Support System for the Detection of Rheumatological Diseases

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Abstract— ***According to geriatric studies performed, there are two very common diseases among the elderly population, rheumatoid arthritis and osteoarthrosis. Because these diseases have similar symptoms, osteoarthrosis is often misdiagnosed as rheumatoid arthritis; however, there are some characteristics that clearly differentiate them. The article presents a computer system to support the diagnosis of rheumatoid diseases through the digital processing of images of photographs, the recognition of patterns through artificial neural networks, obtaining a percentage of success of 80% between reference classes. We consider that the application developed can be of great help for internists specialists in rheumatology.***

Keywords— Rheumatoid Arthritis, Osteoarthritis, image processing, artificial intelligence, Neural Networks.

I. INTRODUCTION

Rheumatological diseases affect around 80% of the population over 60 years of age [1], called elderly or senior population. This disease has a great impact on the functionality and quality life of those who suffer it. The term rheumatism includes various painful disorders in the structures of the corporal support: Bones, ligaments, tendons or muscles. Arthritis is a form of rheumatism in which joint inflammation occurs. There are three major types of arthritis: rheumatoid arthritis, osteoarthrosis and gouty arthritis [2].

Rheumatoid arthritis (RA) is a chronic systemic inflammatory disease of unknown etiology. The patient with RA has, in addition to other clinical affectations, pain, inflammation and deformity in the affected joints.

Osteoarthrosis (OA), also called degenerative joint disease or osteoarthritis, is by far the joint disease most frequently in the elderly. The main manifestations of the disease are pain, stiffness and decreased joint function. On physical examination, an asymmetric volume increase of the joints can be found and sometimes mild inflammation data can be presented.

The similarities between both diseases and the tendency to diagnose rheumatoid arthritis when a patient presents with some joint involvement, leads to a treatment that is complicated due to the lack of diagnostic certainty.

That is why a computer system was developed to support the internist in the detection of rheumatological diseases such as rheumatoid arthritis and osteoarthrosis, from images of a patient's hand using image processing techniques, as well as techniques of artificial intelligence.

II. DEVELOPMENT

The Support System for the Detection of Rheumatic Diseases consisted basically of five large modules: A. Image acquisition, B. Pre-processing, C. Segmentation, D. Representation and description, and E. Recognition and interpretation.

A. Image acquisition

During the process of image acquisition, a closed chamber was designed that served as a controlled environment with a black background, where the images of the patients' hands were taken. The obtained images were captured with a resolution of 2048x1536 pixels, one of these samples can be seen in fig. 1.

Figure 1. Image obtained from the acquisition module

B. Pre-processing

Once the image was captured, it was transformed to a gray scale and a digital image treatment was carried out to clean the noise. To this end, a Gaussian filter was applied, which effected the cleaning of image noise produced by the camera when capturing the image a median filter was also applied to eliminate noise produced by the black background.

C. Segmentation

The objective of the segmentation was to obtain the regions of interest of each image for further analysis and interpretation by the computer system for the detection of rheumatological diseases. During this process, morphological characteristics of each of the patient's fingers were obtained.

1. Extraction of information from the hand: The first step to obtain information on each finger of a patient's hand was to extract the image free of noise, using the Otsu method [3], thereby obtaining a binarized image of the hand of the patient, as shown in fig. 2.

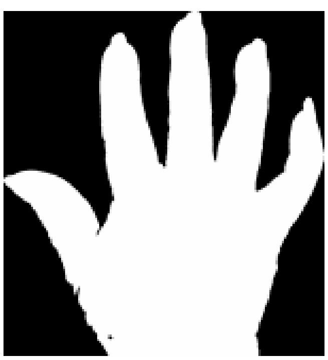

Figure 2. Binarized image of the hand

After that, the operation called thinning [4] was applied to the image of the hand. From this operation, the essential components of the image were extracted, that is, lines of a thickness of one pixel as shown in fig. 3.

