Fuzzy Risk Assessment Model of Environmentally Triggered Illnesses Occurrence

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Abstract

The article deals with the risk assessment model of environmental illnesses every person comes across. It is suggested to compare ecological information with the dynamics of individual’s regulatory systems functional state. The fuzzy risk assessment model of environmentally triggered illnesses occurrence is presented. This fuzzy model is used in the system of urban air environment ecological monitoring. It describes the use of wearable electronics and applications for smartphones to increase the prevention and diagnostics of environmental illnesses for the health and of people of all ages.

1 Introduction

According to statistics, about 85% of all modern diseases are related to unsatisfactory environment conditions. Total contribution of ecological factor in population mortality is estimated at 4-5% and takes the third place after general and social factors. City environmental pollution increases the number of residents with chronic diseases of lung, heart, brain, endocrine and urogenital system, metabolism [1, 2]. Symptoms and diseases related to air pollution are chronical cough, phlegm allocation, infectious lung diseases, lung cancer, heart diseases and heart attack. For example, long contact with environment intoxicated exhaust gas of cars causes general organism weakening – immunodeficiency [3].

Environmentally caused illnesses are the diseases widespread among the population of any territory. People are influenced by bad environmental factors. The disease can be revealed by typical for these causal factors symptoms and syndromes or another nonspecific deviation, provoked by ecologically negative factors.

To increase the effectiveness of diagnostics and treatment of several diseases (cardiovascular, endocrine, respiratory systems, brain and other) it is necessary to know if the disease is a result of negative ecological factors affecting the human, i.e. whether it is environmentally caused disease or not.

It should be noted that currently city environmental services implement the urban air condition monitoring by automatic stations of air pollution control and mobile environmental laboratories. At best but not for all cities, this information is available in the public domain (e.g., on www.mosecom.ru). However, the environmental information related to the influence of negative factors on the individual is not defined and accordingly is not used for a personalized assessment and individual’s condition prediction, support of diagnosis, prevention and treatment of ecologically triggered diseases.

It is possible to suggest a new direction in the development and use of wearable electronics and mobile technologies to improve the efficiency of problem solving, the prevention and diagnostics of the environmentally illnesses.

The work is aimed at the development of fuzzy risk assessment model of environmental illness of specific person.

2 Assessing the Factors Having Negative Impact on Human Condition

The value of influence depends on the following factors: pollutant type; pollutant concentration; influence durations; the volume of the inhaled air (physical activity of the person).

To estimate the risk of ecologically triggered diseases one needs to evaluate the pollutant influence level and the condition of the person’s regulatory systems. It is possible to offer the following principle to prevent ecologically caused diseases for the specific person. This principle is based on the fact that the mobile application installed on the smartphone displays not only the ecological information, but also its continuous collection, account and storage in the background. There should be a definition of the person’s physical activity. Due to this fact it will be possible to estimate the concentration value, duration and volume of the inhaled air during the day. After receiving such data for a time interval (day/week/month), based on the use of the developed indistinct model, it is possible to conclude about the risk of of ecologically caused pathology development, and if necessary to take certain measures to change food allowance, a way of life, etc. In the event of disease, its existence and exacerbation it will be possible to conclude whether a cause of pathology is the effect of negative ecological factors, how it is better to carry out the process of such disease treatment, how to achieve a permanent remission. The condition of regulatory systems can be evaluated, for example, according to the analysis of heart rate variability of the person.

Thus, it is possible to offer the following algorithm to implement this approach [4].

1. Obtaining the predicted value of air pollution level at the point of person’s location.
2. Assessment of person’s physical activity.
3. Accumulation of the predicted values of air pollution level and physical activity of the person.
4. Assessment of air pollution impact.
5. Assessment of regulatory systems condition.
6. Health change forecasting, the need of prevention and treatment.

The value assessment of negative impact can be received based on the use of the developed fuzzy logic model which allows us to connect the impact level with the polluted air, pollutant concentration, air contact duration, breath frequency, weight and human height.

The possibility of statistical ecological data accumulation makes it possible to use them together with control devices forecasting a person’s condition, diagnostics, prevention and treatment. For example, it is possible to create a state ladder based on a heart rate variability analysis [5] and to perform comparison and analysis of changes in person’s condition and his adaptation process to the received ecological information (Fig. 1).

