MULTI BASE KINEMATIC GPS PROCESSING, A CONSTRAINED BATCH SOLUTION APPLIED TO ANTENNA ARRAY

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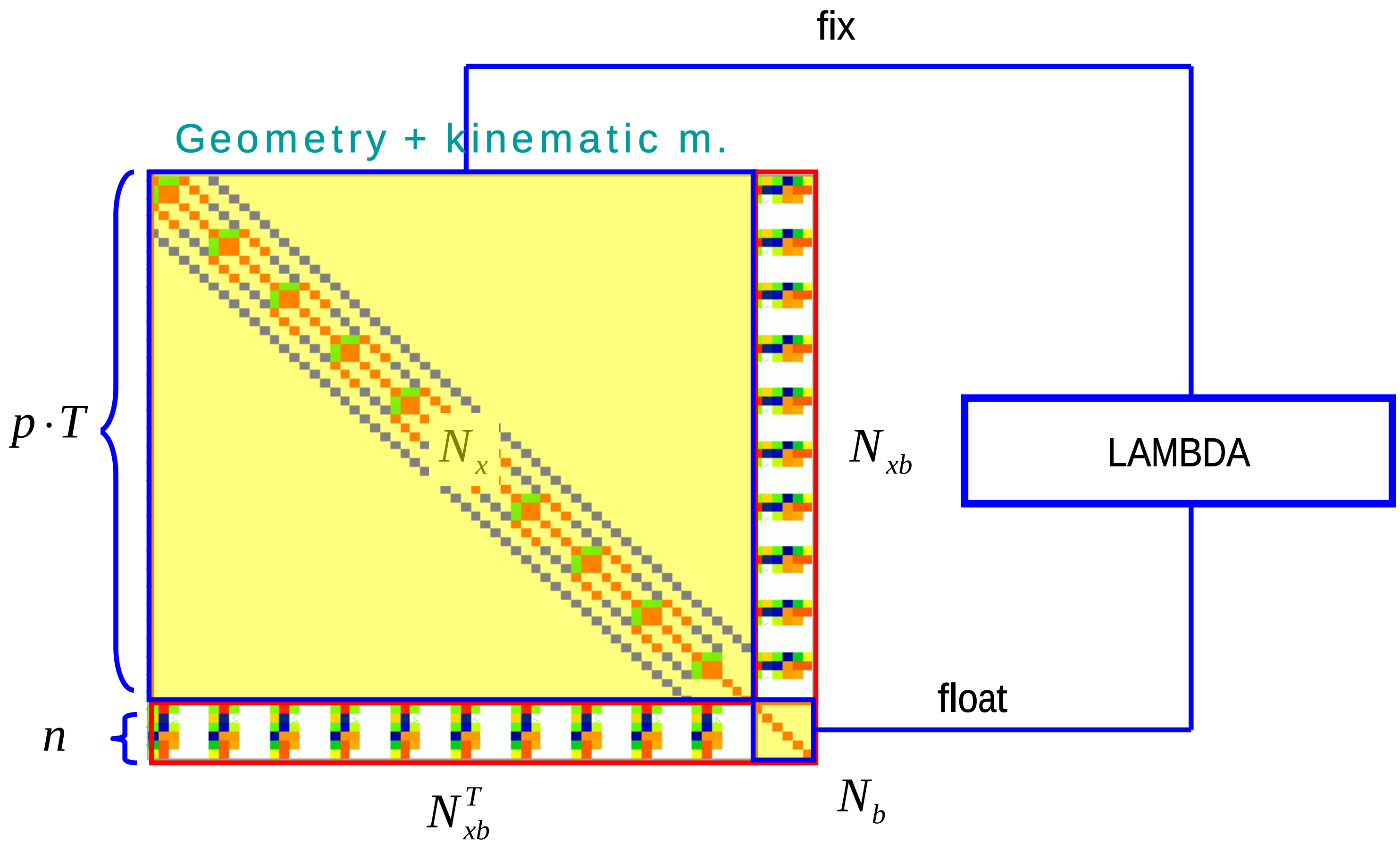
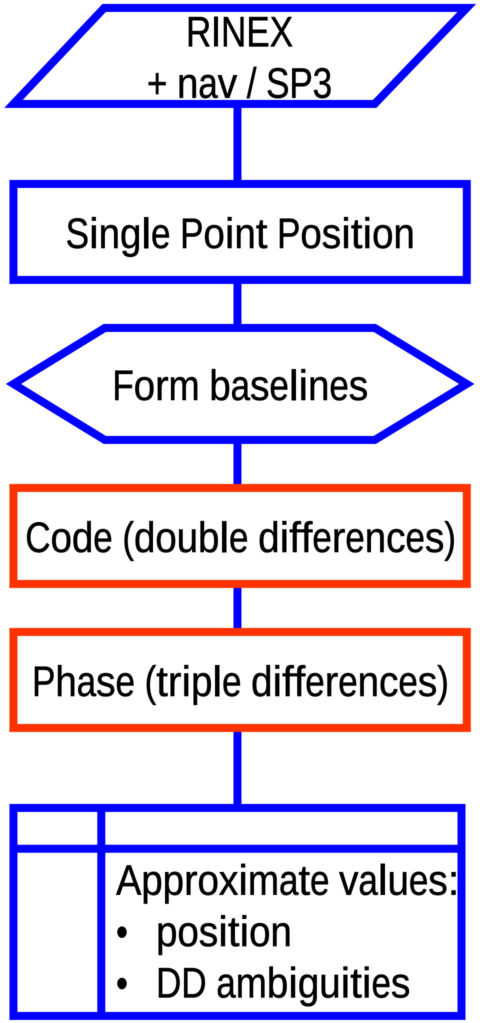
BACKGROUND ON GEODETIC NAVIGATION



