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Fuzzy System of Diagnosing in Oncology Telemedicine

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Abstract: Breast cancer is the most common cancer among women. Cytological images are used to diagnose the breast cancer. In this thesis the fuzzy system of diagnosing of precancerous and cancerous conditions of the breast is proposed. This system is based on the expert evaluation of cytological images and can be used in modern oncology telemedicine.

Keywords: Telemedicine, Oncology, Diagnose, Breast cancer cytological images, Fuzzy knowledge base, Fuzzy system.

1. Introduction

Telemedicine is a modern branch of IT-based development in the field of medicine that involves using of modern information and telecommunication technologies for remote diagnosis and treatment, in emergency situations as well as for health workers training [1, 3].

According to the National Cancer Registry in 2014 in Ukraine there were 14 908 cases. Moreover, almost 25% of tumors are diagnosed at a late stage, and 40% of women over 40 have never been properly examined [1].

Cytological examination of breasts plays an important role in the diagnosis of breast diseases. It is based on the method of fine needle aspiration biopsy. Fine needle aspiration biopsy, followed by cytology is an integral component of diagnosis of breast diseases in most European countries [2].

The diagnosis based on cytology is subjective because in most cases a doctor carries it out alone. Thus we need to create an objective evaluation system in order to examine malignancies based on of several experts knowledge in this field. The problem can be solved using fuzzy logic and its future program implementation.

Today fuzzy systems are becoming increasingly popular as a tool of modern information technology, decision support, pattern recognition and medical diagnostics. They are also the basis of fuzzy controllers that can implement software which can be applied in practice.

Fuzzy logic is used in various areas of industrial process control systems or securities trading. Fuzzy logic mechanisms also can be used in medical diagnostic systems modeling [4-5].Their basis is the expert assessment of input variables and outputs depending on them. Typically, these evaluations are qualitative, not quantitative, which complicates their implementation by standard mathematical methods.

Currently, there are many fuzzy logic conclusion mechanisms, in particular Mamdani and Sugeno mechanisms are the most popular among them.

The development of information technology has left its mark on the development of medicine. Has the opportunity to hold consultations of leading specialists regardless of their location, to monitor the healing process of the patient, to administer surgical operations, to provide psychological help, etc.

2. Experts' Knowledge Basis of Biomedical Image Analysis

Cytological examinations of epithelial cells and structures allow researchers to form suggestions about degrees of epithelial proliferation. The systematization of cytological images with mastitis and fibroadenoma shows the possibility of cytological methods to make a diagnosis [9].

Cytology helps differentiate malignant processes in the following cases: if we find in punctate:

- Ductal cells with nuclear enlargement and prominent nucleoli but they are in large sheets with no single cells;
- Only a few malignant cells are present;
- Malignant cells intermixed with bare bipolar nuclei;
- Comment on presence or absence of ductal -foam cells,
- Atypical ductal epithelial cells: (Paget's disease, invasive carcinoma) [10].

Cytology defines the characteristics of normal cells:

- Often scant cellularity (depends on age, hormonal status);
- Small groups of ductal cells;
- Lobular structures may be seen;
- Myoepithelial cells in cell groups (as elongated nuclei) and in the background (ovoid nuclei stripped of the cytoplasm);
- Adipose tissue and stroma.

Normal cells: a few small cohesive groups of ductal cells at the most; different from adequacy criteria for FNA (Fig.1).

Breast Cyst is shown on Fig. 2.

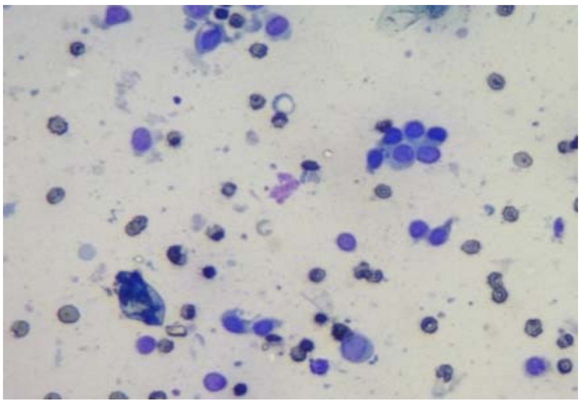

Fig. 1. Normal apocrine cells with abundant granular cytoplasm and prominent central nucleoli.

