Journal of Contemporary Applied Mathematics
V. 12, No 2, 2022, December
ISSN 2222-5498

Application of interpolation method to reduce the number of discrete signal presentations in environmental monitoring issues

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Abstract. In this paper, a methodology was developed to display a discrete signal with N numbers to a smaller number of presentations, provided that the loss of signal information does not exceed a given percentage. Interpolation methods is used in the study, and the interpolation error is compared with the measurement error to estimate the loss of signal information. The effect of selected interpolation methods on information loss is investigated in this study.

Key Words and Phrases: Signal, Discretization, Interpolation, Interpolation error.

2020 Mathematics Subject Classifications: 94A12

1. Introduction

In modern times, there is a rapid development of scientific and practical research in the field of environmental protection and pollution. Ecological classification is made according to the punctual environment and objects. It should be noted that to study the essence of modern environmental processes and attempts to regulate the natural, natural man-made balance is impossible being from beyond the management of systems of different scales on a scientific basis.

At present, special attention is paid attention to the establishment and dissemination of an organized monitoring system in various countries and internationally.

Environmental monitoring is a system of observing, assessment and forecast of changes in the natural environment as a result of anthropogenic impacts. The monitoring system is part of the national information infrastructure.

The accepted block diagram of subsystems of monitoring systems is shown in fiqure [1].

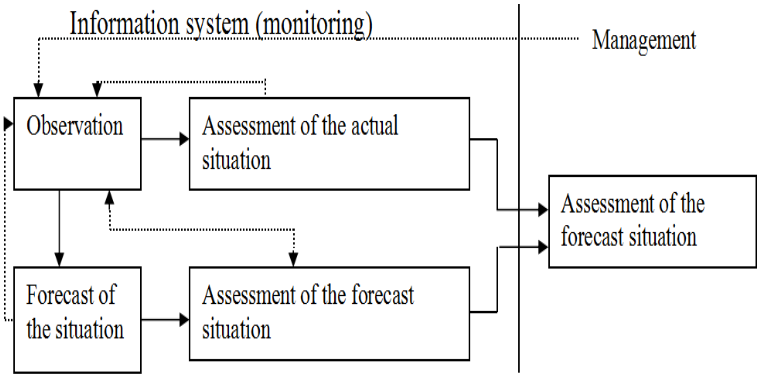

Figure 1. The block diagram of monitoring system

Monitoring is an information system about multi-purpose observation, evaluation and forecasting information system. The basis of the monitoring system is regular observations. These observations are a priori information necessary for mathematical modeling of environmental pollution and a direct source of information that provides statistical validity of the model.

The structure and operation of the existing monitoring systems used in the assessment of the ecological state of the environment are adapted to the specific conditions of the study area. So, the monitoring system is adapting. In this context, there is a need to change the structure of adaptive monitoring systems and the effective organization of observations.

Currently, one of the statistical methods for processing environmental data is time sequence analysis, which examines fairly subtle points. Time sequence is the adjustment of random quantity or process observations over time. This sequence of numbers gives the value of a random quantity observed at a given instant. As a rule, the moments of time can be separated from each other and consist of hourly, daily, monthly, annual prices. The arrangement of the elements of a sequence distinguishes it from a simple set of random values as a key property of a set of observations.

Experimental data in time series are determined by Δt sequence and the step of the values of function Experimental data in time series are determined by Δt sequence and the step of the values of function $S(t)$.

$$S_k(t) = S(t_k),\ t_k = \Delta t * k, k = 0, 1, 2, ..., N,$$

where, Δt -the length of step, N - a number of points in the row [2].

The need to change the number of discrete points during signal processing can arise for various reasons. Sometimes it turns out that the number of discrete points on the signal is not enough or excessive to perform certain operations. The main operation of changing the number of discrete points of the signal is to reduce and increase it several times [3].

In the paper, the issue of estimating the loss of information when changing the number of discrete points of the signal is considered. This is possible based on the following methodology.

