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Physiotherapy Pose Estimation, Detection and Correction

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ABSTRACT:

Physiotherapy exercise recognition is achieved using Deep Convolutional Neural Networks (DCNNs), which analyze the movement of key body joints over a period of time. The development process begins with assembling a relevant dataset, followed by meticulous steps such as data cleaning, labeling, and normalization to align with the model's input standards. After the training phase, the model is preserved using the Pickle module, allowing it to be deployed later without the need for retraining. The trained model is connected to a live camera stream to interpret real-time motion, calculate prediction probabilities, and identify specific exercise poses. This AI-powered system supports independent physiotherapy practice by reliably detecting a wide range of body positions using deep learning. A typical webcam is sufficient for capturing pose information, focusing on essential points of each movement. An enhanced scoring algorithm is implemented to assess pose accuracy across different exercises uniformly. The model is tested in varied environments and with diverse poses to verify its stability and performance. Additionally, a hybrid machine learning approach is used—integrating logistic regression to classify poses in real-time using key-point data extracted from video frames with OpenPose. The system's performance is validated using test data to confirm its effectiveness during live execution.

Keywords - Machine Learning, physiotherapy Pose detection, DCNN, OpenPose, Logistic Regression etc.

INTRODUCTION

Humans are inherently susceptible to a number of illnesses and musculoskeletal problems are particularly prevalent and require prompt attention these conditions which impact a sizable section of the population annually frequently result from things like ageing or unintentional traumas physiotherapy is a useful healing technique that improves and restores physical function even while exercise is generally good for your health it can be dangerous to execute physiotherapy exercises incorrectly making mistakes when self-practicing can have negative consequences rather than positive ones this means that anyone trying physiotherapy exercises on their own needs to have appropriate instruction or professional directionwhen performed properly physiotherapy enhances mental attention and body awareness in addition to physical strength and coordination however during these sessions bad posture or improper movement may result in major problems like nerve-related injuries or other consequences its critical to carefully and accurately follow the suggested physiotherapy treatments in order to prevent such results.

METHODOLOGY

Deep Convolutional Neural Networks (DCNN):

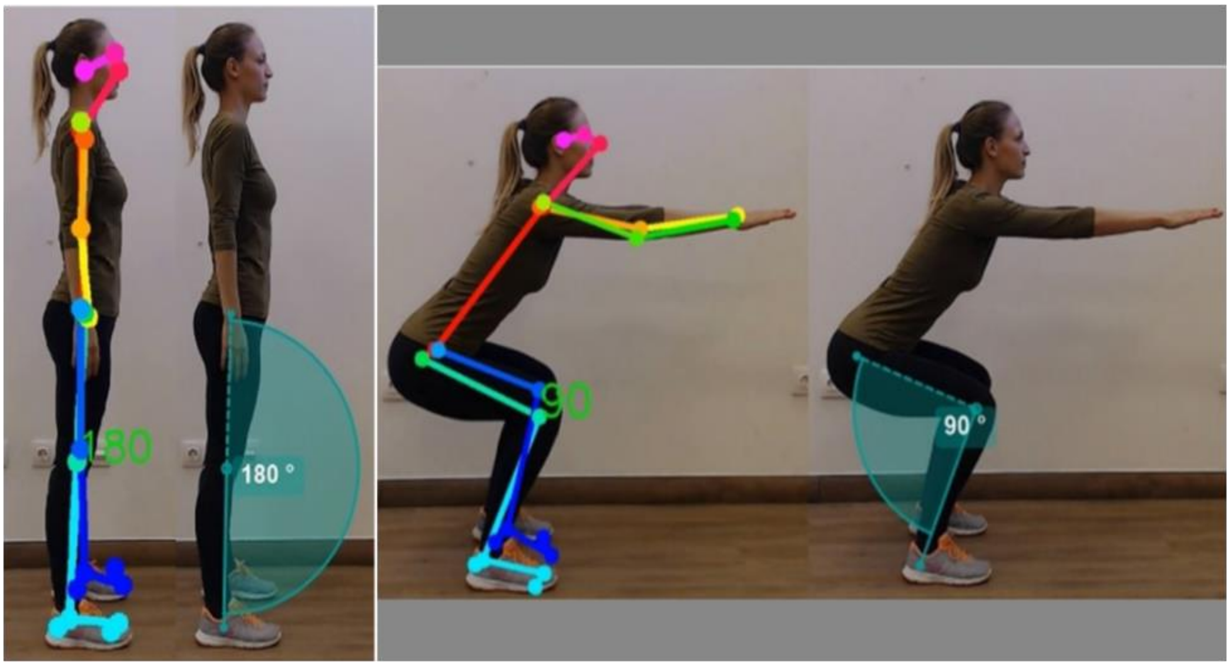
The subject of human posture estimation has made great strides in recent years thanks to the application of deep convolutional neural networks (DCNNs). These models were first used to identify human posture in 2D photos, but they have since developed to more accurately handle 3D pose estimate. Convolutional models—especially the deeper ones—have become more well-liked among the many kinds of deep neural networks (DNNs) due to their effectiveness in processing visual data like images and videos.DCNNs' three-dimensional structure improves their capacity to analyse complicated picture data, and they are somewhat modelled after the way the visual brain of animals analyses information. Personalised recommendation systems, picture classification, object identification, and occasionally even language-based tasks all rely on these models.
The hierarchical architecture of DCNNs is a crucial component that enables them to effectively process an image's RGB (red, green, and blue) channels in simultaneously. By reducing the number of individual processing units, or neurones, needed, this method uses less computing power than standard neural networks.To interpret visual characteristics, DCNNs use a method known as convolution rather than conventional matrix operations. Convolutional layers, which extract features, pooling layers, which reduce dimensionality, activation layers, which incorporate non-linearity, and fully connected layers, which compose the final outputs, are the many types of layers that typically make up the network architecture. Each element contributes in a unique way to the network's ability to recognise, comprehend, and categorise visual patterns.