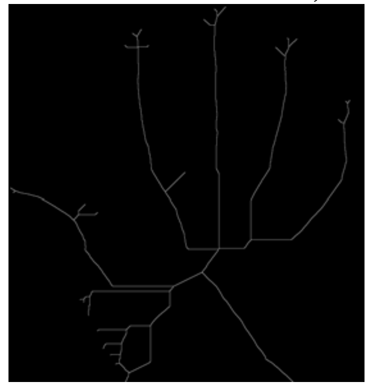

Figure 3. Thinned image

Once obtained from the binarized images and based on the algorithm of labeling of related components; we proceeded to label each finger in the image of the patient's hand, during this process, a different color was assigned to each finger, the result of this algorithm can be seen in fig. 4.

Figure 4. Image Labeled (IE)

2. Separation and vertically alignment of fingers in different images:

For the separation of each finger in an image and its vertical rotation, it was necessary to locate intermediate points between each finger, these points of interest are shown in fig. 5.

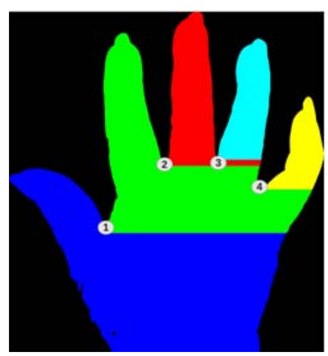

Figure 5. Intermediate points of interest.

With the above information, the fingers were cut in the image, see fig. 6. To determine the necessary angle in the vertical rotation, the Hough transform [4] was applied on a skeletonized process in the image of the trimmed finger; the objective was to find lines in the image and use the line located at the bottom of the finger; finally the previous line was rotated by an angle θ, to place it vertically.

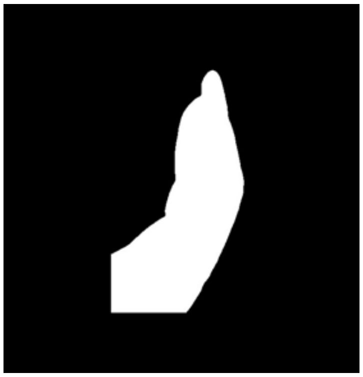

Figure 6. Binarized finger Cropped image

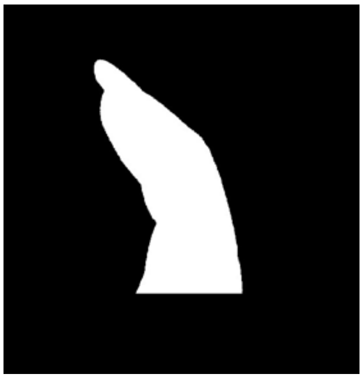

Figure 7. Binarized trimmed finger rotated

Once having obtained the angle θ, to which the finger would be rotated, the image was taken and a cut was made from a left intermediate point to the right intermediate point, the image was rotated according to the angle obtained and, finally, the information that is not necessary from the finger was eliminated generating an image represented in fig. 7

Starting from the angle θ the image of the hand was rotated after the thinning process, obtaining an image like the one shown in fig. 8. After this an intersection was made between the image of the rotated finger (Figure 7) and that of the hand that was thinned and rotated (Figure 8); this new image is shown in fig. 9, which would help the description of the finger.

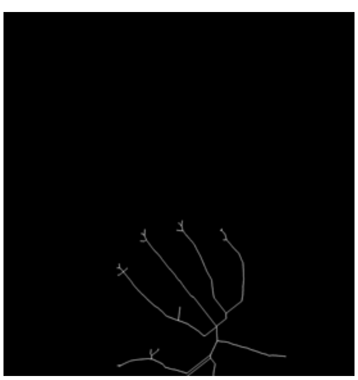

Figure 8. Slimming-Rotating

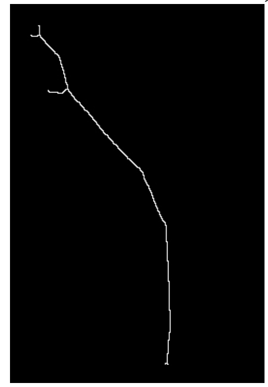

Figure 9. Thinned rotating finger

Before preceding to the stage of *representation and description* it was necessary to have obtained the edge of the rotated finger, this was obtained with the help of the *morphological gradient*, which is given in (1).

$$g = (I \oplus b) - (I \ominus b) \quad (1)$$

Obtainig the image that is shown in fig. 10.

