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Pose detection using deep learning for gait assessment

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Abstract This approach of gait analysis helps in solving the problems associated with the health of aged people by concentrating on the frailty and senility syndromes that affect elderly individuals. Deterioration of cognitive and motor abilities is a common result of ageing and has an effect on elderly people's quality of life. Some studies have connected these changes in gait patterns to the decline in cognitive and motor function. As a result, gait analysis is a useful tool for diagnosing senility and frailty diseases. By transferring the pose estimation data to a correct statistical analysis, gait analysis can be carried out utilizing machine learning and computer vision approach, allowing physiotherapists to analyse and treat patients accordingly. The main problem observed is that physiotherapists will analyse stroke patients' walking patterns on their own. As a result, this approach solves the problem by providing an accurate result of the observation. As everything is computerised, proper treatment can be provided with accurate data. A physiotherapist could also use machine learning classification techniques to analyse and classify the observed disorder and correct it. Our study mainly focuses on using machine learning approach instead of traditional sensor based or consultation just by vision. This will serve as a newer and better proposition of the same.

Keywords: computer vision, physiotherapy, keypoints, pose

1. Introduction

Human walking has typically been discussed in the context of medicine. The association between human walking and disease symptoms like frailty and dementia has been discussed in relation to a number of areas, including orthopaedics, rheumatology, neurology, and rehabilitation.

Gait analysis, which involves quantifying and interpreting measurable gait data, is one of the most popular methods used to learn more about the subject (Saboor 2020). This method, which is based on subjective measurements, is primarily carried out in a clinical setting by experts. Nowdays, many machine learning techniques are involved in the field of medicine. (RV Belfin 2020).

Our study uses computer vision to characterize the environment and people's behaviour in ambient assisted living (Mehdizadeh 2020). We specifically use computer vision to identify frailty and dementia symptoms in elderly individuals by observing how they move and assess the health of a person though there are various other sensor based methods. (Gujarathi 2019)

Using pose estimation, a computer vision approach, we get a pose data of the model. People are one type of flexible object pose. Key points will be in different positions in relation to others when our arms or legs are bent. Rigid posture estimate is the process of predicting where these items will be. Pose estimation gives us the ability to monitor an object or person in actual space quite precisely. A vast array of potential applications are made feasible by this potent feature. There are many gait assessment tools and softwares available out of which pose estimation differs from other common computer vision tasks in some significant ways (Jarchi 2018). Finding objects in an image is a task known as object detection. The object is typically contained within a bounding box in this localization, which is typically coarse-grained. Pose estimation goes one step further by detecting the exact location of the object's key elements. In terms of gait analysis, wearable sensors are mostly used in this process. Until now, physiotherapists have found this to be a useful input device. Sensors attached to the gait are primarily used to evaluate the patients and their gait (Zhang 2020). Predicting poses and estimating the walking pattern utilising key points can serve as an evolving perspective on gait analysis, even though machine learning has taken over the same subject. Squat count can also be used as a tool for evaluating a patient's fitness level for individuals with gait disorders like neuropathic gait, arthritis, and stroke. The image processing-based digital count can be improved upon in addition to the currently available capabilities.

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The goal of gait analysis (Saboor 2020) is to monitor and analyse data from a live video processing project using machine learning to visualize the walking patterns of elderly people or stroke patients and to obtain an observed statistical report or analysis on how the walking pattern is as a data to be provided to physiotherapists for further treatment and analysis.

2. Materials and Methods

Pose estimation can be done using the Deep Learning algorithm as follows:

2.1. Pose Estimation

A computer vision task called pose estimation infers the pose of a person or object in a picture or a video as the raw data (Makihara 2010). Pose estimation can alternatively be defined as the challenge of figuring out the location and orientation of a camera in relation to a specific person or item. We first get the pose skeletal of the live video and display the same (R. Dabral 2019). Pose estimation gives us the ability to monitor an object or person in actual space quite precisely (Figure 1).

Detecting, associating, and tracking semantic key points are all part of the computer vision task of human pose estimation and tracking. "Left knees," "right shoulders," and "vehicle's left brake lights" are a few examples of semantic key points . Pose estimate accuracy has been hampered by the large computer resources needed for semantic key point tracking in the real-time video (Akhtaruzzaman 2016). It is significant because it may be used in numerous applications, including activity identification and higher-level reasoning in the interaction between humans and computers.

Figure 1 Pose estimation.

2.2. Gait Analysis

The gait analysis is a thorough analysis with the primary purpose of examining how people move. As a result, gait analysis is successfully used to estimate poses. It can be done through simple observation or three-dimensional analysis with measured data of joint angles (kinematics), joint forces (kinetics), muscular activity, foot pressure, and energetics (measurement of energy expended during an activity), enables the doctor to create treatments that are specifically suited to each patient's needs.