2. The comptutational method

Figure 2 shows a block diagram of the algorithm for displaying a discrete signal with N numbers with a smaller number of representations, provided that the loss of signal information does not exceed a given percentage.

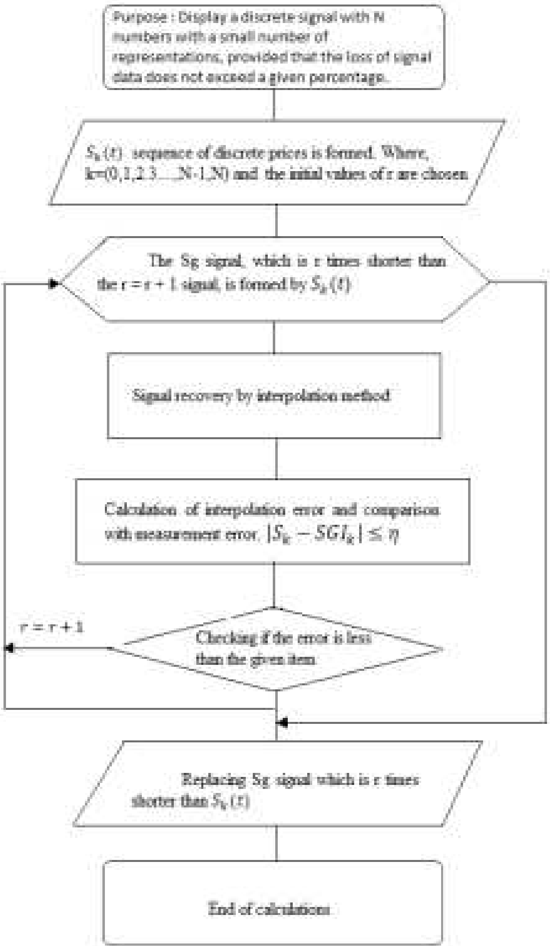

Figure 2. Block diagram of the computational algorithm

3. The conclusions of calculations

As an example, the total radiation values, which is a component of solar radiation measured in the wavelength range of 0.3 μm to 2.4 m with the Peleng SF-06 pyronometer in Baku, were used as preliminary data. Measurements were made at Δt = 2 intervals. Measurements are a component of measurements made on 27.08.2016 and consist of 64 discrete measurements. The value of the measurement error was η =0.0002. $S_k(t)$the original signal, the Sg signal, which is k = 3 times shorter than the signal, and the SGI signal, which is recovered by interpolation is shown in figure 3. It also provides a visual representation of the module value of the interpolation error compared to the measurement error. It can be seen from Figure 3 that conditional $|S_k - SGI_k| \leq \eta$ is broken at 2 discrete points. The number of points recovered by interpolation is 42. Recovery by interpolation is carried out by non-recursive method [5] . In this case, the parameter of the non-recursive interpolation method is taken as l = 4 and the value of the alpha parameter is 0.5.

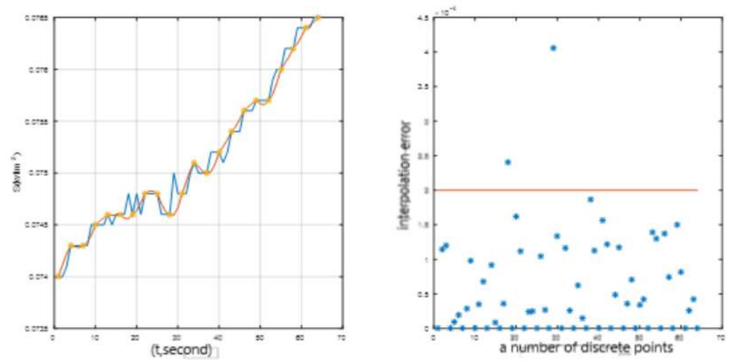

Figure 3. Original signal, signal that is r = 3 times shorter than the signal and signal recovered by interpolation method. Visual description of comparison of interpolation error with measurement error.

