PROJECT REPORT

SUBMITTED FOR PARTIAL FULFILMENT

MASTER IN COMPUTER APPLICATION

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02804092022,00804092022

Masters in Computer Application

Under the Supervision of

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DEPARTMENT OF INFORMATION TECHNOLOGY

YEAR 2022

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Rheumatoid Arthritis Detection using Joint Angle Calculation (in Human Hand)

1. ABSTRACT

In this paper, we propose an approach for the detection of Rheumatoid Arthritis in a human hand using finger joint angle calculation. A deformed finger/hand or a rheumatoid arthritis hand is bent either inward or outward at some angle. To detect whether a person is suffering from Rheumatoid Arthritis or not we need coordinates of all the joints of fingers of a human hand. Once we have the points, we can easily create the equations of lines, joining four points, i.e the tip of the finger, the joint closest to the tip, the middle joint of the finger and the joint at the base of the finger. Using the slopes of these lines, we can easily calculate the angle between them, which is exactly what we need. If any angle is smaller than the threshold, then the person is suffering from Rheumatoid Arthritis. We successfully developed a model to implement the above idea using MediaPipe and OpenCV library in Python.

The model detects possible Rheumatoid Arthritis by calculating the angle at the finger joints.

Keywords: Rheumatoid Arthritis, Computer Vision, Deep Learning, Image Processing, and Understanding.

2. INTRODUCTION

Rheumatoid arthritis (RA) is a chronic autoimmune disease that mainly attacks the synovial tissues within the joints. Within 3 to 6 months of the disease's onset, joints may suffer damage. Its complications can lead to deformity and destruction of joints, due to the erosion of bone and cartilage. Sixty percent of people with inadequately treated RA are unable to work 10 years after onset.[1]

Rheumatoid arthritis (RA) affects about 0.92% of the adult population in India.[2] Findings of population-based studies show RA affects 5–10% of adults in developed countries. The disease is three times more frequent in women than men, and 50% of the risk of developing RA is attributable to genetic factors.[3]

The main symptoms of rheumatoid arthritis are

i) *Constant Joints pain*- It causes constant pain in joints and mostly in the mornings because of inactivity. ii) *Swelling, redness*—joints affected by RA become inflamed, which can cause the joints to swell and become hot and tender to the touch. iii) *Stiffness* –RA-affected hands can not make a fist properly. or inflammation in other parts of the body. iv) *Motion limitations* of the affected joints. v) *Increased joint volume*. vi) *Weakness*- A person is always tired, can be sweating more, can have a poor appetite, and lose weight. Symptoms vary from person to person. In a few, it might take several weeks, but in others, it might get worse in a few days.[4]

If the diagnosis does not happen on time and gets delayed treatment it can cause serious deformities. Here are the few hand deformities that are caused by RA

i) Boutonniere deformity
ii) Swan-neck deformity
iii) Hitchhiker’s thumb
iv) Rheumatoid nodules

There is no single test that can accurately predict early RA. Practically speaking, the diagnosis of RA is based on the patient's history, physical examination,

radiography, and laboratory findings. The American College of Rheumatology (ACR) has prescribed criteria for the characterization of RA (the purported "ACR 1987 revised criteria"). This criterion shows that a subject is said to have RA on the off chance that he or she has fulfilled no less than four of the seven criteria for no less than a month and a half. [5]

Early RA diagnosis and intensive treatments can slow the progression of the condition and, in some people, even lead to a reduction in the need for medication. Instead of immediately getting expensive MRIs and x-rays, a person can use our service to diagnose themselves when they first experience joint pain or are unsure whether they have RA.

Artificial Intelligence is a very advanced technology, which is used for classification, segmentation, and much more. AI(Artificial intelligence) has put a great impact on the healthcare sector, which has made critical things much easier, for example, the Detection of covid-19, Skin-cancer Detection, Fracture Detection in humans, Brain Tumor Detection, Lung Cancer Detection and many more. Some research has been done to detect rheumatoid arthritis, but it is not very accurate or cost-effective. Artificial intelligence is not only saving time but even the life of many people around the world, we can see this with an example that artificial intelligence in the field of radiology can help to get more proper diagnosis [6].