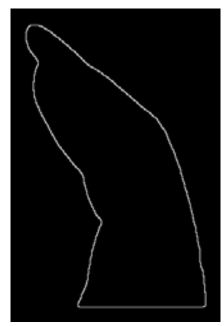

Figure 10. Finger edge.

Finally, the image that was described was obtained from the image of the edge of the finger (Figure 10), and from the image of the thinning of the finger (Figure 9), the points found in the Hough transform, when applied again to the image of fig. 9 and the points marked on the interphalanges by the user, are shown in the image to be described, see fig. 11.

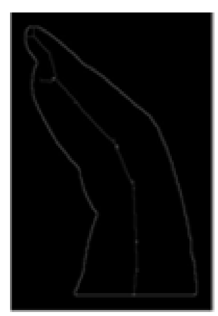

Figure 11. Image to describe

D. *Representation and Description*

To obtain the representation of the characteristics of the image of a patient's finger, two feature vectors were formed.

These vectors were created from the chain code algorithm; the representations of the directions in this algorithm are shown in fig. 12. The characteristic vector was formed from the image of the contours of the patient's finger, at the different levels as shown in fig. 13, therefore, each of the characteristic vectors was constituted as shown in figs. 14, and 15; Comparatively, the main difference between the two vectors is that one vector was considered thinning in the image of the finger and in the other no.

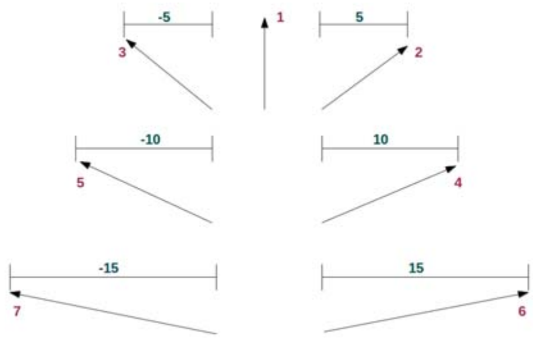

Figure 12. Addresses Chain Codes.

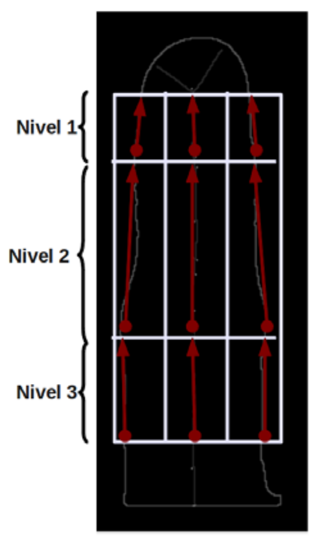

Figure 13. Addresses Chain Codes.

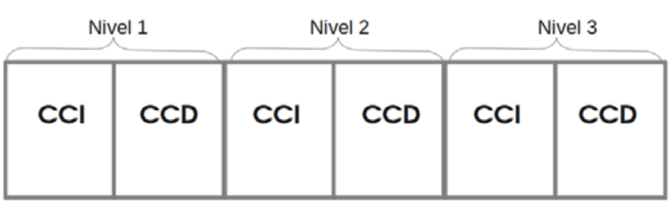

Figure 14. Feature Vector 1

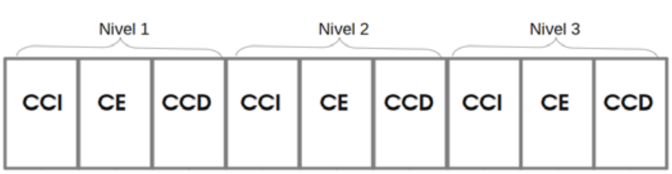

Figure 15. Feature Vector 2

E. Recognition and Interpretation

In this phase of the project, two classifiers were implemented, the first based on the k-nn algorithm and the second on a multilayer artificial neural network. The results obtained from the classifier with the k-nn algorithm allowed us to conclude that the characteristics of both diseases are very similar. The classifier based on a multilayer neuronal network was designed with six inputs, four neurons in the hidden layer and two neurons in the output layer, the results obtained with this allowed to differentiate the two conditions.

