COMPUTER NETWORK USE FOR SIGNAL AND IMAGE ANALYSIS

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Abstract

Methods of signal analysis, modelling, classification and prediction form a general research topic with applications in many areas. The paper is devoted to description of selected basic mathematical principles and algorithms only but its main purpose is in the presentation of a general Matlab Web server to allow their remote processing. The paper presents a very limited database of real biomedical signals and images, selected signals of gas consumption and satellite observations. These signals and user defined signals are then used for their remote analysis using computer network, any Internet browser, and mathematical signal processing algorithms located on the Matlab Web server. The paper presents in this way how real signals can be processed on the remote system and how it is possible to obtain data files and their analysis using computer network. An example of biomedical signal processing forms a fundamental topic of this part of contribution. The goal of this study is the demonstration of modern tools of scientific and educational collaboration between remote research centers.

1 INTRODUCTION

Signal analysis and processing is a very important tool of information engineering with its application in technology, control systems, bioengineering, environmental systems and econometrics. Its theoretical background covers autoregressive models [12, 9, 16] and nonlinear systems based upon artificial neural networks [6, 4, 3, 1, 14] including methods of adaptive signal processing and system optimization [5, 2, 15].

2 TIME-SERIES CORRELATION

Spectral analysis represents a very widely used method for detection of periodic signal components of a given signal $\{x(n)\}$. In case of several time series $\{x(n)\}$ and $\{y(n)\}$ this kind of signal analysis can be combined with evaluation of correlation coefficients inside its stationary windows of selected length using the relation

$$r = \frac{\sum_n (x(n)-\bar{x})(y(n)-\bar{y})}{\sqrt{\sum_n (x(n)-\bar{x})^2 \ \sum_n (y(n)-\bar{y})^2}} \qquad (1)$$

to find relations between two signals. This method can be modified for image correlations, too.

2.1 Satellite Data Processing

One area in which time-series analysis can be applied is processing of satellite images, the purpose of which is examination of air pollution by means of comparison of two satellite channels using correlation methods.

The processed data represent pictures taken by a satellite operated by NOAA (The National Oceanic and Atmospheric Administration). This satellite belongs to the so-called polar

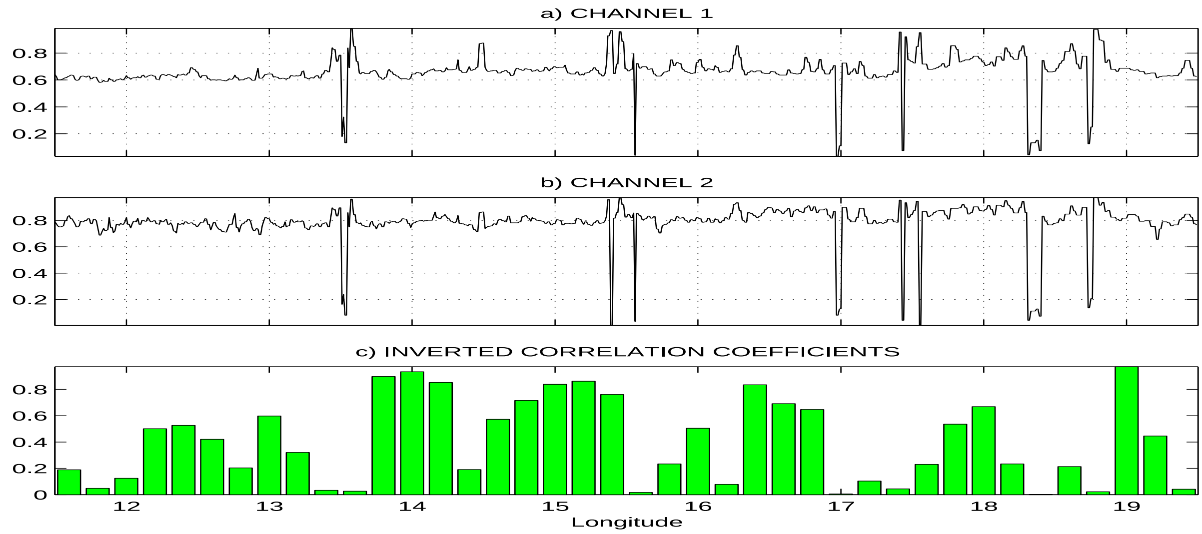

Figure 1: Correlation of satellite data for selected longitude

orbiting satellites. Polar orbiters provide meteorologists with excellent pictures of all parts of the earth including the polar regions. Due to their orbital characteristics they cannot monitor short-term variations. The main apparatus of NOAA satellites is a scanning radiometer marked as AVHRR (Advanced Very High Resolution Radiometer). This is a five-channel apparatus, and every channel covers a different spectral range; here only data from the first and second channel are shown: Channel 1 covers 0.58-0.68μm which is the red region, channel 2 covers 0.725-1.1μm which is the close infrared radiation, and channels 3 to 5 cover 3.55-3.93μm, 10.3-11.3μ.

