A Survey on Different Methods of Detecting Rheumatoid Arthritis

*Ujval D R[1], Vignesh G[1], Vishwas K S[1], Gowrishankar S[1], and Srinivasa A. H[1]

[1] Department of Computer Science and Engineering,
Dr. Ambedkar Institute of Technology,
Bengaluru – 560056, Karnataka, India

[1]{*ujvaldr, vignesh270600,vishwasrao571}@gmail.com
gowrishankarnath@acm.org, srinivasaah.cs@drait.edu.in

Abstract. Rheumatoid Arthritis (RA) is basically a chronic inflammatory autoimmune disorder which causes swelling, pain and stiffness in synovial joints. Hands, feet, elbows, shoulders and ankles are some of those joints which are commonly affected by this disease. RA might occur at all ages, more often it is seen in between the ages of 30 and 50. Women are more likely to get affected by this disease than men and causes difficulty in doing regular activities. People with RA find it very difficult to perform daily activities and in severe cases, people lose their jobs. RA is not totally curable, but proper medication and treatment can control it. Any disease, when detected early, can be controlled and cured. Hence, Detection of RA in early stages would help in controlling it. Detection of RA includes various methods such as CBC, SGPT, Hand radiographs, MRI, CT, etc. We made a survey on different research papers regarding the various ways to detect and diagnose RA. The following survey provides details on the various methods implemented to detect RA and we make a comparison on the various detection methods and their feasibility.

Keywords: Rheumatoid Arthritis, Autoimmune, Synovial, Machine Learning, Deep Learning, Convolutional Neural Network (CNN), Support Vector Machine (SVM).

1 Introduction

Over the years, we have heard a variety of diseases around the world which are so common and take in number of people every year into its control and affecting them. Humans on the other side are always into finding a perfect solution to cure these diseases, though he succeeds in many but with some conditions with uncrackable combinations of the disease he stands behind with the line "to be detected earlier to cure it further".

Here we have taken one such disease called Rheumatoid arthritis, which is autoimmune type and mainly attacks the synovial tissues with joints. This disease requires diagnosis in its early stage and if not, results in affecting other organs of the

body such as eyes, lungs, blood, skin and even causes heart attack and stroke. So, detecting this disease earlier has gained its importance and there are many approaches which have been suggested over the years. This paper throws light on some of those works which are proposed over this problem and also linearly it is trying to convey the way research, technique, technology have evolved in detecting this Rheumatoid Arthritis.

In this survey work, the Section 1 states about the current situation the world is facing with many diseases and focusing on one such disease called RA and giving an overview about how we have to consider it further. In Section 2 and section 3, we have reviewed some of those papers which are related to the detection of RA by categorizing it based on the data namely Statistical Data and Image Data. Here we will look into some of those approaches proposed before and its efficiency in solving this problem. At last, In Section 4, we conclude this survey paper in terms of an overview meaning of what we have gained over referring all those papers and how the approaches have evolved over the time.

2 Detection using Statistical Analysis

Statistical analysis includes the clinical data and analysis includes various computations and calculations on the data. Detection of RA on these clinical data may include the methods to find the joint space width, prediction using ML algorithms on numerical data.

It is imperative to develop techniques for diagnosis of RA as early as possible. Magnetic Resonance Imaging (MRI) of the extremities can provide precise information about the early signs of inflammatory arthritis, specifically Bone Marrow Edema (BME) and synovitis. “Artificial intelligence in Detecting Early RA” [6] signified how the importance of AI in early detection of Rheumatoid Arthritis has grown its interest in recent times [6]. He has mentioned a number of research over this field and finds his interest over using AI techniques such as atlas-based segmentation and fuzzy clustering, to develop a software for detecting very early RA based on automatic quantification of bone marrow edema and tenosynovitis and MRI imagery. This paper is about telling how the detection of RA has evolved its interest towards deep learning and hence forth specifying various upgradation in previous researches has gained much importance in deep learning approach is concluded here.

