A SOFTWARE MODULE FOR QUALITY CONTROL OF CEGRN SITES

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ABSTRACT

GPS observations are still influenced by a whole amount of effects, as for example multiple reflections, ionosphere etc. which have an impact on the accuracy of the observables even on carefully selected sites. Up to now these effects can not be mitigated or modelled satisfactorily. Hence the monitoring of these station specific effects is mandatory in order to judge about data quality and derive weighting or deletion schemes for optimal parameter estimation.

Within the tasks of the work package 4 of the Central Europe Geodynamics Project (CERGOP), a software tool was developed to monitor the continuously operating reference stations of the network. The development was carried out using C++ libraries available for the most common operating systems. Here we describe the basic features of this package and give an overview of its present status.

1. INTRODUCTION

Station monitoring aspects have been analysed by CERGOP-2 work package 4 in a number of papers before. Main aspects were the analysis of signal to noise ratio for multipath detection and elimination, analysis of residuals from double differences and precise point positioning adjustments, among others. Based on these experiences a software tool for station monitoring is presently development which should allow the use of real-time, on-line data at a particular CGPS station for initial data quality estimation and the derivation and initiation of associated actions for optimal processing strategy and data treatment. In this paper three aspects are dealt with. Within the first part of this paper the main feature of the CERGOP Station Monitoring (CSM) software for CEGRN permanent GPS stations, the quality monitoring software part, will be described.

The second part of this paper includes exemplary analyses of CEGRN permanent GPS stations in order to show the usability of the software-modules as well as areas of applications.

Finally, as a first example, the wavelet analysis of signal to noise ratio observations is presented. These analyses where performed in order to identify, filter and compute carrier phase multipath in GNSS data.

2. CERGOP STATION MONITORING (CSM) SOFTWARE

The software is organized in two parts, the processing unit and the graphical user interface, as shown in Fig. 1.

