Recovering Information from Wireless Sensors in Hardware and Software Platforms

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Abstract. The work considers the task of information processing in a subsystem of the hardware-software platform of the simulator complex - a mobile system of simulating isolation breathing apparatuses. The problem of predicting values when data packets are lost during their wireless transmission has been revealed. To solve the problem, an algorithm for data processing based on neural network technology has been developed, which allows reducing the number of data packet losses by predicting the lost values. The experimental studies confirmed the adequacy and effectiveness of the proposed algorithm. The use of neural networks in solving the problems of information processing has improved the accuracy of this process.

1. Introduction

An important problem in monitoring systems is the loss of data due to various sources of interference. To solve this problem different methods are used at different levels of signal transmission, for example, it is possible to use shielding of different elements of the system. But such a solution is not always possible, in the absence of electromagnetic compatibility of equipment. Electromagnetic fields can interfere with wireless data transmission, causing packet loss (for example, the electromagnetic field of an electric motor can cause interference during its operation).

An example of recovery of human respiration data from an isolation breathing apparatus (IBA) simulator will be discussed.

In areas such as the chemical, mining industry, an urgent problem is the development of correct breathing skills in isolation breathing apparatuses (IBA). A sufficient level of proficiency in the IBA will enable a person in the presence of polluted air and toxic impurities to use the IBA within the established regulations limits and obtain the required amount of oxygen (based on the chemical reactions taking place in the IBA).

The practical trials of the IBA imitations system revealed several problems in the area of information collection, analysis and processing that affect the accuracy of the system.

This article will address the problem of the instability of the flow of information received from sensors to the server or mobile devices of the operator who controls the performance exercise [6]. Given the need for active activity during training, it is not possible to transmit data by wire, which leads to the inevitable loss of individual packets due to the instability of the wireless signal, the presence of interference, external conditions, and so on.

• Among the methods for recovering missing data are the following:
  • mean filling,
  • nearest neighbors,
• regression,
• maximum likelihood method,
• EM-algorithm,
• ZET,
• ZetBraid,
• Bartlett,
• resampling,
• evolutionary method.

However, these methods are not universal and do not always show the best accuracy and efficiency.

A promising option for solving this problem is the use of neural network technology and machine learning methods, as they belong to the class of regression [7, 8] and are successfully solved using neural networks with sufficient accuracy [9, 10].

Therefore, the paper considers the development of algorithmic and software aimed at solving the problems of data recovery using neural network technologies, which will automate the processes of information processing in the mobile system of simulation IBA of the software and hardware platform of the training complex.

2. Research problem statement
Let's formalize the designated information processing tasks in the IDA imitations system.

Let a set of initial data be given $X = \{x_n\}$ collected from $K = \{k_q\}$ the components of the imitations system, that is, the following display takes place $k_q \rightarrow \{x^n_q \mid x^n_q \in X_q, X_q \subseteq X\}$.

For the transmission data channel from the component $k_q$ in which the signal arrives with a period $\tau$ (i.e., every $\tau$ seconds), it is necessary to carry out the prediction $FM$ of lost values $\{x^m_q \mid x^m_q \in XM_q\}$ based on the collected data $X_q$ with an error of no more than $\varepsilon$ in the absence of new data over time $t > \tau$:

$$FM : X_q \rightarrow XM_q,$$

$$\left|x^m_q - x^n_q\right| \leq \varepsilon.$$

(1)

To solve the problem (1) let's develop the necessary algorithmic and software, functioning on the basis of neural networks.

3. Information recovery algorithm based on neural network technologies
We will consider the theoretical justification of the possibility of solving problem (1) with the help of neural networks as well [11, 12].

