# AI-based Human Tracking for Remote Rehabilitation Progress Monitoring

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***Abstract*—Human movement analysis takes on great importance in the field of research related to artificial intelligence because it is used in many applications such as sports and rehabilitation. Human action analysis may be accomplished by anticipating the body's essential posture. The two most important parts of video-based human action analysis are recognizing actions and following the body. In this research paper, we present an effective model for human tracking for some human range of motion using artificial intelligence technology. A web application was developed to track the patient's rehabilitation progress at distance.**

***Index Terms*—Pose estimation, rehabilitation, MediaPipe, telerehabilitation**

## I. Introduction

Human activity recognition is a fundamental application in the field of computer vision. Human activity recognition is made up of two main parts: body tracking and action recognition [1]. Human body monitoring may be used for a variety of issues, such as sports or rehabilitation. Due to COVID-19, much research is headed toward telerehabilitation. This is because the method is convenient for the patient and avoids the trouble of traveling, and in many cases, it may be inexpensive. Monitoring the human body may be utilized to address several problems. During physical exercise, injuries may be minimized by observing and forecasting important body points using video streams [2]. Computer-assisted self-training systems for sports and fitness may aid athletes in enhancing their performance while reducing injury [3]. Corrective exercise might also be used to identify the underlying cause of postural, balance, and whole-body coordination difficulties.Patients with lower or upper organ surgeries or other injuries need rehabilitation. These need physiotherapy-supervised rehabilitation. The rehabilitation may used with robots or wearable exoskeletons and without devices with simple exercises monitored by a physiotherapist [4-8].The clinical goniometer allows the doctor to measure the patient's range of motion during rehabilitation. It requires both hands, reducing joint stability. Clinician abilities and experience determine goniometer accuracy. Another device, called the inclinometer was presented. Compared to the goniometer, the inclinometer was more convenient and reliable. The universal goniometer is cheaper than a digital inclinometer. Thus, inertial measurement units (IMUs) containing accelerometers, magnetometers, and gyroscopes are utilized to track the patient's status remotely. IMUs use micro-electromechanical systems technology to detect and quantify human motions. IMUs collect accelerations, magnetic signals, and angular velocities from human motions for activity control, rehabilitation, motion tracking, gait analysis, gesture recognition, and handwriting. Joint angle measurements using wearable IMUs were accurate in several studies [9-11]. Moreover, although the Kinect V1 or V2 is also popular for in telemedicine [12-15], it is inaccurate. They are expensive and not accessible to everyone. A study [16] showed that the Kinect sensor had limitations in following lower limb activities, notably knee rehabilitation. Thus, it's important to create a cost-effective technique for a physiotherapist to remotely monitor a patient's situation. Our goal is to find a solution based on cutting-edge technology that was available to as many people as possible at a reduced cost and with higher efficiency. In this research, we focused on employing the pose estimation approach in the telerehabilitation area, specifically to measure the range of motion of upper and lower limb joints.

The rest of the article is organized as follows, section 2 presents human movement and body tracking and the web application for telerehabilitation. Furthermore, it shows a study of different movements in many positions. Section 3 introduces two methods used to measure the ROM and presents data on the knee flexion/extension of 25 volunteers. Section 4 resumes the reliability and validity analysis of the pose estimation technique called MediaPipe for knee flexion/extension. Section 5 revolves around patients' experimental validation. Section 6 concludes this paper.

## II. Human Movement and Body Tracking

A framework is an interface method that facilitates and accelerates the work of the machine learning model [17]. Apply ML frameworks (Tflite, OpenPose, Pifpaf, Tfjs (Resnet 50), Tfjs (mobileNet), and BlazePose) for posture estimation and correction of the fitness training dataset. As the objective was to identify the quickest and most accurate real-time approaches. In addition, the anomaly of squat exercise has been determined using a Kinect sensor to extract skeletal elements from a dataset [18]. In addition, [19] and [20] recommended using the OpenPose framework to extract keypoint coordinates from RGB data for fall action posture recognition. The

BlazePose framework used by the MediaPipe model provides a topology with 33 human body keypoints, which is greater than the OpenPose and Kinect topologies, which supply just 17 human body keypoints [2].

In this research project, a web application is developed to track the patient's rehabilitation progress, even lower or upper limb. The drivers used is Popper 1.12.9, and Bootstrap 4.0.0 as Frameworks UI. JQuery 3.3.1 as librairies JavaScript, and cdnjs, jQuery CDN, Cloudfiare for content delivery network.

