991; *On optimal filtering of GPS dual frequency observations without using orbit information*; Bullettin Geodesique # 65.
7. MARANA B., 1997; *Il trattamento dei dati GPS: aspetti teorici innovativi ed implementazione di un nuovo programma di calcolo*; Phd. Thesis, 1993-1996.
8. ROTHACHER M., MERVART L. (Eds.), 1996; *Bernese GPS Software Version 4.0*; Astronomical Institute University of Berne.
9. SANSÒ F., VENUTI G., 1995; *Identificazione di discontinuità di segnali immersi nel rumore*; Atti del XIV Convegno Nazionale GNGTS, Roma.
10. TEUNISSEN P. J. G., 1995; *The least squares ambiguity decorrelation adjustment: a method for fast GPS integer ambiguity estimation*; Journal of Geodesy, Volume 70, Number 1, 2.
11. TEUNISSEN P. J. G., 1996; *Ambiguity Fixing Concepts*; GPS for Geodesy, Cap. # 8.