1. Float ambiguities and variance-covariance matrix estimation.
2. Search for integer ambiguities (LAMBDA).
3. Correct double differences for ambiguities.
4. Solve for position inverting N_x.

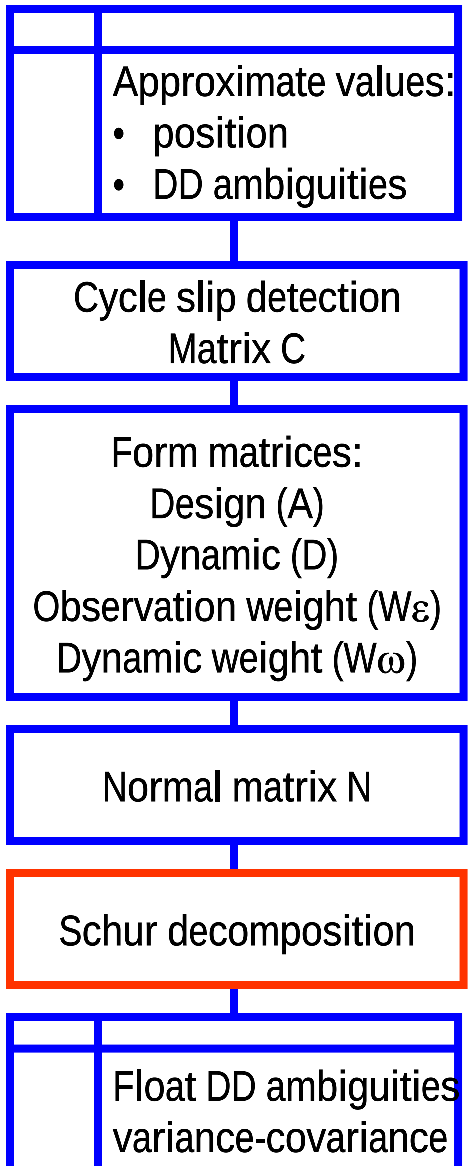
ALGORITHM



APPROXIMATE PARAMETERS

- Are estimated neglecting time correlation
- Double and triple differences are prepared
- Is possible to constrain the baseline length