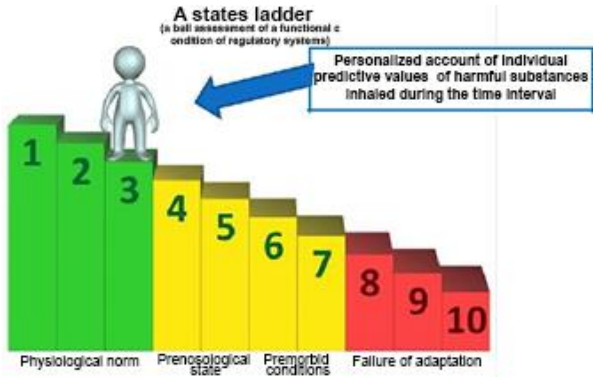

Figure 1: The accounting of ecological information in the analysis of a state ladder

The dynamic comparison of a functional condition assessment of regulatory systems connected with the value of air pollution can be shown in Fig. 2. Here the chart 1 presents a case when the scoring growth estimates a functional condition of regulatory systems, i.e. there is a development of diseases. At the same time points there is a growth of contact with the polluted air. It is possible to conclude that there is a high probability that the reason of the person’s condition deterioration and pathology is the development of air pollutants, and the disease is ecologically caused. Chart 2 also shows the case of scoring growth estimating a functional condition of regulatory systems, i.e. the development of diseases. However, the growth of negative impact of the polluted air in this case was not observed. Respectively, it is possible to conclude that air pollutants are probably the reason of person's condition deterioration and the pathology development can be observed but it is small, and the disease is not ecologically caused. This fact can be used to increase the efficiency of treatment or prevention of the emerging disease.

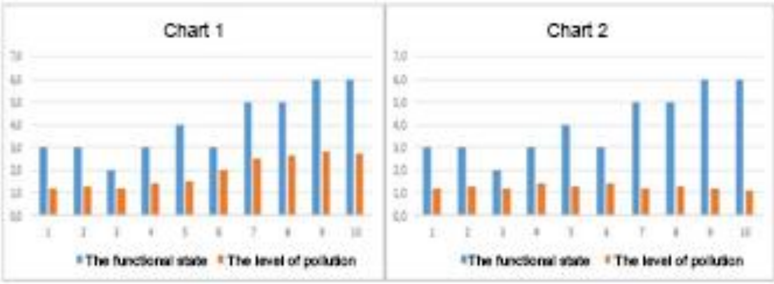

Figure 2: Principle of scoring assessment, functional condition of regulatory systems compared with air pollution value

3 Fuzzy Model of Risk Assessment

The value of the negative environmental factors impact estimated using the total coefficient of the effect value difference of the i-th factor xi from its normative value MPV_i:

$$K = \sum_{i=1}^{k} \frac{x_i}{MPV_i}$$

In order to build the fuzzy model of risk occurrence assessment of ECD, one must specify the input and output linguistic variables, term-set, membership function for each of the linguistic expressions whose values can accept the linguistic variables, rules of fuzzy productions [6].

As the input linguistic variables xi use the original scoring assessment of functional status of the human body regulatory systems (defined on the basis of heart rate variability analysis [7]) F, coefficient K, exposure duration T, the volume of the inhaled air (or physical activity of the person) V. Specifying linguistic variables will have the following term-set, "Low", "Medium" and "High". It may be noted that the increase in the number of terms, on the one hand makes a model become complex, but on the other hand, increases the reliability of the forecasting and assessment. This can also be applied to the number of input variables. To determine the degree of conditioning linguistic variables for each variable x^i, one has to define the membership functions and the corresponding numeric values: for "Low" term - z-shaped and a_1, a_2, for "Medium" term - trapeze-shaped and a_3, a_4, a_5, a_6, for "High" term - s-shaped and a_7, a_8 (Fig. 3):

$$\phi^{x^i}_{"Low"}(x) = \begin{cases} 1,\ if\ x \le a_1; \\ \dfrac{a_2 - x}{a_2 - a_1},\ if\ a_1 < x \le a_2; \\ 0\ else, \end{cases}$$

$$\phi^{x^i}_{"Medium"}(x) = \begin{cases} 1,\ if\ a_4 \le x \le a_5; \\ \dfrac{x - a_3}{a_4 - a_3},\ if\ a_3 < x \le a_4; \\ \dfrac{a_5 - x}{a_5 - a_4},\ if\ a_4 < x \le a_5; \\ 0\ else, \end{cases}$$

$$\phi^{x^i}_{"High"}(x) = \begin{cases} 0, \; if \; x \le a_5; \\ \dfrac{x - a_5}{a_6 - a_5}, \; if \; a_5 < x \le a_6; \\ 1 \; else. \end{cases}$$

