Expert system for determining the technical condition of long-term operational structures of water management facilities of the agro-industrial complex

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Abstract. This paper presents a promising solution to the issue of determining the category of technical condition of hydraulic structures in operation, namely, the collaboration of IT solutions and a set of current building codes and rules in the developed expert system. Most of the reclamation and hydraulic structures operating in the Volgograd region have exceeded their operational life of 25 years laid down in the design. Therefore, it is necessary to control and maintain such structures with the establishment of the technical condition. The developed expert system would contribute to the solution of the listed problems by the operational services of the organizations on the balance of which the structures are located, and the result should comply with all relevant norms and rules.

1. Introduction
At the moment, one of the most urgent problems for the Russian Federation is the problem of maintaining in normal working condition hydraulic structures belonging to different classes.

In Russia, among other things, the new regulation of January 1, 2021 [1] “Regulation on the operation of a hydraulic structure and ensuring the safety of a hydraulic structure whose construction and operation permit has been canceled, as well as a hydraulic structure that does not have an owner” came into force. In short, each hydraulic structure whose construction or operation permit has been revoked is placed under special control, and each owner of such a hydraulic structure or operating organization, in accordance with the instructions of the state supervisory authority, is obliged to develop and implement measures to eliminate the reasons that led to the cancellation of the permit for the construction and operation of the hydraulic structure.

Everywhere on the territory of Russia, the company expires the validity of the permit for the operation of the structure. Most have been in operation for more than 30 years, and some have been in operation for more than 70 years without repair. 3388 hydraulic structures remain unattended [2], most of them are not suitable for operation, for one reason or another, according to Figure 1, 313 more structures were identified compared to the previous year, 5 structures were liquidated during the year, 201 structures were excluded from the list of ownerless hydraulic structures after the survey by the decisions of the emergency commissions, as they lost the signs of hydraulic structures and do not pose a danger. And today there is an acute question of how to profitably and effectively put into operation...
deplorable structures. Designing a hydraulic structure is one of the most challenging engineering tasks, as it requires extensive knowledge in structural engineering, fluid mechanics, geotechnics, and materials science among other fields, as well as innovation skills, since every hydraulic structure is somehow a prototype. While the general purpose of hydraulic structures has not changed since early times, design methods and analysis tools have evolved significantly in recent years. Currently, computational fluid dynamics and artificial intelligence modeling methods are common additions to more classical physical modeling and direct measurement tools that help analyze the complex features of fluid flow around hydraulic structures [3].

Gavrilova and Khoroshevsky define expert systems as follow: “These are complex software systems that accumulate the knowledge of specialists in specific subject areas and replicate this empirical experience for consulting less qualified user” [4].

These tools can help better address the new challenges posed by social and climate change. The underlying uncertainties require greater design flexibility to achieve the current project objectives, while allowing for adaptation to new conditions. Existing hydraulic structures, in turn, are often older than their original intended service life. This is a common problem all over the world, and hydraulic engineers are increasingly faced with the task of finding innovative solutions to ensure the safe operation of the structure in the future, taking into account social, economic and environmental problems. These circumstances indicate the need to create an expert system that allows you to solve these problems.

![Figure 1. Ensuring the safety of ownerless hydraulic structures.](image-url)

2. Materials and methods
During the examination of structures, the technical condition of structures, components and the building as a whole is evaluated for a specific period of time. At the same time, the main thing is to identify defects, damage, assess the causes of occurrence, the degree of danger and the forecast of the remaining strength resource.

The result of the expert examination is a written opinion that competently assesses the causes that led to an accident, an accident of building structures or structures. It can be continuous (for example, design and estimate documentation), one-time, departmental, selective in the order of control of a higher-level organization, etc. However, the results of the classical examination can be obtained after
months of work, but everything can be simplified thanks to the expert system and the competent layout of requests.

Expert systems - automated systems focused on solving problems that are difficult to unambiguously and formalized description and are usually solved on the basis of experience and informal logic (heuristic methods), usually with the involvement of highly qualified experts. Systems are based on the concentration of the maximum possible number of forms and heuristic knowledge from the most qualified specialists in a particular application area, and then use this knowledge to solve the same problems that specialists usually face in this field. A significant difference between developed expert systems and conventional computer systems used to support decision-making is such an element of artificial intelligence as the ability to self-learn.