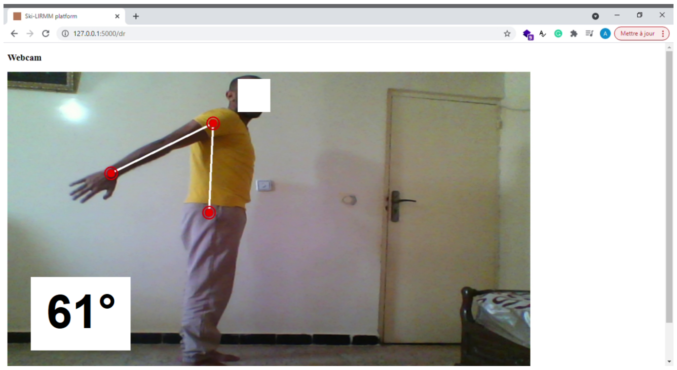


Fig. 1. Doctor's view of the SKI-LIRMM application.

The objective of this chapter is to study the effectiveness of pose detection in different positions in front of the camera and show the best one. We have tried several movements that are usually used in rehabilitation, and these movements include the lower organs, especially the flexion and extension of the knee, as well as the upper organs, and here we experimented with the arm and shoulder movements. To get the best angle of the detection, an assumed triangle is drawn on the image obtained from the pose detection. As can be seen from the fig.1, a triangle is formed with three corresponding positions A, B, C:
Slope of $AB$ is

$$d_1 = (y_2 - y_1)/(x_2 - x_1) \tag{1}$$

BC slope is

$$d_2 = (y_3 - y_2)/(x_3 - x_2) \tag{2}$$

Now, we can calculate the angle between AB and BC :

$$tan\theta = (d_1 - d_2)/(1 + d_1.d_2) \tag{3}$$

Choosing the position in front of the camera is an important factor in obtaining accurate data. In addition, it is advisable to avoid obstructions between the person and the camera, as these may cause fluctuations in the data.

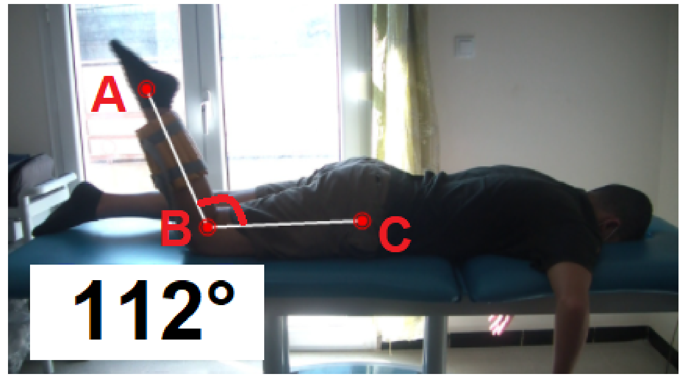


Fig. 2. Angle joint calculation.

## III. Methods and Data of measuring knee flexion/extension

A total of 25 participants, ranging in age from 21 to 40, took part in this study and investigation. The majority of the data was collected at Skikda University. The MediaPipe and universal goniometer were used to measure all participants. We began by measuring the four motions in three repeats with MediaPipe. The purpose of this approach is to compute the ICC in order to demonstrate the technique's reliability. The goniometer was only used once by the physiotherapist.

TABLE I
Data of knee flexion/extension obtained using universal goniometer and MediaPipe.

| Movement | Meth | Mean | SE Mean | StDev | Min | Med | Max |
|---|---|---|---|---|---|---|---|
| Flexion | Go | 20,40° | 0.16° | 0.81° | 19° | 21° | 22° |
| | Me | 20,00° | 0,17° | 0,86° | 19° | 20° | 22° |
| Extension | Go | 179.20° | 0.18° | 0.91° | 178° | 180° | 180° |
| | Me | 179.08° | 0.18° | 0.90° | 177° | 179° | 180° |

Abbreviation : Meth : method, Go : clinical goniometer, Me : MediaPipe, SE Mean :standard error of the mean, StDev : Standard deviation, Min : minimum, Med : median, Max : maximum.

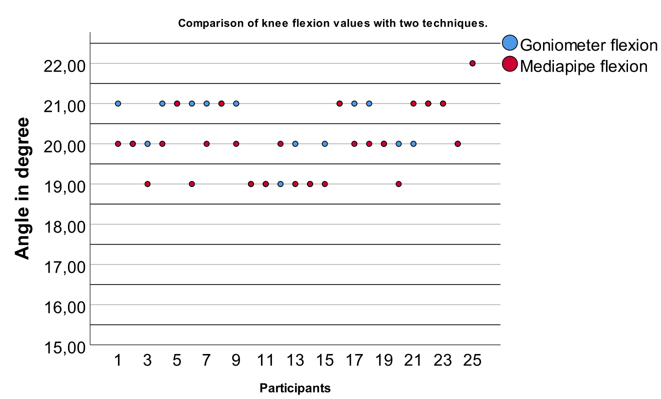


Fig. 3. Comparison of knee flexion values between Mediapipe and goniometer.

