GLOBAL ENVIRONMENTAL MONITORING SYSTEM

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Abstract. This article reveals the problems of creating a monitoring system to assess the ecological state of the environment of the selected area. An information model of the system has been developed, which takes into account the parameters of air, surface water, and soil pollution. The main components of the system, including the logical model of the database, have been designed and implemented. To assess the state of the environment according to the selected pollution parameters, the fuzzy logic model is constructed.

Key words: Ecological state of the environment; Information model; Database; Fuzzy logic model.

1. Introduction

At present, the state of the environment is a quite relevant topic. The constant increase of man-made emissions into the air, surface waters, and soil pollution require reliable monitoring and analysis systems. Another important task of environmental monitoring is the use of new, seemingly environmentally friendly technologies, such as the transition of European countries to electric cars, which according to preliminary findings could dramatically increase the number of air emissions from car production for several years. Thus, a properly designed global environmental monitoring system can provide the functionality needed to analyze changes in the state of the environment and predict future changes.

2. Research Issues

The environmental monitoring system is a system whose task is to collect (automatic or manual) and save data on the state of the external environment for further analysis, evaluation, and forecasting of its changes.

A preliminary review of such systems revealed that global monitoring systems that develop, forecast, and assess the state of the environment in more than one direction (usually air) are very few and their functionality is limited by the display of indicators.

The environmental monitoring system is an open information system, the tasks of which are to protect important ecological parameters for people, preserve natural ecosystems, to prevent critical changes in the ecological state of the environment and emergencies.

Tasks for which environmental monitoring systems are created:

- Improving the level of awareness about the ecological state of the environment;
- Improving the relevance and quality of information;
- Monitoring of environmental protection measures and analysis of efficiency;
- Promoting international cooperation in the field of nature protection, monitoring the use of natural resources, and environmental safety.

Tasks of monitoring subjects:

- Long-term systematic monitoring of the environment.
- Analysis of the state of the environment and forecasting of further changes.
- Information support for decision-making in the field of environmental protection, use of natural resources, and security.
- Servicing state and local authorities, as well as providing environmental information to the population and international organizations.

The operation of the monitoring system is based on the use of existing structures of monitoring entities and operates based on a single regulatory, organizational, methodological, and metrological support and unification of the components of the system.

The tasks of the global environmental monitoring system are to obtain, store and analyze data related to the general ecological situation on the planet, as well as many environmental areas, including air, surface water, soil pollution, and the biosphere, and the history of changes in these indicators time and share of anthropogenic impact on these changes. The extended global monitoring system will also have the functionality for short-term forecasting of the state of each of the areas of supervision.

3. The Goal of the Work

The tasks of the designed system are the accumulation and processing of the necessary input indicators of the ecosystem, assessment, based on fuzzy logic, the state of the environment, the presentation of

this information in an accessible form (including graphics). The system should store historical data from indicators obtained from sensors or environmental bulletins or other documents. The system must also provide a history of changes in the state of the environment over some time. An important component of the designed system is the module for assessing the state of air, surface water, soil, and the formation of a total indicator of the quality of the ecological state using fuzzy logic.

4. Designing a System of Comprehensive Analysis of the Environment

The first stage of designing a comprehensive analysis system of the environment state was to create an information model. The main model parameters are the air pollution state, the surface waters state within the study area, and the soil pollution state. Further data collection takes into account the parameters of the ecological situation in the Lviv region.

The system receives historical data from documents on the environment state, i.e. from environmental passports of the Lviv region. Ecological passport is an official document approved by the head of the Lviv Regional State Administration, which contains information on environmental pollution in the Lviv region. For historical data of the system, sections containing information on atmospheric air, the state of surface river waters, and soils were used. Concentrations of substances are given in milligrams per cubic meter (mg/m^3).

Sensors that analyze the state of air pollution or connect to systems with similar functionality can be used to further obtain current information. In this way, timely information can be obtained, which allows evaluating the state of the most important for human life area of the environment, i. e. atmospheric air. The information model of the system is presented in Fig. 1.