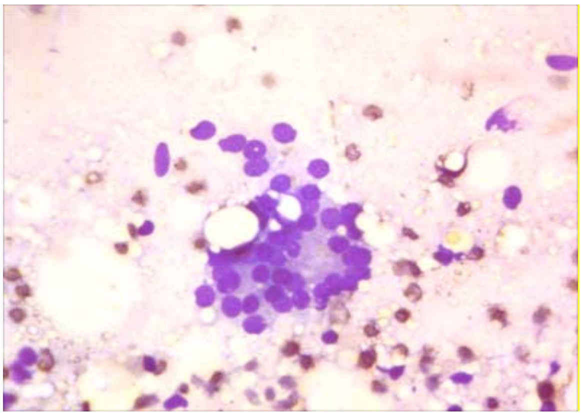

Fig. 2. Breast Cyst.

Cytological structure of the Breast Cyst:

- Background of amorphous material;
- Degenerate cells and debris;
- Foamy macrophages;
- Ductal epithelial cells, often apocrine and balling-up;
- Myoepithelial cells may not be seen (do not overcall aspirate as malignant).

Cytological structure of Fibrocystic change:

- Yariable numbers of apocrine cells and foam cells;
- Variable fat and stroma;
- Low to moderate cellularity;
- Proteinaceous background;
- Cohesive sheets of ductal cells in a honeycomb pattern;
- Bare bipolar nuclei dispersed in the background and within or attached to sheets of epithelial cells.

Cytology defines the characteristics of Fibroadenma is shown on Fig. 3.

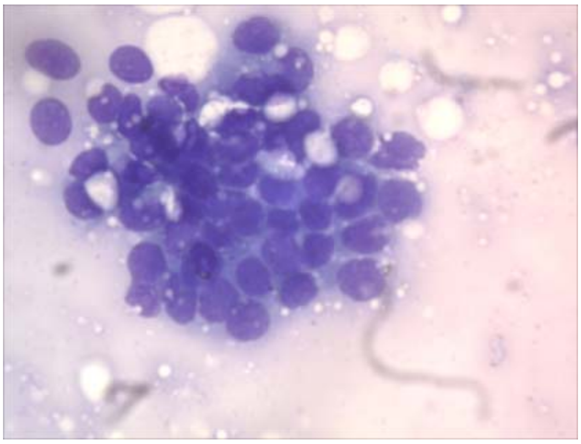

Fig. 3. Fibroadenoma.

Basic structural elements of Fibroadenoma:

- Moderate to high cellularity;
- Tightly cohesive branching antler-horn or finger-like projections of epithelial cells;

- Stromal fragments (metachromatic fibrillary matrix material);
- Both ductal and stromal components need to be diagnostic;
- Numerous bare bipolar nuclei, bordering and within epithelial clusters;
- May see few foam cells or apocrine cells;
- Often mild nuclear atypia with prominent nucleoli, particularly in younger patients.

Invasive dual carcinoma is shown on Fig. 4.

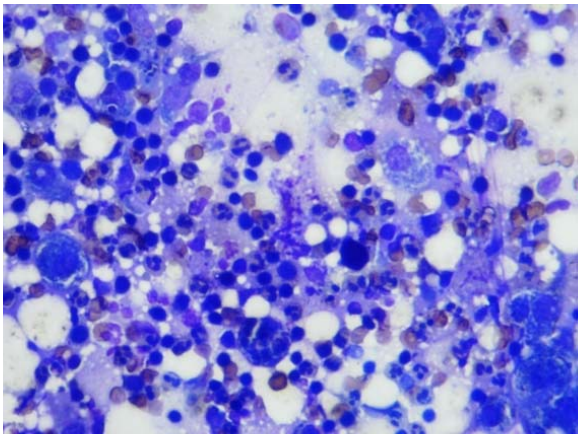

Fig. 4. Invasive ductal carcinoma.