An effective way to differentiate Osteoarthritis Arthritis (OA) and rheumatoid arthritis is to use x-ray image processing. The degenerative bone disorders are diagnosed using X-ray detection. X-ray scans alone do not detect the type of arthritis. Image processing can aid in improving the diagnosis [12]. Through image processing of x-rays, it is possible to detect arthritis from different regions. The image processing includes, Image Acquisition: Images are acquired through sampling. Color conversion: grayscale conversion of the image is performed. Thresholding: the image

is made binary using the threshold function. Compression: the image is resized. Median Filter: the image is made smooth. In order to collect statistical information, the images are analyzed according to the following properties: centroid, extreme, orientation, major axis length, minor axis length, and eccentricity. Feature Extraction: Joint location, orientation, circular features and space detection is done. Image Recognition: classification amongst RA and normal.

With patients having Rheumatoid Arthritis, the radiologists' task of measuring the joint space width (JSW) involves a lengthy and tedious process. A manual assessment lacks accuracy and is observer-dependent, making it difficult to accurately assess joint degeneration in early diagnosis and follow-up studies. The automatic analysis of JSW data is crucial considering standardization, sensitivity, and reproducibility [10]. They focus on joint margin detection and joint location in this paper. Automated joint detection entails Hand mask extraction, which refers to how the intensity varies in the radiographs. Entropy is used as a texture feature to reflect the randomness of a specific region in the radiographs. Multiscale Gaussian blurring was used to detect five peaks and four valleys along the horizontal profiles of the masked image. Extraction of joint features: Joint locations are determined from the midlines found so far. The directional LoG gives strong positive responses for dark joint space and strong negative responses for bright cortical bone and edges. Geometric relationship of finger joints: To restrict the search area in the blob response image, they used knowledge of finger bone lengths. Determining the joint span: The joint span of a PIP and DIP is determined by measuring the upper edge of the lower bone. Upper margin detection and lower margin detection. In this approach, all 70 finger joints were correctly located, from the located joints margins are measured. Using measured values, the presence of rheumatoid arthritis can be known. In comparison with manual joint segmentation, the presented method provides satisfactory results for joint location and margin detection [10].

In cases of extreme pain, RA requires periodic blood testing, including lipids and complete blood counts [1]. They suggested a study about the variation in blood and lipid components of a patient suffering from RA, where many examinations were carried out for 10 months over the patients of age group 40 to 60 years. The pathological laboratory examined blood and serum samples from the patients for ten months. The list of the clinical tests performed in the laboratory are listed as: Blood glucose test, Calcium blood test, Cardiac enzymes test, Cholesterol lipid test, C-Reactive Protein (CRP) test, Erythrocyte Sedimentation Rate (ESR) test, Complete blood and lipid profile tests, Kidney function test, Liver function test, Thyroid function test. After performing the number of tests, the pathological reports conclude the chances of hyperthyroidism, damage in liver and spleen, frequent weakness, chest and joint pain in RA patients [1].

The chance of curing rheumatoid arthritis increases if it is detected and treated early. Rheumatoid arthritis can be diagnosed based on several factors. There are several tests that are typical for judging rheumatoid arthritis, including Rheumatoid Factor, Anti-CCP, SJC, and ESR [3]. The k-means algorithm was used to predict the disease with four factors. K-means algorithm was applied to 60 anonymous data

points to analyze them. Out of the 60 parameters, four clusters were selected since they were performing comparative analysis using the four factors as described above, later to figure out the centroid of their cluster at an initial stage they set it randomly and the setting it to the nearest centroid by adding a number of times. Rheumatoid arthritis can be predicted by two of four factors using the K-Means algorithm.