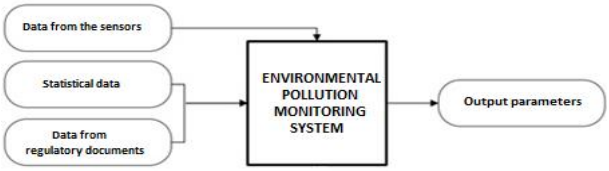

Fig. 1. The information model of the system

The data from the sensors should be the structure of the arrays of indicators obtained for various environmental parameters, including statistics of air quality, water resources, soils (for the main model), as well as the level of radiation safety (advanced model parameter).

Historical data (block of statistical data) includes the history of changes in the state of the environment during 2017–2021. Data from regulatory documents includes standard and limit values of certain parameters to determine the environment elements' general condition. The limit values include the maximum allowable parameters for assessing the pollution level. Table 1 shows the normative maximum concentrations of pollution (MPC are the maximum permissible concentrations) of atmospheric air substances.

Table 1

Standards for the content of elements polluting the air

Substance	Danger	Average daily MPC, mg/m^3	Maximum content, mg/m^3
Dust	3	0.15	0.6
Sulfur dioxide	3	0.05	0.85
Carbon monoxide	4	3	8
Nitrogen dioxide	2	0.04	0.2
Nitric oxide	3	0.06	0.08
Hydrogen fluoride	2	0.005	0.011
Formaldehyde	2	0.003	0.031

Table 2 shows the normative limit concentrations of surface water pollution.

Table 2

Standards for the content of elements polluting surface water

Substance	Maximum content, mg/dm^3
Sulfates	100
Chlorides	300
Nitrogen-Ammonium group	0.39
Nitrogen-Nitrites	0.02
Nitrogen Nitrates	9.1
Phosphates	0.17/3.5
Iron	0.1

The data of the established standards for the content of major pollutants in soils are given in Table 3.

Table 3

Standards for the content of soil contaminants

Substance	Maximum content, mg/dm^3
Cadmium	4.5
Lead	32.0
Benzopyrene	0.02
Benzene	0.3
Nitrates	130.0
Potassium chloride	560.0
Sodium chloride	23.0

4.1. Development of a model for a fuzzy logic controller

For a fuzzy logic controller, the rules will be described using FCL (Fuzzy Control Language), i.e. will meet unconfirmed development standards. The general scheme of the model data structure for the fuzzy system is presented in Fig. 2.

Assessing the state of the environment includes the next agents:

Pollen, Carbon monoxide (CO), Hydrogen fluoride (HF), – to estimate the atmospheric air state,

Sulfates, Chlorides, and Iron (Fe), – to assess the water state,

Lead (Pb), Potassium Chloride (KCl), and Cadmium (Cd) – to estimate the condition of soils.

For all parameters of the term set, the states are "Low" and "High" (concentrations of substances), where the lowest concentration is 0 and the highest in the MPC (Maximum Permissible Concentration). In Fig. 3 is shown a graphical representation of membership functions for each variable.

Assessment of the initial variable and defuzzification take place according to the rules within which air is the most priority part of the environment state, water is the least priority part of the assessment of the environment state, and soils are the least impacts on the general assessment. The resulting variable of the rules of fuzzy logic is a general assessment of the state of the environment (Fig. 4).

