SYSTEM FOR MATHEMATICAL SIMULATIONS OF TIME SERIES

V.M. Loginov and Yu.A. Kalush

Tuva Institute of Complex Exploitation of Natural Resources,
Siberian Branch of the Russian Academy of Sciences, Kyzyl
Received January 8, 1998

We briefly describe here a software package "System for mathematical simulations of time series." The system is intended for processing, simulate, and extrapolate the data of long-term observations. Examples of using the system are presented.

Mathematical simulation of time series obtained as a result of observations of natural processes and phenomena is an important stage in the study of these series. There exists large number of mathematical methods of the time series processing (see, for example, Refs. 1–6). A new approach to the time series simulation based on the idea of dynamic and (or) stochastic switches between the time series segments where it grows and those where it falls off was proposed in our earlier papers (see Refs. 7–10).

This approach allows one to process and simulate different time series using the same approach, and it can be used to create an automated system for time series simulations.

Based on the technique presented in Refs. 7–10 the software complex "System for mathematical simulations of time series" (SMSTS) has been developed.[11] The complex allows the simulation and extrapolation of time series to be performed in an automated operation mode.

The automated system of time series mathematical simulation is the software package of 4 codes united by a common environment with a user interface (Fig. 1). Using the software complex simulation of the time series obtained in different fields of knowledge has been performed. Analytical models that describe to a certain accuracy behavior of a time series on isolated intervals make up the result of the problem solution.

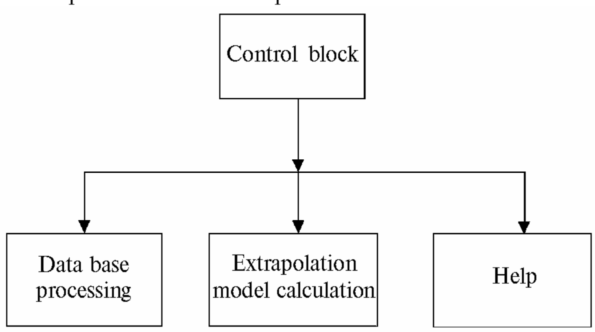


FIG. 1. Generalized flowchart of the software complex SMSTS.

The software complex is for use on an IBM PC 386 as well as on any more sophisticated IBM PC. The calculation codes included into the complex are written on the C computer language while the data base support code is written on CLIPPER 5.01 language. The complex SMSTS can operate in the MS-DOS and WINDOWS environments and realizes the following services: a) the dialog with a user, b) the interface with the DB, c) graphical presentation of time series on a monitor screen, e) graphical representation of the simulation and extrapolation results, f) numerical presentation of the calculated results and analytical expressions obtained.

To support the dialog with a user the program provides for the following options:

– menu to select alternative operations,
– list of requests to select the initial information and the view of simulating functions,
– graphical representation of the simulation domain,
– help in using the program.

The menu of SMSTS consists of four items (Fig. 2):

1. DATA BASE
2. MODEL
3. HELP
4. QUIT TO DOS

The menu item "DATA BASE" supports processing data base in the "dbf" format. Files used by the software complex are binary systems of the point coordinates (t, x) sorted according to increasing time.

The menu item "MODEL" forms the window with the list of "dbf" files for construction and visualization of a model. While constructing a model of the selected file the program supports the interactive dialog with a user.

The following list of options is proposed:

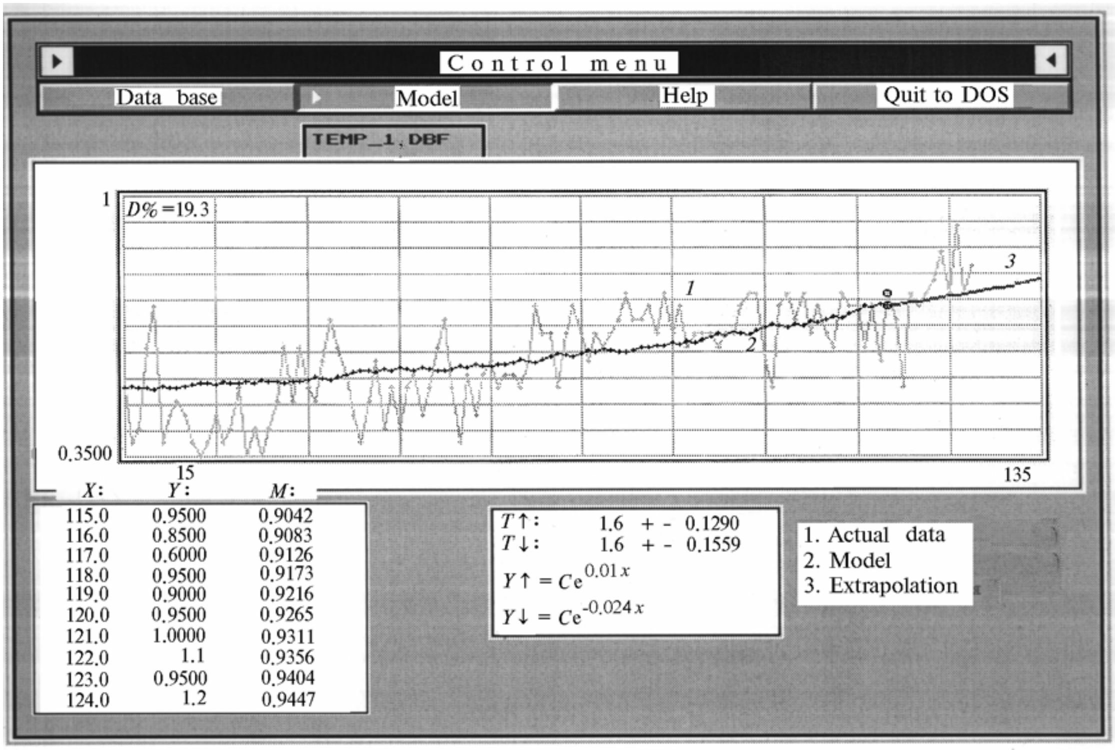
Simulating function – to select a class of simulating functions. The power and exponential dependences are chosen as simulating functions.

Regularity – deviation, in percents, from the average period when a function is considered as a periodic one.

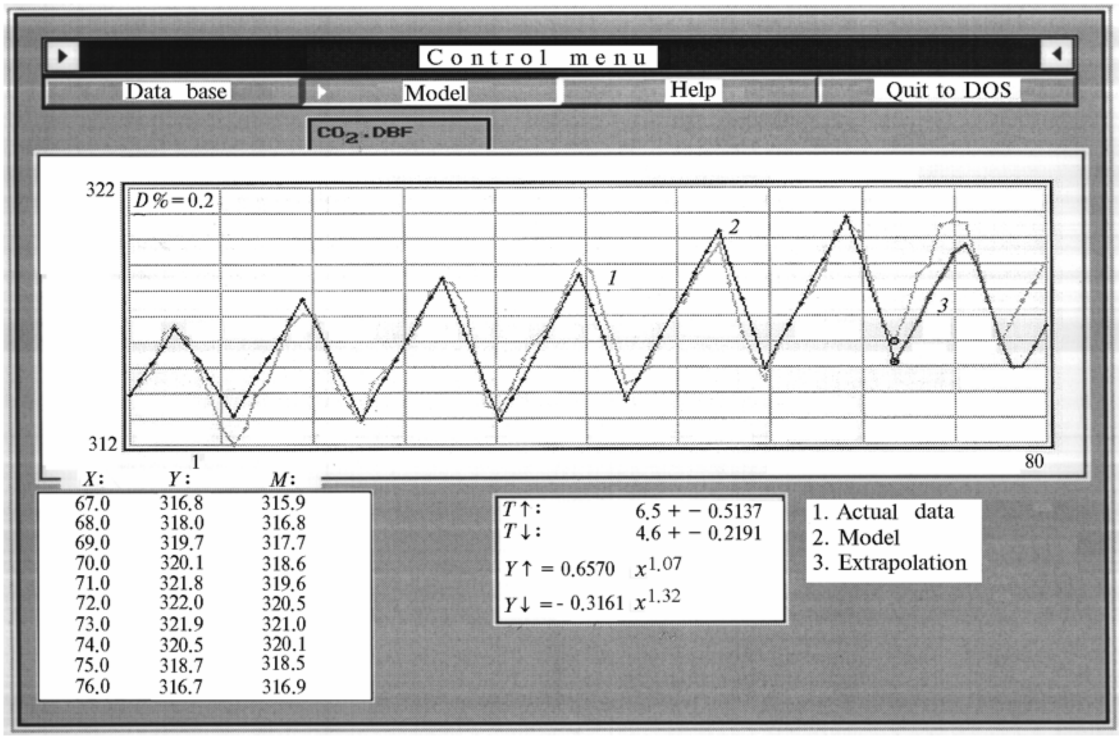
Smoothing – with a smoothing window.

