

Fuzzy Controller of Pathological Conditions Diagnosis based on Analysis of Cytological Images

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Abstract: In this article authors proposed the fuzzy controller for the correct diagnosis of the breast pathological states. This mean can be used in medical practice by the cytologist as an additional way of diagnosis confirming that is the vital sometimes.

Keywords: fuzzy controller, breast cancer, cytological images, pathological conditions.

I. INTRODUCTION

Breast cancer in Ukraine, as well as in most countries of the world, is one of the most widespread tumor processes in women and ranks first in the structure of morbidity and mortality from malignant neoplasms (25% of all cases of cancer).

The cytological research allows to identify pathological changes of cells at early stages of development, since the main object of the study are small cellular structures, namely: nucleus, cytoplasm, mitochondria, as well as determination of nuclear-cytoplasmic ratio, which is a very important indicator. The analysis of the structure of cells is carried out using powerful microscopes with high resolution and high quality optical components.

The cytological analysis is carried out for the purpose of screening of oncological diseases, for the form verification of the pathological process (proliferative, atrophic, atypical, inflammatory, autoimmune), the effectiveness of the performed treatment by identifying the regression of the disease, to control the dynamics of changes in the cells.

The prevalence of cytological images processing software allows the process of establishing the exact diagnosis to be the fastest and most accurate for an expert. To determine the exact diagnosis based on qualitative signs of images, excluding the subjectivity of judgments of the expert, it is worth using a fuzzy logic system.

II. FUZZY SYSTEM

In oncology, fuzzy logic, usually in combination with neural networks, is used mainly for processing the images themselves or some markers of the occurrence of pathological states. For example, Alberto d'Onofrio in his work on the use of fuzzy logic in medicine within the study of the impact of chemotherapy indicates that although the fuzzy system has its disadvantages, but its outcome is biologically more realistic than other approaches.

A group of scientists of the State University of Louisiana also investigated the use of fuzzy logic in order to exclude the

subjectivity of decision making of radiologists when applying the terminology and vocabulary of breast cancer diagnostics.

Another area of using the fuzzy logic is the processing of medical imaging of tissues of various organs. The main advantage of this approach is the rapid training of the system and the high probability of the results [1].

Fuzzy systems can operate incoming information that is unclear, for example, verbally, by expert-physician, perform fuzzy formalizations of evaluation and comparison criteria, carry out qualitative evaluations of input data and output results due to their degree of probability and distribution, carry out rapid simulation of complex dynamic systems and their comparative analysis with a given degree of accuracy. Therefore, this approach will allow to build a diagnostic system for the pathological states of the mammary gland, which will work in real time and is capable of quick adjustment.

The membership function determines the subjective confidence level of the expert in that the given specific value of the base scale corresponds to the value of the fuzzy set. The setting of production rules is based on the definition of such fuzzy rules, so that the control module, constructed on their basis, generates certain output signals when receiving input signals. So that is why, it is necessary to divide the space of incoming and outgoing signals into sets and set the appropriate membership functions for them. Record fuzzy rules based on the experimental sample, create a table for writing the production rule base and the truth table of the rules (presence or absence of signs). Set all the rules of the degree of truth and generate the rules, form the basis of fuzzy rules [2].

Fuzzy modeling in the Matlab setting is based on the application of the Fuzzy Logic Toolbox extension package, which presents a large number of fuzzy logic functions and fuzzy output.

The fuzzy system of processing cytological images for the diagnosis of pathological states of the mammary gland is based on the mechanism of the Mamdani fuzzy conclusion, in which the knowledge data base consists of the rules of the form "if-then". In this case, the input variables are the signs of the pathological states that are present in the image [3-5]. For ease of construction, the following designations are used:

- c1 - flattened apocrine epithelium;
- c2 - formation of papillary structures;
- c3 - the presence of secretory activity in cells;
- c4 - round hyperchromic nuclei, located centrally;

- c5 - a small number of hyperchromic monomorphic cells;
- c6 - the cells are layers;
- c7 - in the background there are many phagocytes and histiocytes;
- c8 - the presence of secretions around the cellular space;
- c9 - formation of cellular complexes;
- c10 - formation of papillary complexes with dense placement of cells in multilayered layers;
- c11 - large cell sizes;
- c12 - large sizes of nuclei with intensively expressed chromatin;
- c13 - intensively expressed nuclei;
- c14 - narrow rim of intensively painted cytoplasm;
- c15 - round hyperchromic nuclei;
- c16 - fibroblasts.

