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Methods for Collecting and Classifying Data using a Soundlet Bayesian Neural Network

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ABSTRACT

The paper substantiates the application of neural networks for prediction of emergency situations and the stages of building a neural network for simulation of emergency situations. The purpose of the work is achieved by developing scientific and technical bases for the technical implementation of a comprehensive within monitoring, prevention and liquidation system of natural and man-made emergency situations and ensuring environmental safety.

Forecasting emergencies and location determination is an urgent task that requires a permanent and effective solution. The basis of this problem is the construction of the effective methods, providing the high speed of the learning pattern recognition models as well as high probability, the adequacy and speed of emergency signals recognition. The article describes the principles of the construction and operation of the system for the recognition of emergency situations using neural networks. Considered apparatus and analysis of the need to use a neural network, to predict the physical parameters the emerging problem. Fulfilled the analysis of the chosen structure and neural networks, which should be used to predict the physical parameters. In article proposed model of a neural network to solve the problem of prediction. Also presented, the mathematical formula for visual understanding of the structure of neural networks and their work.

The article is devoted to the problem of emergencies prevention using modern methods of analysis of acoustic data. Emergencies arise in the conditions of extraordinary situations and management in emergency situations characterized by the need for work in the absence of information, the high rate of change in the situation, the need for operational formation of the most effective solutions, which have high efficiency, which imposes requirements to minimize the time and losses in the elimination of emergency situations. Results of the study can be used for analysis and modelling of stability of emergency service that is for evaluation of the emergency or potentially dangerous object.

Key words : Informing, neural network, classification, data mining.

1. INTRODUCTION

On the verge of the third Millennium, humanity will achieve a fairly high level of scientific, technical and industrial progress, which in turn creates conditions for a large concentration of the probability of emergency situations [1-3]. The article is devoted to the problems of emergency prevention using artificial neural networks for collecting and classifying audio data. Emergencies occur in the context of extraordinary situations [4]. Management in a critical state of vision is complicated by the need to work with a lack of information, with a high rate of change in the situation, requires the rapid formation of the most effective solutions that have high effectiveness. All this imposes requirements to minimize time and losses during liquidation of emergency situations [5-7].

The aim of the work is to develop scientific and technical bases for the technical implementation of a comprehensive system of monitoring, prevention and elimination of natural and man-made emergencies and ensuring environmental safety within Russia [8]. In today's conditions, an important task remains the need to develop new approaches and technologies that will make it possible to obtain all the necessary information. The main problems and directions of their elimination are formulated to improve the quality and informativeness of emergency control.

2. MATERIALS AND METHODS

The effectiveness of a particular system that is used to prevent an emergency is evaluated based on the results that take place after the occurrence of the situation. Therefore, early forecasting of unmanageable aspects of situations before making a decision makes it possible to make an effective choice, which without foresight could have negative consequences for the development of the situation [9-11].

The neuromodel approach originated from the biological neural networks of the human brain, which is capable of self-learning and effectively solves complex problems with heterogeneous parametric data. Some varieties of artificial neural networks are mathematical models and bear only a distant resemblance to their actual prototypes from neurophysiology. Neural networks are a powerful intelligent tool that facilitates the process of making important and non-obvious decisions in conditions of information scarcity and emergency response needs. The main characteristic of modern neural networks is their ability to model their results, depending on the variability of the external environment, taking into account fuzzy and hidden patterns of the information flow of data [12].

The main tool of machine learning is the Bayes theorem, which is represented by the formula (1):

$$P(\theta|D) \ = \ P(\,)\,(\theta \, P \, D\,|\,)\theta\,, \qquad (1)$$

where □ and D are events. P(□) and P(D) are probabilities of

events □ and D that are independent of each other. G(□|D) is a conditional probability, the so – called likelihood, which is the probability of an event □ provided that event D has occurred. P(D|□) – the conditional probability of observing an event D if the event □ occurs . P(D) – the full probability of event D occurring [13].

Conditional probabilities of the form P(□|D) are followed by determining the probability distribution of model parameters after figuring out which data is taken into account. The conditional probability P(□|D) is called posterior probability. In turn, the YMO fidelity of G(□) is a prior probability. It is a mathematical formalization of our intuition about the subject of research, a formalization of our previous experience existing before conducting experimental research [14].

Since the Bayesian network is a complete model for variables and their relationships, it can be used to provide answers to probabilistic questions. The structure of a two-layer soundlet Bayesian neural network model is shown in figure 1.