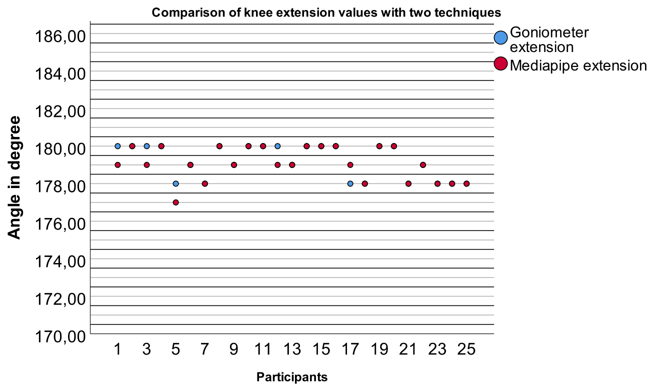


Fig. 4. Comparison of knee extension values between Mediapipe and goniometer.

## IV. Reliability and validity analysis of MediaPipe-based measurement system for knee flexion/extension

A physiotherapist was in charge of engaging with the subjects and obtaining clinical goniometer measurement. The two methods were used to take measurements. The participants performed the prescribed moves in a lighthearted manner. The collected data are compared to the normal interval values, which demonstrates that all of the results are on the normal average. IBM SPSS Statistics version 26 was used to do the statistical analysis. The intraclass correlation coefficient (ICC) was used to determine the dependability of the MediaPipe. The ICC was classified as follows: between 0.81 and 1.0 is "excellent," and good if the result is between 0.61 and 0.80. "Moderate" if the value is between 0.41 and 0.60, and "fair" if it is between 0.21 and 0.40. Finally, it is considered "bad" if it is less than 0.20. The absolute reliability is calculated using the standard error of measurement (SEM) and the minimal detectable change (MDC), as illustrated in the two following equations [21]:

$$SEM = StDev.\sqrt{1 - ICC} \tag{4}$$

$$MDC = SEM.\sqrt{2} \times 1.96 \tag{5}$$

As shown in the table 2, the MediaPipe technique has excellent reliability because the ICC results of both knee flexion and extension are between 0.81 and 1.0.

Then, to demonstrate the validity of the MediaPipe, Bland-Altman analysis [22] is performed. Limits of agreement (LOA) and mean bias measurements are developed to assess MediaPipe's absolute accuracy over the goniometer.

TABLE II
RELIABILITY RESULTS OF THE MEDIAPIPE BASED MEASUREMENT SYSTEM FOR KNEE MOVEMENTS.

| | *ICC* | *StDev* | *SEM* | *MDC* |
|---|---|---|---|---|
| Flexion | 0.92 | 0.81° | 0.23° | 0.63° |
| Extension | 0.87 | 0.91° | 0.33° | 0.91° |

A 95% limit of agreement (LOA) amidst MediaPipe-based measurement and the universal goniometer calculated, is calculated as follows:

$$Upper\ limit = Mean(bias) + 1.96\ .\ StDev \tag{6}$$

$$Lower\ limit = Mean(bias) - 1.96\ .\ StDev \tag{7}$$

TABLE III
BLAND–ALTMAN ANALYSIS RESULTS OF KNEE FLEXION/EXTENSION DATA ACQUIRED USING GONIOMETER AND MEDIAPIPE.

| | Goniometer vs MediaPipe | |
|---|---|---|
| ROM | Mean bias | 95% LOA |
| Flexion | 0,40° | -0,98° to 1,78° |
| Extension | 0,20° | -0,60° to 1,00° |

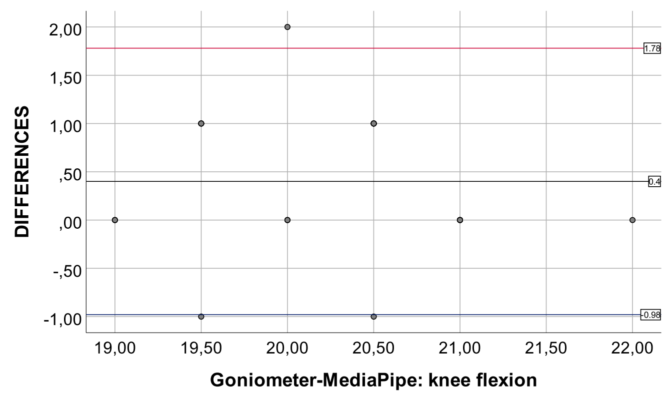


Fig. 5. Bland–Altman plots a comparison between MediaPipe and goniometer for flexion.