In this paper, we have developed an easy and fast practical model for the detection of Rheumatoid Arthritis in a human hand. The model detects possible Rheumatoid Arthritis by calculating the angle at the finger joints.

3. LITERATURE SURVEY

The top 10 highly cited papers received a total of 7045 citations from 2016 to 2021, averaging 705 citations per publication. India's contribution to global output (42312 publications) was estimated to be 5% (1974 articles).

In conclusion, there are few studies on rheumatoid arthritis in a country with the world's second-largest population. There is a need for more research on rheumatoid arthritis in India.[7]

Several classification methods have been used in the literature for classifying RA. They include logistic regression, Naive Bayes, multilayer perceptrons, support vector machines (SVMs with a linear kernel, polynomial kernel, Pearson universal kernel, and Gaussian kernel, all of which are implemented in Weka.[8]

We have proposed the fully automated finger joint detection method and mTSS estimation method for mild-to-severe RA patients using hand X-ray image. The method was achieved by the patch image analysis using SVM (Support Vector Machine).[9]

4. METHODOLOGY

The following chapter focuses on the implementation of our approach.

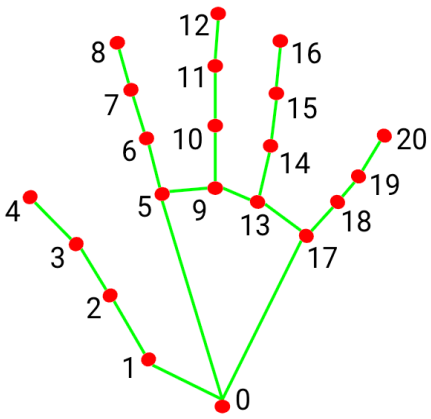
4.1 Hand Landmark Detection using MediaPipe

Our approach focuses on first identifying hand landmarks using MediaPipe and then figuring out how to identify hand abnormalities.

MediaPipe Hands is a high-fidelity hand and finger tracking solution. After the palm detection over the whole image, the subsequent hand landmark model performs precise keypoint localization of 21 3D hand-knuckle coordinates inside the detected hand regions via regression, that is, direct coordinate prediction. The model learns a consistent internal hand pose representation and is robust even to partially visible hands and self-occlusions.

To obtain its data, MediaPipe has manually annotated ~30K real-world images with 21 3D coordinates (it

takes the Z-value from the image depth map if it exists per corresponding coordinate).



0. WRIST
1. THUMB_CMC
2. THUMB_MCP
3. THUMB_IP
4. THUMB_TIP
5. INDEX_FINGER_MCP
6. INDEX_FINGER_PIP
7. INDEX_FINGER_DIP
8. INDEX_FINGER_TIP
9. MIDDLE_FINGER_MCP
10. MIDDLE_FINGER_PIP
11. MIDDLE_FINGER_DIP
12. MIDDLE_FINGER_TIP
13. RING_FINGER_MCP
14. RING_FINGER_PIP
15. RING_FINGER_DIP
16. RING_FINGER_TIP
17. PINKY_MCP
18. PINKY_PIP
19. PINKY_DIP
20. PINKY_TIP

Fig.1 List of Keypoints

The first thing required to detect the key points is the input image. We load and read multiple static images of hands with rheumatoid arthritis using OpenCV and provide them as input to the MediaPipe model for inference as an RGB image.

