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A Correlation Analysis of Measured CO-Concentration Signals

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Abstract – Ideal low-pass filtering can be used as a useful pre-processing method in order to eliminate the measuring noise from signals representing CO-concentration. Thereafter, the correlation coefficient proves to be a suitable tool in a comparative analysis of the data. If the signals are measured simultaneously and in the same location, using different instruments, the correlation analysis allows a comparison of the measuring systems. Applied to signals measured with a single instrument, the correlation analysis can put into evidence diurnal repeatability of CO-concentrations.

Keywords: CO-concentration, ideal filtering, correlation coefficient.

I. INTRODUCTION

CO-concentration signals have a nonstationary, random character. Consequently, certifying the validity of CO-concentration data delivered by different measuring devices can be a difficult task.

In this paper, a method allowing comparative analysis of CO-concentrations measured with two fully different instruments is presented. Thus, the classic HORIBA instrument measures the CO-concentrations locally, in a certain point, while the Siemens-HAWK analyser delivers CO-concentrations spatially averaged over a distance of $10 \div 100\text{m}$. Obviously, the two instruments do not measure the same quantity, but a comparison of the measured data is still meaningful since both signals are representing the pollution level in the same location [1], [2], [3].

II. THE MEASURED SIGNALS

Fig.1 shows three signal pairs measured in a crossroad (C), by day (D) with the Horiba instrument (H) respectively using the Siemens-Hawk (S) analyzer. From top to bottom, the signal pairs represented in fig.1 are: (CDH1-CDS1), (CDH2-CDS2) and (CDH3-CDS3). The signal pairs were measured on consecutive days, in the same hourly interval. Each CO-concentration signal contains 3500 samples achieved at a sampling period of 6 seconds, corresponding to a sampling frequency of (1/6) Hz, or 600 cycles/hour. The temporal length covered by each signal is 5h50'. The concentrations are measured in $[mg/m^3N]$. Such signal pairs were measured, by day and by night, in several parks and crossroads of Timişoara city.

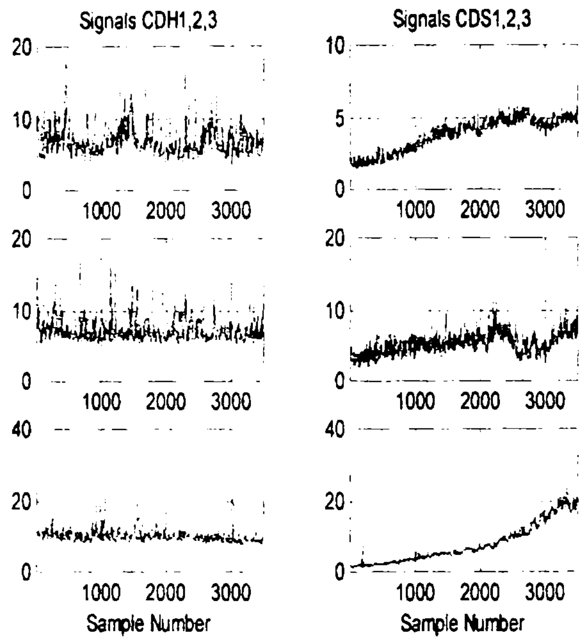

Fig. 1. Typical signals measured with Horiba (CDH*) and with the Siemens-Hawk (CDS*) instrument, respectively.
All concentrations are measured in $[mg/m^3N]$.

III. IDEAL FILTERING

Signal conditioning is an unavoidable step in any signal processing application [4]. "Ideal" filtering can be chosen as an useful pre-processing method. An ideal low-pass filter has the frequency characteristic:

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presented in fig. 1 were filtered using $f_c = 2$ cycles / hour. The low-pass (LP) part of the measured signals can be seen in fig. 2. The rapid fluctuations of the initial signals, including measuring noise, were elliminated through low-pass filtering.

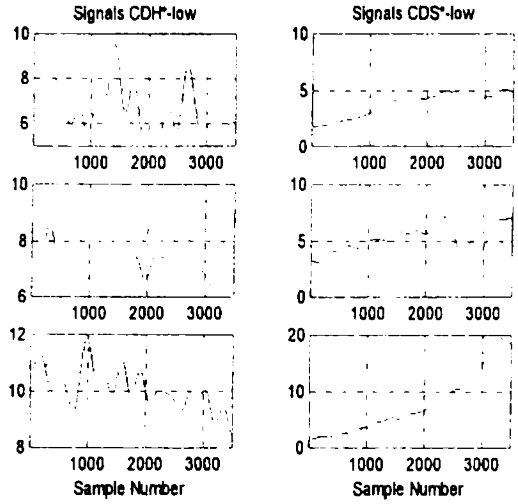

Fig. 2. LP signal pairs CDH*-low and CDS*-low, in [mg/m^3N].