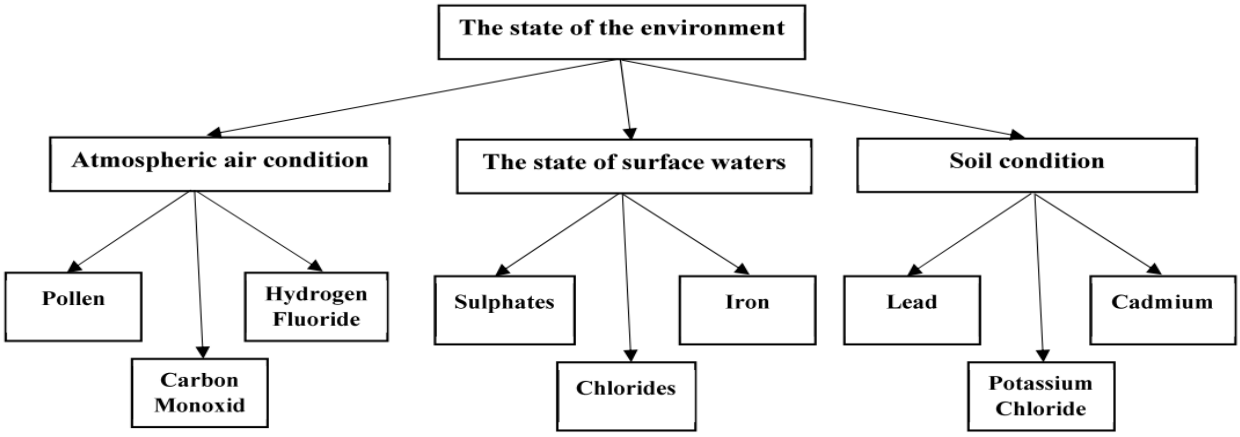

Fig. 2. The data structure in the system

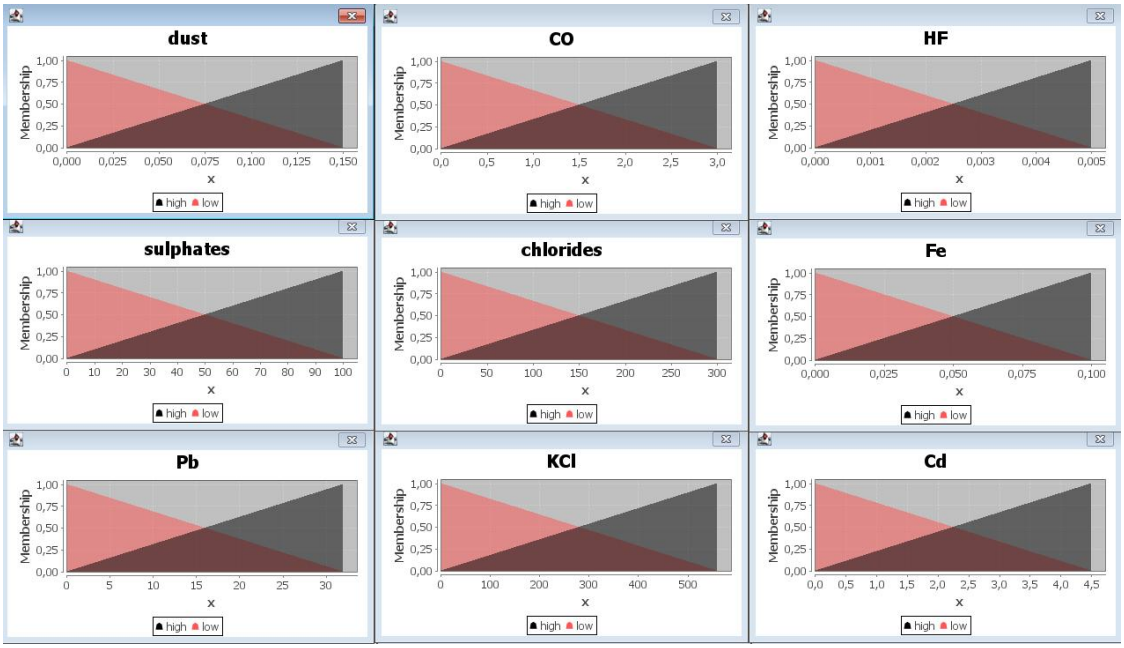

Fig. 3. Rules of fuzzification

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DEFUZZIFY stateEstimation
        TERM Critical := (0,0) (5,1) (10,0);
        TERM Bad := (10,0) (15,1) (20,0);
        TERM Normal := (20,0) (25,1) (30,0);
        TERM Good := (30,0) (35,1) (40,0);
        TERM Excellent := (40,0) (45,1) (50,0);
        METHOD : COG;
        DEFAULT := 0;
END_DEFUZZIFY
```

Fig. 4. The rules of fuzzy logic

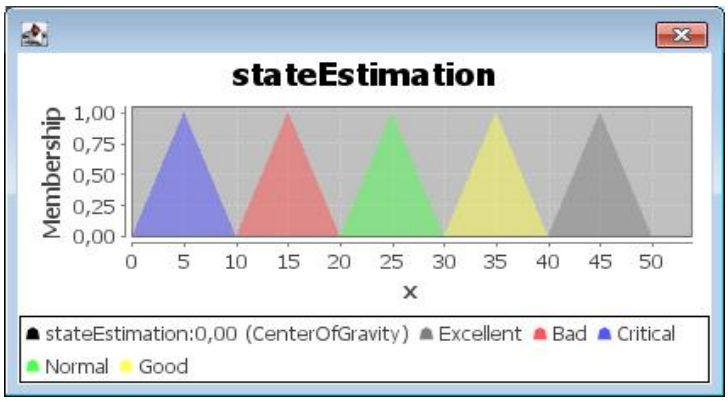

Fig. 5. Functions of membership of the source variable

In Fig. 5 the membership functions of the resulting variable are shown.

The following is part of the membership rules for the resulting fuzzy logic controller variable on FCL (Fuzzy Control Language).

RULE 1: IF dust IS low AND CO IS low AND HF IS low AND sulfates IS low AND chlorides IS low AND Fe IS low AND Cd IS low AND Pb IS low AND KCl IS low THEN state estimation IS Excellent.

RULE 2: IF dust IS low AND CO IS low AND HF IS low AND sulfates IS low AND chlorides IS low AND Fe IS low AND Cd IS low OR Cd IS high AND Pb IS low OR Pb IS high AND KCl IS low OR KCl IS high THEN state estimation IS Good.