Figure 3 shows the original signal, the Sg signal, which is r = 4 times shorter than the signal, and the SGI signal, which is recovered by interpolation. It also provides a visual representation of the module value of ε interpolation error compared to η measurement error. It can be seen from Figure 3 that $|S_k - SGI_k| \leq \eta$ condition is broken at 7 discrete points. The number of points recovered by interpolation is 48.

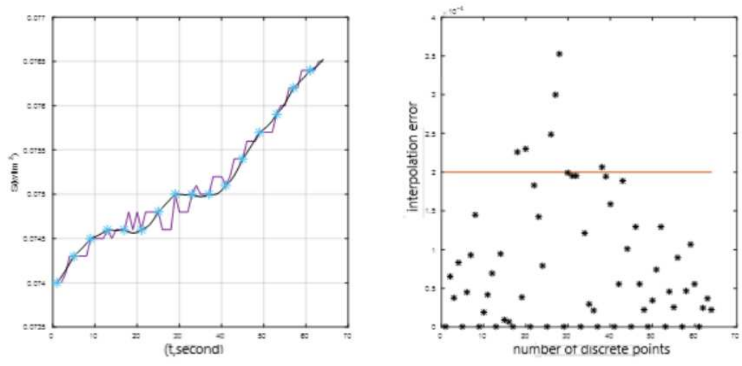

Figure 4. Original signal, signal that is r = 4 times shorter than the signal and signal recovered by interpolation method. Visual description of comparison of interpolation error with measurement error.

Recovery by interpolation is carried out by non-recursive method. In this case, the parameter of the non-recursive interpolation method is taken as l = 4 and the value of the alpha parameter is 0.5. Figure 3 shows that the information loss during r = 3 times reduction of the given signal does not exceed 5%. Figure 4 shows that the information loss during reduction of the given signal to r = 4 times is more than 5 percent. Compliance with the above condition $|S_k - SGI_k| \leq \eta$ depends on the quality of the SGI discrete signal interpolation recovery. Quality recovery depends on the choice of parameters of the interpolation method. Figure 4 shows a visual comparison of the interpolation error of the interpolation method for different values of the parameter l with the measurement error of the modulus value . It can be seen from Figure 5 that $|S_k - SGI_k| \leq \eta$ condition for small values of l parameter is more distorted on discrete points and the recovered signal is more distorted.

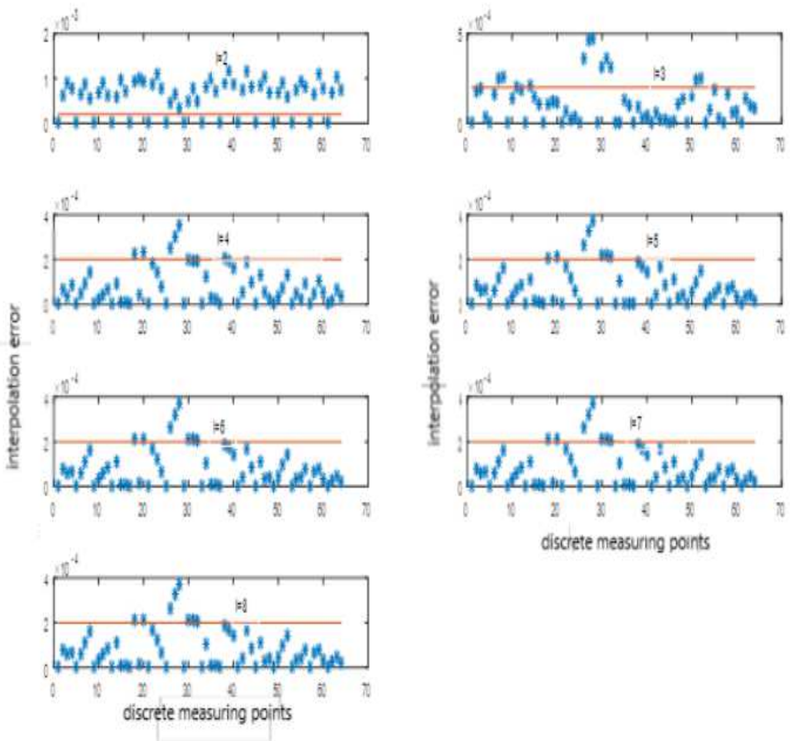

Figure 5. Visual description of the influence of the interpolation parameter l on the loss of information.