In the same manner, using ideal high-pass filtering, one can obtain the high-pass (HP) part of the measured signals. Thus, the signals CDH*-high and CDS*-high represented in fig. 3, contain only frequencies greater then 2 cycles / hour.

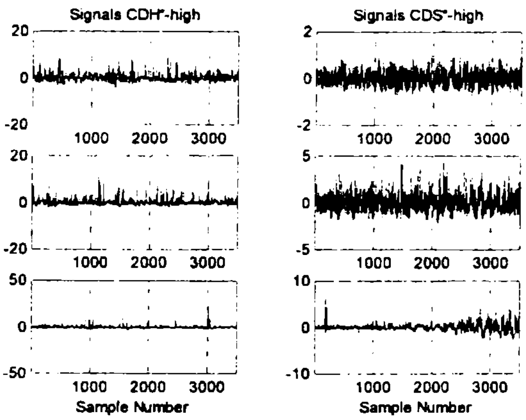

Fig. 3. HP signal pairs CDH*-high and CDS*-high in [mg/m^3N].

The HP part of the signals can be analysed in order to evaluate the measuring noise, to optimise the sampling period, the cut-off frequency etc. However, in the following, we are interested only in the LP part of CO-concentration signals. Using the correlation coefficients between the LP part of the signals measured under similar conditions (the same place and time interval for one signal pair; however, different days for different signal pairs), one can compare the tendencies of the CO-concentrations measured with the Horiba and Siemens devices, respectively. Correlation coefficients of the LP part of the air pollution signals represent also a good measure of the "diurnal" repetition of the CO-concentration level. This correlation is meaningful since the pair of signals were measured on consecutive days or nights, starting at the same hour.

IV. CORRELATION ANALYSIS

The measured CO-concentration samples can be seen as realizations of some random variables. The correlation coefficient of two random variables $x[n]$ and $y[n]$, defined by [5],

$$r_{xy} = \frac{C}{\sigma_x \sigma_y} \qquad (2)$$

where C and σ_x, σ_y are the covariance respectively the variances of $x[n]$ and $y[n]$, can be used as a comparison tool between two or several data series. Since $-1 \le r_{xy} \le 1$, through comparative analysis one can distinguish three different cases:

$$\begin{cases} \textit{positive correlated data} & \textit{for } 0.33 < r_{xy} \le 1; \\ \textit{uncorrelated data} & \textit{for } -0.33 \le r_{xy} \le 0.33 \\ \textit{negative correlated} & \textit{for } -1 \le r_{xy} \le -0.33; \end{cases} \qquad (3)$$

For example, the correlation coefficients matrix for the six LP signals represented in fig. 2 are shown in Table 1. Numbering the LP signals according to Table 2, the correlation coefficient $r_{ij} = r_{ji}$ characterizes the resemblance between signals i and j.

Table 1

1.0000	-0.0774	0.0448	-0.2851	-0.0144	-0.2620
-0.0774	1.0000	-0.4630	0.6906	-0.5757	0.7735
0.0448	-0.4630	1.0000	-0.1601	0.1942	-0.5015
-0.2851	0.6906	-0.1601	1.0000	-0.4156	0.5531
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
-0.2620	0.7735	-0.5015	0.5531	-0.6787	1.0000

Table 2

Signal number i, j	LP Signal
1	CDH1-low
2	CDS1-low
3	CDH2-low
4	CDS2-low
5	CDH3-low
6	CDS3-low

For an easier interpretation, the correlation matrix is graphically represented in fig. 4. Obviously, the signals measured with Horiba instrument are not correlated (absence of diurnal repetition). On the contrary, the signals measured with the Siemens instruments are highly and positive correlated, denoting a diurnal repetition of CO-concentration.

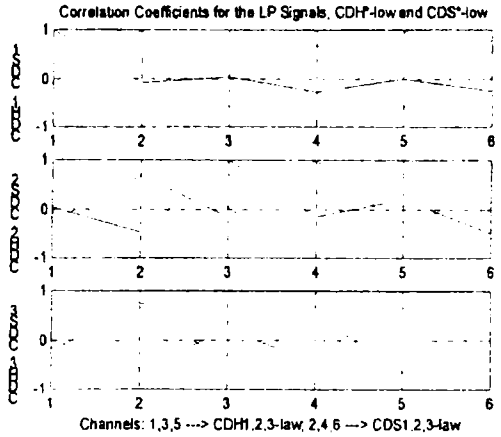

Fig. 4. A graphical representation of the correlation coefficients for the signals CD**-low

A similar representation of the correlation coefficients matrix for signals CN**-low obtained from data measured in a crossroad (C) by night (N), can be seen in fig. 5.

