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SOFTWARE-COMPUTER COMPLEX FOR SPACE WEATHER PREDICTING

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Neural network software-computer complex to search for non-linear causal relationships in the problems of solar-terrestrial physics is developed. The main objective of the program is to ensure neural network numerical experiments for search of non-linear connections between geomagnetic indices and near Earth space parameters. Work program algorithm of an artificial neural network (ANN) include back propagation Elman network, feed forward network, fuzzy logic network and Kohonen layer classification network. The interface of application allows to change neural network architecture (the number of hidden layers, the number of neurons in the layer, the input and target data, and the number of cycles of training).

1. Review of existing computer complexes for space weather forecast

One of the fundamental problems of solar-terrestrial physics are nonlinear laws of cause-effect relationships in system «solar wind – magnetosphere – ionosphere» is establish. Currently, the Internet has large number of web sites that provide information on geomagnetic conditions and the state of interplanetary space in real time runs. The best-known resource for today are the following:

1) World Data Center for Geomagnetism, Kyoto [http://swdcwww.kugi.kyoto-u.ac.jp]. On the web site the data on indices of geomagnetic activity, geomagnetic field is posted.

2) Support site for patrol spacecraft ACE [http://www.srl.caltech.edu/ACE/ASC/level2/index.html]. The resource provides information about the Interplanetary Magnetic Field (IMF) and Solar Wind Parameters (PSW). The description of the spacecraft instruments, data on the location of the spacecraft is posted.

3) Support site for patrol spacecraft WIND [http://pwg.gsfc.nasa.gov/windnrt]. The resource provides information about the IMF and PSW. The description of the spacecraft instruments, data on the location of the spacecraft is posted.

4) Support site for polar patrol spacecraft DMSP/POLAR [http://solar.uleth.ca/www/aurora.php]. The website contains the latest images of the polar regions of Earth, visible areas of the auroral activity. Provided related information.

5) Support site for spacecraft SOHO [http://sohowww.nascom.nasa.gov/data/latestimages.html]. The site contains links to the latest images of the Sun. Data provided in different formats – graphics, video, text.

These resources provide real-time data with a refresh rate of 10-60 minutes. With access to the latest data and prediction/recovery model of any process that uses them in calculations, you can create software and hardware system (internet-machine) on the Internet the results of this forecast published. Currently, most of existing internet machines predicting the dynamics of the global geomagnetic conditions described by the indices aimed, as a consequence of the interaction of Earth's magnetosphere with the interplanetary medium. Most recently internet-machines Dst-index is predicted. Another area of internet-machines with the restoration of maps of the distribution of energies for injected particles in the polar regions of Earth is directed. One more area in real-time data processing is to simulate the state of the magnetosphere – modeling geomagnetic field and distribution maps of the solar wind flow pressure on the magnetosphere is directed. Links to some existing internet-machines are listed below.

1) Neural network restoration of Dst using real-time data N, V and Bz with the ACE spacecraft [http://www2.nict.go.jp/y/y223/sept/ace/nnw].
Advantages: providing data in digital form, providing the history of the forecast for 1 month. Disadvantages: the authors did not provide information about recovery algorithm, not provided description for ANN and comparison with the real Dst index, for example with Kyoto data [http://swdcwww.kugi.kyoto-u.ac.jp]

2) Recovery Dst index for real-time data from the ACE spacecraft based on the Temerin and Li 2006 model [http://lasp.colorado.edu]. Advantages: comparison of the model with actual Dst data from Kyoto [http://swdcwww.kugi.kyoto-u.ac.jp]. Providing data in digital form. Doing history prediction within 1 month. Providing links to real-time data from the ACE spacecraft. Providing links to the description of the model for recovery Dst index.

3) Recovery Dst index for real-time data from the ACE spacecraft and the presentation of the current state of geomagnetic conditions [http://sprg.ssl.berkeley.edu/dst_index/]. Advantages: providing a convenient form to evaluate the current geomagnetic conditions. Disadvantages: not provided information about the recovery algorithm.