The use of a combination of formal and heuristic knowledge and the rejection of formal algorithms, which very conditionally reflect the variety of ways to solve specific problems, increase the adequacy of the actions of the systems under consideration to real conditions in comparison with ordinary ones. At the same time, it becomes possible to quickly process a large amount of information, which is difficult (sometimes impossible) for a human expert. The practical use of such systems looks like an active human-machine dialogue (interactive mode), during which not only a person asks questions to the machine, but also vice versa. In addition, the user can, if desired, find out the reason for making a particular decision, i.e., without delving into the essence of the software, get an explanation of the actions of the machine when justifying the result of the decision. Some of the developments themselves recognize when the user needs help. In practice, a corrective procedure is used to determine the degree of confidence of each potential solution in order to cut off the wrong solutions and leave the acceptable ones.

However, the expert still needs to examine the design to obtain an initial conclusion, but further, the extensive knowledge base of the expert system can quickly make a final conclusion and determine the necessary resources for repairs.

Any expert system should have a data output and a sequence of "thinking" of the system, its structure is shown in Figure 2.

Figure 2. Structure of the expert system.

The basis for the functioning of this system is the knowledge base. Unlike databases, which are the information support of traditional systems, it contains two groups of knowledge: declarative (facts about a specific application area) and procedural (heuristic methods or rules for solving problems, including the development of hypotheses, information processing, and logic for obtaining conclusions). In addition to the knowledge base, the expert system is introduced: for communication of the user in a language that is understandable to him, working memory for storing preliminary hypotheses and results that the system
comes to during the solution of the problem, an acquisition component that performs the correction procedure of knowledge and a component that explains the actions to the user.

3. Results and discussion
The development is based on an expert system [5], it is designed to consult with the user in any application area (for which the downloaded knowledge base is configured) in order to determine probabilities.

To work with the expert system, it is necessary to download the knowledge base, then at the start of the consultation, it offers the specialist to select the necessary categories of structural defects (Figure 3).

![Figure 3. The main form of the expert system.](image)

After the end of the consultation, the program will highlight the status according to the completed list of questions. To determine further work with the structure, it is necessary to familiarize yourself with the state assessments according to the code of rules for design and construction 13-102-2003 [6]. For each condition of the structures, there are necessary recommendations for maintenance or measures to restore and strengthen them. Additional methods of non-destructive quality control of the structure can also be applied, which is the ultrasonic method [7, 8, 9].

With the completion of the software, the addition of a neural network structure capable of analyzing the source data, it is possible to obtain an advanced product in the diagnosis of structures. The essence is simple, the user uploads images of the object, neural networks recognize defects, visually assess the state of the object, only on the recognized defects begins a consultation with the user, and then issues a decision on the state of the object. This will help to reduce the list of consulting issues, thereby coming to a solution in the shortest possible time.
The principle of recognition will work on a ready-made sample, which contains all classes of damage and defects in building structures of buildings and structures. For each image, there is a set of features that have been highlighted by some feature, whether it is Haar, HOG, SURF, or some kind of wavelet. The learning algorithm must build a model that allows it to analyze the new image and decide which of the defects is present in the image. How is this done? Each of the images is a point in the feature space. Its coordinates are the weight of each of the features in the image. Let our signs be: “The presence of bare reinforcement”, “The destruction of a concrete structure”, examples in Figure 4.

![Figure 4. Signs of structural defects.](image)

All these signs will be identified by our existing detectors, which are trained to detect rebar, or the presence of cracks and peeling, all that characterizes a design defect. For a structure with a serious defect in such a space, the correct point will be [1; 1; 1; 1…]. For a less serious defect, the point [1; 0; 1; 0…]. For a serviceable structure [1; 0; 0; 0…]. The classifier is trained from a sample of examples. But not all of the images can be seen as cracks, others are peeling, and on the third, a serviceable structure may have bare reinforcement due to a classifier error. The trained defect classifier automatically splits the feature space in such a way as to say: if the first feature lies in the range 0.5 < x < 1, the second 0.7 < y < 1, etc., then this is definitely a serious design defect.

In essence, the purpose of the classifier is to draw areas in the feature space that are characteristic of classification objects. Figure 5 shows a sequential approximation to the answer for one of the AdaBoost classifiers. AdaBoost combines weak classifiers with specific strategies to produce a strong classifier [10].
4. Conclusion
Expert systems are widely used in our life, design and survey activities should not be an exception when examining structures of water management facilities of the agro-industrial complex. The developed expert system allows solving the problems of long-term diagnostics of the structure, making a practical assessment of the state of the structure immediately after a detailed examination, applying the necessary technological processes in time and constantly predicting design defects at the initial stage for successful control of the structure. Reducing the time of diagnosis will significantly help to solve the problem of the state of hydraulic structures.

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