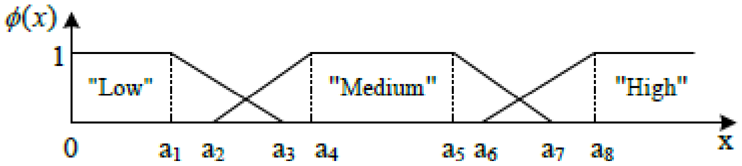

Figure 3: The membership functions of linguistic variables "Low", "Medium" and "High" for x^i

Output linguistic variable y will take the value of the "Occurrence risk of ECD is very high", "Occurrence risk of ECD occurrence is high", "Occurrence risk of ECD is medium", "Occurrence risk of ECD is low", and «Occurrence risk of ECD is very low".

Here are a few rules of fuzzy productions for each value of output linguistic variable.

Rule 1: **IF** F = «High» **AND** K = «High» **OR** K = «Medium» **AND** T = «High» **OR** V = «High», **THEN** y = «Occurrence risk of ECD is very high».

Rule 2: **IF** F = «Medium» **AND** K = «High» **OR** K = «Medium» **AND** T = «High» **OR** T = «Medium» **AND** V = «High» **OR** V = «Medium», **THEN** y = «Occurrence risk of ECD is high».

Rule 3: **IF** F = «Medium» **OR** F = «Low» **AND** K = «Medium» **AND** T = «Medium» **OR** T = «Low» **AND** V = «High» **OR** V = «Medium», **THEN** y = «Occurrence risk of ECD is medium».

Rule 4: **IF** F = «Low» **AND** K = «Medium» **AND** T = «Medium» **OR** T = «Medium» **AND** V = «Low» **OR** V = «Medium», **THEN** y = «Occurrence risk of ECD is low».

Rule 5: **IF** F = «Low» **AND** K = «Low» **AND** T = «Medium» **OR** T = «Low» **AND** V = «Low» **OR** V = «Medium», **THEN** y = «Occurrence risk of ECD is very low».

During the stage of use data model processing, each rule is carried out by calculating the degree of truth-conditions and a rule definition with the maximum degree of truth is implemented, including the risk of ECD occurrence.

Applying these rules, the occurrence of ECD risk forecasting can be implemented and diseases can be prevented while implementing this approach. While using this model,

The information on the environmental impact can be extracted from the environmental monitoring data and the data of the person’s functional status can be obtained by using wearable electronics, for example, fitness-band.

4 The System of Urban Air Environment Ecological Monitoring

The block diagram of the developed system of ecological monitoring consists of the following elements: air pollution sensors, meteo condition sensors, transmitters, receivers, switchboards, servers, smartphones, portable wearable electronics, client’s application (Fig. 4) [4].

The sensors connected to the corresponding transmitters define the information about the current data of air pollution and meteo conditions in a certain place in the city, carrying out wireless transmission to the receivers connected via the switchboard to the server. The server processes the received information and forecasts air pollution value in other points of the city. The server has the Internet connection. In this way, the developed client’s application which is installed on the user's smartphone gets the access to the information on air pollution and its forecast in the city districts. The task of mobile application is to collect environmental and biomedical information for the individual, to compare it and output the results. The task of wearable electronics is to assess the environmental situation where the user is located and receive a signal analyzing heart rate variability transferring the information to the user's smartphone.

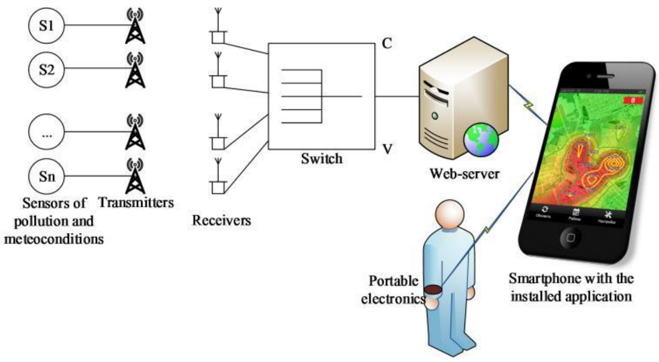

Figure 4: The block diagram of the developed system of ecological monitoring

Now for air pollution assessment and forecasting done at various points of the city, various empirical analytical models are used, such as the regular models of services GO, standard models based on the OND-86 model, Paskuilla-Gifford's model, model of IAEA, etc. Such models forecasting the spread of pollutants in the atmosphere suppose the existence of complex systems of the analytical equations describing dynamics of impurity distribution. The processes of pollution distribution is random, badly reproducible and possess unsteadiness which complicates the analytical description. All the existing models and techniques accept the assumptions of meteo conditions constancy that contradicts reality. The features accounting the atmosphere pollution process in the conditions of incomplete meteo data and data about pollution sources can be achieved by applying neural network models of forecasting.