Basic structural elements of invasive ductal carcinoma, of no special type:

- Usually very cellular;
- Disorganised, loosely cohesive groups;
- Single, polygonal, plasmacytoid epithelial cells (which can look deceptively bland);
- Absence of bare bipolar nuclei;
- Cellular and nuclear pleomorphism (2-4x RBC);
- Nuclear border irregularity;
- Hyperchromasia;
- Nucleoli;
- There may be mucin vacuole / targetoid inclusion within the cytoplasm;
- Mitoses.

On the basis of experimental studies we have provided quantitative microscopic signs of breast tissue [11]. For example there is a comparison of mastitis and cystic papillary cancer.

3. Modern Telemedicine

According to the order ofthe Ministry of Healthof Ukraine №681 the main goal of telemedicine is to improve health of the population by ensuring equal access to high quality health service.

The main objectives of telemedicine are as follows [3]:

- To ensure medical care of a patient, when the distance is a critical factor of maintaining;
- To protect medical confidentiality and privacy, integrity, medical information about the patient's health status;
- To create unified medical space;
- To promote quality care and optimize the processes of the organization and administration of health;
- To develop systematic approaches to implementation and development of telemedicine in the health system.

The network is closely connected with the concept of telemedicine, that is, it's the organization form of medical aid for the population with the help of telemedicine.

The telemedicine network includes the following tasks:

- To organize and systematize the process of medical care providing with telemedicine;
- To ensure the compatibility of information and data for medical care with telemedicine;
- To ensure the use of health information standards in the process of medical care providing with telemedicine;
- To supervise the quality of medical care with telemedicine.

In this work we also discuss telemetry considering it as the combination of all the technologies created for remote measurement, collection and transmission of information about performance (e.g., physiological parameters of the patient's body [3].

Telemedicine may also facilitate closer communication between doctors and patients, as it provides the opportunity to study specific cases, the results of which can finally be used to treat future patients.

Teleconsultations are particularly important in diagnosing difficult diseases. A necessary condition of teleconsultation is to provide a full-fledged source of information for decision-making on the diagnosis. In particular, telemedicine can speed up, increase the likelihood of correct diagnosis and choose the right treatment of cancer. It is very important currently, because the cancer is growing steadily every year.

According to studies conducted in [3], the growth rate of the telemedicine market is growing by 18-30 % per year.

The total annual income of the United States in 2013 amounted to $ 9.6 billion and projected to increase to $ 38.5 billion in revenue by 2018.

37 % of employers in the world have already offered telemedicine service for their employees.

According to the survey conducted by Intel, 72 % of consumers noted that they were ready to visit doctors and use telemedicine for urgent conditions. Three well-known alliances members (Connected Care, Anthem, Teladoc and MD Live) have reported satisfaction with the telemedicine patients more than 95 % [3].

Consumers of health service demand and need convenient care and telemedicine can offer it.

Let's discuss the history of telemedicine. It was founded during the second half of the 19th century, and one of the first published references were at the beginning of the 20th century, when electrocardiogram data were transmitted over telephone cables. The beginning of telemedicine in its modern form was initiated in 1960-ies of the last century, mostly due to the development of military and space technology and the efforts of several specialists who used available equipment on the market.

The beginning of the development of telemedicine in Ukraine is associated with the 1940s, namely the studies that were conducted in the framework of space projects. Thereafter, the development was carried out mainly by ECG transmission via different communication channels and deathculture.

