Innovative Methodology for GNSS Data Processing

Valerio BAIOCCHI, Francesca GIANNONE, Maria Vittoria MILONE, Martina MORMILE, Grazia PIETRANTONIO

Key words: GNSS, GPS, Post-processing,

SUMMARY

In the present paper it will be illustrated the potentialities of an innovative strategy for the post-processing of GLONASS and GPS data. Presently, in fact, the enhanced availability of visible satellites in numerous temporal windows, due to increasing number of GPS satellites and also to the improvement of the Russian system GLONASS as well as to the beginning of the European system Galileo, lead to the search new solutions able to concretely exploit this increased availability. For this reason the new approach defined "Multiconstellation" is studied. The goal is to show as such innovative approach is applicable also under operational GNSS conditions.

SUMMARY IN ITALIAN

Con il presente lavoro si vogliono illustrare le potenzialità di una strategia innovativa per il post-processamento dei dati GLONASS e GPS. Allo stato attuale, infatti, la grande disponibilità di satelliti visibili ormai in numerose finestre temporali, legata sia all'infoltimento della costellazione GPS ma anche al risanamento del sistema russo GLONASS nonchè allo sviluppo del sistema europeo Galileo, spinge alla ricerca di nuove soluzioni in grado di sfruttare concretamente questa aumentata disponibilità satellitare. In tale ambito si colloca appunto l'approccio definito "Multiconstellation". Al fine di dimostrare come tale approccio innovativo sia di fatto applicabile anche in condizioni operative di rilievo GNSS sono stati utilizzati alcuni tra i più diffusi software di post-processamento.

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1. INTRODUCTION

If we consider a global constellation comprehending both GPS and GLONASS satellites, almost always at least 12 satellites are visible. This greater number of satellites allows to realize a new approach that we called "Multi-Constellation." This presently, only concerns the constellations GLONASS and GPS, but in a near future, with the completion of the Galileo constellation, it will also have an advantage from its satellites.
In a traditional GPS survey, in which a network comprehend more receivers, only the baselinelines linearly independent between them acquired in every session of measure, contribute to the final compensation of the net itself. Considering a net composed by a number N of receivers the independent baselinelines in every session is N-1. Is easi understandable as a single observation session is not enough to perform correctly the compensation of the net and this cause longer operations of survey, complex as well as economically onerous because more sessions of measure are needed. Nevertheless the greater number of available satellites if we consider mixed GPS and GLONASS constellations allows to simplify the survey in advantageous way. It exists in fact the possibility to extract from the unique constellation two subconstellations every of which able tobe the reference for two GNSS measurement among them simultaneous and independent, with undeniable advantages of time and necessary costs for the measurements.
Practically the approach Multiconstellation it still realized only through the employment of a sperimental software under experimentation, the Multicon that allows the preprocessing of the GNSS data. Is a specific software written in C++ language that directly operate on the files in formed RINEX format (RINEX is the acronym of Receiver Independent Exchange Format and is the format in which the necessary data for the determination of the position of the satellites are available to all) and it allows to extract from a single RINEX file relative to a specific session of measure, 2 files containing each independent observations coming from different satellites. With the purpose to illustrate better the operation of such innovative approach we can use an example. Starting considering a network constituted by 4 points. Operating in ”classical” way (where we'll call classical way the use of traditional approach to distinguishing it from innovative Multi-Constellation approach) for the determination of the 6 baselinelines, two sessions of measure are necessary. In fact in a first session three vectors among them linearly independent are measured, while the net is completed with the second session where the measurement of the remaining 3 vectors is performed. From this measurements it is possible to perform the compensation of themeasured network.
In the same circumstance, choosing instead the elaboration "Multi-Constellation" a single session of measure would be enough. The available observations of the only performed session are divided through the software Multicon and therefore it is as if, in a certain sense, we measured referring to two different sessions: three baselines can be calculated through the observations coming from the satellites of a group (sub-constellation) and three with the

observations of the satellites of the second group.
The possibility to opportunely divide the observations coming from different satellites and therefore to derive, from a single RINEX file, two separate files, allows therefore to make some baselinelines, that otherwise would not be, independent and that therefore they should necessarily be calculated in different sessions.

