Journal of Technical Science & Technologies; ISSN: 2298-0032; e-ISSN: 2346-8270; Volume 5, Issue 1, 2016

Application of Pseudospectrum Estimation Method Based on Singular Vectors for the Analyzing Cyclic Behavior of the Temperature in an Office Building

Davit DATUASHVILI *

Abstract

Spectral analysis of time series has a huge application in different fields of science, starting from the Radar technologies to vibration processes, economics and finance. Recent research proved that left and right singular vectors of nonstationary time series consist of periodic deterministic components and white noise, have an equivalent pseudospectral structure of original time series. In the given article, application of this property has been demonstrated on the base of analysis of cyclic behavior of the temperature in an office building.

Keywords: Peudospectral Structure, SVD (singular value decomposition), Time of Singular Sweeping

Introduction

Analysis, modeling and forecasting of time series is one of the most actual problems, which has many applications in all areas of science, engineering, economics and finance. That is, everywhere, where the analysis of experimental data and decision making based on it are necessary(Milnikov, 2014),(Datuashvili, Mert, & Milnikov, 2014).

Special interest during the analysis of time series is devoted to such type of time series which consists of sum of periodic determin-istic components with white noise. The formula of such type of time series is given below:

(1)

$$x(t)=\sum_{j=1}^{m} A_j e^{2\pi f_j t} + w(t)$$

In continuous form, where A_j- is magnitude of component j, fj-frequency of deterministic periodic component j, m-number of periodic components, w (t)-is white noise which is independent from pe-riodic components and in discrete form it will have the following form

(2)

$$x(t)=\sum_{j=1}^{m} A_j e^{2\pi f_j t} + w(t)$$

Recent analysis of such type of time series provided fact that principal singular vectors of data matrix constructed on the base of type (1) time series contains equivalent pseudospectral structure of original time series, which gives us possibility to estimate frequency components from the original signal, but on the base of new time series which represents vertical concatenation(ver-tical merging) of principal left and right singular vectors (Milnikov, 2014),(Datuashvili, Mert, & Milnikov, 2014)(Milnikov, 2013).In the article we applied the proved method for the analysis of cyclic behavior of the temperature in an office building.

Problem Definition and numerical examples

By looking at time domain representation of time series, it is diffi-cult to characterize oscillatory behavior in data and identify periodic components. For this purpose, spectral analysis can help deter-mine if a signal is periodic and measures the different cycles. A thermometer in an office building measures the inside temperature every half hour for four months. To load the prepared data, we will use load command load office temp.

Matlab command will generate data with size of 5584 sample. Let us convert the result into Celsius

```
tempC = (temp - 32) *5/9;
```

sampling frequency was taken as

```
fs = 2*24*7;
```

before we will plot the measurement, let us remove mean from the original time series and see its graphical representation.

```
tempnorm = tempC-mean(tempC);
```

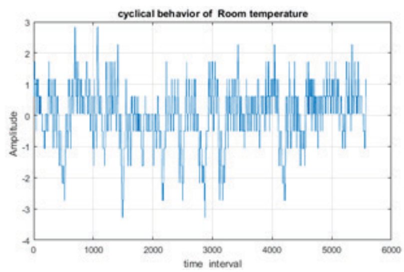

Figure 1. representation of cyclical behavior of temperature

* Ph.D, Faculty of Computer Technologies and Engineering, International Black Sea University, Tbilisi, Georgia.
E-mail: ddatuashvili@ibsu.edu.ge

here mean (temp C) will calculate mean value of measure tem-perature and finally by subtracting of mean value from the original one we are going to concentrate on the temperature fluc-tuations.

The temperature does seem to oscillate, but the lengths of the cycles cannot be determined easily. Let us analyze spectral structure of this time series and also set frequency axis parameters properly.

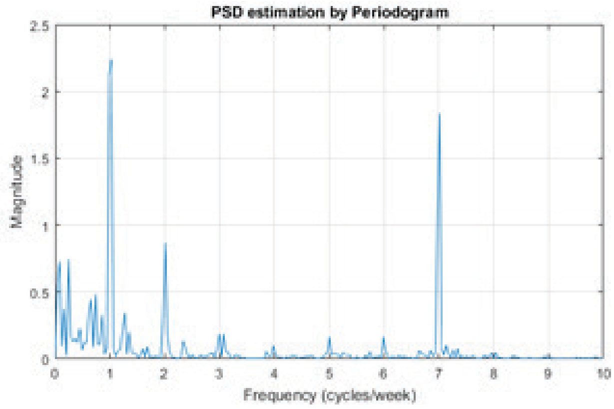

Figure 2. estimation of PSD (Power spectrum density) by Periodogram

```
[pxx,f] = periodogram (tempnorm,[],[],fs);
plot(f,pxx)
ax = gca;
ax.XLim = [0 10];
xlabel('Frequency (cycles/week)')
ylabel('Magnitude')
```

$$x(t) = \sum_{j=1}^{m} A_j e^{2\pi f_j t} + w(t)$$

The temperature clearly has a daily cycle and a weekly cycle. Now let us consider the following data matrix X_d with dimensions of 3585×2000.

After singular value decomposition of the given matrix, it can easily be done in matlab by the following code

```
[U E V] =svd(X);
```

Let us analyze separately second and third singular vectors starting with the second singular vectors.