4) Forecasting Dst index for real-time data from the ACE spacecraft for the next hour using Elman ANN [http://rwc.lund.irf.se/rwc/dst/models.php].
Advantages: free provision of models for calculating Dst in two formats – in the format of MATLAB and the format of the Java application. Providing detailed description of the model. Providing history for prediction within 1 week. Providing data in digital form.
5) Mapping the distribution of energy for injected particles in the polar regions using Dst index value [http://climatology.space.swri.edu/tedimages.html].
Advantages: choice for mapping the range of particle energies, the ability to select source that provides data on Dst index, ability to manually input the values of Dst index. Provide descriptions of the model used. Providing data in digital form.
The main purpose of creating our software and computing complex neural networks series of numerical experiments to find a nonlinear relation between geomagnetic indices among themselves and with the near Earth space parameters and for the complex classification of space weather events are provided. Particular attention to the development of application architecture was paid. The proposed open modular architecture allows you to easily modify it to solve different problems. The core complex a set of neural network algorithms includes: artificial neural network algorithm with Elman back propagation network, feed forward network algorithm, fuzzy logic network, Kohonen layer classification network. Selected algorithms of artificial neural networks in a wide range of tasks such as forecasting and recovering of numerical series with history of process and associated parameters, clustering and division data on feature set have proven themselves.

2. Application interface

Software and computer system for predicting space weather phenomena for work through the Internet is currently available. Service for our complex at Research Laboratory of Physics of solar-terrestrial relationships NNSPU is posted. Its web-interface available on address http://spacelabnnov.110mb.com. For free access to the system select link “Forecast parameters of solar-terrestrial relationships”, and then – “Neural network modeling”. The application interface to fine-tuning the parameters of the experiment allows. The user can select a template architecture and learning algorithm of neural networks, input parameters for training and testing, spline processing parameters for input data, data formats, number of neurons in the layers of the network, the number of hidden layers, data packets for training and testing, modes of processing and presentation of results. The beginning of the training process with selection of ANN input and target data in main window of the program is consists. The result of network work is the plot with results of testing. For simplification the setting of repeating experiments the application allows last trained neural network to use. In this case training is not done: from a previously saved file parameters of experiment are loaded. Previously trained network as a filter for input parameters get through and output parameters with the test event are compared.

3. Used data

For sure of the greater flexibility of the program work with a database in the form of files is stipulated. The created complex for 30 simultaneously processing streams of events in the input data is designed. Database minute numeric data for 30 geomagnetic storms in the period from 2000 to 2003 is contains. In this set of parameters of the Solar wind, Interplanetary Magnetic Field (from spacecraft “ACE”) and geomagnetic indices (Dst, SYM, ASY, AU, AL) are included. These data from the site at http://cdaweb.gsfc.nasa.gov are received. Is it necessary discrete data can be modified using the spline.

4. Statement of experiments through the web-interface

With access to the system the user enters a query to the main page of calculation. This request contains sections. Their consequent fill will perform neuromodelling between the given parameters and get the final product – artificial neural network answer. In a Fig. 1. appearance of the main page of request of calculation in browser Internet Explorer window is presented.