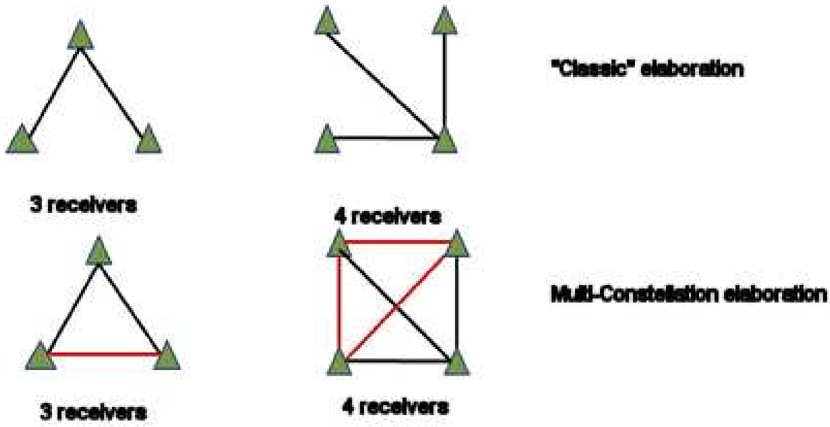

Figure 1- Independent Baselines in a single session with "Classic" and Multiconstellation approach.

During the first conducted experimentations on the Multiconstellation approach, a minimum number of GPS satellites was needed in evru subconstellation it was a limitation for the elaboration of the data in presence of a conspicuous number of satellites Glonass, in this job we'll show that also in presence of 0 satellites GPS for instance in the first subconstellation, the processing and the following compensation of the network are correctly completed. This is a great advantage for the "Multiconstellation" approach because enhanche the gflexibility in the subconstellation division allowing also the inclusion of older "only-GPS" receivers. Various tests were performed with the software Topcon Tools related to the same temporal window dividing the constellations with the Multicon software in such way that in one of them there is a number of GPS satellites that, beginning from 0 progressively increase; these tests have shown the possibility to overcome the limitations imposed by the different softwares in terms of number of satellites GPS with which to operate.

2. THE TEST NETWORK AND USED DATA

The performed experimentations, is based particularly on the data recorded by the permanent stations of:
" Perugia" (UNPG)
" Foligno" (REFO)

" Città della Pieve” (REPI)
The test network with three points that is object of this study, results therefore constituted by permanent stations all part of the GNSS network managed by Regional administration of Umbria.
The choice of the typology of stations has not been casual, on the contrary vertexes were choosen to reconstruct a situation very similar to a field suurvey with point not too much distant among them.

Figure 2 –The tested network

Considering the availability of the data of every station it was chosen to work with a temporal window of the duration of 60 minutes (from the 5:00:00 at 5:59:59 a.m.) of July 20th 2011 for the MultiConstellation approach. For the classical elaboration instead, two baselines among them linearly independent were calculated with a first session of July 19th 2011 while the third independent baseline is calculated using the data related to the same stations of the day after July 20th 2011, always considering the time interval between the 5:00:00 and the 5:59:59 a.m..
The use of the software Multicon it is rather simple, in fact only the name of the RINEX file to ”splice” is needed toghether with the option between automatic or manual subconstellation choice. In these experimentations we choose to use a manual subdivision since specific necessities had to be satisfied in terms of distribution of the satellites inside the two subconstellations.
In Figure 3 a Sky-Plot in which the satellites that have been attributed to the one and the other group result underlined.