MediaPipe takes the input image as NumPy array and offers different models based on complexity for accuracy and speed. Here is the list of configuration options that we can use with it:
STATIC_IMAGE_MODE: If input is single image we set it to true, otherwise set false to track frames
MAX_NUM_HANDS: Maximum number of hands in frame, default 2
MODEL_COMPLEXITY: Two models 0 or 1 where 1 provides better results than 0
MIN_DETECTION_CONFIDENCE: Detections confidence
MIN_TRACKING_CONFIDENCE: If tracking frames, then tracking confidence

The output contains a list of detected/tracked hands, where each hand is represented as a list of 21 hand landmarks, and each landmark is composed of x, y and z. x and y are normalized, and we have to multiply all x values by image width and all y values by image height.
Output for the input image could contain these values:
MULTI_HAND_LANDMARKS: Detection or tracked landmarks as a list
MULTI_HAND_WORLD_LANDMARKS: Real world 3D coordinates
MULTI_HANDEDNESS: Handness detection as left or right hand with score.

Once the keypoints are detected, the next step is to plot them on the image. We create a function that processes all results from the model and labels the points for each finger separately on the input images using MediaPipe drawing utilities. The skeleton is drawn by joining the pairs since we have the indices of the points. [10,11]

4.2 Angle calculation

Joints are formed wherever two or more bones meet. Each of the fingers has three joints:
Metacarpophalangeal joint (MCP) – the joint at the base of the finger
Proximal interphalangeal joint (PIP) – the joint in the middle of the finger
Distal interphalangeal joint (DIP) – the joint closest to the fingertip.
Each thumb has two joints.[12]

Now that we have acquired 21 two-dimensional landmarks on our input images of RA hands using MediaPipe, we can easily calculate the angles at finger joints.
Using the finger landmarks (Fig.1) [4,3,2,1], [8,7,6,5], [12,11,10,9], [16,15,14,13], [20,19,18,17], we can

easily create the equations of lines, joining four points, i.e., the tip of the finger (a), the joint closest to the tip (b), the middle joint of the finger (c), and the joint at the base of the finger (d).

For calculating the angles between joint a, b, c and b, c, d; we'll use the arctan2 function of numpy library of python. The numpy.arctan2() method computes the element-wise arc tangent of arr1/arr2, choosing the quadrant correctly (the "y-coordinate" is the first function parameter, the "x-coordinate" is the second). It returns the angle in radians, in the range [-pi, pi]. [13]

If this angle is smaller than the set threshold, then there is a possibility that the person is suffering from Rheumatoid Arthritis.

