DISPLACEMENT MONITORING OF ENGINEERING OBJECTS USING GPS-RTK TECHNIQUE

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Abstract

Determination of the geometrical characteristic of engineering objects is necessary to their safe exploitation. Modern terrestrial and satellite measuring techniques make possible the permanent monitoring of the objects. The techniques make also possible measuring reference object and moving object at the same time.
Poster presents a concept how to take advantage of kinematics satellite GPS-RTK measurements and FIR filters to determine of few millimetres displacement.

INTRODUCTION

We face the problem of digital signal filtering in most common devices such as cellular phones, audio players, television sets, etc. They are all the site of execution of more or less advanced signal digital filtering algorithms. Geodetic measurements performed using modern equipment such as digital levelling instruments or total stations are also incapable of operation without the elimination of various types of interference resulting from the measuring processes themselves. This method can also eliminate or significantly weaken interference from external factors (e.g. atmospheric influence, the effects of secondary wave interference, etc.). This article, in its sections below, presents an analysis of the possibility of utilizing SOI filters (filters with a finite impulse response) to develop RTK kinematic observations conducted in experiments performed at a specially designed research station.

APPLICATION OF DISCRETE FOURIER TRANSFORMATIONS IN THE PROCESS OF FILTERING OBSERVATIONS

The algorithm for discrete Fourier transformations has a property making possible its use as a band filter. The midpoint of the band is located near the mfs/N frequency (where fs is the sampling frequency and N is the number of samples). The significant feature of the Fourier algorithm is primarily the potential for strengthening the signal, but the algorithm also makes it possible to decrease the width of the band by decreasing the number of signal samples N. Decreasing the width of the band primarily improves signal resolution, which in turn facilitates the extraction of the signal from background noise that is also found in the carrier band itself. The quantitative representation of gains from applying the Fourier discrete transformation may be defined as the ratio of output signal strength of the discrete Fourier transformation to the medium output noise level (Signal to Noise Ratio SNR). There is a general dependence which states that

as the number of samples N increases, the value of the SNR grows. The gain in the Fourier discrete transformation increases by approximately 3 dB if N is doubled .
A major problem appearing in Fourier analysis is what is known as the frequency leakage. Spectral lines of large amplitude interfere with spectral lines size of small amplitude. This phenomenon is responsible for the result of discrete Fourier transformation being an approximation of the real spectrum of the input series. In order to minimize such effects it is necessary to apply a procedure that is known as windowing. Many windowing procedures are described in literature. Rectangular windows were used in analyzing the results of measurement experiments; they do not decrease frequency leakage and do not distort the input signal envelope. From a technical point of view, the solution to the problem of reducing noise that interferes with the signal comes down to subtracting the noise from the signal in the field of the signal's spectrum.

RESEARCH STATION EXPERIMENT

Interesting investigations into the geometry of the upper reservoir of the pumpedstorage power station at Żarnowiec resulted in a decision to design a special research station that would allow for more objective and detailed studies of the measurement techniques and methods for analyzing satellite observations used there. The concept for this station assumed that it is possible to precisely shift the GPS antenna in only one direction. The speed and size of the shift as well as the duration of the experiment were programmed by the user. Use of a stepping motor as well as the precision execution of mechanical components make it possible to estimate the accuracy of shift specification using this device at approximately 0.1 mm (Fig. 1).

Fig. 1. Experimental equipment

The measurement experiments encompassed two days (2 X 24 hours), where the GPS antenna was shifted in a different manner each day (different experiment duration and antenna path). The first experiment involved the shifting of the antenna over a range of 10 mm at a speed of approximately 0.15 mm/min (the surface shifted along a path equal to 1 cm over a period of 66 minutes). The second experiment was based on the shifting of the antenna along a 5 mm path, but at a significantly lower speed (the antenna traveled 5 mm over a period of 6 hours). Positions defined using the GPS RTK mode (sent to the computer by means of radio) and the registration of raw observations by the “mobile” instrument were recorded by the computer over the course of the experiment. The

graphs below (Fig. 2 and Fig. 3) present time series registered during the course of both experiments.

