Skin Diseases Diagnosis using Artificial Neural Networks

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Abstract — Medical informatics is an interdisciplinary area (combining more academic fields), which benefits of technology’s progress that reflects on any domain. This paper is an example about how artificial neural networks prove their capacities in medical field. They are successfully used in decision-making, having a strong impact on physicians, who can benefit of a faster diagnosis process for some diseases with multiple and confusing symptoms.

I. INTRODUCTION

The artificial neural networks are a branch of artificial intelligence and also a research domain of neuro-informatics. They are made of simple processing units (artificial neurons) that are strongly interconnected and that work in parallel. The artificial neurons are a conceptual model of biological neurons that are part of human nervous system. Therefore, these networks can be considered a simplified form of a human brain. Their aim is to interact with the environment the same way a biological brain would do this. They have some properties [9] that bring them very close to this aim: the ability to perform distributed computations, to tolerate noisy inputs, and to learn.

The interest in artificial neural networks experienced significant variations, starting with an extremely intense research activity, going through times when the domain was considered “dead”, but now days it is returning on the top of researchers’ concern. This revival of artificial neural networks was due to the multitude of directions where they can be developed: medicine, robotics, economy, etc.

This paper focuses on the applications of artificial neural networks in medicine. The medical informatics field evolved around the structure, the storing and the processing of medical information for various purposes. One of these purposes is to develop algorithms able to make predictions regarding the diagnosis, the treatment or the medical evolution of a patient. The diagnosis phase is often a long-term process; its duration is proportionally extended by the complexity of the disease and by the number of features (symptoms, laboratory tests, specific descriptions of the patient) that must be analyzed. For instance, there is a lot of significant information connected to the patient’s environment very important for the diagnosis, but this information is often difficult to be synthesized by a human brain. This is the point where the artificial neural networks prove their power. They have the ability to learn patterns of symptoms that lead to specific diseases and to provide a diagnosis faster than a human physician.

The system described by this paper uses the current knowledge about artificial neural networks, being able to suggest a diagnosis regarding skin diseases from erythematous-squamous class. The feed-forward neural networks with back-propagation learning algorithm are frequently used by medical applications. The most important benefit is recorded for diseases with a large number of symptoms, diseases that are difficult to be identified even after a detailed analysis of a human physician.

II. RELATED WORK

This diagnosis system was developed after an extensive examination of similar products. Relevant recent research in this field is hereby presented. They demonstrate that artificial neural networks are extensively used in medical decision-making (section A) and that skin diseases need – and even are suitable for – an automatic diagnosis system (section B). For these reasons, a decisional system for erythematous-squamous skin diseases, implemented using artificial neural networks, was developed and than presented in this paper.

A. Artificial Neural Networks for Various Diseases

There are many papers that describe the applications of artificial neural networks in medical decision-making. For instance, they have been used for the diagnosis of [2]: cardiovascular diseases, different types of cancer (colorectal cancer, breast cancer, thyroid cancer, colon cancer, ovarian cancer, brain tumors, lung carcinoma), multiple sclerosis lesions, gynecological diseases, pancreatic diseases, diabetes, etc.

The artificial neural networks can be successfully used to work with medical images. An example is a diagnosis system that was developed for lung cancer [7]. Some statistical parameters (like mean, standard deviation, and others) were extracted from the segmented CT images. Lung cancer can also be detected from laboratory tests results, not only from images. Several artificial neural networks, that analyze six serum tumor markers and other parameters, were trained in order to distinguish between lung cancer, gastrointestinal cancer, benign lung diseases, and healthy people [4].

Other research shows that artificial neural networks are efficient tools for creating prediction models regarding the cardiovascular autonomic dysfunction among the general population [8]. This system was developed for Chinese population.

Seizure and epilepsy can also be detected automatically. An artificial neural network was used in this field in order to classify electroencephalogram signals [10].
One more example of artificial neural networks used in medical diagnosis comes to make predictions regarding iron deficiency anemia and iron serum level [3]. This automatic system was developed because measuring serum iron is time consuming, it is expensive and it is not available in most hospitals. The results show that the system has acceptable precision.

All these diagnosis systems have over 90% accuracy, most of them even over 95%. This proves that artificial neural networks can successfully be used in medical diagnosis, having a great potential in this field.