Logistic Regression Algorithm:

A supervised learning classification approach called logistic regression is used to forecast the probability of a particular result. The method uses the Sigmoid function to assign probabilities and assess correlations between different variables, transforming the rawresults into a probability range of 0–

1.0. By serving as a classifier and determining if particular body parts or important details are present in a frame, logistic regression can aid with posture estimation and detection.Logistic regression is comparatively easy to use and can function as an effective model for classification tasks within larger pose estimation, in contrast to other deep learning techniques that need substantial processing resources. pipelines.

Binary Key Point Classification: Within a frame, logistic regression may categorise each key point's visibility in a certain position (e.g., hands, elbows, or knees). Utilising input characteristics such as processed coordinates, edge detection outputs, or pixel intensities, it forecasts the probability of each critical point'sexistenceFeature selection and pre-processing: To improve the efficiency of the key-point identification process, logistic regression may be used in conjunction with features produced by other models in a hybrid pose estimation framework. posture Verification: Following initial posture estimate using key-point detection, logistic regression may categorise the identified key points into specified categories, such as "correct" or "incorrect," to determine whether they correspond with a legitimate pose.Real-Time Detection Support: Logistic regression offers a quicker substitute for intricate neural networks in situations where processing speed is essential. The use of logistic regression to validate postures or find key-point presence helps speed up identification, which is particularly useful for real-time physiotherapy applications.Since some important points—like the shoulders, elbows, and knees—are crucial in establishing the stance, logistic regression may be used to categorise whether they are visible in every frame.



OpenPose:

OpenPose is a free, open-source toolkit for real-time human joint identification that can recognise 135 important locations on the hands, feet, face, and torso. It has gained popularity in the research community as a tool for 2D multi-person human pose estimation (HPE) since its debut in 2017. OpenPose takes a bottom-up method that uses 2D vector fields called Part Affinity Fields (PAFs) to record the orientation and bodily parts' locations in a picture. A new version of OpenPose was released in 2019 that combined foot and body keypoint detectors into a single framework, cutting down on inference time without sacrificing accuracy. Utilising PCs with an Nvidia GTX 1080Ti, this library achieves up to 22 frames per second (FPS) with efficiency.135 key spots on the hands, feet, face, and torso may be identified using OpenPose, a free and open-source toolbox for real-time human joint identification. Since its introduction in 2017, it has been a popular tool for 2D multi-person human pose estimation (HPE) in the research community. Using 2D vector fields known as Part Affinity Fields (PAFs), OpenPose employs a bottom-up approach to capture the orientation 2019 saw the introduction of an updated version of OpenPose that reduced inference time without compromising accuracy by integrating body and foot keypoint detectors into a single framework. This library efficiently reaches up to 22 frames per second (FPS) on PCs with an Nvidia GTX 1080Ti.