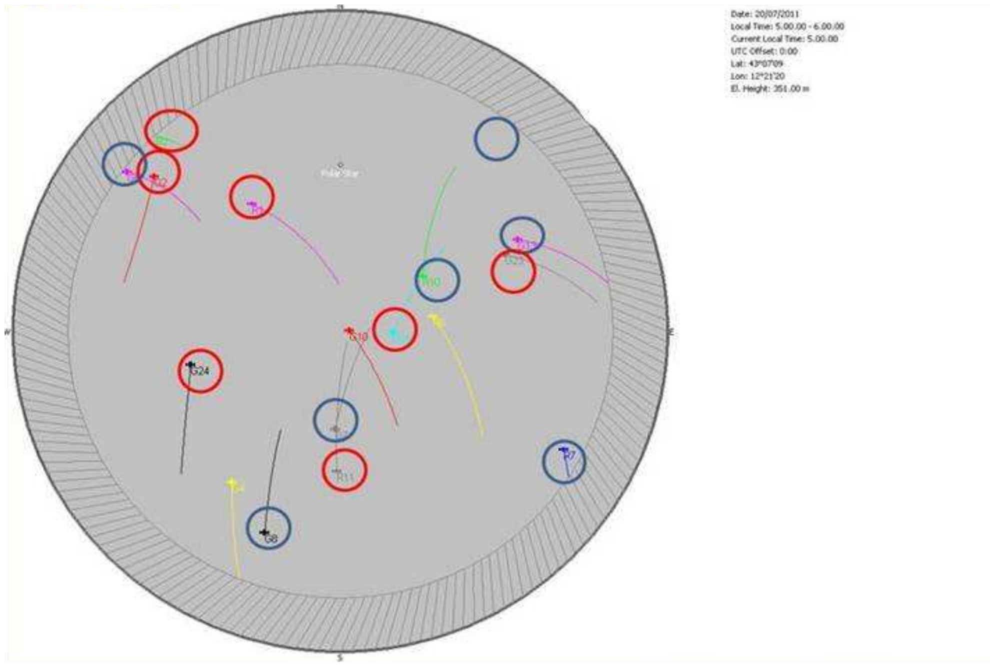

Figure 3 - Skyplot of the chosen time interval with blue and red circled the satellites assigned to the two different subconstellation

From the figure above we can observe as through the manual division we tried to get, for both the constellations, a best geometric configuration, trying to distribute in homogeneous way the satellites and avoiding, above all, discontinuites between a subconstellation and yhe other.

The observations preprocessed with the Multicon has then imported inside the commercial software Topcon Tools. The procedure used for succeeding to calculate the net exploiting as two separated sessions the contained measures in the same file RINEX but related to different groups of satellites, has been to proceed for separate projects. Therefore a first project is realized to process the files of the three stations related to the first subconstellation (called ”G1”) of satellites. Before starting the elaboration once more the station of Perugia was fixed as control point using the values of available precise coordinates reported in the website of the station itself. At the end of the baseline processing it ids possible to select the two independent baselines (the vectors UNPG-REFO and UNPG-REPI) elaborate and to export them in the format '. tvf' managed by the software. In a second project have been loaded the data related to the constellation G2 instead; only the files of the stations REPI and REFO were used after fixing as reference the station REPI. Also the new baseline has been exported and saved. The last performed operation has finally been that to open a third definitive project, to elaborate the three independent vectors calculated in the two preceding phases and to perform the compensation of the net.

3. RESULTS

In Table 1 the ellipsocentric coordinates of the stations of Perugia, Città della Pieve and

Foligno as reported by on the site of the university of Perugia;

	X (m)	Y (m)	Z (m)
UNPG	4555146.162	997822.219	4337432.566
REFO	4561083.779	1028178.388	4324106.922
REPI	4573777.964	972388.553	4324002.439

Tabele 1 – Reference coordinates of Perugia, Città della Pieve e Foligno stations as reported on Perugia university web site

At first was chosen to effect a test according to a classical approach, calculating the first two vectors (UNPG-REPI, UNPG-REFO) with the data of the first session of measure related to July 19 th 2011 and the remaining vector (REPI-REFO) with the data of the second session related to July 20 th 2011.