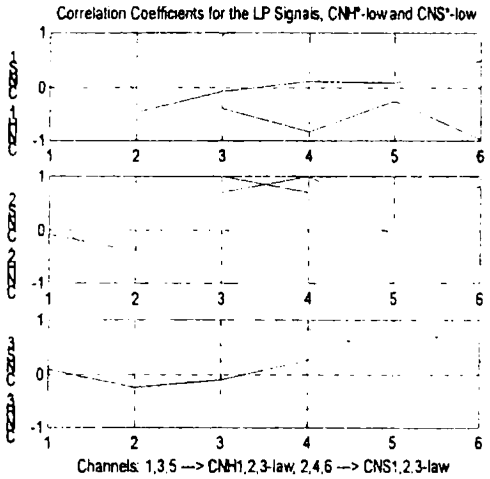

Fig. 5 A graphical representation of the correlation coefficients for the signals CN**-low

As shown in fig. 5, there is no correlation between the signals CNH*-low. The uncorrelatedness of these signals proves the absence of diurnal repetition of the concentrations measured with Horiba instrument. The signal CNS1-low is negative correlated with all other sequences. However, the signals CNS2 and CNS3 are highly positive correlated, denoting good diurnal repetition of the pollution level measured with the Siemens-Hawk analyser.

In fig. 6 the correlation coefficients between the signals PD**-low are presented. The coefficients have moderate positive values with a single exception: the signal PDS3 (number 6) follows a decreasing tendency, in contradiction with the other five sequences.

Fig. 7 shows the correlation coefficients computed for the signals PN**-low. All coefficients are positive. One can remark very good correlation between all signals. An exception is the signal PNH3

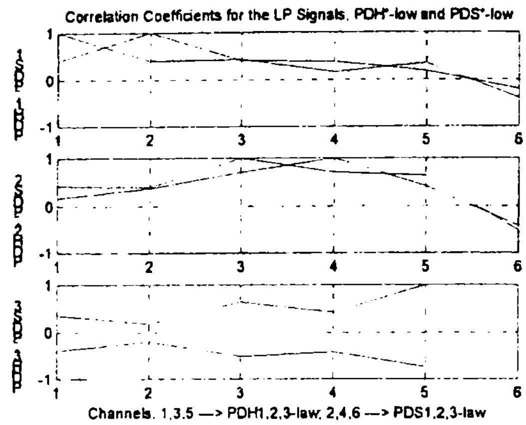

Fig. 6. A graphical representation of the correlation coefficients for the signals PD**-low

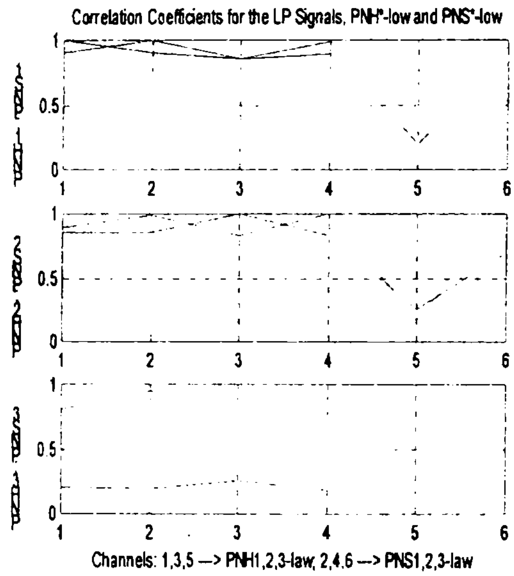

Fig. 7 A graphical representation of the correlation coefficients for the signals PN**-low

which is weakly but still positive correlated with the other signals.

V. CONCLUSIONS

The pair of signals measured in a place with low air-pollution level (park), are, with some exceptions, positively correlated. In such environments, the measured signals put into evidence diurnal repetition of the concentrations levels.

The signals measured with Horiba instrument in a crossroad (high polluted medium) are practically not correlated, denoting absence of diurnal periodicity. In such environment, the CO-concentrations measured with the Siemens devices, show diurnal repetition. This cold be explained by the fact that the concentrations measured by the Siemens instruments are average values, i.e. signals in which the low frequencies (denoting diurnal periodicity) are accentuated.

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