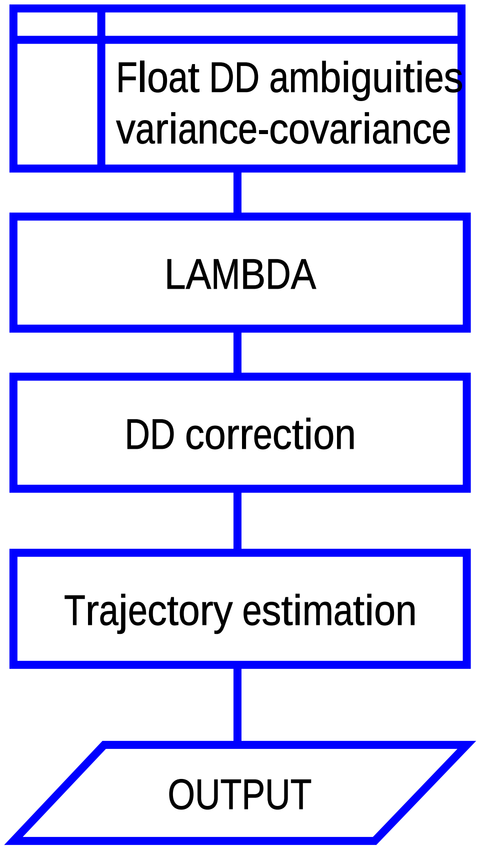
ALGORITHM



FLOAT AMBIGUITIES

- Cycle slip are detected in the observations
- Estimation of float ambiguities:
  - To consider time correlation require large matrices. As example: a data set of 15’ at 1” data rate and double precision (8 byte) GPS single frequency observations produce a design matrix of ~120 Mbyte.
  - Is necessary to treat the matrices as sparse. Matrices are stored in CSR (Compact Sparse Row) format or equivalent specific compact format. Design matrix reduces to ~1 Mbyte.
  - Matrix - vector operations (sum, multiplication, transpose, inversion) speed up thanks to the sparse structure.
  - The system is solved for carrier phase ambiguity only, using Schur decomposition

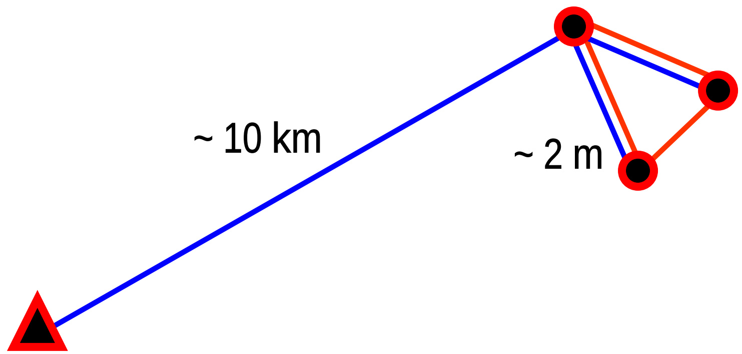
ALGORITHM



FIX INTEGER AMBIGUITIES

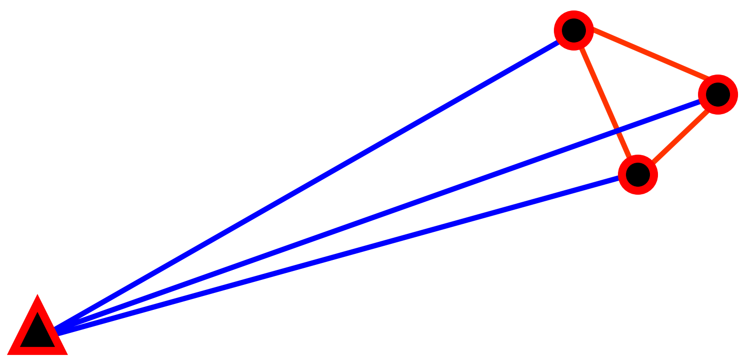
- Estimation of the fix solution (the bias term is now known and removed from the observation vector)

NETWORK DESIGN



Design 1

- Very short baselines
- Very small differential biases
- (Large number of cycle slips)



Design 2

- Longer baselines
- (Fewer cycle slips)

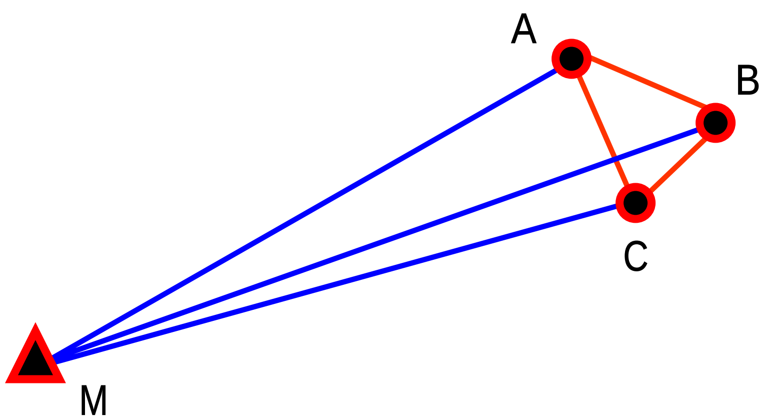
Master antenna
Rover antenna
Independent baseline
Constraint

Solutions

- Single base
- Multibase

Double differences

- Hypothesis (quite near to the reality):
  - no cycle slip originated into the master station M;
  - (no common cycle slip between the antennas A, B and C.)



