Software Package for Identification and Processing of Multidimensional Time Series by Spline Functions

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ABSTRACT

Constructive approaches, principles, new methods are proposed to ensure timely and efficient transformation and processing of large volumes of non-stationary time series based on the use of neural networks. Algorithms and software tools for restoring time series and training neural networks for modeling by methods of spline functions have been developed and implemented.

Keywords: Time Series, Non-Stationarity, Identification, Neural Network, Learning Algorithms, Software Package.

Relevance of the topic. The solution of many important practical problems, such as the processing and recovery of geophysical data, image analysis and processing, and the prediction of random events, is associated with the construction of neural network systems for processing information of a continuous nature. In this case, new methods, algorithms and software systems are of paramount importance, which ensure the timely and efficient conversion and processing of large amounts of non-stationary information based on neural networks (NN), which, in turn, requires the development and implementation of new algorithms and software tools for processing and restoration of time series (signals) for training the NN [1,2]. In this regard, the study of methods, the development of algorithms for processing and smoothing a non-stationary process for modeling the processes of processing multidimensional data using the methods of spline functions for learning neural networks, as well as solving problems of practical application of the developed algorithms and software in specific application areas is relevant [3,4]

On the basis of the methods and algorithms for smoothing the dynamic process described in [5,6], when optimizing NN training, we have developed a set of programs for processing and restoring time series presented for solving problems of image visualization and recognition of micro-objects, analysis and prediction of technological parameters and interpretation of experimental data [7,8].

The software package is developed on the basis of the following algorithms.

Algorithm 1. "Formation and processing of one-dimensional time series (signals)" performs the functions of restoration and spectral processing of one-dimensional signals by cubic basic splines and converts the values of the restored signal into MS Excel format. In addition, the module software determines the recovery parameters from the experimental values of one variable and includes subroutines for calculating a one-dimensional basic spline, calculating expansion coefficients for one-dimensional signals, and approximating one-dimensional signals using point formulas.

Algorithm 2. "Formation and processing of two-dimensional time series" performs the functions of restoration and spectral processing of multidimensional (two-dimensional) signals by bicubic basic splines, visualization of graphs of the restored signals, and also exports the values of the restored signal to MS Excel and a text file.

The algorithm determines recovery parameters from two-dimensional experimental data and includes procedures for calculating a two-dimensional basic spline and expansion coefficients for two-dimensional signals, and approximating two-dimensional signals using point formulas.

Algorithm 3. "Smoothing of signals by splines" are intended for smoothing various signals and functions and include procedures for smoothing one-dimensional, two-dimensional, multidimensional signals by the average value and smoothing using point formulas.

Algorithm 4. "Estimation and control of the recovery error" is designed to calculate and evaluate the recovery errors of one-dimensional and multidimensional signals. The evaluation of the recovery and control error is carried out according to the criterion of the minimum root-mean-square error.

Algorithm 5. "Setting signal processing parameters" adapts the parameters of the models to calculate the expansion coefficients of cubic basic splines.

Note that the software package is designed as a single software package consisting of interconnected programs with certain parameters. When installing the package, all software modules are implemented simultaneously and this allows you to be a full-fledged product and use all kinds of functions of the complex.

The software package is designed for use in computers such as Pentium IV, compatible with the operating system Windows XP and above, and in digital signal processors such as Blackfinm from Analog Devices. The software complex occupies 872 KB of external memory and, when loaded into RAM, takes 15 KB.

The user interface of the software package. The interface of the complex is based on the existing VisualDSP++ package, which is the same for all series of signal processors from Analog Devices, including 16-, 32-bit ones [9,10].

The user interface of the software package with an example of an illustration of the graph of the results of the restoration of the $z = \sin(x^2 + y^2)$ function is shown in Figure 1.

The interface of the complex consists of a menu bar - П1;

toolbars - П2;

display panels - П3.

The menu bar of the interface of the software complex includes buttons:

K1 – approximations;

K2 - calculation of standard deviation;

K3 - smoothing of the non-stationary process;

K4 - issuing the output of information processing.

The software package **interface toolbar** consists of five groups of command buttons:

O1 - processing of one-dimensional signals;

O2 - processing of multidimensional signals;

O3 - signal smoothing;

O4 - calculation of the standard deviation of signals;

O5 - setting the parameters of intelligent signal processing.

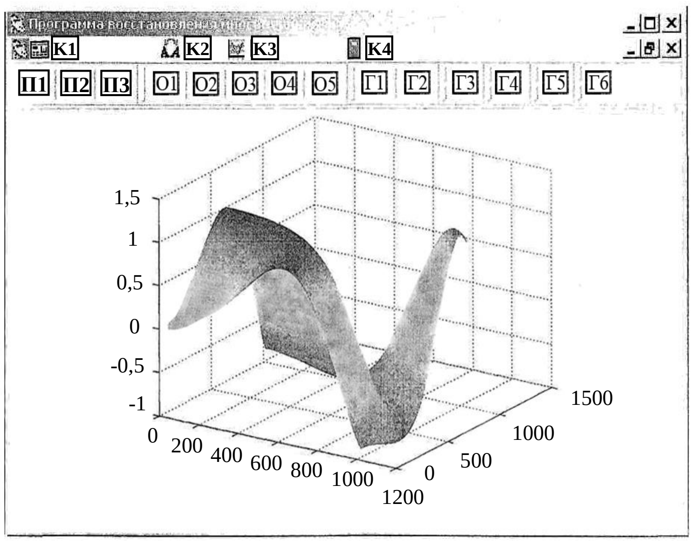

Figure 1. Interface of the software package with an example.

The display panel consists of buttons:

G1 - visualization of graphs of one-dimensional information;

D2 - visualization of two-dimensional data;

G3 - visualization of multidimensional data;

G4 - visualization of graphs of the restored one-dimensional values;

G5 - two-dimensional;

G6 - multidimensional data (signals).

The software package is represented by the following software-implemented modules designed for processing one-dimensional, two-dimensional and multidimensional time series (signals) [11,12].

The software modules included in the software package are mainly intended for the restoration and graphical visualization of the results of processing various one-dimensional, two-dimensional, multidimensional data given in tabular form [13,14].

It should be noted that the developed set of programs for processing one-dimensional and multidimensional data to form a training subset and control the learning error of the NN has been tested on real experimental data measured when visualizing images of micro-objects, in particular, pollen grains [15].

The study of signals was carried out on the basis of modeling harmonic, exponential and logarithmic functions.

Conclusion. Thus, algorithms and a software package for processing and restoring one-dimensional and multidimensional time series of a non-stationary nature based on spline functions presented for training the NN have been developed.

The developed programs determine the parameters of experimental data recovery, calculate the values of one-dimensional and two-dimensional basic spline, expansion coefficients and data approximation using point formulas.

The data processing methods included in the software package can be used in many areas of science, such as bench test results processing, image processing, dynamic process filtering, and others.

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