$$MP1 = P1 - \frac{9529}{2329} * L1 + \frac{7200}{2329} * L2 - mp_{L1}$$

$$MP2 = P2 - \frac{11858}{2329} * L1 + \frac{9529}{2329} * L2 - mp_{L2}$$

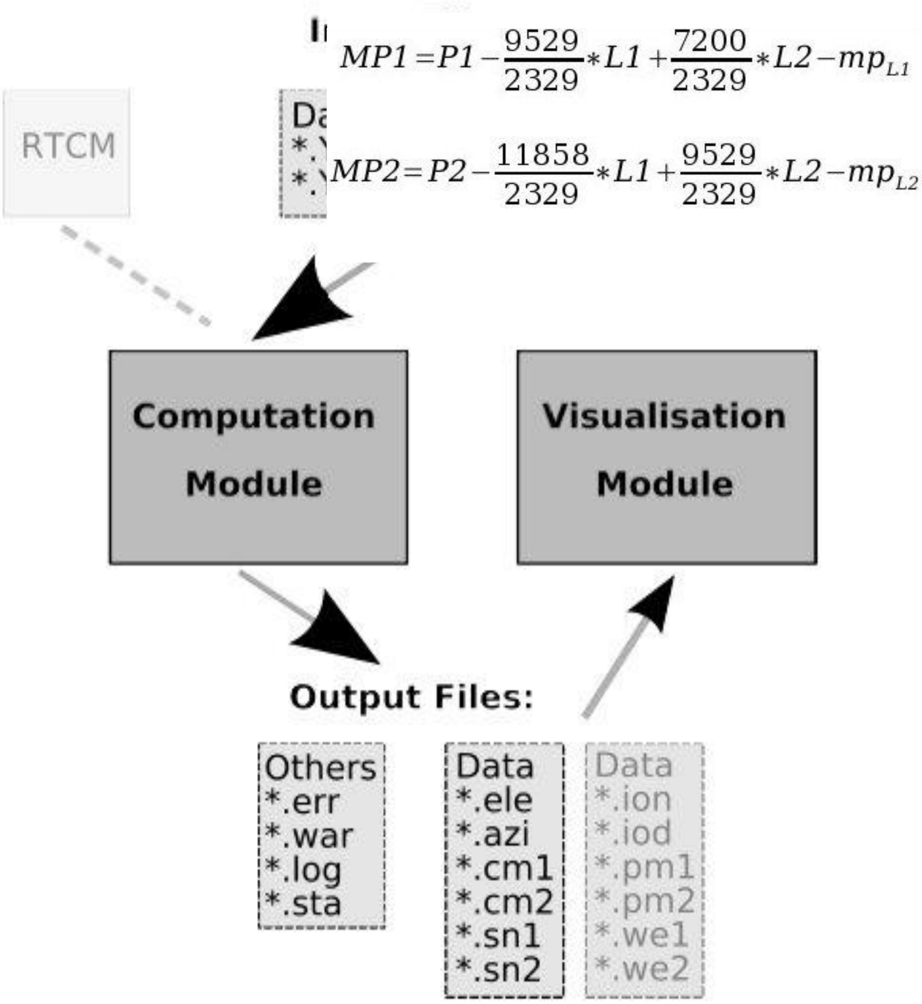
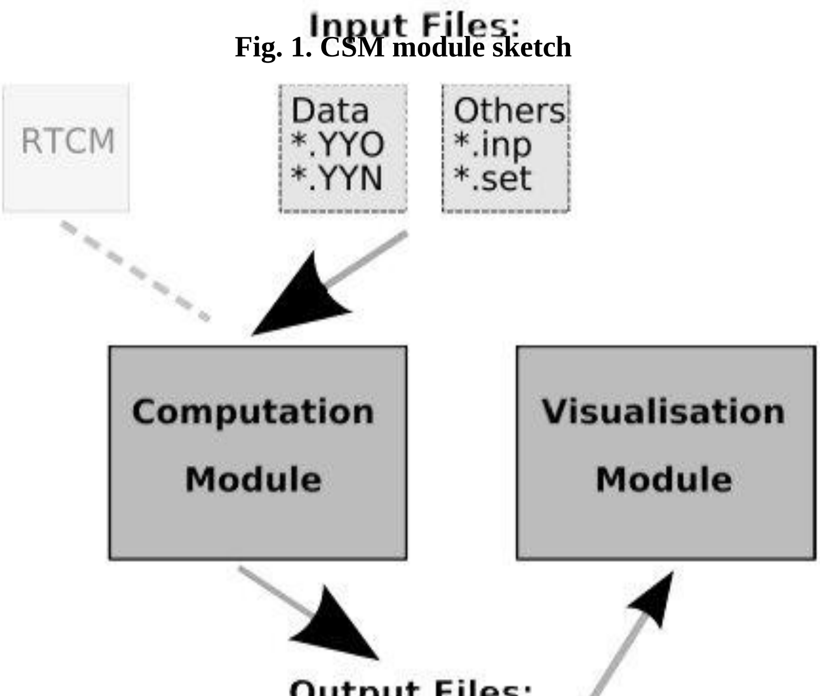


Fig. 1. CSM module sketch



The processi … e a real-time proces … on GPS observation … is signal to noise file … quality criteria etc. … euse the stored resul … alarms, weighting in …

The comput … ll phase multipath ef … wing the discussion o …

Phase multipath detection is not yet implemented. Up to now, separate software is used to get a first approximation of these effects. There are currently two different approaches to model phase multipath effects: the first is based on double difference residuals [Kirchner et al., 2004] and the second is based on the signal to noise ratio (SNR) analyses [Bilich A. et al., 2003], [Kirchner et al., 2005]. In view of real-time monitoring, the SNR approach is the one to be implemented.

The user interface to visualise the results was developed independently as a separate tool. Fig. 2 and Fig. 3 exemplarily show elevation and azimuth dependent effects along the satellite tracks. For the final version of CSM, additional visualisation modes are planed.

3. CEGRN STATION ANALYSES

As an example for areas of application, the observation data of two stations used within EUREF Permanent Reference Network (EPN) and the Central Europe GPS Geodynamic Reference Network (CEGRN), Zimmerwald (Switzerland) and Bolzano (Italy) was analysed using the CSM processing unit without implying any cut-off elevation. This analysis produces station statistics based on the complete time span included in the RINEX observation file (24). Furthermore SNR, code multipath, azimuth and elevation files were generated and analysed. As an example, the results of the code multipath analyses on L1 are shown.