It is assumed that images obtained by the NOAA satellite for these two channels contain the same information about surface objects, and they differ in reflection of presence of dust particles in the air. Correlation between these two images can thus be used for detection of these dust particles, localization of sources of their immission and possible prediction of this type of air pollution.

After performing two dimensional correlation between the original satellite images we obtain one image showing differences which correspond with presence of pollution caused by solid particles in the air. This result can be further studied for selected rows of observed images shown as an example in Fig. 1. Parts a) and b) represent one row of intensity levels within images from channel 1 and channel 2, respectively, with such longitude so that it goes through the Prague region. The more the shown signals from channel 1 and 2 are similar, the less pollution caused by solid particles is present in the air. The greater the difference, the greater the pollution. Part c) of the figure shows inverted correlation coefficients of the selected signals from channel 1 and 2. The lower the inverted correlation coefficient, the less pollution is present in the air (images from channel 1 and 2 are similar), and vice versa.

The mentioned topic is discussed in greater detail in articles devoted exclusively to the issue of satellite images processing. For more information on this topic refer to [11, 10] for example.

2.2 Gas Consumption Data Analysis

Basic methods of time-frequency signal analysis form a fundamental tool in signal analysis and processing. Signal described by the function *x(t)* with the free variable representing time t is transformed to the function *X(f)* the free variable of which is frequency f. After passing to the discrete area and assuming a general signal in the form $\{x(n)\}_{n=0}^{N-1}$, it is possible to apply the discrete Fourier transform (DFT) and namely its fast algorithm (FFT) that allows for finding

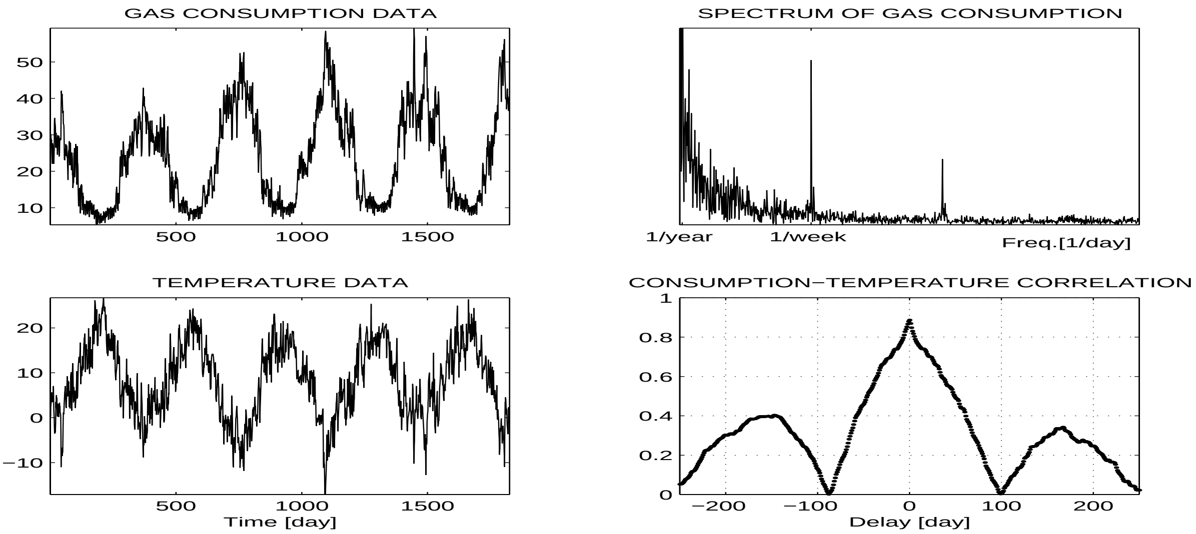

Figure 2: (a) Gas consumption data (b) Spectrum of gas consumption (c) Temperature data (d) Correlation between temperature and gas consumption

its transform in the form

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{-j\ k\ n\ 2\pi/N} \tag{2}$$

and inverse transform

$$x(n) = \frac{1}{N} \sum_{k=0}^{N-1} X(k) e^{j\ k\ n\ 2\pi/N} \tag{3}$$

for $k = 0, \cdots, N-1$ standing for frequency component $f_k = k/N$ in case of the normalized sampling frequency $f_s = 1$. This transform can be applied either to a selected signal segment or in case of the non-stationary signal it can be applied in the form of a moving window as the short-time Fourier transform (STFT).