Long baselines

- MA : Na cycle slips
- MB : Nb cycle slips
- MC : Nc cycle slips

Short baselines

- AB : Na+Nb cycle slips
- AC : Na+Nc cycle slips
- BC : Nb+Nc cycle slips

CONSTRAINING BASELINE LENGHT

Background on geodetic navigation
Algorithm
Network design
Constraining baseline lenght
Sparse matrices
Applications
Conclusions

Hypothesis :

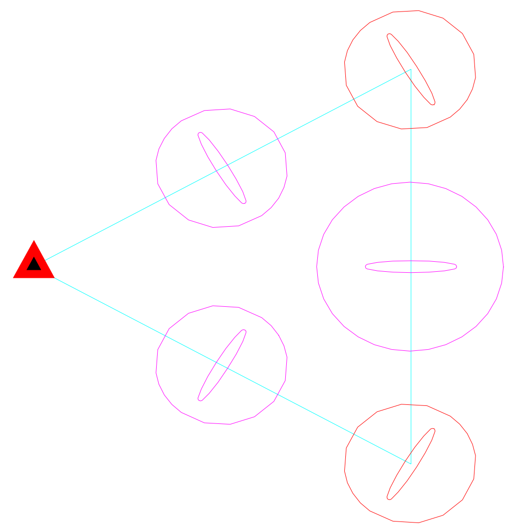
- the tree antennas have the same 3D precision (σ = 1 cm);
- baseline length is not constrained;
- the three baselines have the same length (2 m).

Result :

- We obtain σ = 0.32 gon for the three attitude angles.

WITHOUT CONSTRAINT

σ_E	=	10.0 mm
σ_N	=	10.0 mm
σ_h	=	10.0 mm
σ_κ	=	0.32 gon
$\sigma_{\omega,\phi}$	=	0.32 gon



Hypothesis :

- The baselines are now constrained (σ = 1 mm);

Results :

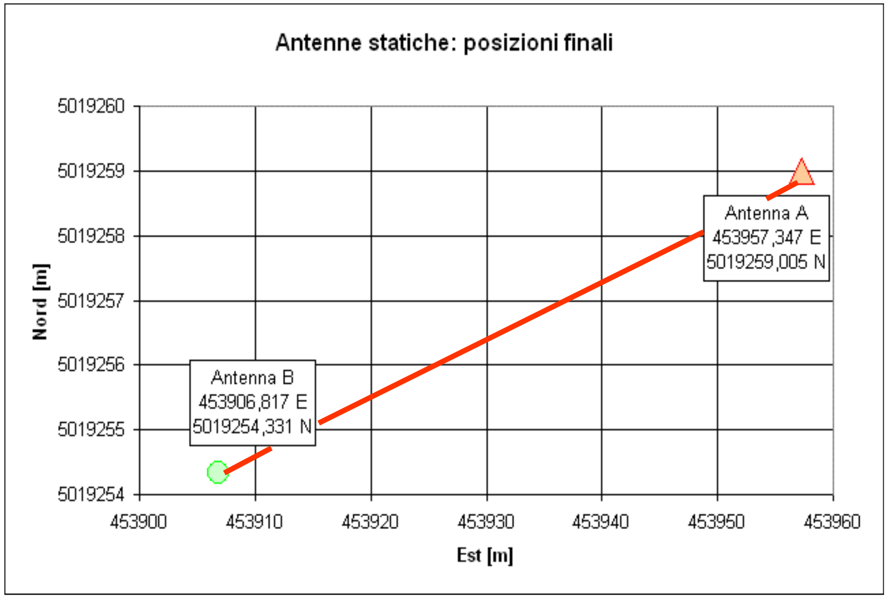
- better horizontal precision;
- the vertical precision is unchanged;
- better precision of the drift angle κ (σ = 0.14 gon).