This is frequently employed in clinical research to assist in understanding gait irregularities and their association with a particular underlying medical condition for better diagnosis and prognosis.This is done using machine leanring techniques involving different deep learning algorithms (Zeng 2020). For this, a variety of technologies that are integrated into specialised devices are being used, which include wearable devices, force platforms embedded in walkways, Inertial Measurement Unit (IMU) sensors, and computer-interfaced video cameras to measure patient motion (M Asif 2022). Electrodes placed on the skin's surface also help to understand muscle activity.

2.3 Pose Estimation in Gait Analysis

The approach to gait analysis using Machine Learning is discussed in this method. With the obtained pose estimation, we classify and analyse the pattern using algorithms specifically for the same implemented with high knowledge in the domain of physiotherapy, thereby providing solutions with the obtained statistical data. Using Human Pose Estimation, the joints in the human body can be first identified and then classified based on a predefined set of coordinates for each joint in the body (L.Lee 2002)(Figures 2 and 3). Using the CNN algorithm, the key points and patterns are recognized and fed as input to the gait analysis system (Figures 4 and 5).

These key points are defined by two metrics whether the joints are found or not - Percentage of Detected Joints (PDJ) and Object Key point Similarity (OKS), out of which Percentage of Detected Joints (PDJ) is computed by equation (1),

$$\text{PDJ} = \sum_{i=1}^{n} bool\,(d_i < 0.05 * diagnol) / n \qquad (1)$$

Where the mentioned values represent the following:
di denotes the Euclidian distance between the ground truth key point and the predicted key point;
bool denotes the condition stating 1 if the condition is true and 0 if the condition is false;
n is the number of key points.

Our study uses computer vision to characterize the environment and people's behaviour in ambient assisted living. Widely, gait analysis is used for elderly people to detect syndromes and treat stroke patients (Ye 2015). However, our goal goes beyond the analysis of this particular set of people to encompass all ages and activities, including sports, rehabilitation, paediatric syndromes, and a wide range of other instances.

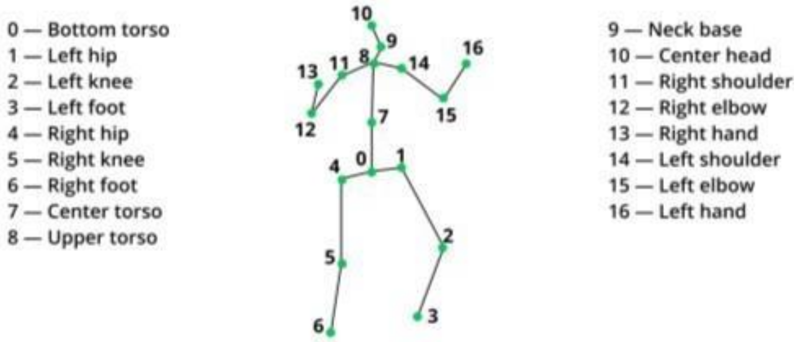

Figure 2 Key points and their specification.

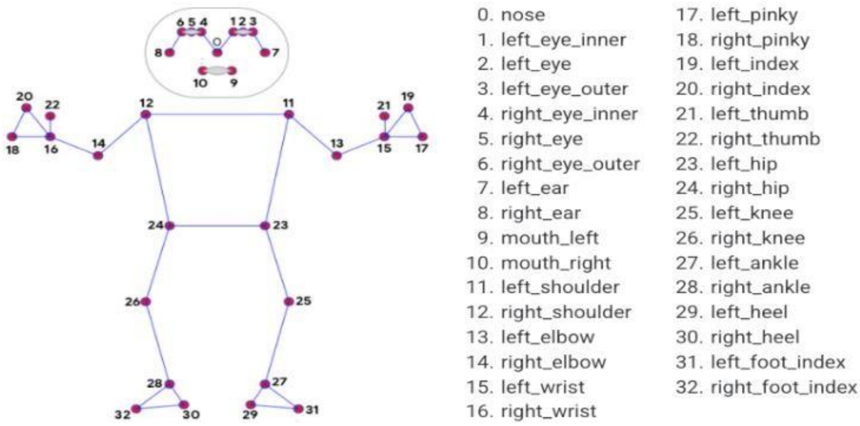

Figure 3 Joints and respective key points.