It is proposed that each of the signs is given only by two fuzzy states “present” or “missing” in the image.

For the diagnosis of nonproliferative, proliferative mastopathy and fibroadenomas, there are no cytological images of mutually exclusive features. However, there are some signs that may be present at the same time or must be present.

In particular, to confirm the diagnosis of nonproliferative mastopathy in a cytological image, the diagnostician must always observe the signs c1, c3, c4 and c5. In addition, the signs are preferably at the same time c2, c5, c6 or c1, c3, or c1, c3, c8. On that basis we can conclude that in order to confirm the diagnosis of nonproliferative mastopathy, it is necessary to work out a database of 16 rules.

The proliferative mastopathy and fibroadenoma can only be confirmed by the physician if there are simultaneously signs of c9, c10, c11 and c12 (in the case of mastopathy) and c1, c2, c11, c13, c14, c15, c16 (in the case of fibroadenoma). In other words, in general, the fuzzy system is working on the basis of 18 rules of the type “if, then”:

1. If (c1 is present) and (c3 is present) and (c4 is present) and (c5 is present) then (diagnosis-cytology is nonproliferative mastopathy).
2. If (c1 is present) and (c2 is present) and (c3 is present) and (c4 is present) and (c5 is present) then (diagnosis-cytology is nonproliferative mastopathy).
3. If (c1 is present) and (c3 is present) and (c4 is present) and (c5 is present) and (c6 is present) then (diagnosis-cytology is nonproliferative mastopathy).
4. If (c1 is present) and (c3 is present) and (c4 is present) and (c5 is present) and (c7 is present) then (diagnosis-cytology is nonproliferative mastopathy).
5. If (c1 is present) and (c3 is present) and (c4 is present) and (c5 is present) and (c8 is present) then (diagnosis-cytology is nonproliferative mastopathy).
6. If (c1 is present) and (c2 is present) and (c3 is present) and (c4 is present) and (c5 is present) and (c6 is present) then (diagnosis-cytology is nonproliferative mastopathy).
7. If (c1 is present) and (c2 is present) and (c3 is present) and (c4 is present) and (c5 is present) and (c7 is present) then (diagnosis-cytology is nonproliferative mastopathy).
8. If (c1 is present) and (c2 is present) and (c3 is present) and (c4 is present) and (c5 is present) and (c8 is present) then (diagnosis-cytology is nonproliferative mastopathy).

9. If (c1 is present) and (c3 is present) and (c4 is present) and (c5 is present) and (c6 is present) and (c7 is present) then (diagnosis-cytology is nonproliferative mastopathy).

10. If (c1 is present) and (c3 is present) and (c4 is present) and (c5 is present) and (c6 is present) and (c8 is present) then (diagnosis-cytology is nonproliferative mastopathy).

11. If (c1 is present) and (c3 is present) and (c4 is present) and (c5 is present) and (c7 is present) and (c8 is present) then (diagnosis-cytology is nonproliferative mastopathy).

12. If (c1 is present) and (c2 is present) and (c3 is present) and (c4 is present) and (c5 is present) and (c6 is present) and (c7 is present) then (diagnosis-cytology is nonproliferative mastopathy).

13. If (c1 is present) and (c2 is present) and (c3 is present) and (c4 is present) and (c5 is present) and (c6 is present) and (c8 is present) then (diagnosis-cytology is nonproliferative mastopathy).

14. If (c1 is present) and (c2 is present) and (c3 is present) and (c4 is present) and (c5 is present) and (c7 is present) and (c8 is present) then (diagnosis-cytology is nonproliferative mastopathy).

15. If (c1 is present) and (c3 is present) and (c4 is present) and (c5 is present) and (c6 is present) and (c7 is present) and (c8 is present) then (diagnosis-cytology is nonproliferative mastopathy).

16. If (c1 is present) and (c2 is present) and (c3 is present) and (c4 is present) and (c5 is present) and (c6 is present) and (c7 is present) and (c8 is present) then (diagnosis-cytology is nonproliferative mastopathy).

17. If (c9 is present) and (c10 is present) and (c11 is present) and (c12 is present) then (diagnosis-cytology is proliferative mastopathy).