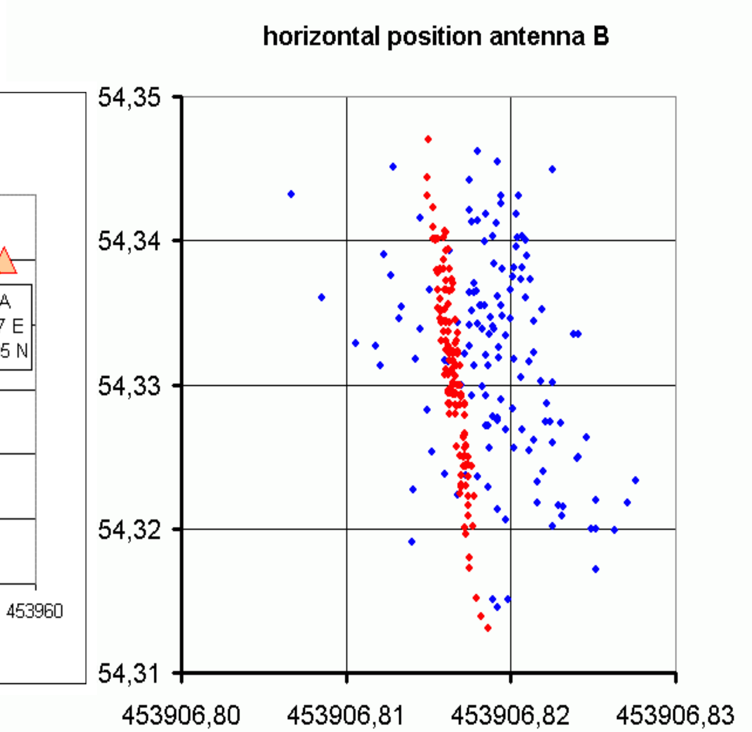
WITH CONSTRAINT

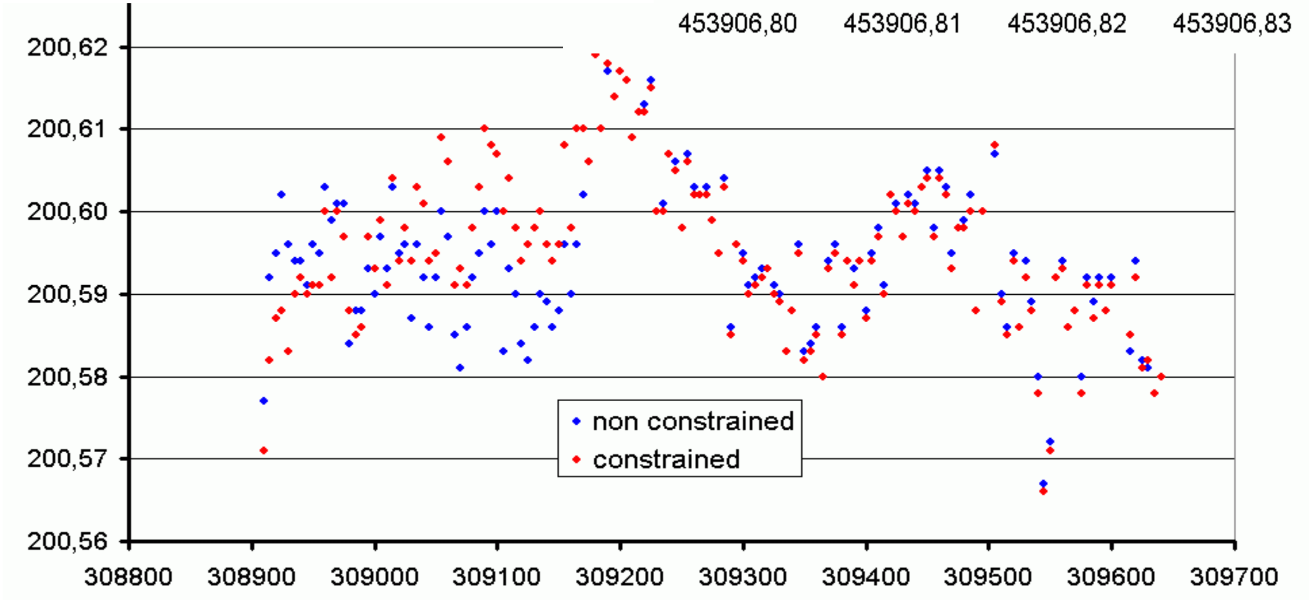
σ_E	=	3.7 mm
σ_N	=	6.1 mm
σ_h	=	10.0 mm
σ_κ	=	0.14 gon
$\sigma_{w,\phi}$	=	0.31 gon