B. Decisional Mechanisms for Skin Diseases

The diagnosis of skin diseases, especially of those from the erythematous-squamous class (which are the most commonly seen diseases in dermatology departments [11]), is a difficult problem, being very challenging to identify which particular disease is present for a patient. Many researchers tried to develop automatic systems that could be able to make predictions for this field.

Reliable automatic tools were created in the area of pigmented skin lesions in order to recognize skin cancer from microscopic and macroscopic images. The reviews show that even if these tools are extremely necessary, they are not developed enough in order to provide the best diagnosis results [6].

There are many algorithms belonging to the artificial intelligence domain that are suitable for developing diagnosis systems for skin diseases. Several examples are hereby presented.

Particle swarm optimization, support vector machines and association rules were all used together in a diagnosis model, created to make the difference between erythematous-squamous diseases [1]. This type of methods, where several techniques are put together in order to have a maximum benefit of their features, is a very promising one.

A larger expert system for differential diagnosis of erythematous-squamous diseases was developed for both physicians and students from dermatology domain [5]. It uses three different algorithms: nearest neighbor classifier, naïve Bayesian classifier and voting feature intervals-5. The tool also gives explanations for the result it proposes (a very useful feature for such systems).

All this research proves that the automatic diagnosis systems are essential in dermatology. This field is not saturated; it still needs this sort of tools.

III. MEDICAL ASPECTS

The system presented here was developed to make predictions regarding skin’s diseases. The diagnosis of these diseases is difficult and sometimes inaccurate because patients have multiple and vague symptoms. This software is created to improve physicians’ activity from this point of view.

The skin is an uninterrupted protective cover of the human body and a huge sensitive field (thanks to a variety of nerve endings). For an adult, it weighs almost three kilograms and it has a surface of two square meters, being the biggest organ of the body. The skin is made of three layers (from the surface to the depth): epidermis, which is in direct contact with the external environment, dermis and hypodermis or subcutaneous tissue. The human skin performs several important functions:

- it protects the body against external agents (bacteria, toxic, radiation), being the first line of defense;
- it is one of the sensitive organs, containing nerve endings that react to touch, temperature (heat and cold), tissue injury, pressure and vibration;
- it ensures the thermoregulation, maintaining a constant temperature of the body;
- it is a storage center for lipids and water;
- it controls the evaporation of the water in order to reduce the overheating;
- it acts as a water resistant barrier.

The branch of medicine that is dealing with the skin and its diseases is the dermatology. It aims to explain, to diagnose, to treat contagious and non-contagious skin diseases and to care the patients with these diseases.

The skin diseases have various causes: fungal infections, bacterial infections, allergic reactions, and even insect bites. They can also occur because of other diseases (of the skin or not) or because of the environment. Sometimes the genetic aspects have an important influence in the occurrence of a skin disease.

One of the skin diseases’ categories is erythematous-squamous class. It is characterized by redness skin (erythema) caused by the loss of cells (squamous). It is difficult to diagnose these diseases or to make the difference between some of them because they have similar symptoms. This class of diseases includes [12]:

- psoriasis, that is characterized by pink or red skin lesions, of different dimensions, covered with white scales and accompanied by itching and flaking; the most commonly affected parts of the skin are the scalp and the joints of the knee and of the elbow;
- seborrheic dermatitis, that is a common, itchy, non-infectious eczema made up of shiny, slightly flaky, white or yellowish scales (dandruff) that appear on oily areas such as the scalp, the eyebrows, the forehead, the nose area or around the ear; the skin in the affected area could be red and itchy;
- lichen planus, that is a common, itchy, non-infectious eczema made up of shiny, slightly raised purple-red spots that arise around the ankles and on the lower back; it can also affect oral and genital mucosa; its cause is still unknown, but it seems to be connected to immune system;
- pityriasis rosea, that is a skin rash of red lesions which cover the entire body; the rash is often severe and is accompanied by itching;
- chronic dermatitis, that is an eczema which manifests by redness skin, inflammation, itching, skin lesions, and sometimes scars; these lesions are located on neck, wrist, forearm, thigh, ankle, elbow, knee, scalp;
- pityriasis rubra pilaris, that indicates a group of chronic diseases characterized by reddish
orange scales, severe flaking, uncomfortable itching, thickening of the skin on some parts of the body (scalp, feet, hands).