In 1994 the negotiations were held with international experts about telemedicine implementation in Ukraine and then the first telemedicine consultationwas presented. Since the late 1990-ies a national network of tele-ECG has been developed. In 2000 a telemedicine centre (Donetsk Research Institute of Traumatology and Orthopedics) was the first created in Ukraine). Later, the telemedicine began to be implemented in clinical work in several areas of the country (teledramaturgia and alertpedia, teledermatology, teleradiology).

Regional telemedical networks have been functioning since 2002. In 2006 the national public organization (the Association of development of Ukrainian telemedicine and e-health) was founded [3].

Currently there is a rapid development and rapid implementation of telemedicine in all countries of the world.

The telemedicine network includes the following tasks:

- To organize and systematize the process of medical care with the help oftelemedicine;
- To ensure the compatibility of information and data in medical care using telemedicine;
- To ensure the use of health information standards in the process of medical care with the help of telemedicine;
- To supervise the quality of the medical care.

In the process of telemedicinethe consultation involves:

- Patient,
- His/her doctor,
- Medical personnel (doctors) who provide advice (hereinafter - the consultant),
- The telemedicinestaff.

Despite the considerable spread of telemedicine in the world and its development in Ukraine,it can be identified by the following main challenges during the implementation. Primarily important thing is also if telemedicine is legal according to the laws. However, nowadays there are some doubts about its legal regulation in different countries of the world. In Ukraine, the introduction of telemedicine should follow the order of the MOH of Ukraine №681 and DSTU of Ukraine concerning protection of information.

The next problem concerns the hardware and software of telemedicine. In particular, it is necessary to consider their value, that is, they must be economically beneficial not only for commercial but also for state medical institutions.

In addition, software and hardware must have a simple interface for users, in particular for doctors and patients. It should be noted that hardware and software is chosen depending on the task which can be solved with telemedicine (e.g., the need for imaging in Oncology or video calling when online transactionsare conducted, etc.). These characteristics must be consideredin case of developing of both new and existing hardware and software.

Many scientific works are devoted to information protection of telemedicine. In particular, in order to protect personal data of a patient it is necessary to apply different cryptographic algorithms and to confirm the diagnosis or transmitted information. The physician is requested to apply an electronic digital signature. Some scientists use watermarksto protect images. However, it should be noted that security policy must be developed in each case of telemedicineintroduction [4-6].

One of the last studied problems is the choice of experts for consultation. In some papers it is noted that the medical consultant should be highly skilled and experienced in the field of medicine. However, expert opinion is always subjective and sometimes the diagnosis can be false.

This problem can be solved with the help of fuzzy logic, taking into account the entire knowledge base of an expert. Such fuzzy system can perform diagnosis in real time, eliminating all disadvantages of the classical method of diagnosis.

Finally, in order to implement telemedicine the following tasks should be solved:

1. Determining the course of medical consultations in telemedicine applications;
2. The choice of legal base;
3. Development of it security policies with the definition of telemedicine participants, distribution of their rights and of appropriate cryptographic protection of information;
4. The choice or the development of new hardware and software taking into account the above defined characteristics;
5. Development of the system of selection of experts;
6. Development of a fuzzy diagnosissystem;
7. Testing and verification of the established telemedicine.

Furthermore, to developtelemedicine one shouldconsider all the above-mentioned problems and to choose the optimal ways of their solution.

4. Structure of the Fuzzy System

The main objective of creating a fuzzy system is the definition of fuzzy sets and fuzzy rules that require deep expertise in a particular subject area. The aim of this research is to develop a fuzzy system for the diagnosis of dysplastic processes in the breast based on the morphometric parameters of cytological images.

In order to develop the fuzzy system it is better to choose the Mamdani fuzzy conclusion algorithm, which is based on the "if-then" rules.

The Mamdani mechanism is based on "min-max" composition. The first phase of the fuzzy conclusion algorithm determines the functions of each variable and builds a rule set. The next one is the relevant functions "cut-off" of each rule by a "minimum" operation. On the third phase of the Mamdani algorithm the "uniting" of all "cut off" functions is used with the help of "maximum" operation. The defuzzification, that brings the fuzzy output to clarity is usually implemented by finding the gravity center of the final received figures.