Here is the workflow of our approach:-

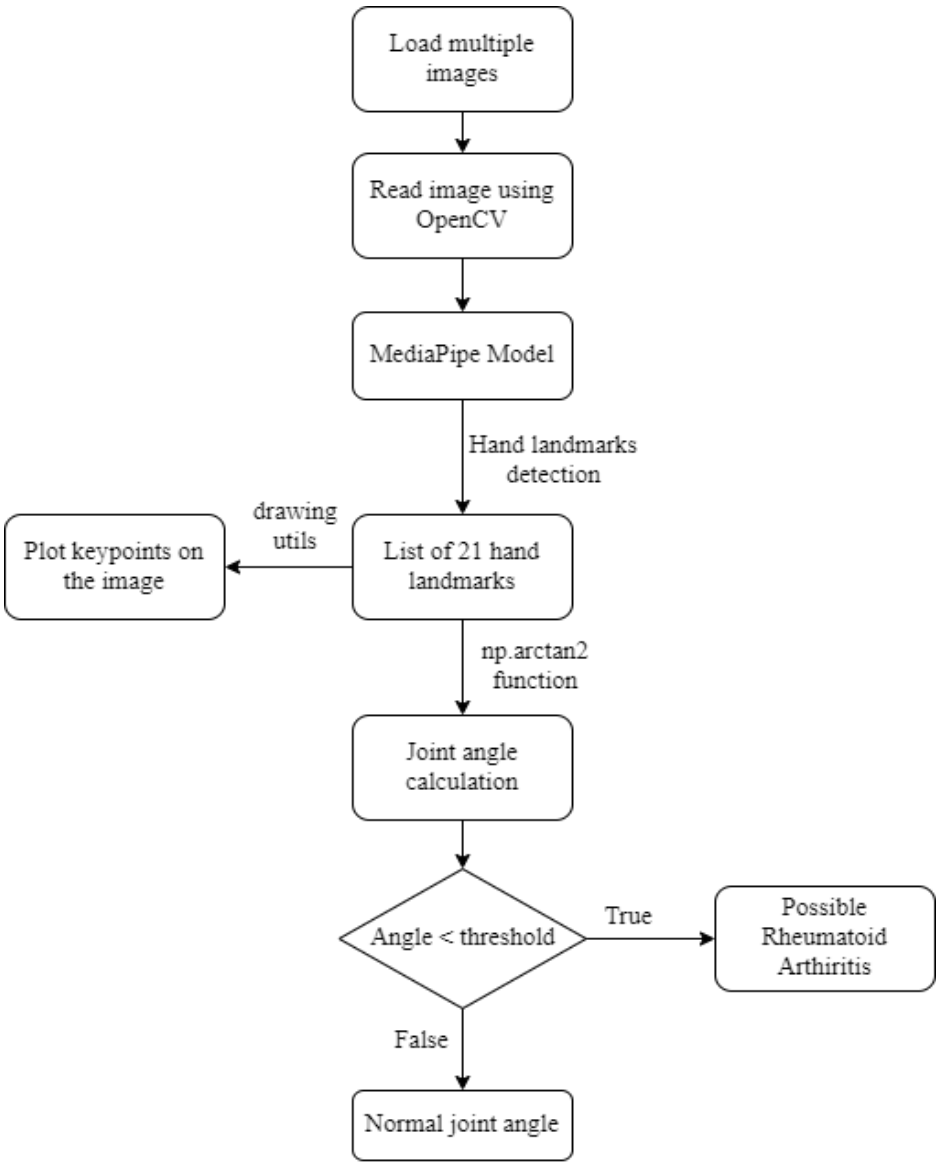
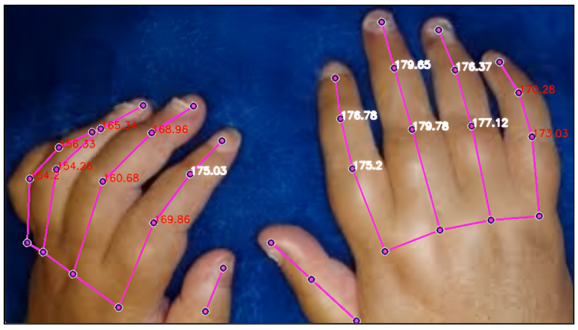


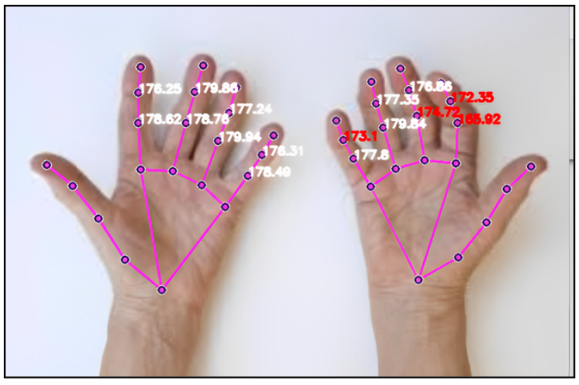
Fig.2 Workflow

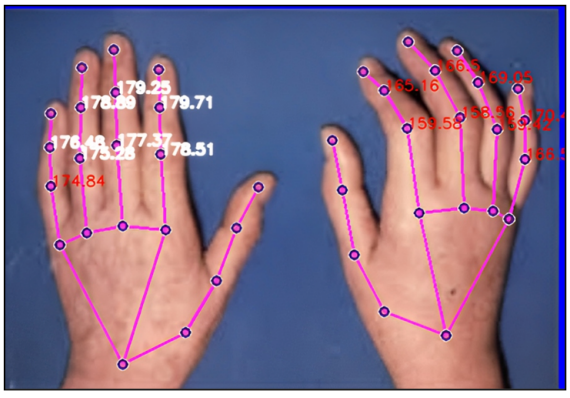
5. RESULTS

Our output includes a skeleton of 21 hand landmark points joined together, as well as calculated angle labels drawn over the input image. Then all the output images are stored inside a folder. Here, we can visually distinguish between angles with values less than or greater than the threshold (red values being less than the threshold).