Capture Video: A webcam is used to record live video.
Frame Processing: Before being submitted to OpenPose, each frame undergoes preprocessing.
Pose Detection: OpenPose uses deep learning to identify body joints and create a skeleton.
Keypoint Extraction: It gives each joint's coordinates (x, y).
Pose Comparison: Joint angles or lengths are used to compare the detected pose to the proper physiotherapy pose.
Feedback on proper or improper posture is provided in real time by the system.
Accuracy is the basis for calculating a performance score.
Logging: Information may be stored to monitor development over time.

Tools/ Library	Accuracy	Key Points	Use Case
OpenPose	Very High	Full body, hands, face	Physiotherapy, sports, research

MediaPipe	Moderate to high	33 body landmarks	Mobile health apps, quick demos
PoseNet	Moderate	17 body keypoints	Fitness apps, browser-based tools

OpenPose can follow the entire body, face, and hands and recognise human joints with great precision. For physiotherapy, where proper body posture is essential, this makes it perfect. OpenPose produces more thorough and dependable data, making it appropriate for clinical or research-oriented settings, in contrast to lightweight tools like MediaPipe and PoseNet, which are designed for speed and mobile devices. Applications in both solo and group rehabilitation sessions are made possible by its support for real-time multi-person posture estimation. OpenPose's precision and thorough keypoint identification make it a solid option for applications that require dependability and in-depth feedback, such self-guided physiotherapy systems, even

though it necessitates GPU support and setup work.

Many non-programmers, including scientists and accountants, have embraced Python because it's very simple to learn and can be used for a range of daily chores, including financial organisation. Python is a versatile programming language that can be used for a wide range of tasks. Python is utilised in operating systems, video games, AI, machine learning, web development, and mobile application development. Python has a structured structure and is a rather simple programming language to learn. Python is a high-level, all-purpose programming language. Python may be used to create websites, online apps, and desktop graphical user interfaces.

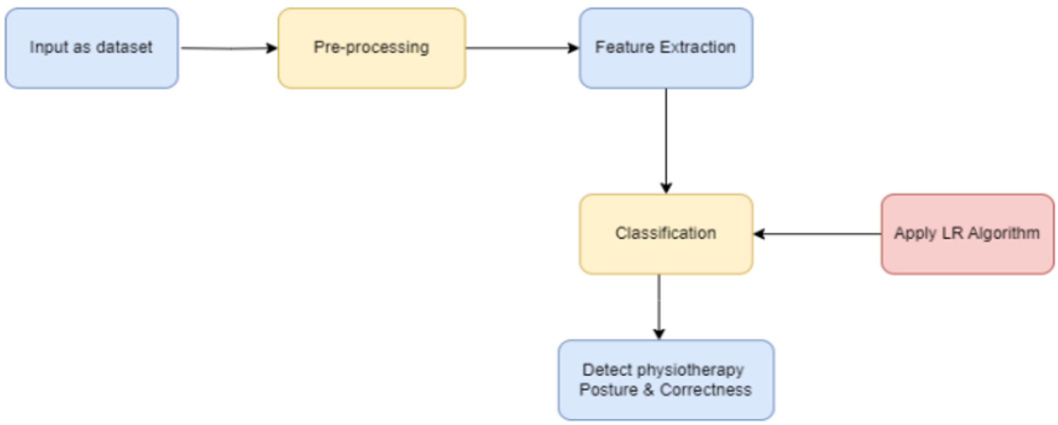
Data Collection

Python objects may be serialised and deserialised using the Python pickle module, allowing them to be stored in a file for later use. Serialisation, sometimes known as "pickling," is the process of transforming a Python object—such as a dictionary or list—into a stream of bytes that include all the data required to reconstruct the object. in a different Python application. Create the object (such as my object) before serialising it using pickle. Next, use pickle to open a file in binary write mode (wb). To store the item, use dump(). The item is safely stored in binary format thanks to this procedure. Open the file in binary read mode (rb) and use pickle to get the stored object back. To return the data to Python and return the object to its initial state, use load().By using the == operator to compare the two, you can make sure they are equivalent and verify that the loaded object matches the original.