Let's see the examples of the rules of the proposed fuzzy knowledge's base:

If a small number of hypochromic mono-morphiccells and narrow rim intensely colored cytoplasm and rounded hyperchromic nuclei, then we talk about a fibrous nonproliferative breast disease (70 %).

If papillary structures and flattened apocrine epithelium are formed, and we notice intense expression of the nucleus, and narrow rim intensely colored cytoplasm, and rounded hyperchromatic nuclei then we talk about a fibroadenoma (80 %) [5].The proposed fuzzy system of diagnosing breast cancers includes nine inputs and one output (Fig. 5).

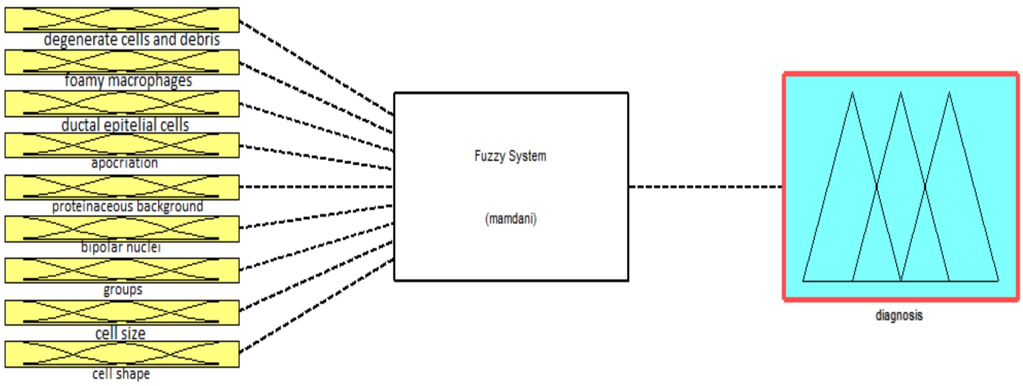

Fig. 5. The fuzzy system of diagnosing breast cancers.

Due to the information of part I of this article, the inputs of proposed fuzzy system are:

- Degeneratecellsanddebris;
- Foamymacrophages;
- Ductalepithelialcells;
- Apocriation;
- Proteinaceousbackground;
- Bipolarnuclei;
- Groups;
- Cellsize;
- Cellshape.

The output "diagnosis" of fuzzy system describes the malignant process in breast:

- Breastcyst;
- Fibrocysticchange;
- Fibroadenoma;
- Invasiveductalcarcinoma.

Most of these inputs are described by quality descriptions. For example, the first input — "degenerate cells and debris" is described by "low", "medium" and "high" fuzzy variables, that show these cells presence in the cytology images. Analogically, the inputs of "foamy macrophages", "ductal epithelial cells", "apocriation", "proteinaceous background" and "bipolar nuclei" can be described by the same variables. The member functions of these inputs can be described by bell function as shown in Fig. 6.

However, the input "groups" can be described by the variables "clibriform", "tulubar", "finger-like" and "cup-shaped". The member functions of this input are shown in Fig. 7.

The "cell size" and "cell shape" are described by quantitative descriptions, which are shown in Table 1. The member functions of those inputs are shown in Fig. 8 and Fig. 9.

Table 1. Comparative characteristics of papillary cancer and cystic mastitis.

	Papillarycancer	**Cysticdisease**
Nucleararea	13610.87392	5581.726
Cytoplasmarea	28833.08333	114426.8
Nuclear-cytoplasmicratic ratio	0.472057524	0.048779884