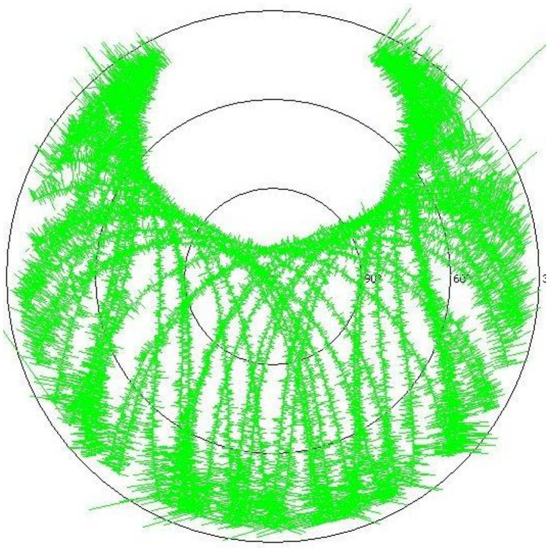


Fig. 2. Code multipath on L1 (Zimmerwald, GPS permanent reference station included to CEGRN)

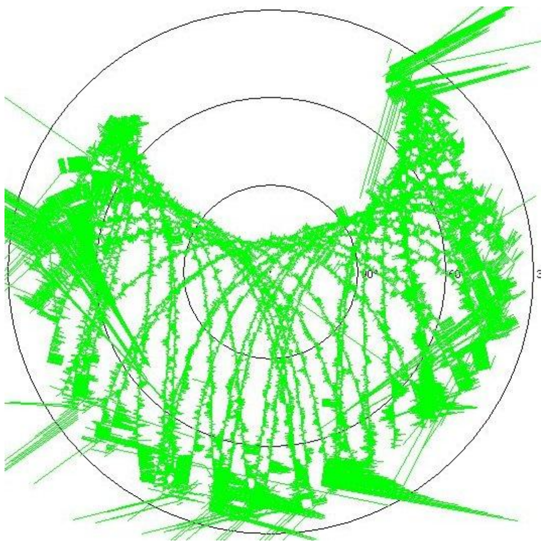


Fig. 3. Code multipath on L1 (Bolzano, GPS permanent reference station included to CEGRN)

The code multipath plot for Zimmerwald (Fig. 2) shows no obstructions or special multipath sources. Periodic behaviour can be found on the multipath, plotted along the satellite tracks. Furthermore an increase of the code multipath effects for lower elevations can be seen. The missing observations for elevations below 6° are caused by a cut-off angle set in the receiver.

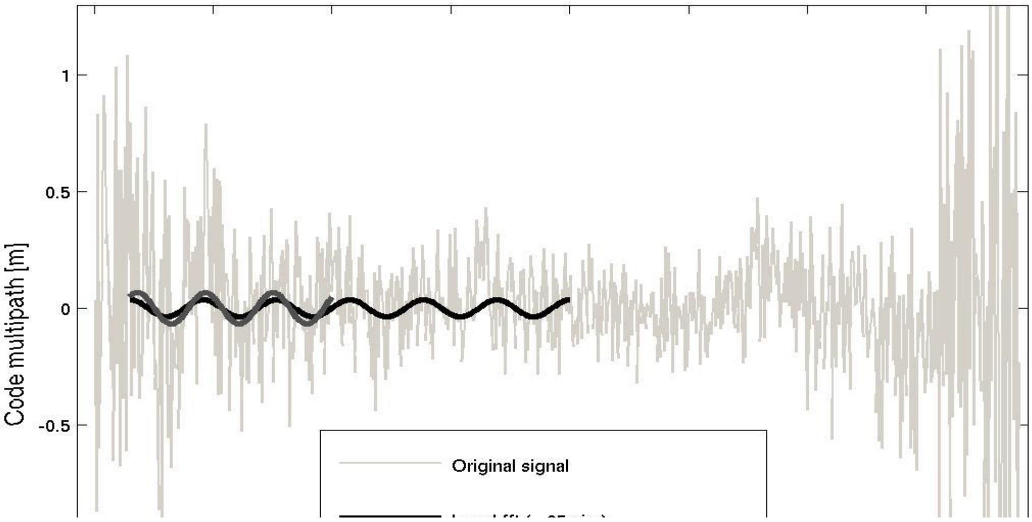
Looking at the sky plot for Bolzano (Fig. 3), areas of missing observation as for example in the North West or the south east can be localised. The missing observation may be caused by obstructions.