18. If (c1 is present) and (c2 is present) and (c11 is present) and (c13 is present) and (c14 is present) and (c15 is present) and (c16 is present) then (diagnosis-cytology is fibroadenoma).

FuzzyLogicToolbox Matlab setting is used to build a fuzzy system.

The input variables of this fuzzy system are the signs c1-c16 described above. The output of the proposed system (diagnosis-cytology) is the diagnosis of nonproliferative, proliferative mastopathy and fibroadenoma. The general view of the fuzzy system for the diagnosis of a cytological image is given in Fig. 1.

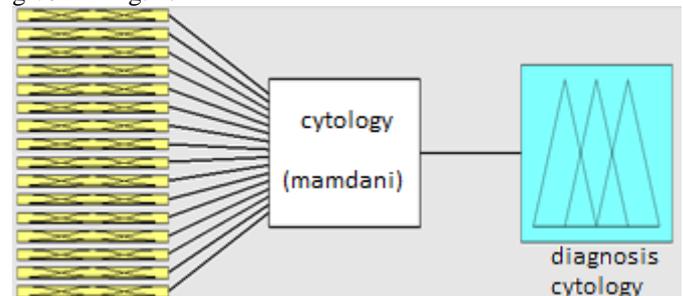


Fig. 1. A general view of the developed fuzzy system.

The membership functions of the input variables, that is the signs c1-c16, are given by a bell-shaped form that best reflects the two sets of values of each of them, namely, the present or the missing attribute on the image (Fig. 2) [17].

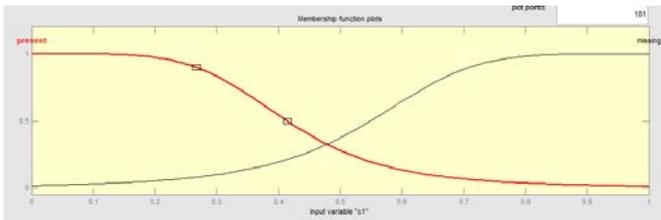


Fig. 2. The membership functions of input variables for example c1 signs.

To set the membership functions, a triangular shape is used (Fig. 3).

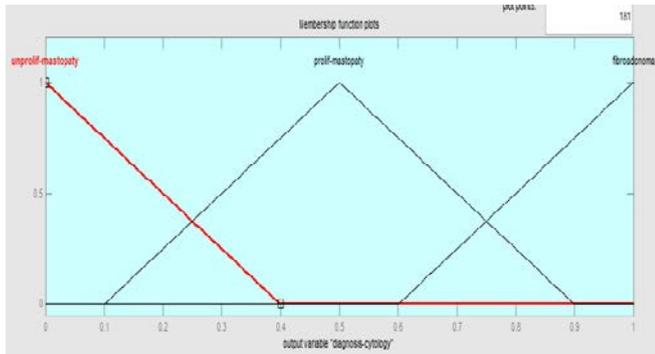


Fig. 3. The membership functions of target variable diagnosis-cytology.

The correctness of the work of the developed fuzzy system follows from the analysis of the fuzzy conclusion obtained when the given rule base is working (Fig. 4).

On the basis of the developed rules of the fuzzy conclusion a system of diagnostics of pathological states of the mammary gland was constructed.

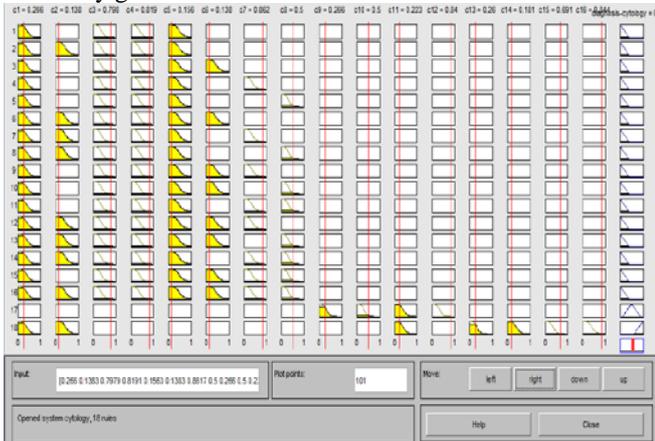


Fig. 4. The result of the fuzzy diagnostic system of pathological states of the mammary gland.