In figure 5 gives a visual description of the comparison of the modulus of the interpolation error value with the measurement error for different values of the parameter l of the interpolation method. Figure 5 shows that for small values of the parameter l, the condition is violated at a more discrete point and the reconstructed signal is more distorted.

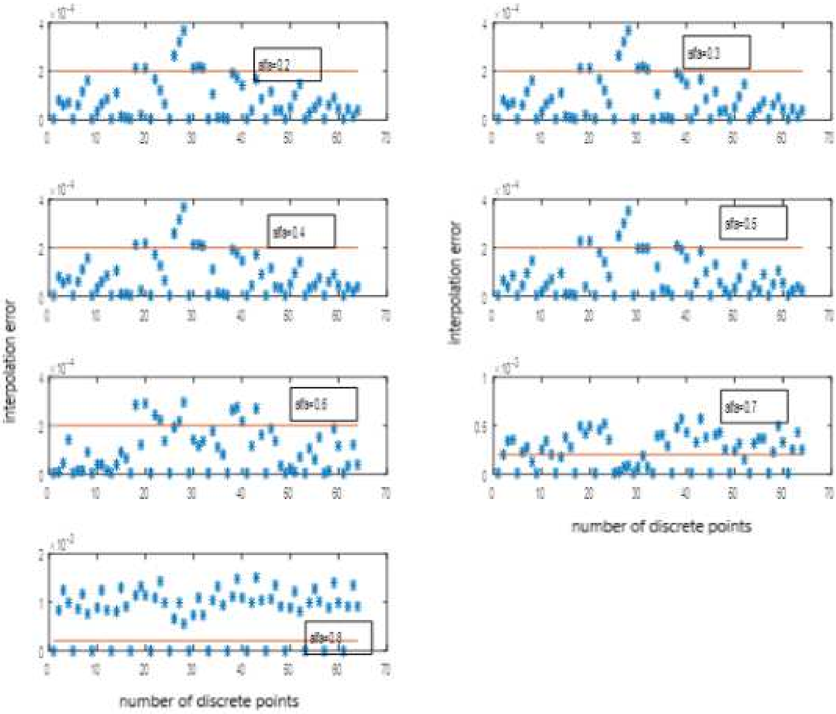

Figure 6. Visual description of the effect of the alpha interpolation parameter on information loss.

In figure 6 is a visual description of the comparison of the magnitude of the interpolation error with the measurement error for different values of the alpha parameter of the interpolation method. Figure 6 shows that for large values of the alpha parameter, the condition is violated at a more discrete point, and the signal reconstructed by the interpolation method is more distorted.

4. Conclusion

Display of a discrete signal with N numbers with a smaller number of representations, provided that the loss of signal information does not exceed a given percentage, is performed by the algorithm described above. The loss of signal information varies sensitively to the choice of parameter l of the interpolation method.

References

[1] M.A. Pashkevich, G.F., V.F. Shuisky Environmental monitoring, Petersburg, Gidrometeoizdat,2002,89 p.(in Russian)

[2] Vityazev V.V. Wavelet analysis of time series, Leningrad, Saint Petersburg State University,2001,60 p.(in Russian)

[3] Titov D.A., Vasilevsky V.V., Kosykh A.V. Digital signal processing: Methodological guidelines for laboratory work. 0msk, 2011, 44 p.(in Russian)

[4] Gandin L.S., Kagan R.A. Statistical methods for the interpretation of meteorological data, Leningrad, Gidrometeoizdat, 1978, 360p. (in Russian)

[5] Sergienko A. B. Digital signal processing, Petersburg,2011,768 p. (in Russian)

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Received 12 January 2022
Accepted 23 June 2022