CONSTRAINING BASELINE LENGTH

Static test







CONSTRAINING BASELINE LENGTH
Kinematic test

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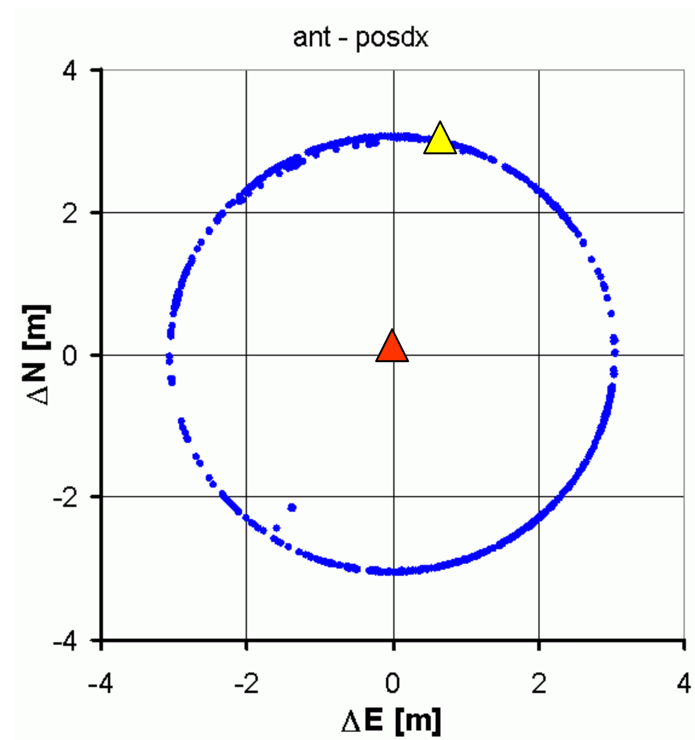
	Deviazione standard caso statico senza vincolo [m]				Deviazione standard caso statico con vincolo [m]			
	Posizione antenna B			$\sigma_{lunghezza\ baseline}$	Posizione antenna B			$\sigma_{lunghezza\ baseline}$
	σ_E	σ_N	σ_h		σ_E	σ_N	σ_h	
SP	0,43	0,68	0,93	0,40	0,43	0,68	0,93	0,40
SD	0,41	1,10	0,95	0,38	0,41	1,10	0,95	0,38
DDC	0,45	1,07	1,02	0,41	0,10	1,16	1,05	0,02
TD	0,004	0,008	0,009	0,004	0,001	0,008	0,026	0,0003
DD Float	0,011	0,010	0,030	0,012	0,001	0,007	0,011	0,0003
DD Fixed	0,003	0,007	0,009	0,003	0,001	0,006	0,010	0,0003

- Constraining the baseline length:
  - Improve the estimation of the drift angle (that usually is the worst estimated by IMU), and σ_k reduces up to 50%;
  - Ambiguity fixing is more robust ;
- We need a multibase solution to correctly apply the constraints.



APPLICATIONS

The algorithm has been used to process data by two multi antenna systems for mobile mapping applications:

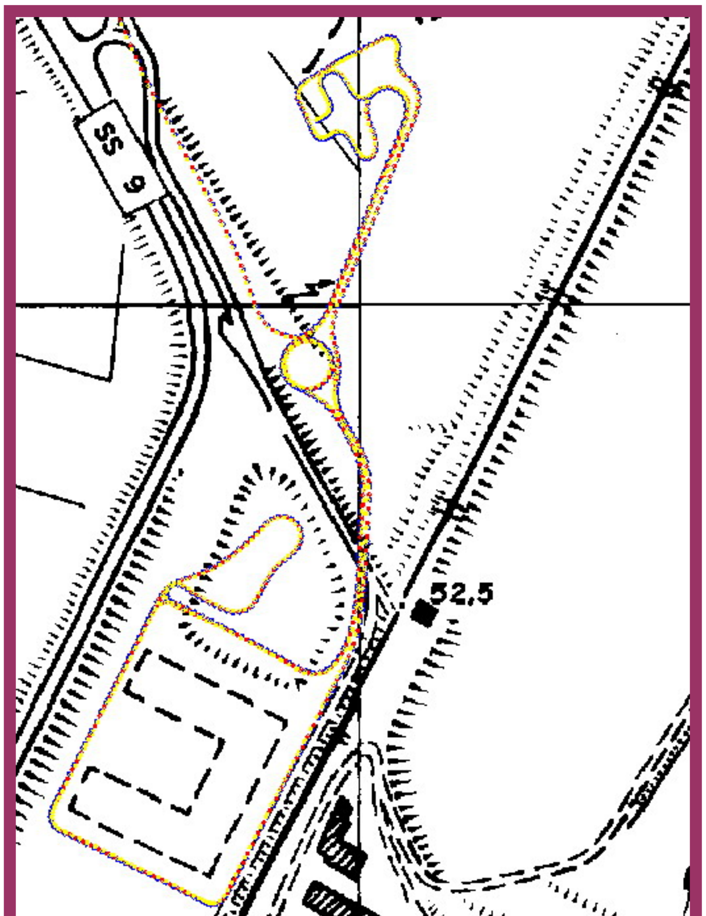
1. Mobile Mapping Vehicle for road cadastre surveying.
2. Boat for river bathymetry.