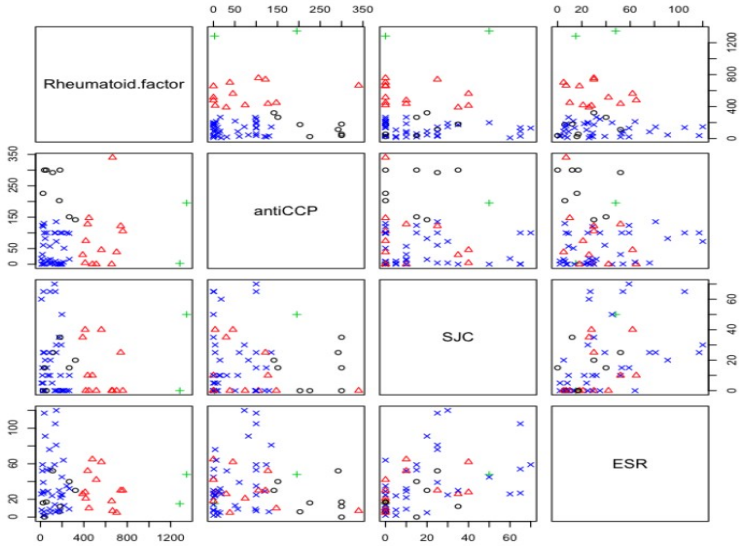

Fig. 1. Visualization of K-means model [4]

By adopting this approach over the factor values, average values and cluster estimations the results were concluded with 84% accuracy with this explanatory model [3].

As Rheumatoid Arthritis (RA) progresses and improves, joint stiffness becomes a determinant factor. [14]. A new method to determine joint range of movements and stiffness in RA patients was proposed by James Connolly and team [14]. The study is focused on developing a hand Range of Motion (ROM) measurement tool that continuously measures joint stiffness using a control glove and software. Using a 5DT Data glove with 14 sensors placed on the metacarpophalangeal (MCP) and Proximal Interphalangeal (PIP) joints, a system was designed and developed. Measurements of joint stiffness were made by measuring the maximum velocity captured during extension and flexion of the hand. The angular movement data and velocity data was collected during an objective routine. The time taken during the entire objective was recorded in addition to the angular movement of the joints. Tabular and graphical analysis was performed on the data collected. Normal people had good angular movement and time taken was very less to extend and fold the hand. RA people with damaged joints took so much time to perform the objective. The angular movement of

the joints was very low and the velocity was too less when compared to normal people. Initial results show differences between normal and stiff joints in movement patterns and stiffness that can be calculated from velocity and angle measurements. The purpose of this research was to explore the potential of using a data glove and an application for measuring finger movement and stiffness.

Thermal imaging provides information about temperature variations in human skin on different parts of the body and can help in analyzing human body dysfunctions alternatively to existing diagnostic methods. [15RA is primarily characterized by inflammation, so thermography can be used as a diagnostic tool to monitor dysfunctions in any part of the body. Sudhir Rathore and team [15] has developed a portable hardware thermographic system for detection of RA. Initially thermal images of the RA affected areas such as knees, wrists etc., are captured with emissivity set to 0.98. Image segmentation was performed on the captured images to find the Region of Interest (ROI) using the FCM algorithm. In the next step, image analysis was done to find the Mean, Variance, Skewness, Kurtosis. Then the decision is made by a Neural Network (NN) to produce reliable results with minimized error. A feed forward neural network with three layers containing four neurons each in the input layer and one neuron in the output layer is applied. As inputs to the Neural Network, we have Mean, Variance, Skewness, and Kurtosis. The NN was first trained and then validated. Finally, a new image is loaded, Statistical parameters are given to NN and a decision is made by comparing the output value to the threshold value. Thermographic images of RA patients show higher levels of temperature in abnormal areas than in normal areas. In conclusion, artificial neural networks for thermal imaging provide an alternative way to analyze information concerning Rheumatoid Arthritis.

3 Detection using Image Dataset

Image dataset includes X-ray hand radiographs, Ultrasound images of joints, MRI images, Thermal images and so on. Among them, the hand radiographs stand out in detecting the disease in an effective way and it is cost-effective. The following section briefs about the various detection methods and their advantages and disadvantages. The image dataset can detect RA using Machine Learning algorithms, image processing techniques, Deep learning and many more.