III. RESULTS

Support System for the Detection of Rheumatic Diseases was developed in the C ++ programming language in conjunction with the libraries provided by QT and OpenCV under the MacOs X operating system.

The training set of the k-nn algorithm consists of 59 vectors, of which 15 were considered to classify them once more and there are 10 unknown vectors. The results obtained considering the 7 closest neighbors for the vector of six characteristics are shown in tables 1 and 2.

TABLE I. VECTOR 6 FEATURES TRAINING SET KNN = 7

	OA	**AR**
OA	8	7
AR	6	9

TABLE II. VECTOR 6 UNKNOWN CHARACTERISTICS KNN = 7

	OA	**AR**
OA	4	1
AR	1	4

While the results obtained with the vector of nine characteristics are shown in table 3.

TABLE III. VECTOR 9 TRAINING CHARACTERISTICS KNN = 7

	OA	**AR**
OA	14	1s
AR	13	2

As can be seen in tables 1-3, the correct classification percentage, with the classifier based on the algorithm k-nn, ranges between 50% and 60%. That is why a classifier based on a multilayer neural network was developed, with supervised learning to overcome the previous results. Proposing a training set of 59 known vectors and 10 unknown vectors. The results obtained based on the classifier with a multilayer neural network, with a vector of six characteristics, are shown in Tables 4 and 5.

Fig.16 illustrates the architecture of a multilayer neural network, which was implemented with a hidden layer of four neurons, with an input vector of six characteristics, and two neurons in the output layer. The training process was carried out considering 1000 times or 0.8 of effectiveness as limits, while the parameters of moment and threshold were initialized with 0.1.

Figure 16. Multilayer Neural Network with Supervised Learning

Using the classifier based on a multilayer neural network, the results of table 4 were obtained. The classification of the patterns with the multilayer neuronal network reached 80% effectiveness.

TABLE IV. VECTOR OF 6 FEATURES WITH THE TRAINING SET.

	OA	AR
OA	20	5
AR	7	27

TABLE V. VECTOR OF 6 UNKNOWN CHARACTERISTICS.

	OA	AR
OA	3	2
AR	1	4

The results obtained with the vector of nine characteristics are shown in tables 6 and 7.

TABLE VI. VECTOR OF 9 FEATURES WITH TRAINING SET.

	OA	AR
OA	18	7
AR	8	26

TABLE VII. VECTOR OF 9 UNKNOWN CHARACTERISTICS..

	OA	AR
OA	3	2
AR	1	4

IV. CONCLUSIONS

The first vector formed from the chain codes presented nine characteristics; three of them being characteristics of the description of the skeleton of the finger. However, when testing with this vector it was observed that the skeleton did not provide enough information to help differentiate these two diseases. Even achieving a correct classification of 70% of the vectors to classify, both with the classifier based on the algorithm k-nn, and the classifier based on a multilayer neural network, it was decided to eliminate the three characteristics that describe the skeleton of this vector, in addition to expanding the grid to make the code of the chain.

With a new vector of six characteristics, better results were obtained; both with the classifier based on the algorithm of k-nn, and with the classifier based on an artificial neural network, with supervised learning algorithm, reaching an 80% effectiveness on average, considering the same training set and unknown vectors for its generalization.

Therefore, considering all the tests carried out a Rheumatological Disease Detection System, was implemented. and a vector with six characteristics to describe each finger and a multilayer neuronal network with a hidden layer, which contains four neurons and two neurons in the output layer, to achieve classification.

In addition considering the vectors formed by string codes, two more vectors were implemented; one of them was obtained by performing several calculations to obtain lines that measured the width of the interphalanges, as well as the angles that formed the interfalanges with respect to the lines located.

Another of these vectors was formed from the displacements that were observed in the lines located in the interfalanges and the thinning of the finger. However, none of these two vectors reached a correct classification percentage greater than 50%.

ACKNOWLEDGMENTS

The authors thank the INSTITUTO POLITECNICO NACIONAL,for the support provided throughout the realization of this project

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