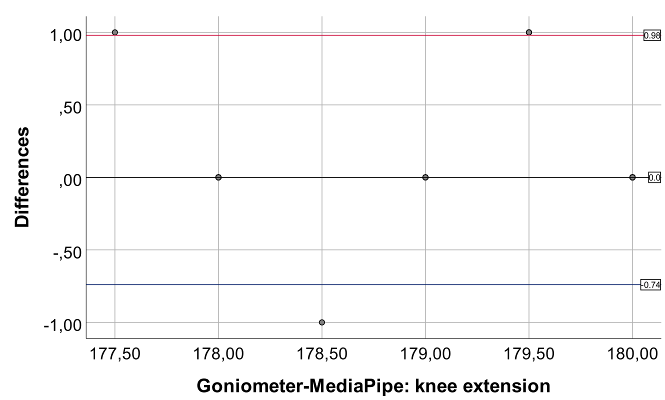


Fig. 6. Bland–Altman plots a comparison between MediaPipe and goniometer for extension.

As indicated in [21], the table 3 and Fig.5 and Fig.6, the MediaPipe is valid for using to measure the knee flexion extension in the telerehabilitation platform.

## V. Patients experimental validation

The case of three patients was followed up, the first suffers from a subtotal rupture of the anterior cruciate ligament, and the second was admitted for surgical management of anterointernal laxity of the right knee. Regarding the third, he was operated on for a fractured right kneecap.

We followed their cases and the development of their rehabilitation process as we focused on one movement, which is the flexion and extension of the knee. The average person usually reaches a value between 15° and 20° in the flexion. We noticed through the results (table 4) and the graphs (Fig.7), we can resume the following observations and results:

It is noted that the second and third patients had greater improvements in their cases compared to the first patient. Although the first patient was better at the beginning of the rehabilitation process than the second and third, he did not attend the rehabilitation sessions like the other two, as there were many interruptions. The first patient was able to bend his knee to 130°, while the second and third patients could bend their knees to 125° and 142°, respectively. In the second week, we noticed an improvement in the first and second patients, and this was due to the beginning of their acceptance of treatment. As for the third patient, he did not integrate well with rehabilitation. In the third week, we noticed a significant improvement in the second and third patients, and this was due to the maintenance of rehabilitation exercises, especially at home. In the fourth week, the flexion optimum reached approximately 66° for the first patient and 56° and 54° for the second and third patients, respectively. The following week, there was an improvement in the second and third patients, while the first did not notice any improvement, and this is due, as we mentioned earlier, to the fact that he stopped performing rehabilitation operations. In the sixth week, there was a slight improvement in the three patients. Through this study, it became clear to us that we can use the MediaPipe as a technique to measure some range of motions, and therefore, we can use it in telerehabilitation.

TABLE IV
DATA OF RANGE OF MOTION IN FOUR RECORDS IN FOUR MONTHS.

| | Optimal flexion | | | | | |
|---|---|---|---|---|---|---|
| | ***D1*** | ***D2*** | ***D3*** | ***D4*** | ***D5*** | ***D6*** |
| Patient 1 | 130.00° | 102.32° | 95.86° | 66.60° | 67.83° | 60.83° |
| Patient 2 | 125.49° | 95.08° | 59.52° | 56.10° | 46.62° | 40.00° |
| Patient 3 | 142.26° | 143.36° | 88.60° | 54.57° | 42.93° | 37.00° |

D: Data.

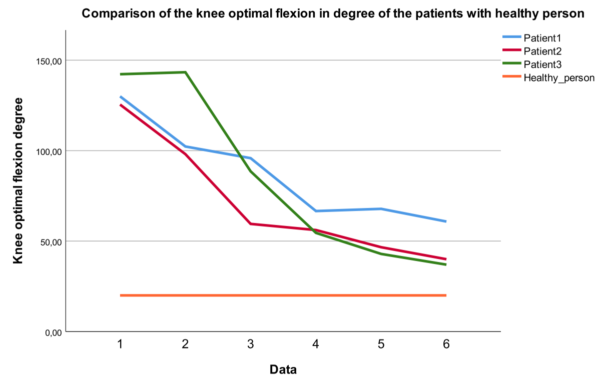


Fig. 7. Flexion differences between a healthy subject with the progression of the patients through four months.

## VI. Conclussion

Due to the COVID-19 pandemic, telerehabilitation reached a new level, given its importance to the patient and the doctor. The use of telerehabilitation to monitor the patient's improvement in the field of kinesitherapy plays an important role, especially when using techniques and devices available to the patient and the doctor at lower costs. This is why using MediaPipe technology to measure ROM is an ideal solution for integrating it into a telerehabilitation system. Our future project is to develop a website and test and study the technique with different movements [23,24].

Consent for publication

Permission has been taken from all patients and participants in this research project to share their data or photographs.

Availability of data and materials

The data that support the findings of this study are available upon request from the authors.

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