2.4. Working flow - Process

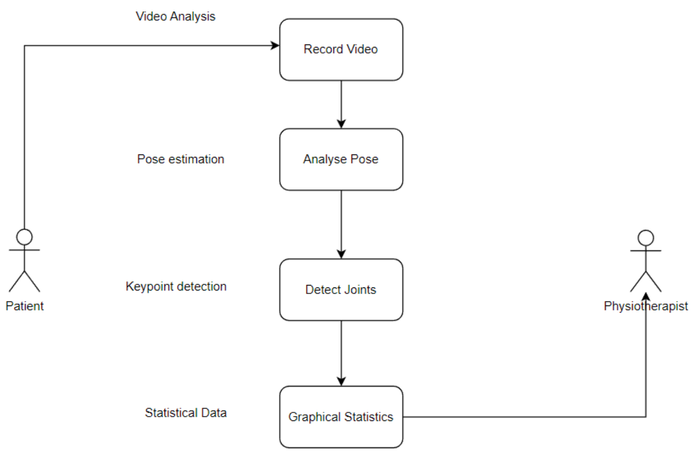

Figure 4 Process flow diagram.

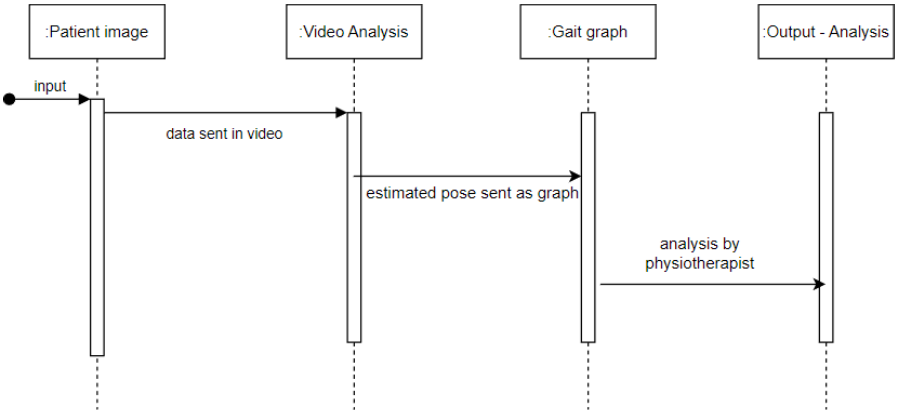

Figure 5 Sequence diagram.

3. Results and discussion

3.1 Observations based on the study

We have noted throughout our examination of the state of the art that the parameters of gait that have been studied are primarily related to the physiology of gait, which we find causally coherent because a phenomenon is characterized in terms of the parameters that control it. Pose estimation gives us the ability to monitor an object or person in actual space quite precisely. A vast array of potential applications is made feasible by this potent feature. Pose estimation also differs in some significant ways from other typical computer vision tasks. Object detection is a task that locates objects in an image. However, this localization is usually coarse-grained and consists of a bounding box that contains the object. Pose estimation takes a step further by foretelling the precise location of the object's key points. We haven't implemented gait assessment using the internet of things because usage of the same will cost a lot of sensors, and the integration part can be tedious. Considering the factors such as latency and environmental requirements for the proper working of the sensors and wearable sensors require monitoring. Therefore, this would be an easy way of analysing the gait. This perspective of gait analysis is very affordable because of the fact that it requires only a camera of good quality and a developed program to view the patient's skeletal image. Hence, this can be considered a very affordable system.

A gait graph can be generated by implementing the above, where the curves represent how a single gait variable varies over the gait cycle. The vertical lines across the full height of the graph represent foot-off and the tick marks represent opposite foot-off (to the left of the graph) and opposite foot contact (to the right. With the obtained graph, physiotherapists can analyse the abnormalities in gait. Eight fundamental pathological gaits, including hemiplegia, spastic diplegia, neuropathic, myopathic, Parkinsonian, choreiform, ataxic (cerebellar), and sensory, can be linked to neurological diseases.

Observing these gaits is a crucial part of diagnosis and can reveal details about a number of neurological and musculoskeletal problems. For calculating angles, we need coordinates of the **shoulder**, **hip**, **knee**, and **ankle**, which can be obtained from landmark points. Pose predicts the location of 33 pose landmarks.

3.2 Types of Models

It is studied and observed that there are basically three main human body models, out of which pose estimation uses the skeleton-based model to analyse the gait (Figures 6, 7.1, 7.2, 7.3, and 7.4).

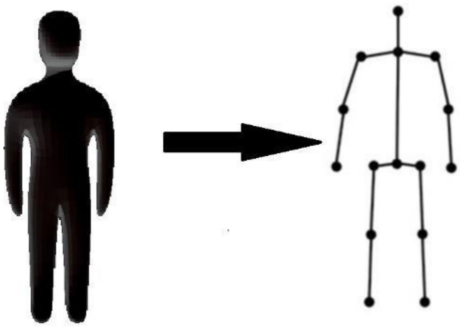

Figure 6 Types of human body models.

