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On Application of Artificial Neural Networks to Control Quality of Protection Environment

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Abstract- The principles of constructing artificial neural networks for a quality control system for the operation of ship equipment related to environmental protection are considered. The concentration of harmful substances in exhaust gases and bilge waters depends on many factors related to both the condition of the equipment and external conditions. Analytically describing this dependence is extremely difficult, therefore, it is proposed to use artificial neural networks to monitor the state of equipment. The paper describes how to create a neural network such as a self-organizing feature map and methods for its training.

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Introduction

Intensive use of fuel is accompanied by significant environmental pollution. The increasing spread of pollutants from fuel combustion, especially the emission of sulfur oxides into the atmosphere, is causing increasing concern, and this problem is compounded as global fuel consumption increases.

Despite the numerous studies conducted in the direction of combating environmental pollution, many issues remain unresolved. In particular, an important task remains the search for quality control methods for ship power plants and the development of modern means of analysis and processing of measurement results of various parameters characterizing the state of ship equipment and its impact on the environment.

In this regard, the urgent task is to identify factors affecting the appearance of harmful emissions, as well as the development of methods for monitoring the technical characteristics and operation modes of power plants and their elements in order to predict the occurrence of undesirable consequences associated with environmental pollution.

One of the main toxic components of exhaust gases is sulfur oxides. Based on an analysis of the literature, it was found that the combustible substance of a fuel consists mainly of three chemical elements: carbon, hydrogen, and sulfur. During combustion, oxygen combines rapidly with these combustible elements, accompanied by heat.

For the vast majority of fuels, only carbon and oxygen are important, since the sulfur content is too low to make a significant contribution to the heat generation. However, from the point of view of air pollution by combustion products, sulfur dioxide occupies the first place by mass. Sulfur oxides are formed during the burning of sulfur-containing fuels. The main sulfur oxide formed during the combustion of sulfur-containing fuel is sulfur dioxide (SO_2) and only 5-7% mole falls on sulfur trioxide (SO_3).

An analysis of literary sources over the past few years allows us to conclude that the study of the problem of environmental pollution comes down either to the search for new cleaning technologies, or to modernize, improve existing systems and methods. There are relatively few works related to the problem of diagnostics, the identification of relationships between the operating conditions of marine equipment and environmental pollution. However, this kind of research is of interest from the point of view of organizing the quality control of the cleaning systems and predicting the possible onset of undesirable consequences for the environment.

In order to be able to quickly influence the state of the environment, or at least to predict its changes, it is necessary to have a mathematical model that describes the relationship between the parameters of the power plant and the amount of harmful substances in emissions. However, as was said above, these relations are essentially nonlinear and very difficult to formalize.

The fact is that the amount of harmful substances in the emissions of a power plant depends not only on the cleaning method used and the type of treatment equipment, but also on many other factors, such as equipment wear, quality of the fuel used at the moment, ambient temperature, etc.

A power plant can be considered as a dynamic system, the state of which at each moment of time is characterized by a set of output parameters that can affect the state of the environment. The task of optimal control of such a system is to find input control actions, some integral indicator characterizing the damage to the environment is minimized.

To solve such a difficult formalized problem, two main approaches are traditionally applied. The first is associated with the use of expert systems, the basis of which is the knowledge base of the subject area under consideration. This knowledge base contains a set of rules of the form "if ... then ..." and a set of rules for constructing a chain of logical conclusions leading to the desired solution.

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Another approach is based on the use of neural networks [1]. An important property of a neural network is the ability to learn and to generalize the knowledge gained. Trained on a limited set of training samples, it summarizes the accumulated information and produces the expected response in relation to data that was not processed in the training process. The most suitable type of neural network for solving this problem is a self-organizing map of Kohonen signs [2].

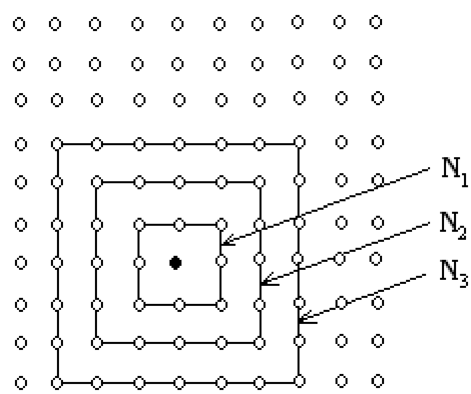
Consider some technical system or device, the state of which at each moment of time is described by a set of n real numbers, the range of possible values of which is given. We call this set the vector of n-dimensional space and denote

$$x = [\xi_1, \xi_2, \ldots, \xi_n] \in \Re^n. \quad (1)$$

If the minimum and maximum possible values of these parameters are known, then they can be normalized, that is, go to dimensionless quantities whose values lie in the interval (0,1). We assume that all components of vector (1) satisfy this condition.

As components of the vector x, all device parameters available for measurement (power, crankshaft speed, air flow, etc.) and environmental parameters (temperature, pressure, humidity) can be used. This set should contain both examples of standard situations when the amount of harmful substances is within acceptable limits during the system's operation, and when measures are taken where the emission of harmful substances is higher than the permissible one. In some cases, abnormal situations can be reproduced during system tests, but in a number of cases it is too expensive to simulate serious failures. In such cases, emergency situations have to be modeled.

The division of the input signal vectors into subgroups is called the clustering problem. This problem can be solved using the Kohonen network, which is an effective software tool for visualizing multidimensional data. The network converts nonlinear statistical relationships between multidimensional data into simple geometric relationships between the points representing them on a low-dimensional display device, in the form of a regular two-dimensional grid of nodes, an example of which is shown in Fig. 1.



Fin.1: Kohonen Self-Organizing Feature Map 10x10 in size. For a node highlighted in color, its topological neighborhoods N1, N2, N3 are shown

The nodes of the output layer are numbered in a certain order, for example, in turn from left to right and from top to bottom. Each neuron of the output layer is associated with each input element, to which the input signals ξ_1, ξ_2, ..., ξ_n are applied.

Initially, n weight coefficients (according to the number of input parameters) are assigned to each neuron – the vector mi (0), i = 1,2, ..., k, where k is the number of nodes. In the learning process, for each vector x from the training set, the index c of that neuron is found, the weight vector of which is closest to the given:

$$c = \arg\min_i \{\|x - m_i\|\},$$

where || x - mi || – Euclidean distance between vectors.

The weighting coefficients of this neuron, as well as the closest to it (see Fig. 1), change according to the formula

$$m_c(t+1) = m_c(t) + h_{ci}(t)[x(t) - m_i(t)],$$

where t = 0, 1,2, ... is the discrete time, $h_{ci}(t)$ is a certain neighborhood function that monotonically decreases to zero (smoothing core).

In the learning process, the weighting factors are ordered and the map is divided into a number of areas (clusters), which at the end of the training can be marked out (for example, by coloring them with different shades of gray), indicating acceptable combinations of the measured parameters and those that lead to deviations from the norm. If now we send a signal with data on the state of the controlled system to the network input, a neuron with a weight vector will be found, the closest to the input vector and a point in one or another cluster will be displayed on the map. Thus, it becomes possible not only to evaluate the current state of the equipment, but also to predict its behavior.

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