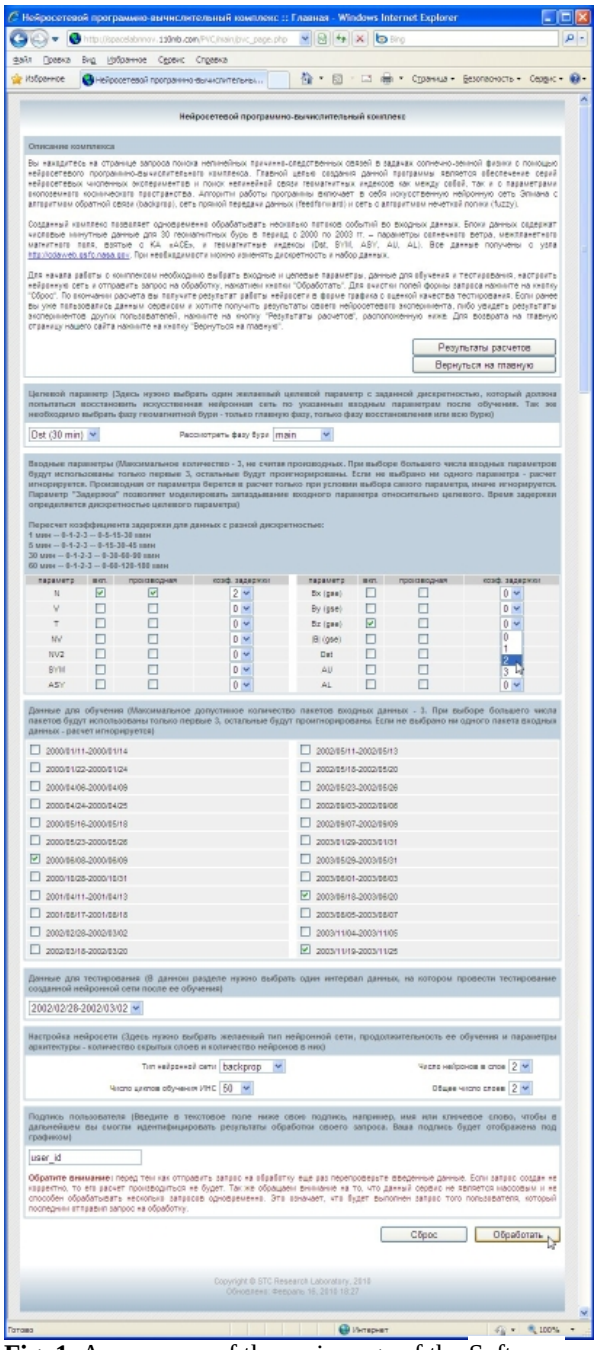

Fig. 1. Appearance of the main page of the Software and computer complex.

To start working with the complex to select the input and target parameters, the data for training and testing, set up a neural network and send a request for processing by click button “Process” at the bottom of the form. By clicking the “Results of the calculations”, you can get to the page with the results of previous experiments. In section «Target parameter» it is necessary to choose one desirable parameter with the set step-type which the artificial neural network on the specified input parameters after training should try to restore. It is also necessary to choose the phase of the studied geomagnetic storms – only the main phase, only the recovery phase, or the entire storm. In the section “Input parameters” user can select the input data sequence of the indices Dst, AU, AL, SYM, ASY, PSW and IMF. It is possible to simulate the time delay between the target and inputs. Sections «Data for training» and «Data for testing» give possibility of a choice of packages of the data for ANN the selected lonely geomagnetic storms are containing. To configure and run the experiment, go to the section “Setting up a neural network”, select the desired type of neural network, the duration of training and parameters of architecture – the number of hidden layers and the number of neurons. Text box “User signature” to further it was possible to identify the results of processing your request is intended. The signature will be displayed under the final plot. By clicking “Process” request is sent to our server for automated processing of neural network software and computing complex. In Fig. 2. redirected page with waitbar is presented.