Furthermore different areas strongly affected by code multipath can be found, as for example in the west or the south.

For the further examples, a special satellite (GPS PRN3) on the station Zimmerwald was selected. In order to show that there are different code multipath effects even for stations without obstructions and strong multipath effects, the code multipath on L1 is plotted against the elevation (Fig. 4) for satellite rise and satellite set. A difference is noticeable between satellite rise and set. Assuming similar behaviour for phase multipath, the knowledge of these effects, as well as the proper consideration of these effects is important. Up to now, mainly the elevation is used for the weighting of satellite observations within the processing, neglecting the information about station dependent effects at a particular site.

In order to show the time dependent behaviour of code multipath, the same data is plotted as a function of time (Fig. 5). This figure shows the periodic behaviour of code multipath, as well as the problem for the analyses. As noticeable, the multipath frequencies vary over time, depending on the reflector(s), the satellite elevation and the distance between reflector and antenna.

Assuming the frequencies being



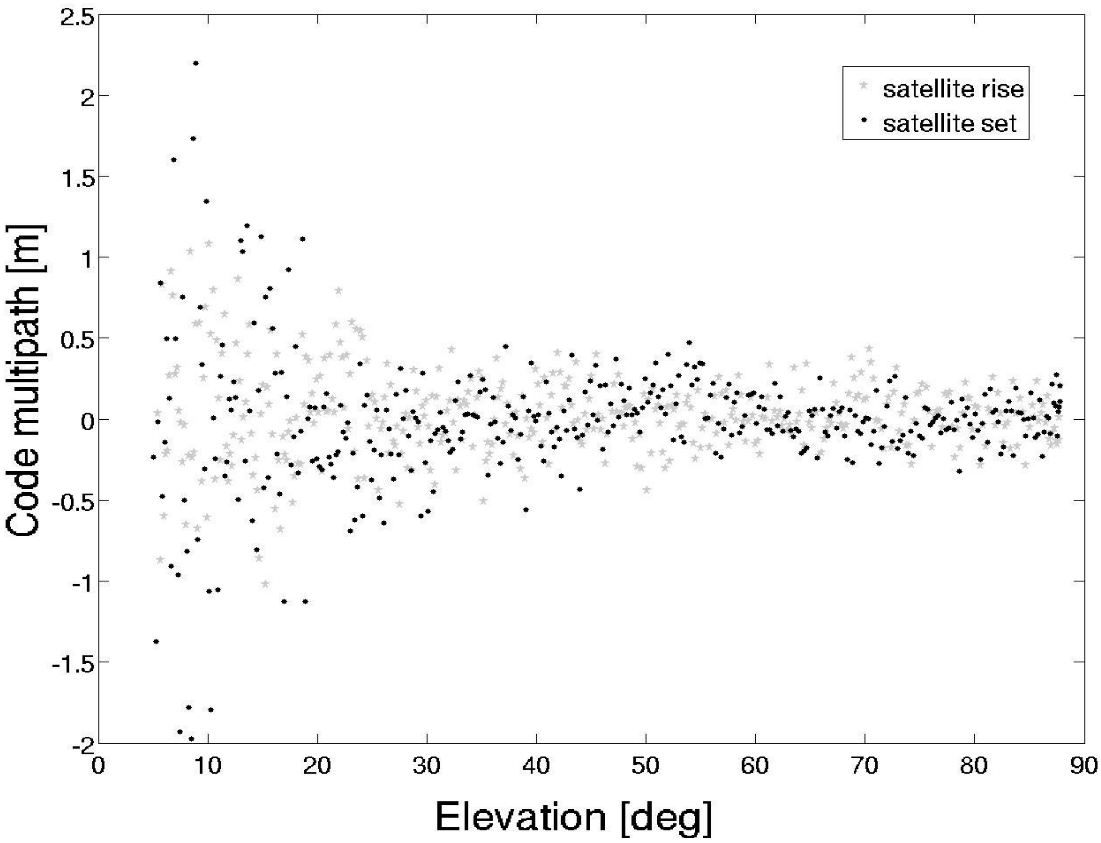


Fig. 4. Code multipath on L1 computed using CSM, showing azimuth dependent multipath for equal elevations

constant for a small period of time, individual frequencies can be detected by using Fourier transformation (FFT). The main problem using this technique is the choice of a window size, small enough to keep the frequency approximately constant and long enough to get a sufficient set of sampling points.