Simulation section start – the first point where the model construction should begin.

0235-6880/98/09 863-03 $02.00



a



b

FIG. 2. The time series "Global change of temperature" and its model (a); the time series "Carbon dioxide concentration in the atmosphere" and its model (b): the actual data (1), the time series model (2), and the extrapolation domain in the section with the actual data (3).

Simulation section end – the last point where the model construction is to be ended.

When the calculation is finished the window with actual and calculated values of the simulated series is formed in the left lower corner. These values can be viewed with the cursor control keys. In a table to the right the values of calculated parameters of the simulating functions are presented: $Y\uparrow$ for the sections of time series growth and $Y\downarrow$ for the sections of its decrease, and also the average values of the growing sections $T\uparrow$ and decreasing ones $T\downarrow$ of a time series (see Fig. 2).

The menu item "HELP" allows one to view the short explanations of the program usage, and, finally, the menu item "QUIT TO DOS" allows one to terminate the program operation.

In Ref. 9 the simulation of the time series describing the global climate warming in the current century was presented, the time series of "global temperature change" and "carbon dioxide concentration in the atmosphere" were also considered.

Let us present the same series processed by SMSTS, by positioning, for clarity reasons, the model and extrapolation so that the extrapolation section is overlapped by actual data (see Fig. 2).

Figure 2*a* presents a series of the global change of average temperature over 126 years (the last point of the actual data belongs to 1992), its model and extrapolation from 115th to 135th years (the simulating functions are $Y\uparrow = e^{0.01x}$ for the growing sections and $Y\downarrow = e^{-0.01x}$ for the falling off ones). Figure 2*b* shows an extrapolation of the series describing the carbon dioxide concentration in the atmosphere over 80 months (the simulating functions are $Y\uparrow = 0.657x^{1.07}$ for growing sections and $Y\downarrow = -0.3161x^{1.32}$ for the falling off ones). The standard deviation D, %, of the model from the actual data presented in the upper left corner of the operating screen of the program (see Fig. 2) is 19.3% in the first case and 0.2% in the second case. One can see from the Fig. 2 a close coincidence of the extrapolating curve with the actual data. Deviation of the extrapolating curve is close to the standard deviation of the model. Obtained functions $Y\uparrow(x)$ and $Y\downarrow(x)$ allow one to write the nonlinear model differential first-order equation for the variable $x(t)$.

REFERENCES

1. T. Anderson, in: *Statistical Analysis of Time Series* [Russian translation] (Mir, Moscow, 1976), 745 pp.
2. J. Boks and G. Jenkins, *Analysis of Time Series. Forecast and Control* [Russian translation] (Mir, Moscow, 1974), Issue 1, 402 pp.
3. J. Boks and G. Jenkins, *Analysis of Time Series. Forecast and Control* [Russian translation] (Mir, Moscow, 1974), Issue 2, 200 pp.
4. D. Brillinger, *Time Series. Data Processing and Theory* [Russian translation] (Mir, Moscow, 1980), 524 pp.
5. K. Grenger and M. Hatanaka, *Spectral Analysis of Time Series in the Economics* (Statistika, Moscow, 1972), 312 pp.
6. M. Kendall and A. Stuart, *Multidimensional Statistical Analysis and Time Series* (Nauka, Moscow, 1976), 725 pp.
7. V.M. Loginov, Modeling, Measurement & Control **53**, No. 3, 57–63 (1995).
8. V.M. Loginov and Yu.A. Kalush, Sibirskii Ekologicheskii Zhurnal **2**, No. 3, 196–210 (1995).
9. V.M. Loginov and Yu.A. Kalush, Atmos. Oceanic Optics **9**, No. 5, 433–437 (1996).
10. V.M. Loginov and Yu.A. Kalush, in: *Proceedings of the Fourth International Symposium on Ubsu-Nur Experiment* (Intellekt, Moscow, 1996), pp. 127–135.
11. V.M. Loginov and Yu.A. Kalush, "*System of mathematical simulation of time series*, "Inventor's Certificate No. 970532, 1997.