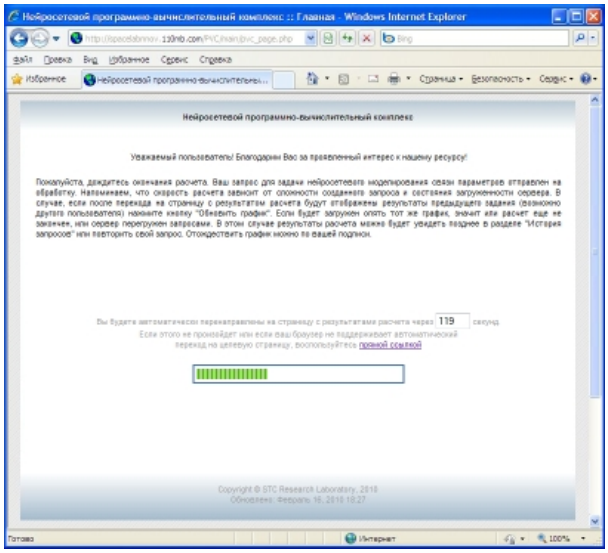

Fig. 2. Appearance of user redirection page

Upon termination of process of calculation the user gets on page «Results of calculation». On the plot will be presented: a dark blue continuous curve – real values of parameter, red dotted – the answer of a neural network. Above: ANN type (Elm, FF, Fuzzy), correlation between the target and restored signal (R), prediction efficiency (PE), ANN inputs (Input) with present values of delays and a target exit (Output) are listed. The green marker allocates time/date of creation of the plot and the user signature who has requested calculation of the data. The Fig. 3 page with results of calculations is shown.

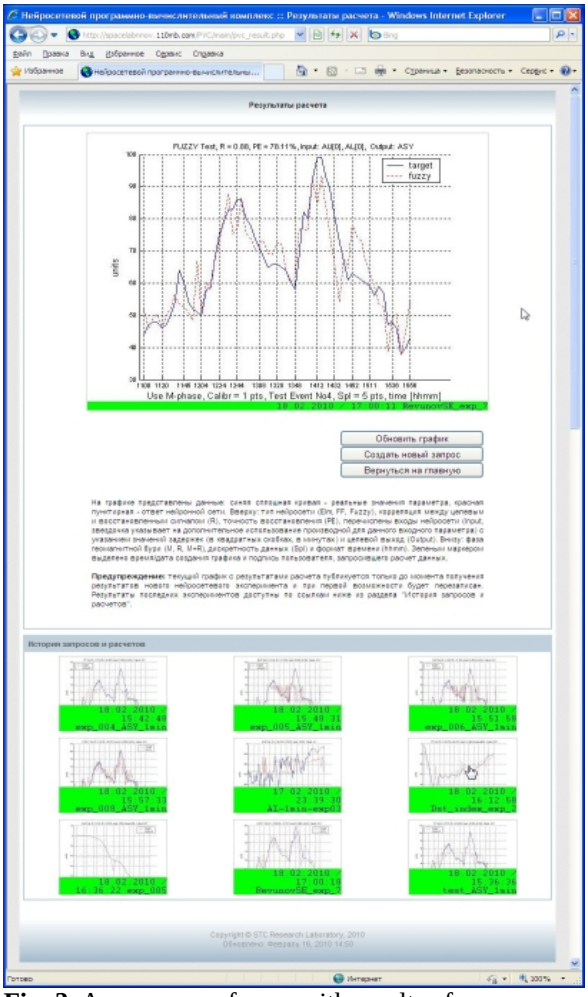

Fig. 3. Appearance of page with results of calculations.

The current basic plot with results of calculation is published only till the moment of reception of results new ANN experiment and as soon as possible will be rewritten. Results of last experiments are accessible under references from section «History of requests and calculations». Here references to the last a few ANN experiments are stored. Click on the reduced image it is possible to open the full-size plot. To identify results of the experiment under the user signature is possible.

5. Conclusion

This tool for solving a wide range of tasks can be applied. It is the study of the general trends of nonlinear connections between the different parameters determining the causal relationships in the system «interplanetary space-magnetosphere-ionosphere» would be useful. It has already in different studies applied. Example studies: search the nonlinear connection the auroral electrojet activity between Solar wind parameters and Interplanetary Magnetic Field [*Barkhatov et. al., 2008*], restoration and prediction of geomagnetic activity index [*Barkhatov et. al., 2001*], restoration and the forecast maximum observed frequencies on the traces of oblique HF ionospheric sounding with perturbation heliogeophysical parameters [*Barkhatov et. al., 2004; Barkhatov et. al., 2005a; Barkhatov et. al., 2006a; Barkhatova et. al., 2009*], complex classification of global geomagnetic disturbances [*Barkhatov et. al., 2005b; Barkhatov et. al., 2006b; Barkhatov et. al., 2006c*] and space plasma jumps parameters [*Barkhatov et. al., 2009*]. Further it is planned to expand possibilities of web service and to give to users possibility ANN classification of data packages.

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