4. PHASE MULTIPATH ANALYSES BASED ON SNR VARIATIONS

In order to implement the computation of phase multipath effects, different analyses and tests have been carried out. The effects of signal deterioration due to reflections show up in a reduced and varying signal to noise ratio (SNR). Assuming the phase multipath effects as periodic signals within a special range of frequencies, the detection of phase multipath is carried out in the frequency domain.

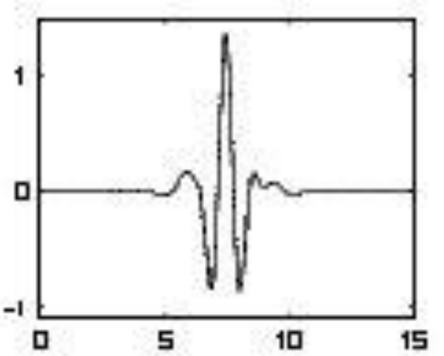


Fig. 6. Symlet8

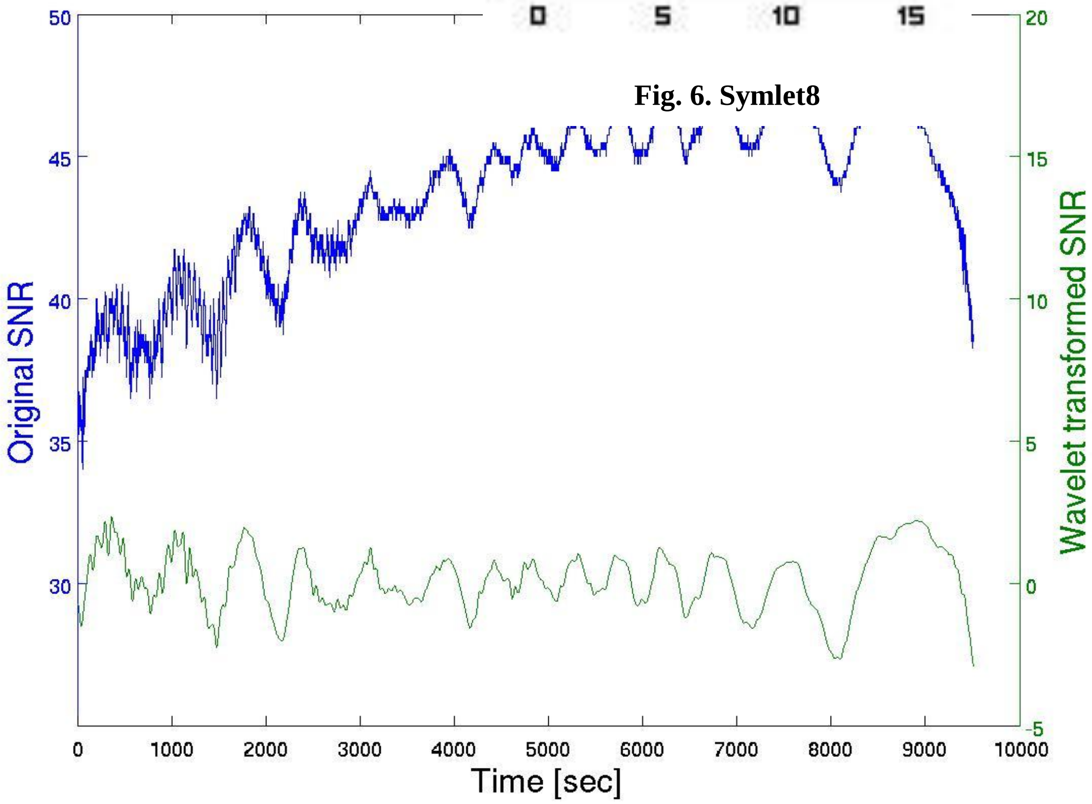


Fig. 7. Original SNR versus wavelet transformed SNR (only periods between 1min and 51min)