In the first problem given vector $XM_q$ of missing values, it has the same dimensionality as the vectors coming from the component $k_q : \left|XM_q\right| = \left|X_q\right|$. However, this vector refers to different time intervals: $t_0 \rightarrow X_q, t_0 + \tau \rightarrow XM_q$. Thus, it is possible to form a time series from ordered pairs $\{(X_{q,i}, t_i) \mid i = 0 \ldots T\}$. Since at time $t_0 + \tau$ no new data vector corresponding to it has arrived in the IBA simulation system, it is necessary to carry out its prediction by the function $FM$. Continuation of time series on the basis of previous values also belongs to the class of regression tasks and similarly can be performed by using neural networks at the expense of continuity of mapping $\{(X_{q,j}, t_j) \mid j = i - h, t_i \rightarrow (XM_q, t_i + \tau)\}$. This mapping uses a plurality of pairs from $t_{i-h}$ to $t_i$ to predict values at time $t_i + \tau$. The variable $h$ reflects the amount of data that is used to generate the prediction.

An algorithm for predicting lost values was developed for the task using neural network technologies (Figure 1).
The considered mathematical and algorithmic software will make it possible to solve the problem of information processing in the system of simulation of IBA and increase the accuracy of the collected data.

![Algorithm for predicting lost values in the IBA imitation system.](image)

**Figure 1.** Algorithm for predicting lost values in the IBA imitation system.

### 4. Practical implementation of the algorithm

To verify the adequacy of the developed algorithm and its approbation, the following experimental studies were carried out on the basis of the implemented IBA imitation system [4].

The experimental setup consists of the following main components: imitator IBA (includes differential pressure, flow, temperature, control mechanisms and controller for data acquisition and transmission) [13, 14], mobile terminal to collect and monitor information about the user's pulmonary activity (implemented on the basis of the application for the Android operating system [15]), mobile device for pulse measurement [16], router to create a wireless network [17] (Figure 2).
The IBA imitator implements the following functionality:
1) full compliance with the external parameters of the real IBA;
2) elimination of a chemical product for oxygen regeneration, which made it possible to realize the possibility of reusable use;
3) heating the gas-breathing mixture in various ranges (from room temperature to 60 degrees Celsius);
4) imitation of filling the breathing bag during breathing;
5) continuous registration of spirogram and pneumotachogram;
6) calculation of the probable time of the protective action of IBA based on the intensity of respiration processes.

The experiment consists in predicting values of the differential pressure sensor and, accordingly, values on the spiromgrams and pneumotachographs in cases of communication failure with the imitator and loss of packets.

To solve this problem we will train a recurrent neural network [18,19], the input of which is a vector of dimension (20, 3) - 20 last records of 3 values each (differential pressure, spirogram, pneumotachogram), the output is a predicted value. no new data packet is received from the imitator within the set time interval (50 milliseconds), the neural network generates possible values of pressure, spiromgrams, pneumotachograms. The training set included more than 18000 records. The prediction accuracy of the trained neural network was 85%.

Then practical tests on the recovery of lost data packets of different dimensions (from 8 to 20 measurements) were carried out. The average error of the neural network in data prediction was 14.6 (4.4%), which can be considered a satisfactory result. The model of the neural network is shown in Figure 3.

Figure 4 shows the original graph of the values from the differential pressure sensor and the recovered points at the loss of data in different time intervals.

Thus, the application of algorithms based on neural network technologies [20, 21] for data processing in the IBA imitations system show sufficient efficiency and allows recovering lost values with sufficient accuracy.
Figure 3. Neural network model.

Figure 4. Experimental studies on lost data recovery.
5. Conclusion
The paper considers the problem of lost data recovery in training complexes on the example of mobile breathing apparatus imitations system. In this subject area the actual problem is identified: prediction and recovery of lost data packets.

To solve this problem, algorithmic software based on the application of neural network technologies to automate information processing was developed. During the practical implementation of the algorithms, the problem was successfully solved.

When solving the prediction problem during the experimental study, the neural network successfully reconstructed missing data packets (up to 20 packets) with an average error of 4.4 %.

The results confirm the applicability and effectiveness of the proposed approaches based on neural network technologies.

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