Sample output below:

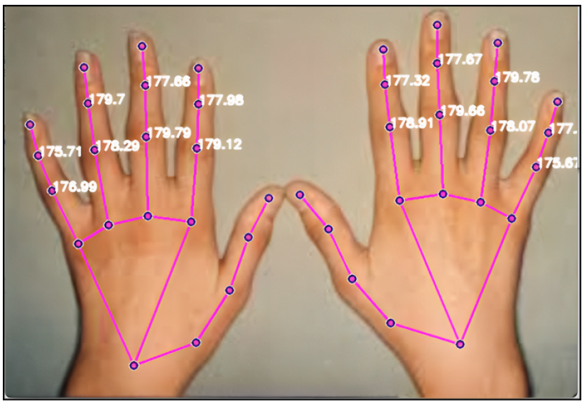


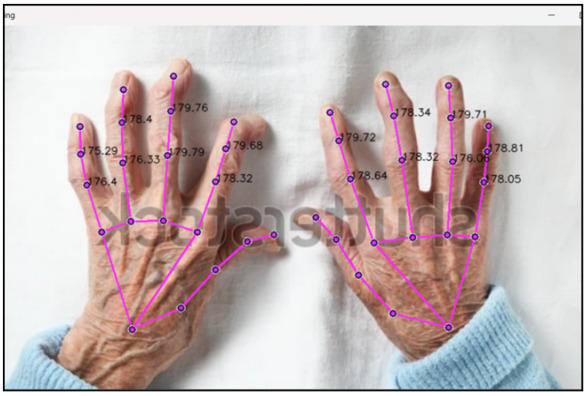


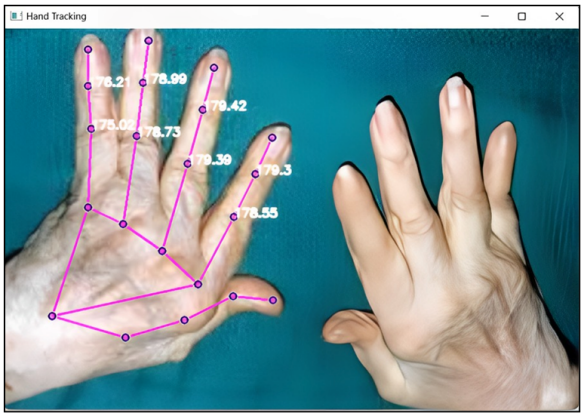


5.1 Drawbacks

While working, we found drawbacks of our model. Our model was not able to detect those hands that are inflamed or where the fingers are tilted toward the palm and not to the sides. It also failed for hands with knuckle joint deviations.







6. CONCLUSION

The objective of this paper is to classify Rheumatoid hands from normal hands. We studied various research works by people who tried to solve this problem in the past. They used different approaches to solve it, each unique and interesting. The approach proposed in this paper is to predict rheumatoid arthritis using joint angles. We used the MediaPipe Hands solution for identifying 21 3D landmarks of a hand from just a single frame. Using the coordinates, we calculated the joint angles in each finger and distinguished between the angles of rheumatoid fingers and normal fingers. When compared to other approaches proposed by different researchers, our approach is unique and efficient. By going through various images, we were able to find a threshold, i.e., approximately 175°.

MediaPipe essentially provides us with excellent accuracy for all hand landmark identification. However, it still has to be evaluated to see if it can successfully recognize landmarks for a hand with severe RA symptoms.

We were able to implement everything we intended to implement, but we do have some future goals. We aim to find a suitable threshold or range of angles for which we can distinguish between images of RA hands and normal hands.

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