Wavelets are employed to detect time periods affected by phase multipath, as well as its dominant frequency bands. Within the first step of this analysis, data sets long enough to search for the expected frequency spectrum were selected. In order to get continuous data, gaps within the data up to 10 missing observations were interpolated linearly.
Within these analyses, the “symlet 8” wavelet (Fig. 6) turned out to be best suited best. Via the wavelet analysis, high frequency noise and low frequency atmospheric effects as well as the variations of antenna gain could be removed. Fig. 7 shows the original SNR signal (black) and the transformed signal (grey) containing only pseudo frequencies between 1min and 51min. As noticeable in this graphic, the transformed signal still contains the frequencies of periodic multipath effects.

In order to detect the time of appearance for frequencies within the expected range, the wavelet coefficients were analysed. Fig. 8. shows wavelet results with the appearance of pseudo frequencies at special time periods, the colour specifies the correlation to the scale wave, i.e. the intensity of multipath at these frequencies. Based on the results of the wavelet analysis (power of pseudo frequencies, and time periods), a least squares adjustment can be used to compute the amplitude and the phase of multipath in that particular time window and to potentially assign it to a particular reflector active in that interval.

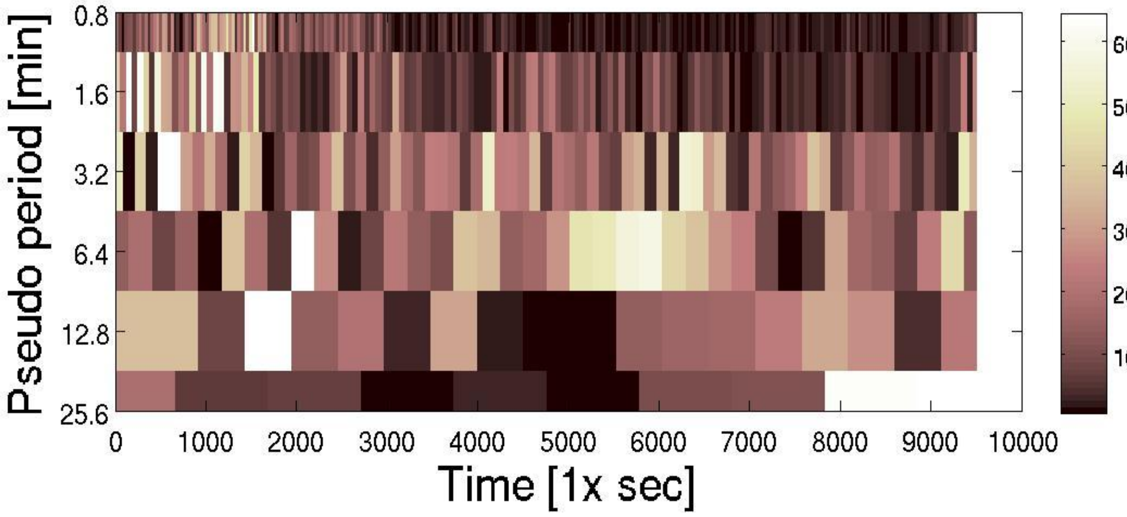


Fig. 8. Wavelet analyse for the SNR signal on L1

5. Conclusion

The CERGOP Station Monitor software (CSM) is a tool to analyse GPS observation data, generate statistics, compute code multipath and extract signal to noise ratios. The graphical user interface is used to visualise the computed code multipath, signal to noise ratios and in future also the phase multipath e.g. as sky plots.

Within this paper, a code multipath analysis for two stations of different station quality using CSM was shown. This example also demonstrates that code multipath is not exclusively depending on the elevation of the satellites only.

A wavelet band pass filter was used to separate the multipath prone frequency band. Within the latter analyses multipath frequencies and intensities are identified. Further works will concentrate on the operational use of the wavelet analysis to identify, isolate and remove phase multipath from CEGRN station data.

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