The software has been designed to handle GPS single frequency observations, over short baselines (2 -10 km); moreover:

- the software can process the data in multi-base approach;
- allows to constrain the baseline length between the antennas of the antenna array;
- final products are trajectories and orientation angles.

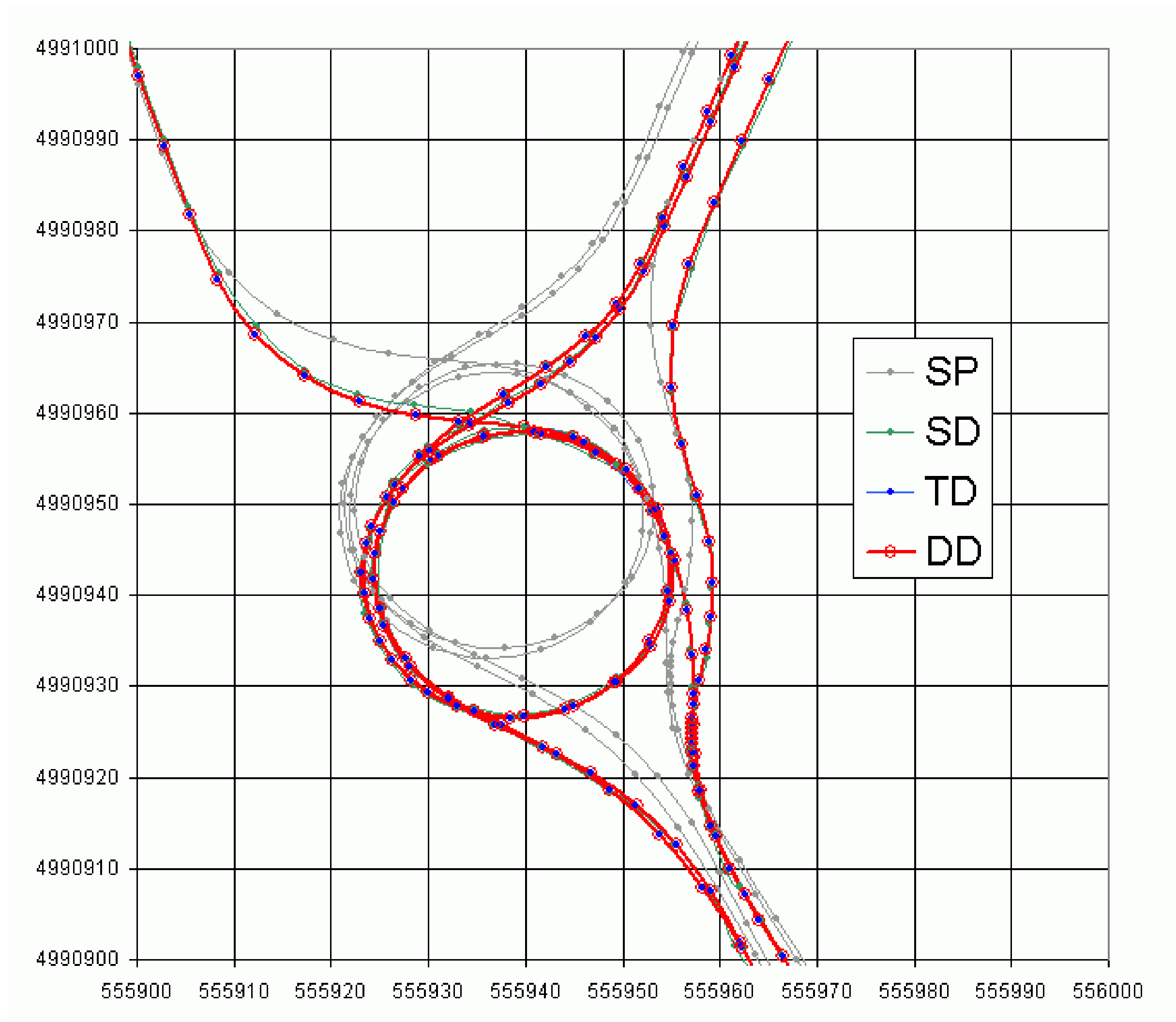
APPLICATIONS
Mobile mapping test

One hour of GPS data have been acquired at 1” data rate, surveying new roads and traffic flows.