Detection of periodicities in signals is one of possible applications of DFT. By applying DFT to a time series, we obtain information on periodical components of the signal [7, 8]. An example of the application is given in Fig. 2(b). The discrete Fourier transform has been applied to the data of gas consumption in the Czech Republic. It results in mathematical confirmation of the expected periodicity of 1 year and 1 week.

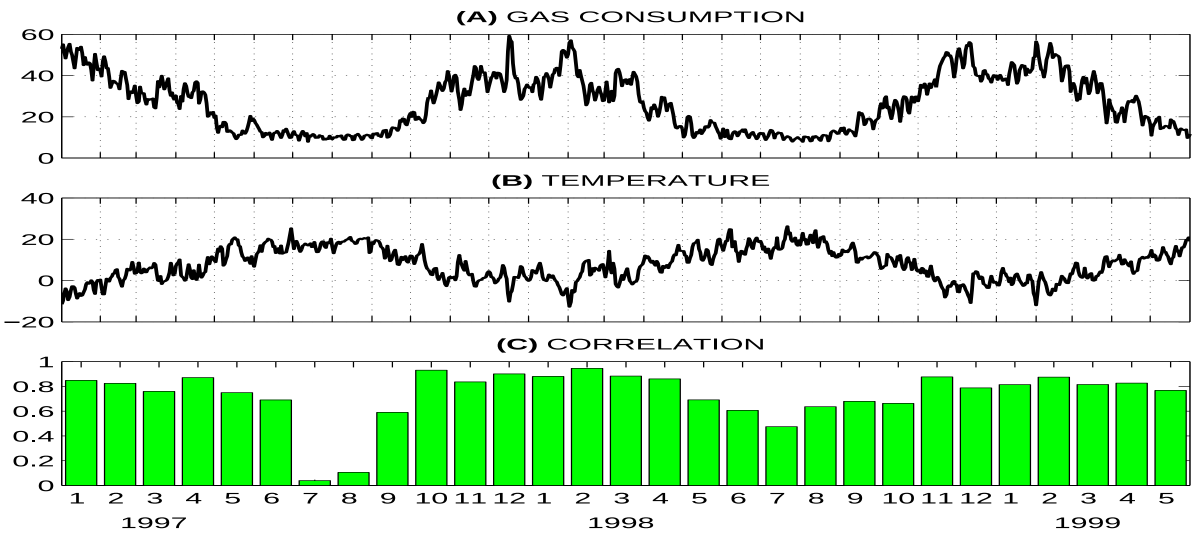

Figure 3: Correlation between temperature and gas consumption (months)

Besides the gas consumption, other information is recorded as well - the temperature, air humidity etc. For further signal processing (to perform one- or multi-step prediction for example), signal properties must be known in greater detail. Periodicity is already known, the second step is finding of correlation of time series. From Fig. 2(d), strong dependence of gas consumption on temperature can be observed. By simplifying equation 1 and applying it to the given time series, we obtain confirmation of dependence for winter months of the year and information on non-dependence of both time series in the course of the summer months (Fig. 3).

3 BIOMEDICAL SIGNAL AND IMAGE ANALYSIS

Processing of biomedical signals is another application area. With regard to the fact that here we have nonstationary one-dimensional signals, for their further processing quasi-stationary parts need to be used. But even for the segmentation, it is usually necessary to remove the noise component. To realize both of these steps, we can use a modern signal processing tool represented by the wavelet transform (WT). The methods and use of WT for these purposes has been discussed in [13]. Another rather modern application is processing of biomedical images. It is especially processing of MR images, and increasing of their resolution capability. It would be quite a logical procedure to remove the noise component and search for "interesting" parts in the images for timely diagnostics. For noise removal, the two-dimensional WT can be used. Regarding to the fact that the processed images also contains parts less interesting for the diagnostics, it is possible to work only with a certain cutout of the image. The cutout could be too small for visual evaluation, therefore the relevant section is enlarged. We can make the situation clear using a simple one-dimensional signal. One of the methods is to inlay a line through two adjacent points. This method is called linear interpolation.