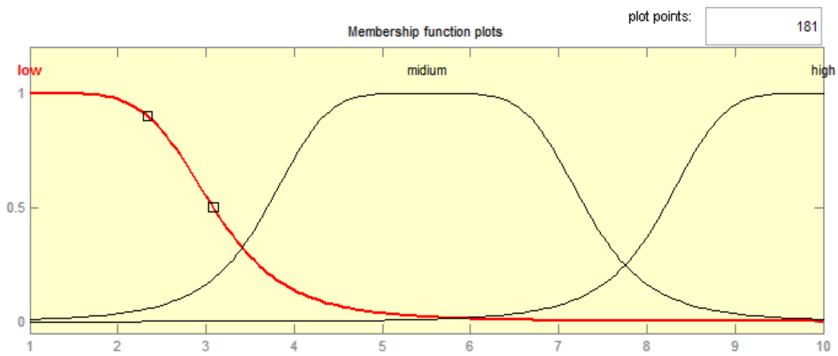

Fig. 6. The member functions of input "degenerate cells and debris".

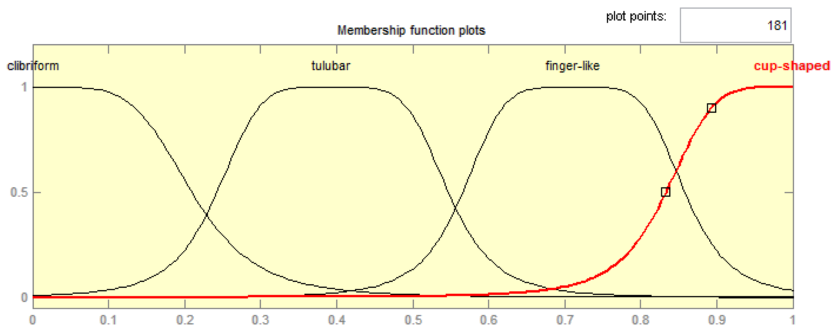

Fig. 7. The member functions of input "groups".

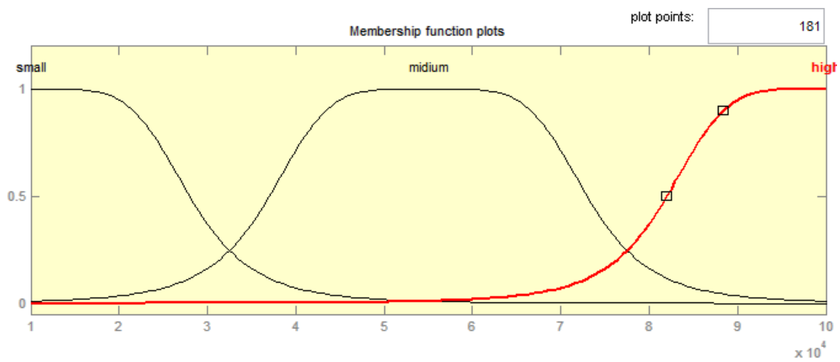

Fig. 8. The member functions of input "cell size".

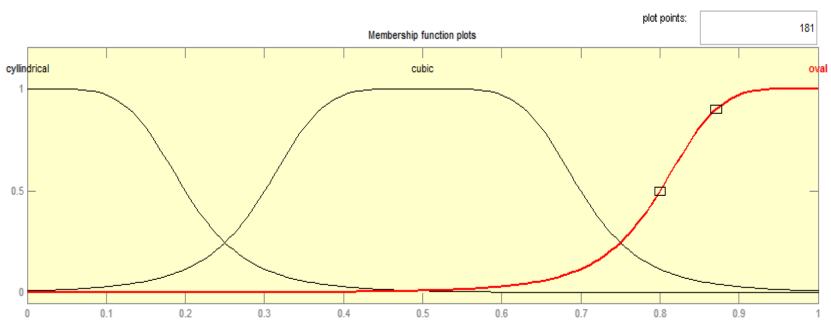

Fig. 9. The member functions of input "cell shape".

5. Conclusions

The proposed fuzzy system can be realized using such tools as Fuzzy Logic Toolbox of Matlab [8] with the further construction of fuzzy controller in the Simulink environment. This fuzzy controller can be used in medical practice for diagnosing of precancerous and cancerous processes of breasts obtaining exact results [12].

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