III. FUZZY CONTROLLER

The basic fuzzy controller consists of four main components:

- Fuzzyfication unit (just changes the inputs, so they can be interpreted and compared with the rules from the base knowledge);
- Knowledge base (base rules and database that holds knowledge, in the form of a set of rules, on how to better manage the system);
- decision-making unit (logical conclusion mechanism, which evaluates which rule is now relevant, and then decides

what should be submitted to the input);

- unit of defuzzyfication (transmits the conclusions made by using the mechanism of logical conclusion, to the inputs). The model of the fuzzy controller of access to the system of assessment of a general educational institution can be done by using Simulink. Simulink is an interactive tool for modeling, simulating and analyzing dynamic systems, including discrete, continuous and hybrid, nonlinear and discontinuous systems.

The general scheme of the fuzzy controller is shown in Fig. 5.

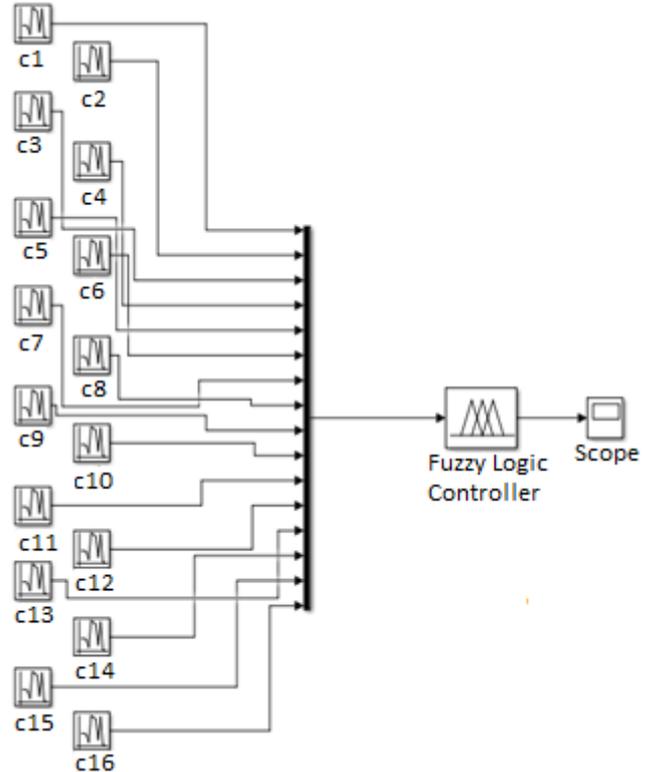


Fig. 5. General scheme of the fuzzy controller.

Input variables are set like Random Number.

General scheme of input and output values are shown in Fig. 6.

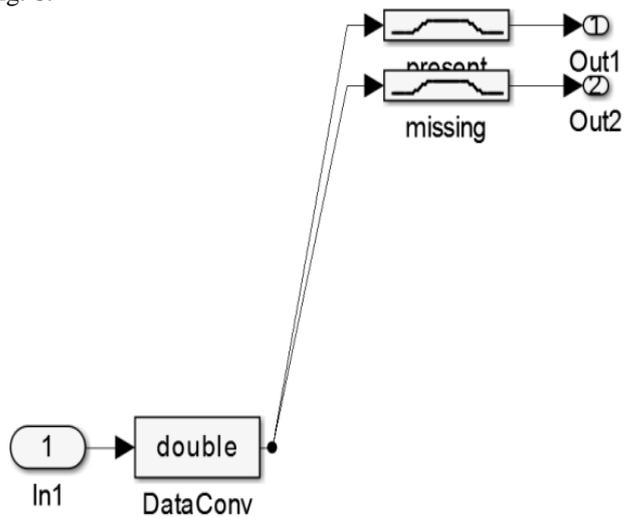


Fig. 6. General scheme of input values.

Fig. 7 depicts the scheme for processing incoming fuzzy

values by the rule of the type “if-then”. Simulink handles rules from the knowledge base, taking into account the rating displayed by the constant Weight.