The main advantage of artificial neural networks is the ability to learn on the basis of available expeditious selection. Besides, the neural networks can be trained, using constantly arriving actual data about pollution and meteoconditions.

As input variables there are selected wind speed (U, m/s), wind direction (W, °), air temperature (T, °C), pollutant concentration (Cp, mg/m^3). The realization of neural network model was enabled in the program Matlab using the Neural Network Toolbox appendix.

Eight types of neural networks were analyzed: a cascade network with direct distribution of a signal and the return distribution of a mistake; a network with direct distribution of a signal and the return distribution of a mistake; a network with a delay and the return distribution of a mistake; the generalized regression network; a radial basic network with a zero mistake; a radial basic network with the minimum number of neurons; Elman's network with the return distribution of a mistake [6].

To determine the effectiveness of the neural networks studied the mean square mistake was used by the quantity of output variables of a neural network and counted on the basis of the predicted and real values of a test selection according to the formula [6]:

$$E = \frac{1}{N \cdot K} \sum_{i=1}^{K} \sum_{j=1}^{N} \left(q_{ij}^{r} - q_{ij}^{p}\right)^2,$$

where *r* - value *i* of an output variable neural network for *j* of the training or test example;

q_{ij} - the predicted i value of an output variable neural network for j of the training or test example;

N - quantity of examples in the training or test selection;

K - quantity of output variables of a neural network.

While creating a model, based on the calculation results of the mean square mistake, the choice of an optimum configuration of a neural network for the task was carried out. The learning algorithm by the Levenberg-Markar's method and a cascade network with direct distribution of a signal and the return distribution of a mistake with 11 neurons is chosen was selected.

This neural network model is put in the program for forecasting air pollution in the developed system of environmental monitoring.

A virtual device which presents the demonstration version of the developed automated system for the personified support process of diagnostics was created with the help of sensors and data acquisition card USB-6008 in LabView. It carries out the prevention and treatment of ecologically caused pathologies on the basis of the accounting of individual predictive value of the inhaled polluted air per time interval (Fig. 5).

5 Conclusion

Fuzzy risk assessment model of ecologically triggered diseases is presented. The structure of ecological monitoring system of air space of the city is suggested. The key element of the system is the client's application installed on the smartphone of the user which has the air pollution forecast in any user's location. Due to this, the principle of prevention and diagnostics of ecologically caused diseases is suggested. It is based on the fact that the mobile application performs in the background continuously collecting, accounting and storing the ecological information. Thus, it will be possible to estimate the concentration value, duration and volume of the inhaled air during the time interval. The information above makes it possible to conclude that it is vital to prevent and diagnose ecologically caused diseases. It is also offered to compare this information with the dynamics of regulatory systems condition estimated by the results of heart rate variability analysis.

The implementation of the developed system and smartphones application will allow:

1. quickly get information about air pollution at the location of the user and in other districts of the city, in contrast to the information from city services through the internet in a number of cities;
2. to increase the efficiency of prevention and diagnostics of ecologically triggered diseases of the individual.

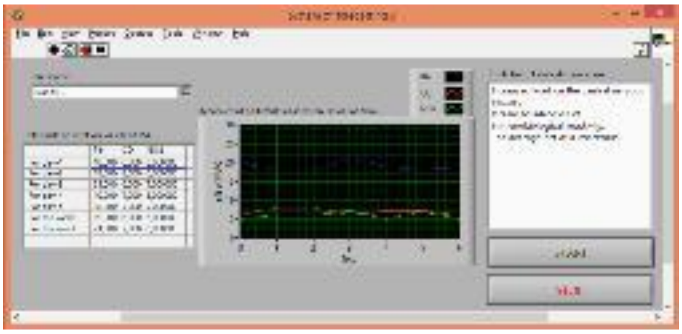

Figure 5: The developed automated system forecasting of diseases emergence risk based on statistical data of contact with the polluted air for time interval

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