The coordinates of the stations after the compensation are been compared with those furnished by the site of the university of Perugia, and differences are been calculated in comparison to these last. To highlit this on table 2 the differences related to the coordinates of the stations calculated after the compensation and those brought on the site;

	ΔX (m)	**ΔY (m)**	**ΔZ (m)**
UNPG	0	0	0
REFO	-0.004	-0.008	-0.016
REPI	0.006	0.006	0.008

Table 2 - Differences between reference coordinates and coordinates adjusted following a classical approach

It can be observed that the differences of the first baselines are all negative and the second positive: this may be caused by a mismanagement of the antenna heights but this aspect need further investigation. Anyway, in the following tables, the comparison between "classical" and Multiconstellation results can be observed. The compensation in this test, and in all the following tests, has been conducted fixing using the station of Perugia as reference, for such reason the differences gotten by the comparison are void.

As it regards the test related to the innovative approach Multiconstellation we choose, as before specified, to use a manual subdivision of the satellites as shown in table 3.

1° SUBCONSTELLATION	**2° SUBCONSTELLATION**
G1, G3, G6, G16, G18, G25, G32,R1, R7, R8, R12, R13	G5, G11, G14, G19, G21, G22, G24, G29, G30, G31, R2, R11, R15, R17,R21, R22 R23, R24

Table 3 - Subdivision of satellites of two subconstellation

Insofar with the RINEXs related to the first subconstellation, the first two independent vectors

UNPG-REFO and UNPG-REPI have been calculated, while with those of the second subconstellation the third vector REPI-REFO has been calculated.
Also in this case the table of the coordinates differences between those calculated after the compensation of the net and the reference coordinates;

	ΔX (m)	ΔY (m)	ΔZ (m)
UNPG	0	0	0
REFO	0.002	-0.002	-0.015
REPI	0.015	0.002	0.02

Table 4 - Differences between ellipsocentric reference coordinates and Multiconstellation approach coordinates

From a first comparison among the results obtained with the classical approach and with the innovative approach, it emerges that the differences in the two cases is indeed very little
The results of further tests effected have shown the possibility to overcome the limitations imposed by the different softwares in terms of number of satellites GPS with which to operate. The data related to the session of measure of July 20 th 2011 from the 5 to 6 a.m. or of the same files that have been till now mentioned. The first performed operation has been that to visualize in detail the content of the whole observable files related to the three stations of the net, with the purpose to study the total number of satellites that they contained and to evaluate the satellites (both GLONASS and GPS) that were contemporarily visible from the three receivers. Subsequentlty the aforesaid data were imported inside the software Multicon for the subdivision of the files in two subconstellations characterized the one from a number of GPS satellites equal to zero and from a congruous number of GLONASS satellites, the other instead from both the GPS and GLONASS (the remaining excluded by the first subconstellation) satellites. Subsequently a series of test was performed with increasing number of GPS satellites till a maximum of 4.

	ΔX (m)	ΔY (m)	ΔZ (m)
UNPG	0	0	0
REFO	0.002	0.002	-0.015
REPI	0.015	0.002	0.02

Table 5 - Differences between reference coordinates and Multiconstellation (0 GPS) coordinates

	ΔX (m)	ΔY (m)	ΔZ (m)
UNPG	0	0	0
REFO	-0.002	-0.006	-0.014
REPI	0.008	-0.007	0.019

Table 6- Differences between reference coordinates and Multiconstellation (1 GPS) coordinates

	ΔX (m)	ΔY (m)	ΔZ (m)
UNPG	0	0	0
REFO	-0.002	-0.008	-0.012
REPI	0.003	-0.007	0.002

Table 7 - Differences between reference coordinates and Multiconstellation (2 GPS) coordinates

	ΔX (m)	ΔY (m)	ΔZ (m)
UNPG	0	0	0
REFO	-0.016	-0.039	-0.041
REPI	-0.01	-0.049	-0.02

Table 8 - Differences between reference coordinates and Multiconstellation (3 GPS) coordinates

	ΔX (m)	ΔY (m)	ΔZ (m)
UNPG	0	0	0
REFO	0	0.004	-0.018
REPI	0.01	0	0.007

Table 9 - Differences between reference coordinates and Multiconstellation (4 GPS)coordinates

4. CONCLUSIONS

In the present contribution is shown the real applicability of the "Multiconstellation" approach under operational conditions of GNSS survey, it represents a confirmation of the results previously shown in earlier work but with more flexible possibilites to choose the subconstellations. These evaluations following from the fact that the tests have been conducted varying the number of the GPS satellites in one of the two subconstellations also reaching the case limit of only GLONASS satellites in a subconstellation. It must be underlined that, although the reported results are exclusively those related to the tests effected with the software Topcon Tools, "Multiconstellation" was tested with other commercial softwares, as LGO by Leica and TTC by Trimble, finding nevertheless greater difficulty in the management of this innovative technique of data pre-processing.