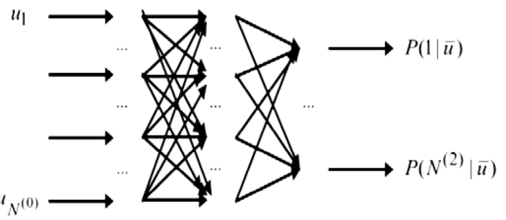

Figure 1: Structure of theBayesian neural network

Features of the designed neural network model:

- input layer neurons correspond to the components of the vector describing the test audio sample;
- neurons of the first (hidden) layer correspond to the reference samples;
- neurons of the second layer correspond to sounds;
- adaptation to the sound characteristics of a particular operator is carried out by adding reference vectors of samples to the model;
- each neuron of the first (hidden) layer processes information based on the normalizedstate between the reference and test samples.;
- the weights of connections between neurons of the first (hidden) and second (output) layer are equal to one or zero, these weights do not need a training procedure;
- aggregation of neuronal outputs of the first (hidden) layer is performed based on the maximum;
- in the second (output) layer, posterior probabilities are calculated using the Bayes formula, which allows us to determine the probabilities of belonging to the test sample of sound [15].

The General mathematical formulation of the classification problem, which can serve as a basis for constructing metric classification models, will be as follows: let x be the function that classifies the sample, and y be the class number of the sample (emergency). The task is to determine the valueofthe value y from the value x. Then the construction of a neural network classification model is reduced to determining the dependence between the class number y and the value x by means of neural network technologies. A model for classifying audio data based on a soundlet-by-ear neural network can be represented as [16]:

$$\bar{u} \ = \ (u1,\ldots\ldots,uN(0),un \ = \ (Fx)(n-1),n$$
$$\in \{1,\ldots\ldots,N\ (0)\},$$
$$\sum_{j\,=\,1} P\,j\,P(\,)\,(\bar{u}|\,)j$$
$$P(\bar{u}|)j \ = \ max_z w\ Pzj\,_j(\bar{u}|\bar{v}z\,),z$$
$$\in \{1,\ldots\ldots,N\ (1)\},j$$
$$\in \{1,\ldots\ldots N\ (2)\},$$
$$P(\bar{u}|\bar{v}_z) \ = \ -1\,\rho_\rho(\bar{v}_z\,,)\bar{u},z \in \{1,\ldots\ldots,N\ _{(1)}\},$$
$$\rho\rho(\bar{v}z\,,)\bar{u} \ = \ p\sum_{k\,=\,1}|vzk\ -uk\,|\,,p$$

where ***y*** is the number of sound; ~*y* – maximum a posteriori probability; ***x*** is an integer restricted fntn a discrete function that describes the test sample is a discrete sound signal; $\bar{u}$ is an integer vector, obtained by transformation of a function ***x*** to a single amplitude-time window on the basis of soundsets and soundleech mappings to the input of the artificial neural network; $\bar{v}_z$is an integer vector associated with the ***z***-th neuron of the hidden layer, the corresponding z-th reference sample; *P* (*j*|╫) – a posteriori probability (conditional probabilityb of the appearance of a test sample *of the j*-th sound during observation╫) calculated for each *j*-th neuron of the second (output) layer; *P* (╫ / *j*) – emission probability (observation probability provided that the provided test sample corresponds *to the j-th*of the sound); *P*(╫ | $\bar{v}_z$) - conditional probability (observation probability╫ provided that the test sample matches the reference vector of samples $\bar{v}_z$), which is calculated for each ***z***-th neuron of the first (hidden) layer; *P* (*j*) – a priori probability of sample *j*-th sound (probability), which due to the limited statistics, that is, in the formula (2) the variable $P\,j(\,) \ = \ N\underline{1}(2)$; *A* maximum the value of the vector ╫; $N^{(0)}$ – the number of neurons of the input layer corresponding to the length of the vector╫; $N^{(1)}$ – the number of neurons of the hidden layer corresponds to the number of reference samples of all sounds; $N^{(2)}$ – number of neurons in the output layer, corresponding to the number of sounds; w_{zj} – weight **z**-th reference sample, $w_{zj} \in [0, 1]$, and if the **z**-thneuron of the hidden layer is notknitted with the *j*-th neuron of the output layer (**z**-th reference sample corresponds to the *j*-th sound), then $w_{zj} = 0$. If the weight is not taken into account, then $w_z \in \{0, 1\}$ [17].