3.3 Test Cases

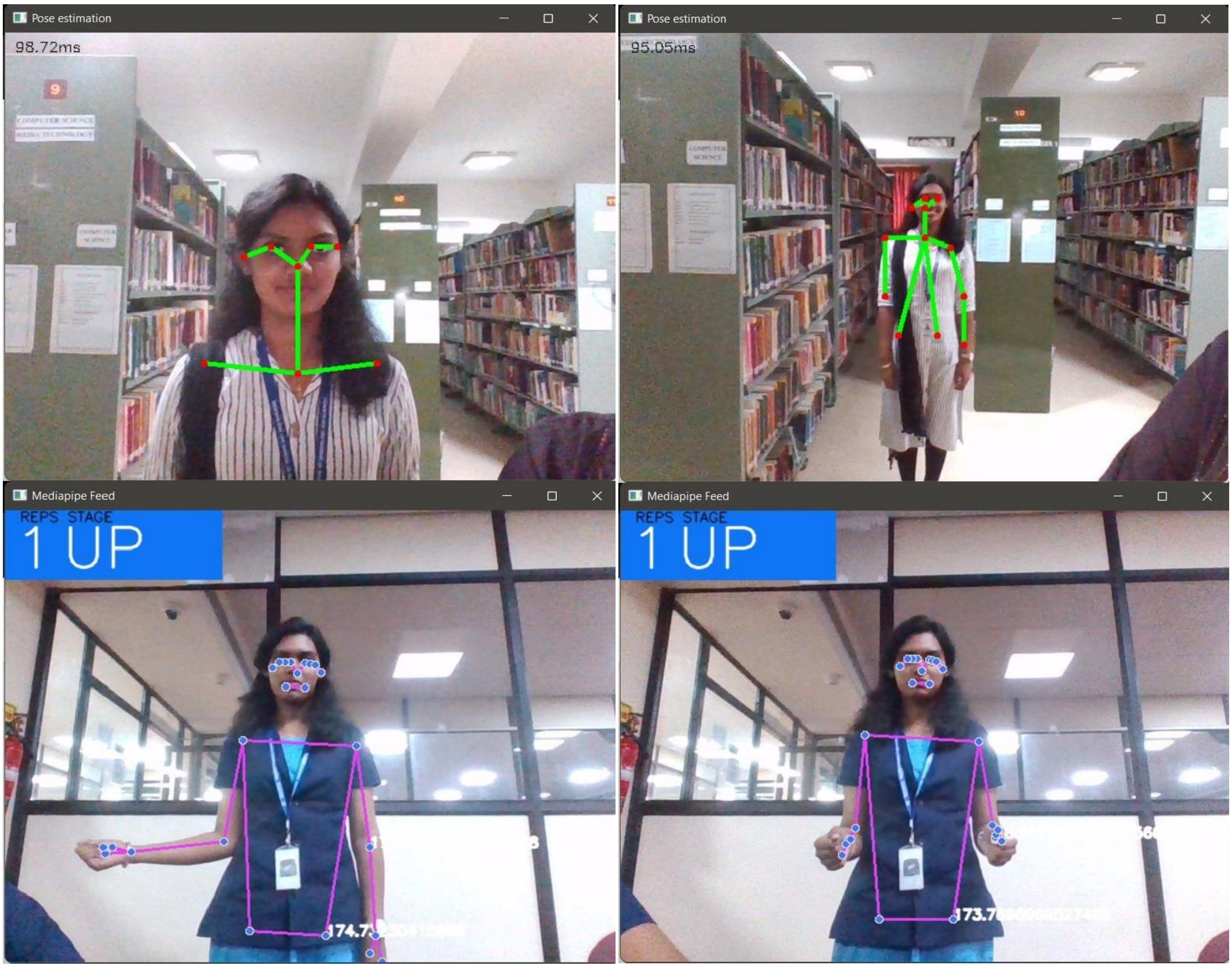

Figure 7.1 Face point detection. **7.2** Pose to detect points in the shoulders and hands. **7.3** Angle detections. **7.4** Curvatures and angles estimation.

4. Conclusions

The results for diagnosis have improved as the sensor-based approach has given way to sensor-less methods, and now the advancement of computer vision gives a better view of gait, along with different gait parameters being studied and taken into account. Though, clinical gait analysis is extremely important in the diagnosis, prevention, and monitoring of various ailments, whether they are neurological, cardiopathic, or orthopaedic in nature, this approach serves as helpful. Machine learning algorithms are used to estimate the graphical analysis of the poses. The outcome is obtained after analysing the obtained data. The fact that implementing machine learning specializing in the field of pose estimation can help in analysing the gait. The accuracy can be a matter of concern due to just the video feed as the input. In the case of implementation with sensors, the accuracy can be further improvised.

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Ethical considerations

Not applicable.

Conflict of Interest

The authors declare no conflicts of interest.

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