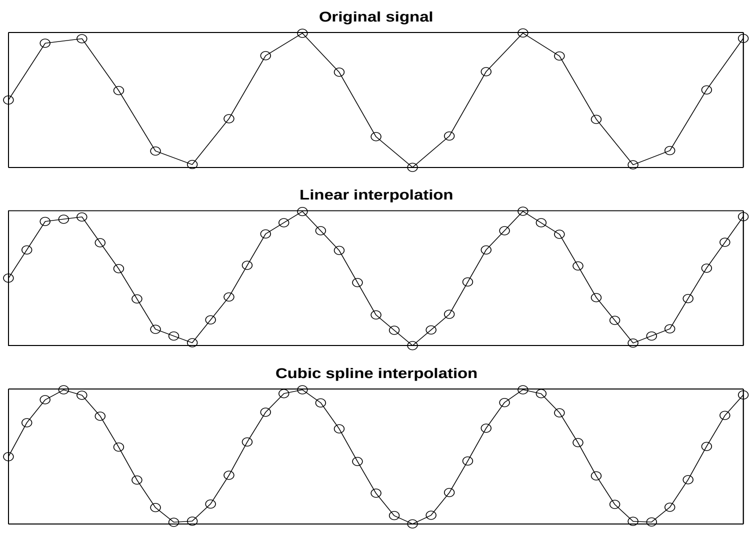

Figure 4: Linear and spline interpolation

However, in the case of image enlargement, linear interpolation is entirely insufficient. The so called spline interpolation brings substantial improvement. Conditions for its use are continuity of the first and second derivations, and thus the inlaid line is calculated in several steps for the very reason to ensure the continuity. Fig. 4 shows the difference between linear and spline interpolation on a one-dimensional signal. In the case of images, the same principle is used, with the only difference the whole calculation must be performed for both directions. An example of the cutout of an image after such a modification twice enlarged is shown in Fig. 5.

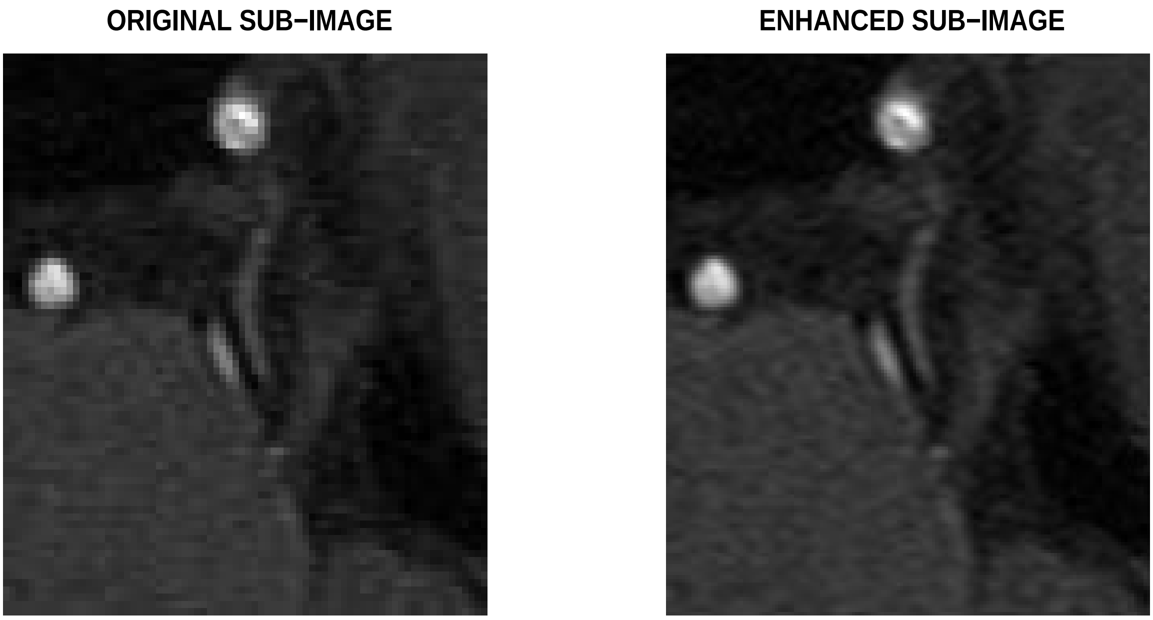

Figure 5: Spline interpolation

4 MATLAB WEB SERVER

Matlab Web Server represents superstructure of some of commonly available web servers. In its essence, it represents improvement of the classical servers with the possibility to use the mathematical environment of Matlab. With respect to the fact that Matlab Web Server behaves as a service of the operating system, it is designed only for the systems Windows NT and UNIX. It runs on the remote server side and nothing additional is needed to be installed on the client side besides a WWW browser. The client communicates with the Matlab Web Server through a form from which the data are passed to the Matlab program. This program must be written as an independent function able to overtake information from the form and input the results to a HTML page prepared in advance. All Matlab functions are supported. The system, together with some applications, is available at the address: *http://phobos.vscht.cz*. The server is largely aimed at processing of various signals and images. Advantage of the system is the possibility to use a remote Matlab computational environment for example to preprocess a signal, for primary view of a signal, etc. Fig. 6 shows the introductory server screen and one of output screens of image processing. Other examples are intended to be placed on the server, and gradually the possibility of remote processing of one's own signals is planned to be made available as well. Matlab Web Server can be used in cooperation of research workplaces and in education.