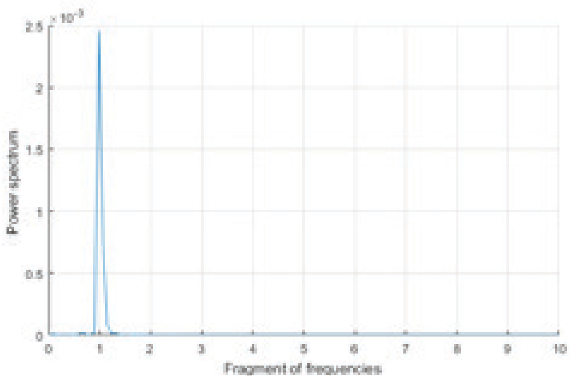

Figure 3. Analysis of second singular vector

From the figure, we can easily detect one periodical component which obviously is the same compared to the original one. Now let us consider the third singular vector

From figure 4, we can see also weekly component which finally confirms the statement that singular vectors of the given data matrix contain identical pseudospectral structure of the original time series. Now let us consider vertical merging of those singular vectors.

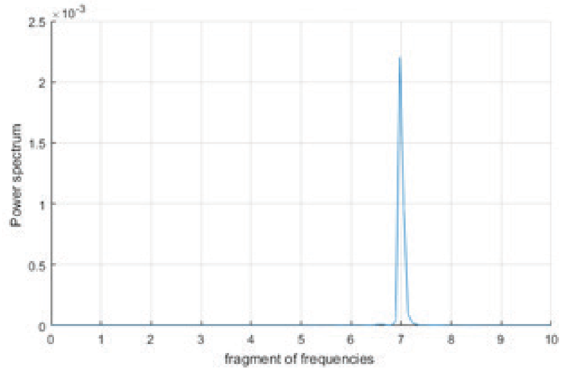

Figure 4. analysis of third singular vector

From figure 5, we can see daily and weekly cyclical compo-nent which is identical to the original time series. Let us also con-sider pseudospectral structure on the base of histogram analysis.

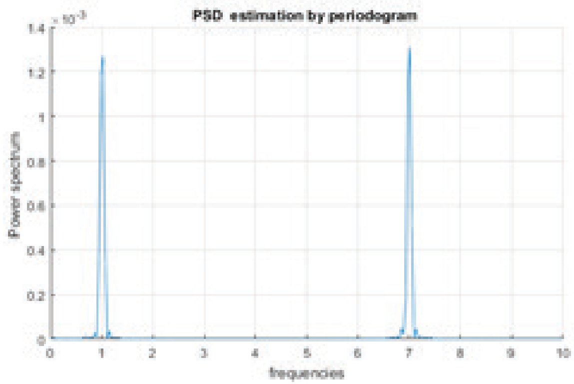

Figure 5. vertical merging of second and third singular vectors

From figure 6, we can see two confidently separated zones, one that corresponds to measurement noise and the second zone which corresponds to periodic components. Large interval of sep-aration between them increases the reliability of identification of cyclical components which corresponds to daily and weekly cy-

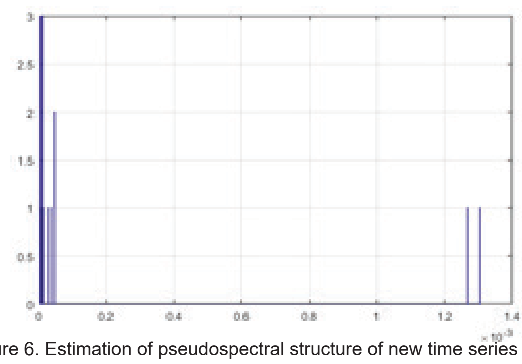

Figure 6. Estimation of pseudospectral structure of new time series on the base of histogram

Journal of Technical Science & Technologies; ISSN: 2298-0032; e-ISSN: 2346-8270; Volume 5, Issue 1, 2016

cli-cal behavior and increases statistical stability of the determina-tion correct components by specially written matlab codes. Actual fre-quencies can easily be estimated

f_1=1.0254Hz,f_2=7.0137Hz

Conclusion

In the given article, a new method has been applied to real world data, measurement of temperature in the building, using a ther-mometer, on the base of analysis of singular vectors of giv-en real nonstationary time series. It has been demonstrated once again that singular vectors of matrix of nonstationary time series that con-sist of sum of periodic deterministic components, have an equiv-alent pseudospectral structure of the original time series and by concatenation of principal singular vectors, we can successfully identify cyclical components.

References

Datuashvili, D., Mert, C., & Milnikov, A. (2014). New Approach to De-tecting Deterministic Periodic Components in Noise. Pro-ceedings of of the 5th international Conferences on Circuits, Sys-tems,Com-munications, Computers and Applications (CSCCA'15), (pp. 70-75). Salerno.

Milnikov, A. (2013). Singular decomposition of data matrix of time series with periodic components and resolving capacity of their pseudospectra estimation. Proceedings of of the 2nd international Conferences on Circuits, Systems, Communications, Computers and Applications (CSCCA'13),, (pp. 64-68). Cratia.

Milnikov, A. (2014). Pseudospectral Structure of the Singular Vec-tors of Nonstationary Time Series. Proceedings of of the 5th inter-national Conferences on Circuits, Systems, Communica-tions,Com-puters and Applications (CSCCA'15). Salerno.

http://www.mathworks.com/help/signal/ug/determine-cyclic-be-hav-ior-in-data.html