3.1 Machine Learning

Among various Machine Learning approaches, a diagnosis system based on Vision API and Auto ML was proposed [2], where the system's one half is about training the model with image dataset and classify them based on grading. The images used for the training data is around 130 for grade 0-2 and for grade-3 around 65. These grading is according to the seriousness in RA patients. The latter part is about taking real time ultrasound images and diagnose them. The proposed system predicted around 70% accuracy for grade 0 to grade 2 whereas for other grades it predicted above 55%.

Correct Grade	Grade 0	Grade 1	Grade 2	Grade 3
Grade0	0.754	0.014	0.009	0.002
Grade1	0.204	0.568	0.137	0.010
Grade2	0.024	0.404	0.704	0.319
Grade3	0.002	0.005	0.100	0.656

Fig. 2. Implementation Results [2]

The system was built as a webpage, to be available for easy means for doctors to train and diagnose regarding the ultrasonic images.

In [4] a recognition system to locate the joints in hands by analyzing X-ray images and also to evaluate those images towards Rheumatoid Arthritis by assigning scores with respect to each joint through machine learning. Here, only the recognition system is taken more concern and implemented using the python with OpenCV, where the identification of each joint is also validated at the end of the recognition procedure. The accuracy in recognizing those joints is found to be 90% through this approach.

Modified Total Sharp (mTS) scores are widely used to assess Rheumatoid Arthritis progression. Regarding it, there's an approach estimating it using Support Vector Machine (SVM) [9]. A histogram of oriented gradients (HOG) is used to represent the rough shape of finger joints in the study. Based on HOG, a support vector machine detects finger joints in an X-ray image, and a support vector regression (SVR) method is used to estimate the modified Total Sharp (mTS) score. They have also performed the finger join detection by clustering the evaluated patches on X-ray image. The patches are sorted in descending order by the SVM output. This method detects finger joints with 81.4% accuracy in 45 RA patients' X-ray images, and with an estimation of erosion score at 50.9% accuracy and JSN score at 64.3% accuracy when analyzing 45 RA patients' X-ray images.

3.2 Deep Learning

There is a deep learning approach to assigning the Rheumatoid arthritis score for all joints, specifically the narrowing and erosion scores for each joint [5], where 42 joint area scores for joint space narrowing and 44 joint area scores for joint erosion are summed up. Narrowing scores range from 0 to 4, and erosion scores range from 0 to 5, with the sum of these scores determining the patient's RA severity. The deep

learning model is designed and implemented in MATLAB, and the training is done on the dataset collected from the RA2 Dream challenge. They used 1662 training samples to train the model and 416 test samples to evaluate its performance. The accuracy of assigning scores to joints was found to be 90.8 percent on average, with an error magnitude of about 4.6 percent.

In addition, Janick Rohrbach provided another deep convolutional neural network-based method for scoring X-ray images of patients with rheumatoid arthritis that is fully automated, fast, and reproducible. The dataset was collected from Swiss Clinical Quality Management and restricted their dataset to only have left hand radiographs. They pre-processed the dataset to have only the images of joints of 150 x 150. They have used the Ratingen Scoring method of assessing bone erosion and this deep learning model is inspired by VGG16 with six blocks of two convolutional layers and a max pooling layer. The number of filters per convolutional layer increases by 32, 64 and 128 every second block.