As already confirmed various times, the great advantage of the approach introduced in this job consists in the possibility to opportunely divide the observations of a same session of measure, but coming from different satellites, with the purpose to make independent observations that otherwise would not be. In the future, with the definitive completion of the constellation GLONASS with further satellites as well as with the full operativity of the European constellation GALILEO, this will be applicable in a greater number of circumstances. With the full activity of the GNSS systems in fact it could be hypotized on realizing from a single constellation more than two subconstellations among them independent so that to maximize the number of independent baselinelines in a single session of measure. Obviously this would be possible only upgrading the software Multicon that presently assumes as input mixed observations GLONASS/GPS and it realizes subdivisions of aforesaid files in two only subgroups of satellites. The development and the success of the approach Multi-Constellation they will depend, besides, also from the changes that necessarily it must be operated in the commercial softwares for the treatment of the GNSS data.

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BIOGRAPHICAL NOTES

Valerio Baiocchi, graduated with full marks in Geological sciences at "la Sapienza" University of Rome during 1993. In 1999 he obtained his first PhD degrees in Geodesy ad Cartografy and in 2010 he obtained his second PhD in Infrastructure and Roads at "La Sapienza" University. From 2008 he is Researcher-Adjointed professor at "La Sapienza" University, Department of Civil, Environmental and Building Engineering. He is the author of more than 150 scientific papers, published on specialized scientific journals and in the proceedings of national and international conferences.

Francesca Giannone, graduated in physics at the University of Rome La Sapienza in 2002. In 2007 she obtained her PhD degrees in Infrastructures and Transportation at University of Rome “Sapienza”, with PhD Thesis: “A rigorous model for High Resolution Satellite Imagery Orientation” (tutor: Prof. Mattia Crespi). Post-doc research activity at the University of Rome “Sapienza”, Department of Civil, Environmental and Building Engineering, main topic: geomatic monitoring of historical buildings, high-resolution satellite imagery, GNSS data processing.

Maria Vittoria Milone, graduated in Environmental Engineering at the University of Rome "La Sapienza" in 2011, with a rating of 110 out 110 with laude. From 2011 she is a PhD student in Infrastructures and Transportation, Department DICEA at University of Rome "La Sapienza" (tutor: Prof V. Baiocchi).
Main research topic: GNSS data processing, high-resolution satellite optical imagery.

Martina Mormile, graduated in Environmental Engineering at the University of Rome "La Sapienza" in 2011, with a rating of 110 out 110 with laude. From 2011 she is a PhD student in Infrastructures and Transportation, Department DICEA at University of Rome "La Sapienza" (tutor: Prof V. Baiocchi).
Main research topic: GNSS data processing, high-resolution radar satellite imagery.

Grazia Pietrantonio, PhD in Geodetic and Surveying Sciences. Researcher at Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy.

CONTACTS

Prof. Valerio Baiocchi, Dott. Francesca Giannone, Dott. Maria Vittoria Milone, Dott. Martina Mormile

"Sapienza" University of Rome- DICEA - Area of Geodesy and Geomatics
Via Eudossiana 18 , I-00184
Rome
ITALY
Tel. +39 0644585068
Fax +39 0644585515
Email: valerio.baiocchi@uniroma1.it
Web site:w3.uniroma1.it/valerio.baiocchi/index.htm

Dott.ssa Grazia Pietrantonio
Istituto Nazionale di Geofisica e Vulcanologia, sez. CNT
via di Vigna Murata, 605 00143
Rome,
ITALY
Tel. +390651860266
e-mail: grazia.pietrantonio@ingv.it