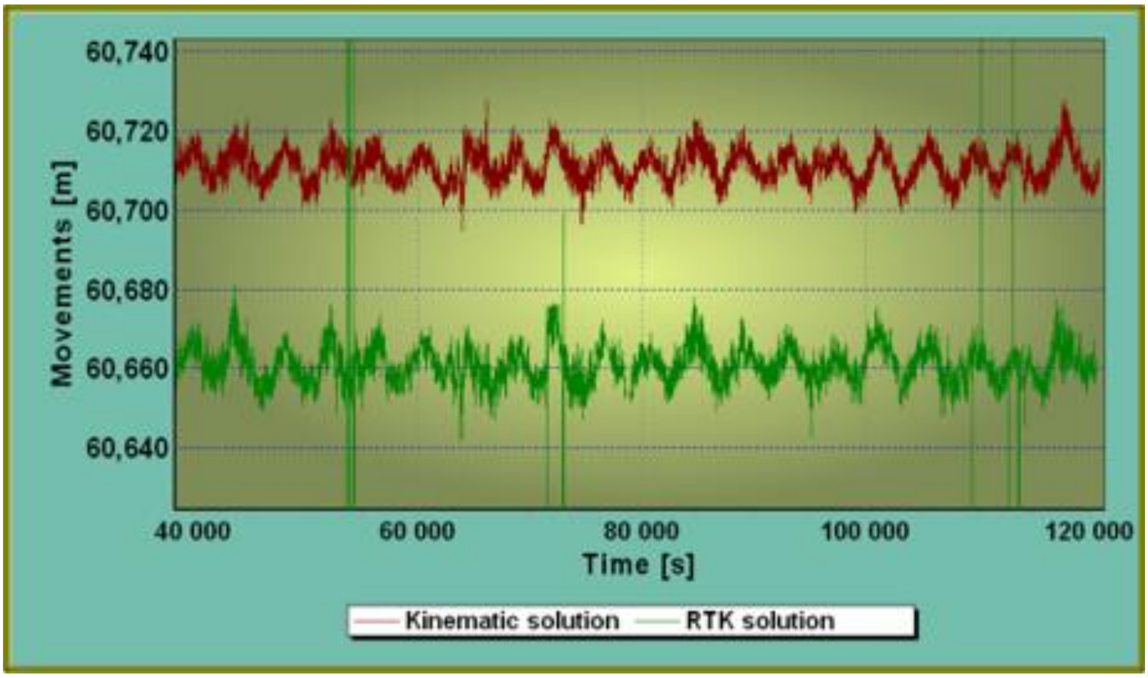

Fig. 2. Ten-milimetres displacements

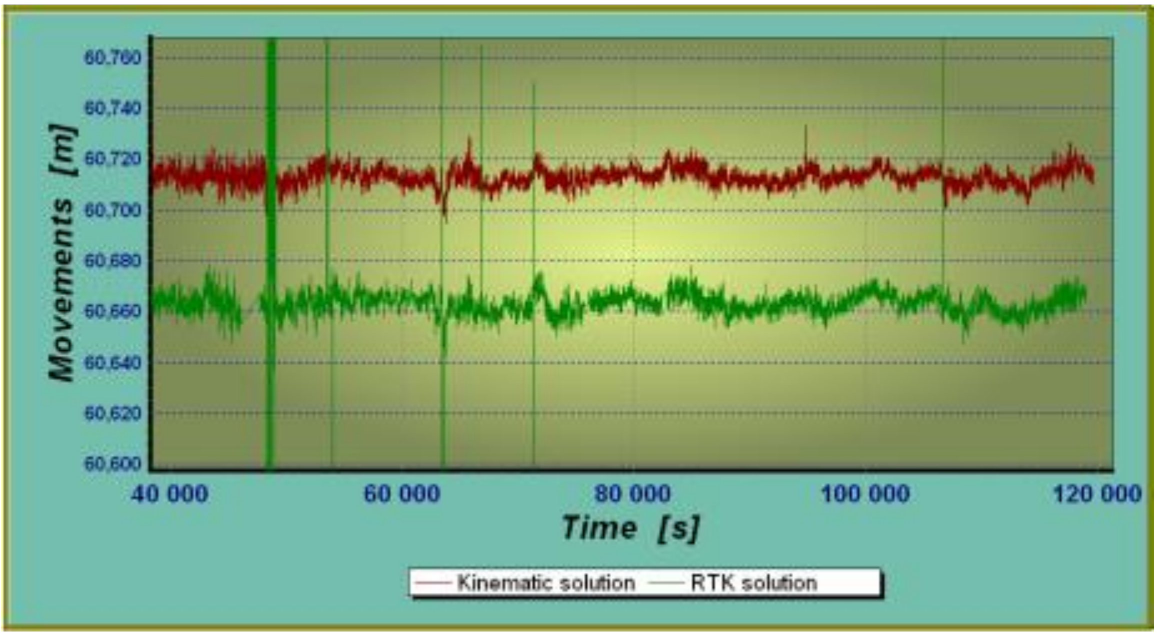

Fig. 3. Five-milimetres displacements

For greater legibility, the time series from the kinematic and RTK solutions have been mutually shifted. Note should be taken of the characteristic peaks occurring in the RTK solution. They are caused by a momentary loss of the differential correction transmitted from the reference station. Such interference was removed from further analyses by a median filter.

A statistical compression of the postprocessing kinematic solution (ks) and the RTK solution demonstrate that the standard deviation of the results of the RTK solution is significantly greater (sd RT = 0.014 0.015, sd. Kp = 0.003 0.004) (Tab. 1 and Tab. 2) than the solution achieved in postprocessing. A lowpass filter based on discrete Fourier transformation was designed for the further part of the analysis.

Table. 1. 5 milimitres displacements

Kinematic solution		
Observations	**Observations - model**	**FFT - model**
Standard deviation	*Mean error*	*Mean error*
0.0034 m	***0.0033 m***	***0.0008 m***

RTK solution		
Observations	**Observations - model**	**FFT - model**
Standard deviation	*Mean error*	*Mean error*
0.0140 m	***0.0141 m***	***0.0011 m***

Table. 2 10 milimetres displacements

Kinematic solution		
Observations	Observations - model	FFT - model
Standard deviation	*Mean error*	*Mean errori*
0.0039 m	***0.0030 m***	***0.0010 m***

RTK solution		
Observations	Observations - model	FFT - model
Standard deviation	*Mean error*	*Mean error*
0.0152 m	***0.0150 m***	***0.0020 m***

The accuracy analysis was performed with respect to no model and the implemented model of antenna movement. In comparing the shift model with the results of filtering operations it is possible to note significant convergence between them. The average calculation error based on differences between the model and the series with observation noise is at a level of 0.001 - 0.002 mm for both types of solutions (the difference between measured and model values is thus a real error in observation or in the filter applying discrete Fourier transformations).

SUMMARY

Experiment results demonstrate that the monitoring of engineering objects applying GPS RTK techniques may serve as an effective, reliable, and precise method for defining shifts in real time. Moreover, in analyzing the results of the measurement experiments it is possible to note that:

- ✓ **Observations conducted using RTK techniques are encumbered by significantly greater random noise as compared with the kinematic solution with postprocessing. The application of the registered signal filtering method as proposed in the publication facilitates the achievement of an accuracy to several millimetres for defining shift, including in RTK solutions.**
- ✓ **Harmonic analysis of the observation using discrete Fourier transformation may serve as a starting point to the building of cause and effect models of the motions of examined objects. However, in applying filtering procedures it is important to remember the physical characteristics of the investigated phenomenon so algorithms reducing observational noise do not deform real changes occurring in the object.**

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