From this short description of the diseases it can be observed that these medical conditions have some similar features; therefore, the distinction can be difficult. For this reason, an automatic diagnosis system is required in the field of erythemato-squamous skin diseases.

IV. THE DIAGNOSIS SYSTEM

The system presented here was developed in Matlab environment, using Neural Network Toolbox for artificial neural network modeling. A multilayer feed-forward artificial neural network was chosen for this system; it was trained in a supervised manner, using the back-propagation algorithm.

An artificial neural network learns by examples; therefore, a database of 366 patients with erythemato-squamous diseases was used [13]. Each patient has 33 symptoms and an established diagnosis (one of the six possible diseases). The patients’ distribution regarding the diagnosis reflects the reality: 112 patients with psoriasis, 61 with seborrheic dermatitis, 72 with lichen planus, 49 with pityriasis rosea, 52 with chronic dermatitis, and 20 with pityriasis rubra pilaris. The information from the database was imported in Matlab in two matrices: an input matrix of 366x33 elements, representing the symptoms of all the patients, and a target matrix of 366x6 elements, representing the diagnosis of all the patients.

A differential diagnosis of erythemato-squamous diseases is very difficult because, at a first view, all these diseases look in the same way. When a carefully inspection is made, some patients distinguish by typical clinical features. Therefore, there are 12 clinical features that are evaluated when a patient is suspected to have an erythemato-squamous disease [11]: the degree of erythema and scaling, whether the borders of lesions are definite or not, the presence of itching and koebner phenomenon, the formation of papules (polygonal and follicular), the presence of oral mucosa, whether the elbows, the knees and the scalp are involved or not, whether there is a family history or not. The age of the patient is also part of these clinical features, but it was not included into the process presented by this paper. All these features are important in order to make the difference between diseases and to set a correct diagnosis [11]:

- in chronic dermatitis the erythema and scaling is less than in psoriasis;
- psoriasis, lichen planus and pityriasis rosea are characterized by the koebner phenomenon; the others are not;
- lichen planus is described by polygonal papules, whereas pityriasis rubra pilaris by follicular papules;
- lichen planus can affect oral mucosa, whereas psoriasis is mostly located on knee, elbow and scalp;
- psoriasis may have a connection with the family history.

Some of these diseases can be detected using clinical features only. Nevertheless, a biopsy is also required for a correct diagnosis; 22 histopathological features can be evaluated from skin samples. But the diagnosis remains difficult for a human. For instance, at the beginning stage, a disease may have the histopathological features of another disease or some skin samples do not show the typical histopathological features of a disease.

An artificial neural network has the ability to overcome these problems because it learns by examples and than it can identify patterns. Once it is trained on a representative set of data, it can be used to diagnose a new patient.

Fig. 1 is the user interface for the diagnosis system presented by this paper. The physician has to enter the clinical and the histopathological features of the new patient. The family history has the value 1 if an erythemato-squamous disease have been observed in the family (otherwise, it is 0). All the other features have an intensity degree between 0 (meaning that it is not present) and 3 (meaning that it is acute). The values 1 and 2 are intermediate intensities. The artificial neural network takes these features as input values and analyzes them, producing an output that is the diagnosis. One of the six diseases will receive the value 1 – meaning that this is the diagnosis – and all the others the value 0. If the patient doesn’t have any of these six diseases, then none of them will receive the value 1.

A diagnosis system like this has two distinct parts:

- the network development – it is made once, at the beginning and it has several steps:
  - selection of the features that will represent the inputs of the network (redundant information should be avoided);
  - gathering data from a relevant number of patients (as the number of patients is higher, the results are more accurate);
  - processing data, because some of the collected data should be standardized;
  - establishing the type and the architecture of the artificial neural network (the number of layers, the number of neurons on each layer, the weights, the transfer functions); the properties of the network are determined by its topology and by the properties of the neurons [9];
  - establishing the learning algorithm;
  - training the network;
  - determining the accuracy of the system;
- the diagnosis for a new patient – it is made each time a patient should be diagnosed and supposes:
  - selection of patient’s features that are required for the artificial neural network;
  - automatic diagnosis;
  - evaluation of the result by a human physician.