We will formulate performance criteria for the created model. Criteria for evaluating the effectiveness of the model [18]:

The classification speed criterion means selecting a metric from a given set of metrics that requires the least number of reference samples at the stage of model training

$$F = T \rightarrow \min \text{ (3) } p$$

To evaluate the results of classification of vocal sounds, it is necessary to formulate the conditions for their classification.

Conditions for classifying a test sample of an emergency sound by reference samples.

Let's give a test sample of the emergency sound, which is describedby an integer vector╫. For each *j*-th sound of the crisis state, let the calculated emission probability *P*(╫/*j*), that is, the probability of observing the vector╫, which describes the test sample, provided that the test sample corresponds *to the j-th*of the sound. Necessary condition for classifying the test sample. The test sample is classified if,

$$\forall \in n\{1,\ldots\ldots,J\}\forall \in m\{1,\ldots\ldots,J\}$$
$$(P(\text{ʉ}|\,n) = max\,P(\text{ʉ}|\,j) \wedge (P(\text{ʉ}|\,m)$$
$$= max\,P(\text{ʉ}|\,j) \rightarrow 6)$$
$$\_\,(n = m) \wedge (P(\text{ʉ}|\,n) > \varepsilon), j \in \{1,\ldots\ldots,J\},$$

where □is a given emission probability of classification, 0<$\varepsilon \leq 1$.

Sufficient condition for classifying the test sample. The test sample is classified if [19]

$$\forall \in n\{1,\ldots\ldots,J\}\forall \in m\{1,\ldots\ldots,J\}$$
$$(P(\text{ʉ}|\,n) = max\,P(\text{ʉ}|\,j) \wedge (P(\text{ʉ}|\,m)$$
$$= max\,P(\text{ʉ}|\,j) \quad \rightarrow (7)\,(n$$
$$= m) \wedge (P(\text{ʉ}|\,n) = 1), j$$
$$\in \{1,\ldots\ldots,J\},$$

Based on the obtained conditions, you can form logical-formal rules for evaluating classification results.

Logicaland formal rules for evaluating the classification result**.** To evaluate the classification results, the following logical and formal rules are formed [20]:

$$if\ ((P\,\text{ʉ}|\,y) >> \varepsilon max), then\,q$$
$$= y, (8)\,if\,(\,(P\,\text{ʉ}|\,)n$$
$$\leq \varepsilon max), then\,q = 0,$$

where *q* is the sound number, $□_{max}$ is the calculated maximum of emission probabilities $P(\text{ʉ}|\,y)$ for a set of vectors of test samples of non-critical (non-periodic) sounds [21].

Numerical study of the metric method of classifying sounds of emergency situations. Table 1 shows a comparison of the proposed method and existing neural network methods based on a database of acoustic signals. All sounds of an extremelydangerous situation (broken Windows, screams for help, sounds of gunshots, sounds of walls collapsing, etc.) were subject to classification [22].

Table 1: Subject to classification to neural network

N	**Artificial neural network**	**Erroneous classification, %**
1	Three-layer MLP	0.80
2	RBFNN	0.81
3	GRNN	0.82
4	PNN	0.84
5	A three-layer RMLP	0.90
6	Saundlet NN	0.95

In commonly accepted and currently widespread methods, vectors of low frequency cepstral coefficients (MFCC) calculated on equal-length sections, i.e. frames, were used as samples [23]. The classification error is the ratio of the number of correctly classified samples containing sounds of an emergency to their totalnumber in percentages, while samples containing the end of the first pre-crisis sound and the beginning of another pre-crisis sound were not taken into account [24-25]. The standard neural network methods listed in table 1 are implemented in the proposed article using the Matlab package. Experience allows us to conclude that the proposed method provides a high probability of classifying sounds of pre-crisis and crisis States of emergency situations.

3. CONCLUSION

The paper considers the possibilities and effectiveness of using artificial neural networks to solve problems of predicting the occurrence of emergencies of any nature.

It is proposed to use soundlets and soundlets reflection relative to pieceneural networks and a neuromodel approach to the classification of acoustic signals of NS, which is characterized by the ability to take into account the different characteristic structure of audio signals and generalize samples of one type of sound of different lengths with different amplitude ranges, which greatly exceeds the efficiency of classifying emergency signals. The ability to use a variety of audio signals that indicate the pre-crisis state, will allow rapid response and early identification of the site of possible emergency situations, which in turn will provide more effective opportunities to prevent the development of the situation in a critical state.

The logical continuation of the activity in this direction is the design of a unified state security system using artificial neural networks. Scientific research on ensuring the interoperability of existing disparate systems is also a promising direction. All these actions will allow for a consolidated response to any threats and emergencies of pre-war origin.

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