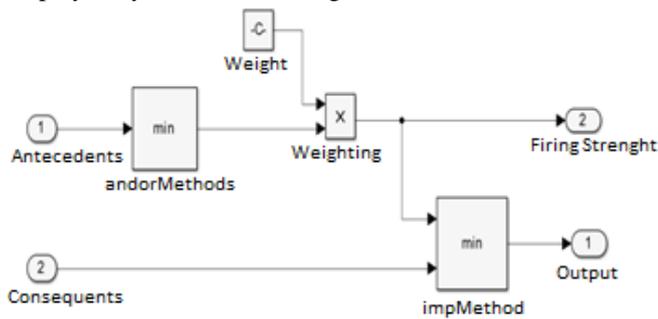


Fig. 7. Scheme for handling incoming fuzzy values using the rule “if-then”.

To make a conclusion on the Mamdani mechanism, the fuzzy controller carries out defuzzification. Defuzzification scheme is shown in Fig. 8.

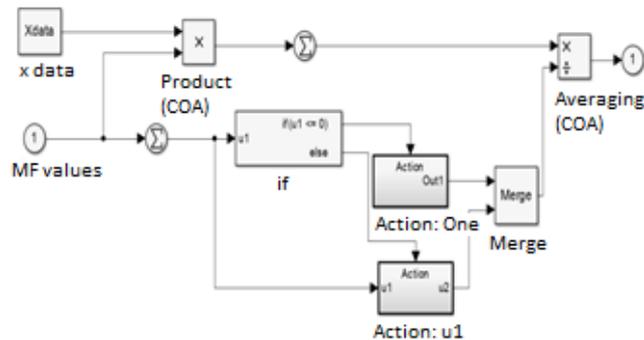


Fig. 8. Defuzzification scheme of the fuzzy conclusion.

In order to analyze the work of the fuzzy controller, it is necessary to use data from the Scope units, which are shown in Fig. 9.

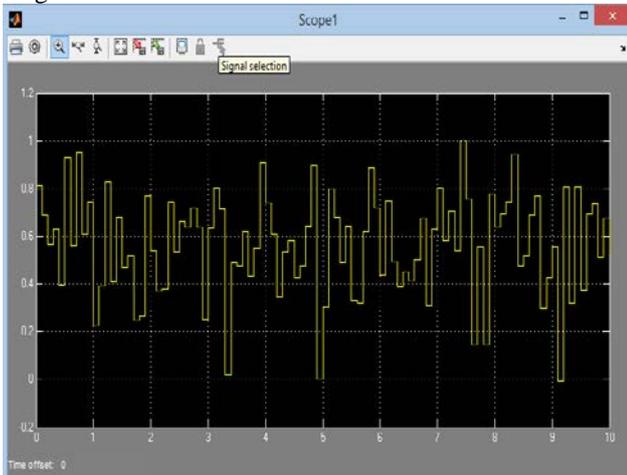


Fig. 9. Evenly distributed task of random values of the input variable c_1 .

The result of the model at given input values of the presence of breast pathological states signs is shown in Fig. 10.

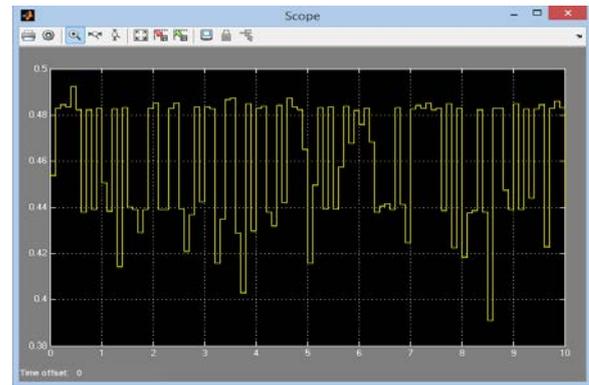


Fig. 10. Results of the developed fuzzy controller.

According to the data presented in Fig. 9 and 10, it can be assumed that the developed fuzzy controller is working correctly and can be used with aim of the correct diagnosis of the breast pathological states. Moreover, this controller can be coded in VHDL with help of Simulink and realized on FPGA.

IV. CONCLUSION

The given fuzzy system solves the basic problem of diagnosing the pathological states of the mammary gland, namely, the subjectivity of the judgments of the diagnostician in the analysis of cytological images. In addition, such a system can be used for doubtful diagnoses as confirmation of expert opinion.

The proposed fuzzy controller is a prototype of the hardware tool, which can be used in telemedicine system.

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