The artificial neural network created for this diagnosis system has 33 inputs (the clinical and the histopathological features) and six outputs (each one is the output of a neuron from the output layer and it is associated to a disease). Table I contains several examples (one for each disease) of inputs and outputs from the data.
set [13] that was used in the network’s training. Fig. 1 also includes an example of real values.

Between inputs and outputs the artificial neural network has two layers of neurons:

--- a hidden layer with 10 neurons;
--- an output layer with 6 neurons.

The output layer contains 6 neurons because this is the number of diseases that can be diagnosed by this system. The outputs of these neurons are in fact the outputs of the system. Fig. 2 represents a diagram of the artificial neural network during the training process. It also contains, in its upper part, the structure of this artificial neural network.

V. RESULTS

Once the artificial neural network was created and trained, it is almost ready to be used. There is one more important aspect: its performance. Fig. 3 presents the confusion matrices for training, test, and validation. As can be observed from these matrices, the outputs of the artificial neural network are accurate. This result is proved by the large number of correct answers displayed inside the green squares of the main diagonal and by the small number of wrong answers displayed inside the red squares of the lower and upper triangles. The blue square from the bottom right corner displays the precision of the artificial neural network, which is 93.7%.

Therefore, this system has a good precision. A better one could be obtained if several aspects would be analyzed and solved. For instance, if two diagnoses could be plausible, the artificial neural network will emphasize one of them only (because it predicts if a diagnosis is present – 1 – or not present – 0 – and doesn’t associate a plausibility score for each of the six possible diagnosis).

<table>
<thead>
<tr>
<th>Record</th>
<th>Input vector</th>
<th>Output vector</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>{2, 3, 3, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0}</td>
<td>{1, 0, 0, 0, 0, 0}</td>
<td>psoriasis</td>
</tr>
<tr>
<td>2</td>
<td>{2, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 1, 1, 0, 0, 0, 0}</td>
<td>{0, 1, 0, 0, 0, 0}</td>
<td>seborrheic dermatitis</td>
</tr>
<tr>
<td>3</td>
<td>{2, 1, 1, 1, 2, 0, 1, 0, 0, 0, 2, 0, 0, 0, 3, 2, 1, 1, 0, 0, 0}</td>
<td>{0, 0, 1, 0, 0, 0}</td>
<td>lichen planus</td>
</tr>
<tr>
<td>4</td>
<td>{1, 1, 1, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 0, 0, 0}</td>
<td>{0, 0, 0, 1, 0, 0}</td>
<td>pityriasis rosea</td>
</tr>
<tr>
<td>5</td>
<td>{2, 2, 1, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 1, 1, 1, 0, 0}</td>
<td>{0, 0, 0, 0, 1, 0}</td>
<td>chronic dermatitis</td>
</tr>
<tr>
<td>6</td>
<td>{2, 2, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 0, 0}</td>
<td>{0, 0, 0, 0, 0, 1}</td>
<td>pityriasis rubra pilaris</td>
</tr>
</tbody>
</table>
Another aspect is connected to uncommon diseases. If one of the diseases that can be identified by the artificial neural network has less than 1% patients in the training set, then the system could interpret the results as errors and that disease won’t be selected.

VI. CONCLUSIONS

The artificial neural networks can be applied in various medical fields; the system presented by this paper needs few changes only in order to be used for the diagnosis of other categories of diseases. It was implemented for skin diseases from erythemato-squamous class because these diseases have a lot of similar symptoms; therefore, it is very difficult to make the difference between them. But other systems can be easily created starting from this one if a representative data set of required elements (patients with symptoms and diagnosis) is available. The precision of this system (93.7%) is comparable to that of a human physician, but it is infinitely faster.

The aim of this paper was to emphasize the importance of using artificial neural networks in medical decision-making. Their computing power, their ability to make predictions, and the impact they have on medical life brought them on the top of artificial intelligence tools that are used in this domain.

A fast and correct diagnosis is essential for the patient’s life. For this reason, a computational-based diagnosis tool is a must.
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