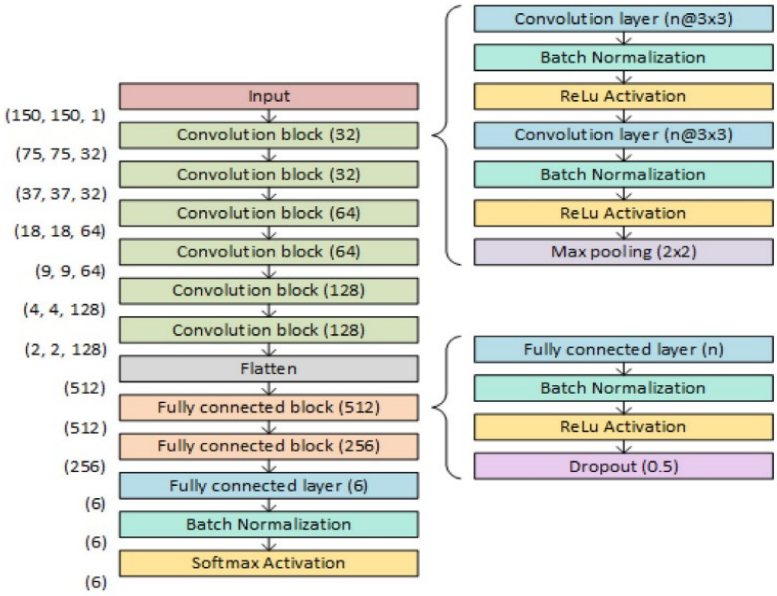

Fig. 3. Architecture of the neural network. All convolution blocks are identical, differing only in the number of convolutional filters. The two fully connected blocks are also identical except for the number of neurons in the fully connected layer. [7]

Cohen's Quadratic Kappa was used to evaluating the agreement between different scorers. The model and the two human experts have inter-rater reliability scores of 0.675 and 0.580, respectively, and thus outperform the human scorers. This clearly shows that their model is on par with a human expert. The main advantages of a deep learning approach over human scorers are the speed with which the scoring process

can be completed, i.e., milliseconds rather than minutes, and the consistency with which the results can be replicated. (i.e., same images always get the same scores).

Discussing the various diagnosis methods of RA, Kemal Ureter [8] specifies juxta-articular erosion on hand radiographs is one of the seven criteria for RA classification. One of the criteria for RA classification is imaging-proven synovitis, demonstrating the importance of imaging in RA diagnosis. They consider plain radiography to be the most widely used and first-line imaging method for diagnosing and differentiating RA, as well as monitoring the disease's activity, because it is relatively inexpensive and easily accessible. They proposed a CNN model architecture with six convolution layers: a convolution layer, a batch normalization layer, a ReLU, and five max-pooling layers, followed by one fully connected layer with a SoftMax layer. The dataset comprised 180 radiograph images of both hands with different sizes. 81 patients were normal and 99 were RA affected. Data pre-processing and splitting was done on the collected dataset and images were resized to 160 x 240. Data augmentation was also done. A number of performance metrics were used to evaluate the efficiency of the developed CNN model, including sensitivity, specificity, precision, F1 score, false negative rate, false discovery rate, false positive rate, negative predictive value, and classification accuracy. The confusion matrix was used to evaluate these metrics. The proposed CNN model correctly classified 33 out of 45 patients. However, as shown above, their model failed to identify 5 normal and 7 RA patients. The network's accuracy was 73.33%. The network's sensitivity was 68.18 percent, while its specificity was 78.26%. The accuracy was 0.75. As a result, the model can aid specialists in their diagnosis. The model may be useful even for non-specialists during the initial examination [8].

There are two approaches for hand X-ray classification of rheumatoid arthritis using CNN models, one is described in Bhupesh Kumar Singh's paper [11] where they collected around 662 images of patients suffering from RA regarding the MCP (Metacarpophalangeal) joints, and the other incorporates 315 images of the PIP (proximal interphalangeal) joints. The collected images were resized to 100x100 and considered 80% data for training and 20% for testing. The processed image dataset was fed into the CNN model, which contains one or more number of convolutional layer and pooling layer.