5 CONCLUSION

Submitted paper describes possibilities the Matlab Web Server uses for remote signal analysis and processing to allow efficient research and educational activities.

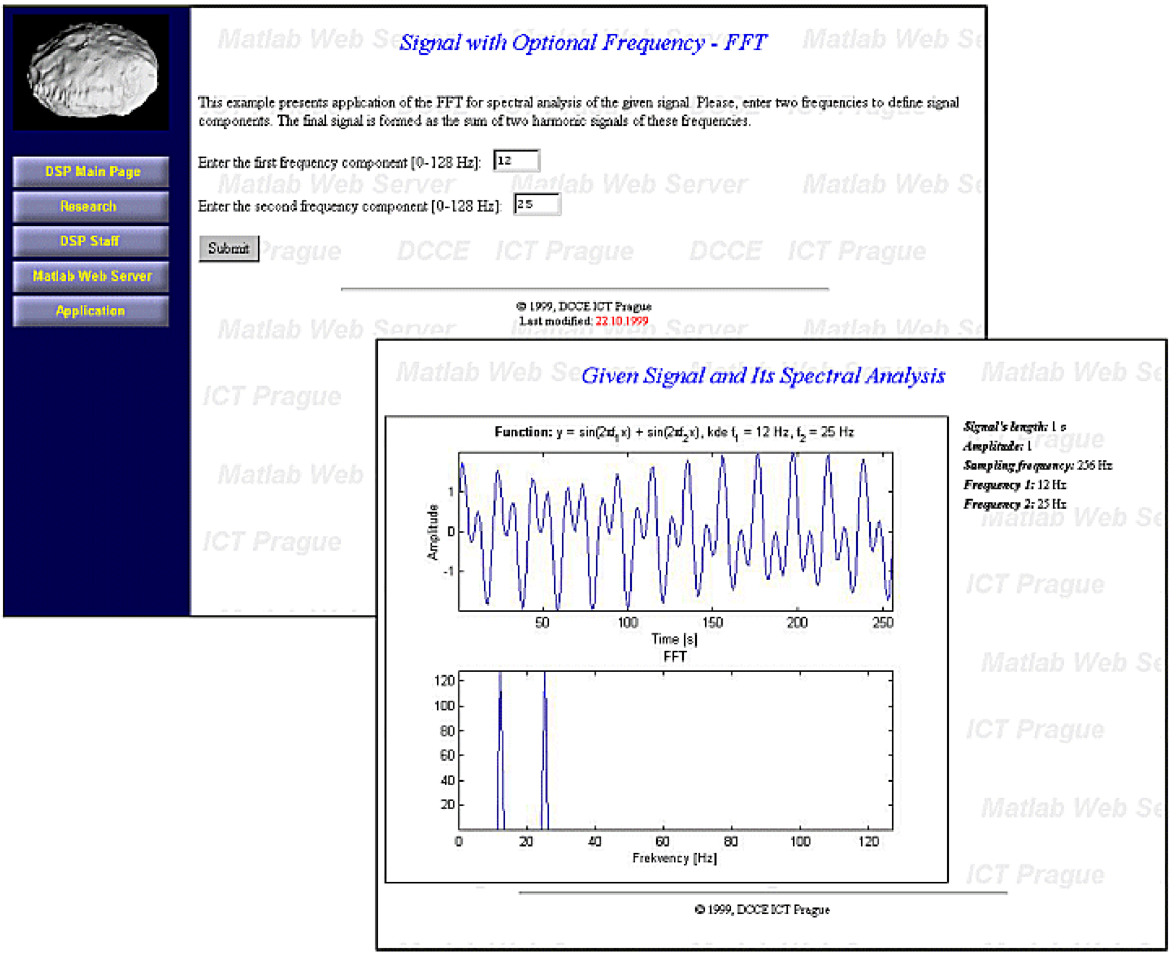

Figure 6: Matlab Web Server

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