Literature Review

The development of human posture estimating systems has been greatly aided by recent developments in deep learning and computer vision. Convolutional neural networks (CNNs) and their deep variations (DCNNs) have been utilised in a number of studies to identify and analyse human body motions. Key body joints may be detected with varied degrees of precision, speed, and complexity using tools like OpenPose, MediaPipe, PoseNet, AlphaPose, and HRNet. The capacity of OpenPose to precisely identify full-body, hand, and face keypoints in real time has made it one of the most dependable frameworks among these. Research indicates that OpenPose performs better in terms of accuracy and multi-person tracking than lightweight competitors like MediaPipe and PoseNet, although requiring more processing power.Accurate posture identification is necessary to prevent improper exercise routines that might cause bodily injury, according to research including pose estimate for medical and physiotherapy applications. To enhance the categorisation or scoring of human postures based on extracted keypoints, several studies have also included hybrid models that combine

deep learning with conventional machine learning techniques, including logistic regression or SVM. In physical rehabilitation, the application of 2D and 3D pose estimation models has drawn interest, especially in initiatives where self-guided physiotherapy requires real-time input.



Proposed Work

Through real-time body posture analysis, the suggested physiotherapy pose recognition system helps users conduct rehabilitation activities properly. The technology recognises and assesses physiotherapy positions by combining machine learning methods with computer vision capabilities. There are many crucial phases that make up the implementation process:

1. Information Gathering and Input Recording

When users are completing physiotherapy exercises, the system first records visual information in the form of pictures or video feeds. Any appropriate video capture device, such as a normal camera, can be used to gather this data. The system's fundamental input is the collected frames, which allow for the identification and evaluation of human body motions.

2. Pre-processing data

Pre-processing is applied to the raw picture or video data to guarantee high-quality input for further analysis. noise reduction by removing unnecessary background interference with filters or denoising algorithms.To increase contrast and visibility of important body areas, use colour normalisation and picture enhancement.To improve the accuracy and dependability of later keypoint extraction and categorisation, these procedures are crucial.

3. Identifying Keypoints and Extracting Features

The system uses a pose estimation framework, like OpenPose, to identify important human body keypoints once the input data has been pre-processed. Anatomical landmarks such as the shoulders, elbows, wrists, hips, knees, and ankles are represented by these keypoints. The classification model uses the coordinates of these joints as input once they have been retrieved as feature vectors. The system can conduct consistent analysis across different frames and users because to its organised representation of the human stance.

4. Training and Preparing Datasets

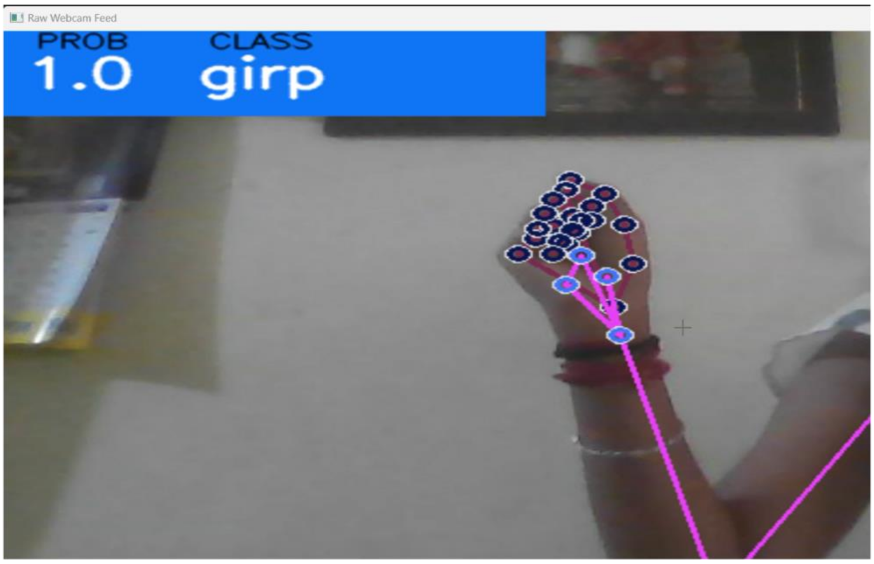
A collection of physiotherapy positions is selected in order to teach the system. Labelled examples of various workout postures, each linked to the proper and improper forms of the movements, make up this collection. Outliers are eliminated from the data, which is then labelled to differentiate between proper and improper postures and normalised to preserve feature representation consistency. For the classification model to be successfully trained, these pre-processed datasets are essential.