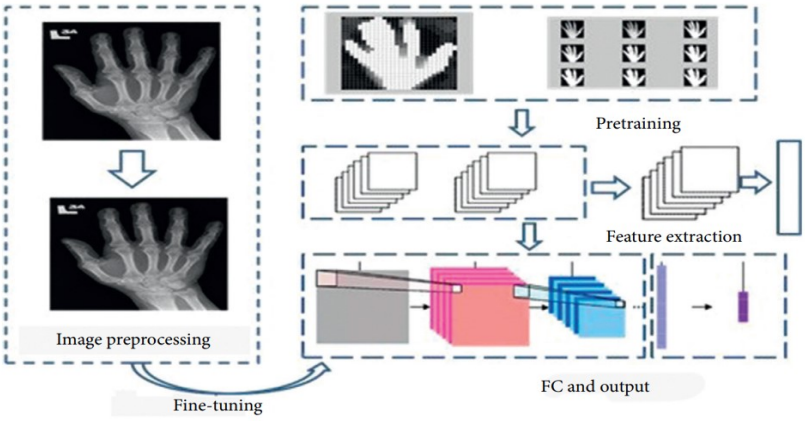

Fig. 4. Using a convolutional neural network, a framework for automatically classifying hand X-rays has been developed. [11]

After training and testing the accuracy was about 95% and they also compared the result with SVM (Support Vector Machine) which was around 60% accuracy and ANN (Artificial Neural Network) around 80% accuracy.

In [13], as a CNN approach over hand radiographs have gathered about 92 gray scale radiographs images then they reduced the size of those images from 4280x3520 pixels to 256 x 204 pixels and values of the pixels was normalized in a range between 0 and 1. As training a model with small amounts of data was a challenging task, they transform the original radiographs with a random combination of rotation, zooming, stretching and flipping as shown below. The dataset was split into two after data augmentation, one for training and the other for validation. Their dataset was trained with such type of models to take smaller number of parameters and having a smaller number of operations. First, with LeNet architecture with 3*3 kernels, ReLU as activation function and SoftMax as output function resulted in 93% accuracy. Secondly, with a minimalistic variant of Network in Network was used to reduce computational cost and achieved the same 93% accuracy. Later, with SqueezeNet architecture having same activation function and output function as for LeNet but with 5*5 kernel strides achieved 100% accuracy.

Table 1. implications from the survey

Authors	Techniques	Advantages	Disadvantages
[1] Saurav Bharadwaj and Pallab Sharma	Study about variation in blood and lipid components	Clinical Findings	So many tests, and cost is high.

[2] Takashi Muronosono et al [2021]	Machine learning (using Vision API and Auto ML) to diagnose RA	Stable Accuracy	Usage of ultrasound images.
[3] Jihyung Yoo et al	k-means algorithm	Quick results	Statistical data analysis
[4] Koji Makino et al	x-ray image processing using OpenCV	90% accuracy	Location of joints using ROI and scoring each joint
[5] Son Do Hai Dang and Leigh Allison	MATLAB DL model	Decent accuracy	Less Dataset
[6] Berend C. Stoel [2019]	CNN on MRI dataset	Predicting RA with high sensitivity	MRI scanning is not cost-effective.
[7] Janick Rohrbach et al [2019]	CNN on X-ray images	Cost effective and balanced accuracy.	Image size was 150x150
[9] Kento Morita et al [2017]	SVM with HOG	Good modified Total Sharp (mTS)	Error rate was high.
[14] James Connolly et al	5DT Data glove with 14 sensors	Joint stiffness calculation	Dependent on sensor values.
[15] Sudhir Rathore et al	ANN on thermographic images.	Affordable and cost efficient	Accuracy of thermal images is poor and inflammation cannot alone predict.

4 Conclusion

Every paper discussed above has found its uniqueness in the way of approaching the problem, it might be in the type of data used, the learning model deployed or by considering some factors causing Rheumatoid Arthritis. As an overview, these approaches are proving that there are new possibilities to detect rheumatoid arthritis. All these things contribute to our motive of doing this survey paper, which is basically exploring new solutions and finding the gap of opportunity for the readers to fill it with their creative and innovative approach towards solving this global problem.

From our perspective to discuss about the gap of research we can evidently see that there are disadvantages in all the above methods discussed but yet the hunger in finding the best solution is always the drive for us and this survey paper is undoubtedly a supportive tool.

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