RULE 3: IF dust IS low OR dust IS high AND CO IS low AND HF IS low AND sulfates IS low AND chlorides IS low AND Fe IS low OR Fe IS high AND Cd IS low OR Cd IS high AND Pb IS low OR Pb IS high AND KCl IS low OR KCl IS high THEN state estimation IS Normal.

RULE 4: IF dust IS low OR dust IS high AND CO IS low AND HF IS low AND sulfates IS low OR sulfates IS high AND chlorides IS low OR chlorides IS high AND Fe IS low OR Fe IS high AND Cd IS low OR Cd IS high AND Pb IS low OR Pb IS high AND KCl IS low OR KCl IS high THEN state estimation IS Bad.

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The developed fuzzy subsystem for assessing the environment state includes the indicators of only a few pollutants with the most effect on the overall level of quality of the ecological situation in the region.

4.2. Development of system components

The system consists of a client part of the system, a web server with a fuzzy logic controller, and a server with a database. An important component of a full-featured system of analysis and assessment of the ecological state of the environment is a database.

Fig. 6 demonstrates the logical diagram of the database for designing the system software.

The following relationships are considered in the database below:

Region – a relation to store data, such as the name of the region of observation (city, region, etc.)

State_estimation – a relation to collect the history of environmental assessments. In particular, data on the creation date of the assessment, the characteristics of the assessment, and the assessment of the condition itself are collected. The environment condition assessment is linked with the particular region.

History – a relation for the history of data from sensors and regulations. Also in this respect, the average data for the day is transferred. In this regard, the year and date of receipt of values and concentrations of pollutants are preserved. Data on pollutants (their names and maximum concentration limits) are obtained by linking to the table of pollutants. Based on this relationship, the condition is assessed.

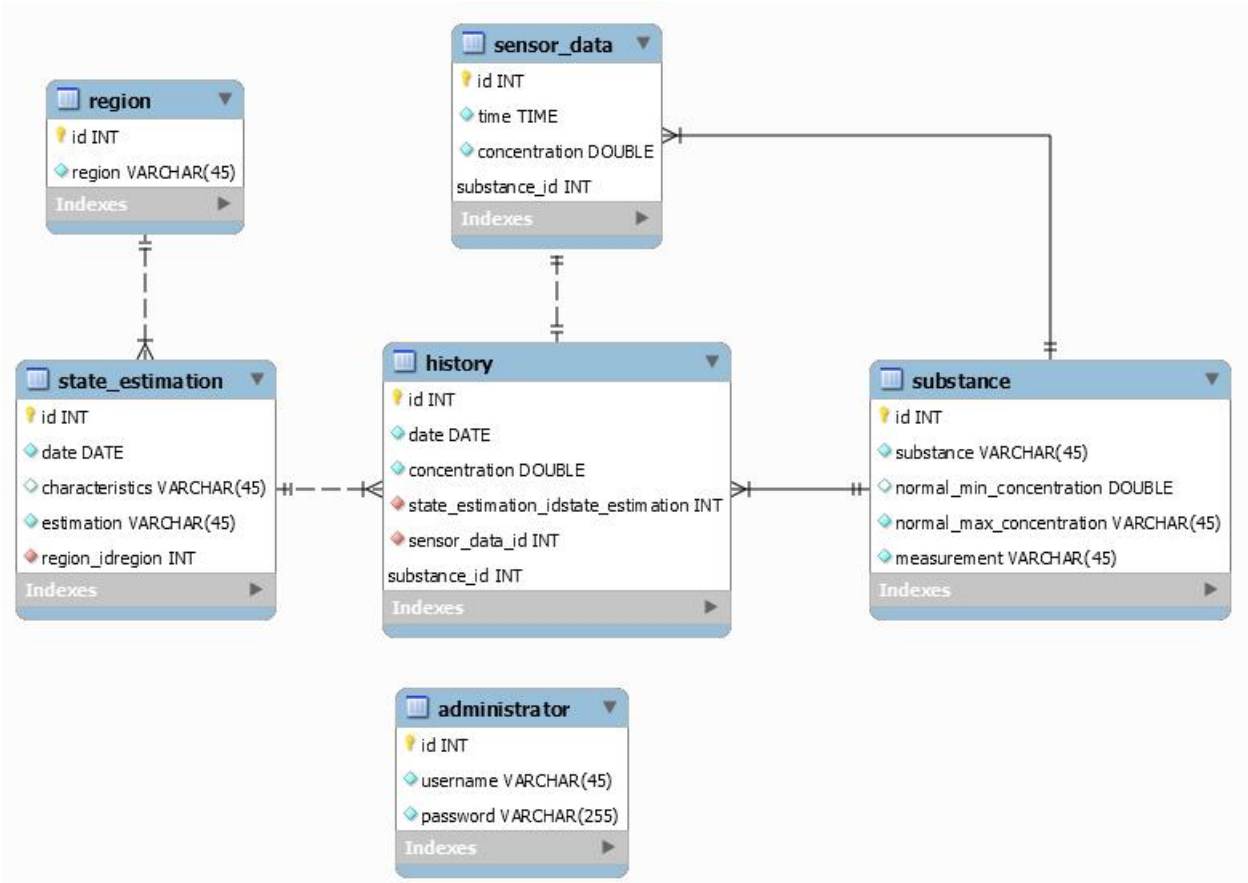

Fig. 6. Logic diagram of the database

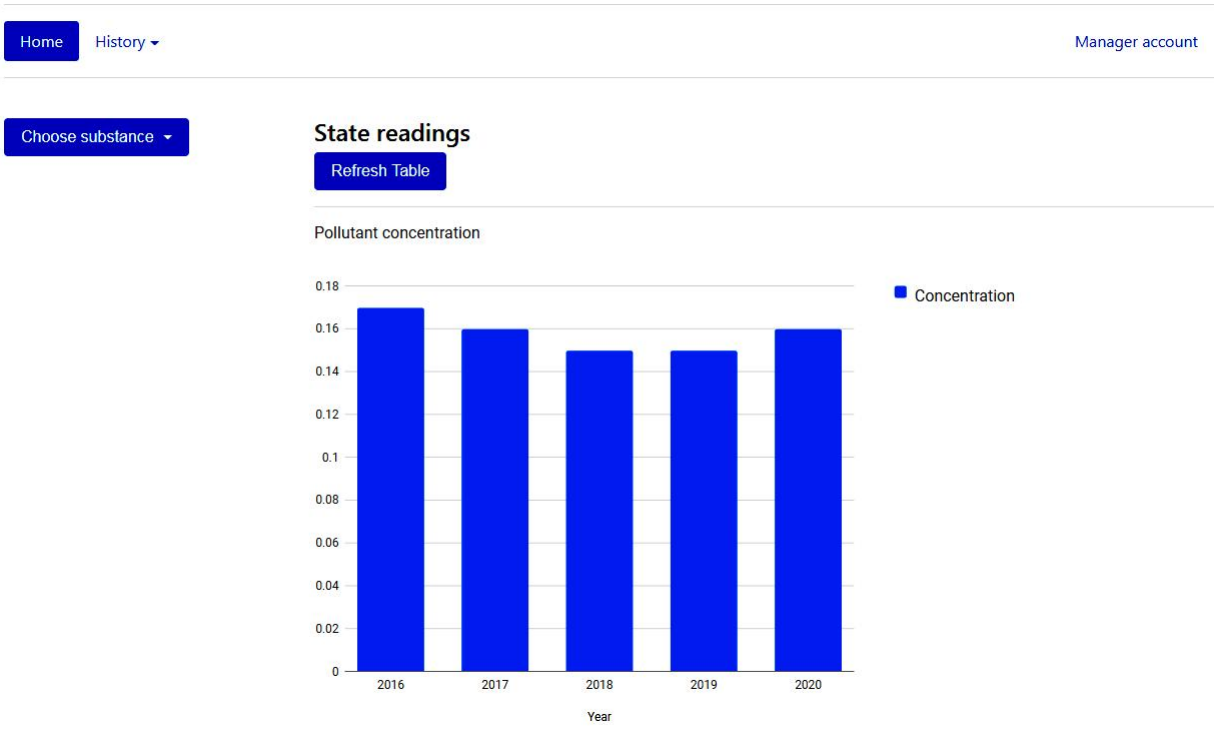

Fig. 7. Graph of the dynamics of changes in the amount of dust in the air

Sensor_data – a relation for data received from sensors. In this regard, the time and concentration of substances are preserved.

Substance – the ratio in which data on pollutants are stored, in particular the name of the substance, the minimum, and maximum permissible concentrations.

Administrator – a relation for data about database administrators. This relation includes the username and encrypted account password. Registration of new users through the system is not provided.

The database is created and deployed on the server with the Spring Data JPA framework. Database creation is performed automatically, based on DTO (Data Transfer Object), which were created, reproducing the architecture of fields and keys in the database.

Fig. 7 shows a graph of changes in the concentration of pollutants in the environment. The schedule is created by the Google Charts library.

5. Conclusions

The market of environmental analysis systems is filled with systems of different types. But there are very few systems for Ukraine that analyze more areas than the state of the air. The development of a quality system of analysis of the global environment state can introduce a positive impact on the development and improvement of monitoring the ecosystems. The developed system is designed for the collection, processing, and analysis of indicators of air pollution, surface water, and soil. The assessment of the state of the environment is carried out based on the developed model of fuzzy logic as a component of the implemented software.

6. Conflict of interest

The author claims that there are no possible financial or other conflicts over the work.

7. Gratitude

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