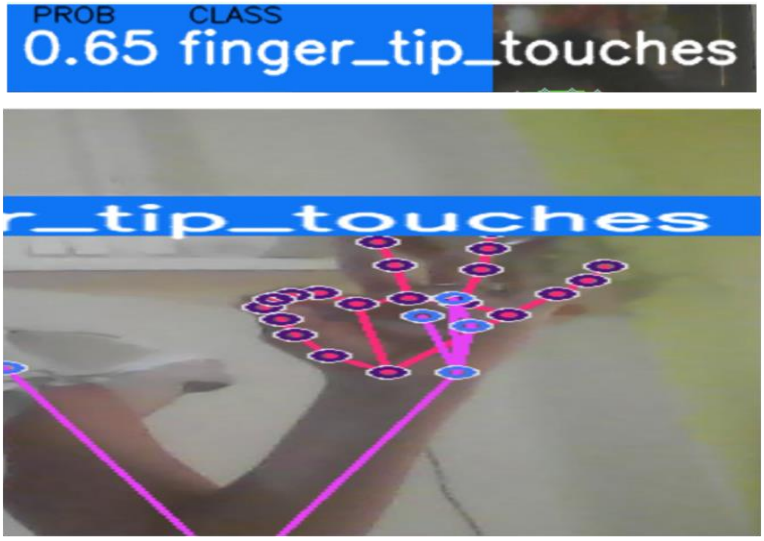
5. Developing Models using Logistic Regression

The user's stance is classified as either right or improper using a Logistic Regression (LR) classifier. The keypoint characteristics that were collected from the labelled dataset are used to train this model. The model gains the ability to link certain joint configurations to appropriate posture labels during training. The result is a trained model that can forecast if a certain position is right and generalise to new data.

6. Pose Classification and Feedback in Real Time

The user's camera provides real-time input to the trained model while it is in use. The model analyses the current pose and uses learnt patterns to classify it. After that, feedback is produced to let the user know if their posture matches the ideal physiotherapy stance. This feedback might be written or visual (such as green/red marks). The suggested method uses machine learning and position estimation to assist physiotherapy sessions without the need for continual physician monitoring. The safety, effectiveness, and accessibility of physiotherapy are improved by this system's precise body position detection and real-time feedback, particularly in remote or home-based settings.





Testing:

testable and free of critical issues. System Testing evaluates the fully integrated system to verify that it meets all functional requirements. Integration The testing process for the proposed physiotherapy pose detection system is structured and comprehensive, aimed at ensuring the software's reliability, functionality, and performance. Two key tools are utilized during the design and planning phase: Edraw Max for creating diagrams like flowcharts and UML models, and StarUML for detailed software architecture modeling using standard UML practices. These tools support effective planning and visualization of the system's structure. The test plan follows a sequential and layered approach. It begins with GUI testing to validate user interface functionality, followed by integration testing to ensure that combined software modules interact correctly. Subsequent testing phases include high-level scenario testing and validation of data handling across different modules, ensuring that the application performs accurately under various input and output conditions. Several types of testing are employed: Unit Testing verifies the correctness of individual components before they are integrated. This helps detect logic or functionality issues early by checking specific code paths and outputs against expected results. Regression Testing ensures that recent code changes do not adversely affect existing features or overall stability. Smoke Testing is conducted immediately after receiving new builds, focusing on core features to confirm the software is Testing focuses on the interaction between modules, aiming to detect faults that may not be evident during unit testing. This multi-layered testing strategy ensures the developed system is robust, accurate, and user-friendly, minimizing the risk of functional errors and enhancing its reliability for end users.

Conclusion

The proposed physiotherapy pose detection system demonstrates the effective integration of deep learning, computer vision, and machine learning to enhance physiotherapy practices, especially in home-based or unsupervised settings. By utilizing real-time video input and advanced pose estimation techniques, such as those provided by OpenPose, the system accurately identifies key human body joints and analyzes them to assess the correctness of performed exercises. The project follows a structured workflow starting from data acquisition and pre-processing, to feature extraction and classification using a Logistic Regression model. This approach ensures that only clean and meaningful data is used for training and testing, which improves the model's prediction accuracy. The feedback provided by the system helps users understand whether their posture is correct or needs adjustment, thereby minimizing the risk of injury due to improper form. Multiple layers of testing—including unit, integration, system, and GUI testing—have been applied to validate the system's performance, functionality, and usability.This system addresses a critical healthcare need by making physiotherapy more accessible and effective through technological intervention. It reduces the dependency on constant physiotherapist supervision, offers a cost-effective solution for remote rehabilitation, and promotes better user engagement in therapy sessions. In conclusion, the system not only contributes to the advancement of smart healthcare applications but also lays the groundwork for future improvements such as support for a wider range of exercises, personalized progress tracking, and integration with wearable devices for enhanced accuracy.

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