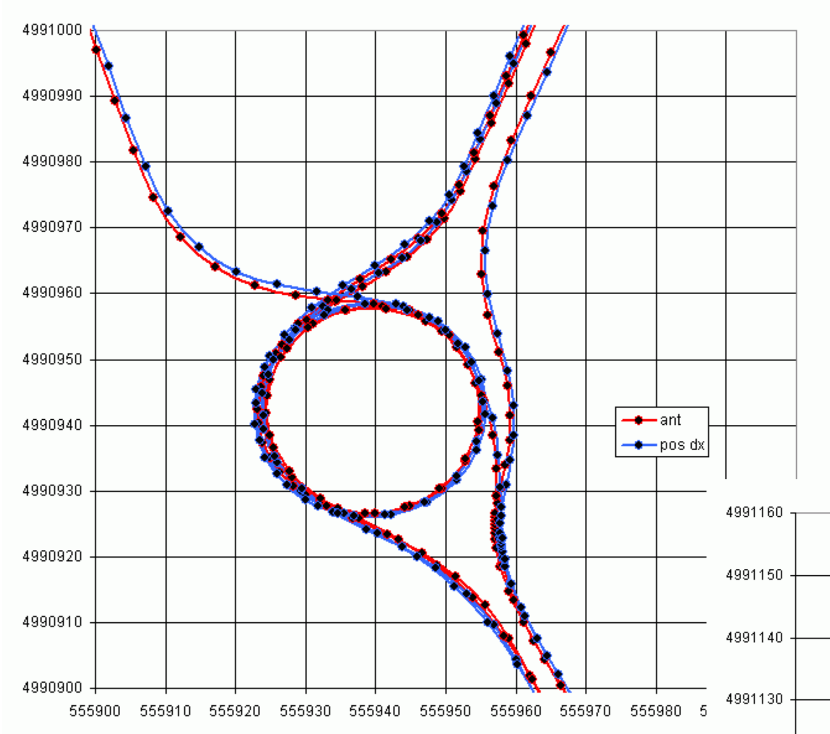


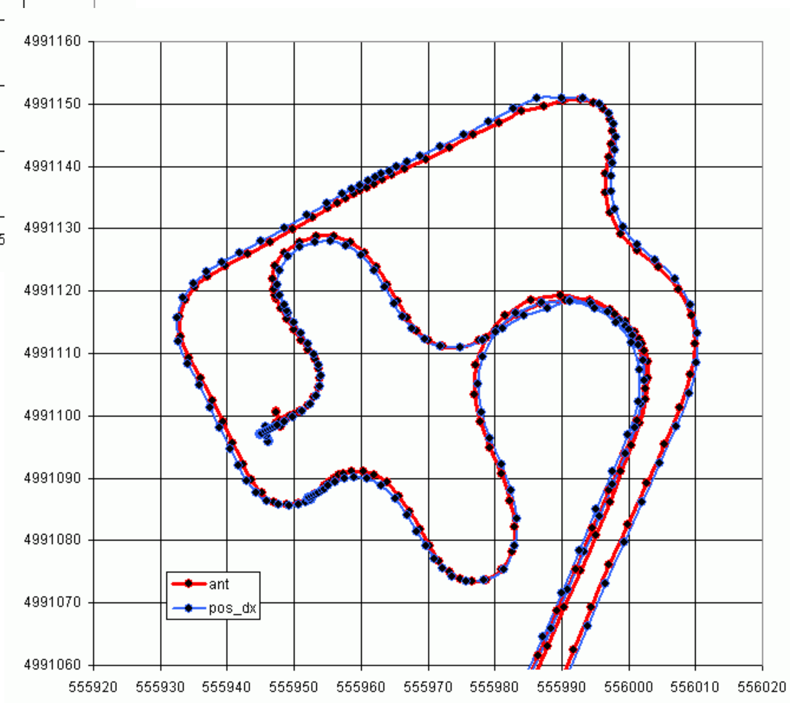
APPLICATIONS
Mobile mapping test

Approximation levels of the algorithm used for post processing.



APPLICATIONS
Mobile mapping test





Details of the surveyed areas

CONCLUSIONS

- We take advantage of the least squares approach, applying static constraints to kinematic observations.
- The multi base approach is necessary to correctly apply the constraints to the baseline length.
- Constraining the base line length in kinematic GPS data processing:
  - the robustness of cycle slip fixing have been increased;
  - the accuracy of estimated drift has been improved.
- However, the overall accuracy of the antenna array system is not improved by baseline length constraining; the main effect of constraining is only the robustness against cycle slips.