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A Standalone Reinforced Physiotherapy Equipment

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Abstract: Healthcare technology has advanced beyond human endeavors and is used in the human environment to help the humans raise healthy and well organized standards of our daily existence. The emergence of Human pose estimation in computer vision tracks human movement from simple visuals using commonly used low cost cameras (e.g. laptop cameras). These technologies offer a clear and exciting monitoring performance of the physiotherapeutic patients from home. A Doctor or a person could monitor and analyze movement of patients remotely. In fields like rehabilitation, healthcare and fitness there has been a recent trend toward implementing computer vision based equipment to enhance health monitoring efficiency and quality. These Computer vision based systems are designed to perform tasks such as monitoring the visuals and extracting the movements information from the videos or images. This project introduces a model of a standalone reinforced physiotherapy equipment which enhances the physiotherapeutic patients with well lit physiotherapy treatment according to the doctors prescription. The aim is to address common challenges encountered in the field of traditional rehabilitation. The research outlines the development of a standalone reinforced physiotherapy equipment which is equipped with a Raspberry Pi 4 and a web camera. We focus specifically on the physiotherapeutic patients who need treatment in the absence of the doctor or the fitness trainer. We review relevant literature, share views on future prospects to improve human health and performance and discuss perceived limitations.

Keywords: Pose estimation; Reinforced Physiotherapy Equipment; rehabilitation; video based monitoring device; at-home physiotherapy participation.

1. INTRODUCTION :

In the competitive landscape of Rehabilitation healthcare services, creating an unforgettable experience for the physiotherapeutic patients is essential to sustained success. Treatments that fail to leave a lasting impression will fail to fill the hope in patients. Humans have always been interested in measuring and observing the movements. This is evident in many of the hospitals, Olympics, even a running coach observes the running foot pattern to prevent the damage[1]. This observing of the movements of humans results in the state or health condition of the person.

In this research paper we focused on one of the applications of human pose estimation which is an emerging technology for monitoring human movements using various open source libraries[2,3].
The Human Pose estimation uses computer vision to identify key landmarks on the human body (e.g. nose, elbow, hip, knee, shoulder) from simple web cameras. This simplicity makes the equipment potential for measuring whole body movements in nearly any setting, with minimum costs of money, time and effort.

The Human pose estimation is a challenging task in the computer vision field, its perfect estimation of joints, and clothing make it difficult to estimate. The pose

estimation of humans depends on various axes such as single person human pose estimation. Pose Estimation of humans rely on shape, cone and mesh - based models also. The approach in which features are extracted plays a crucial role in estimating the human poses. The human pose estimation consists of a holistic view and the local view. The holistic view depends upon the joint position regression, whereas the local view is the body parts detection. After a period of time Deep Learning algorithms came into form to overcome the difficulties in the earlier approaches[5].

Furthermore, the inherent flexibility of these healthcare technologies allows the humans to adapt to the dynamic demands in the field of rehabilitation. Whether it's quantitative measurement of human movements or monitoring of the patients kinematics[4].

2. RELATED WORK

The Articulated pose estimation was traditionally structured as a prediction task that requires an inference step which combines the local observation of the joints in the body along with the spatial constraints. There are enormous formulas which have been given based on tree[6,7,8] and non - tree models. The main goal of the inference process was to refine the observations of local part detectors into coherent estimates of configurations of the body.

Top-down approach method is a straight forward expanded work of a single human pose estimation method, as the first is to detect the and crop each person and then apply the single human pose estimation algorithms [9]. And some of the papers focus on the multi - person tracking by running a different method on the ground-truth human bounding boxes. In order to detect multiple persons in a given image is one of the challenging tasks to perform, because of various poses and occlusions among the individuals. Moreover, in this approach several factors need to be taken into consideration such as number of people in the picture.The Top-down Approach applies its algorithm to group the key points of the human body into the body parts and the person. Most of the researchers use this method for multiple person pose estimation.

Bottom-up approach method predicts the overall body parts first and then assembles the all body parts to infer the full body human poses. In this method the DeepCut as a first build a pairwise graph between the detections and then parts are clustered belonging to one person. In this DeepCut, the part of the labeling task is changed into an Integer Linear Program formulation. And then finally, all the person's clusters are mixed with labeled body parts and the final multi person human poses are extracted[9]. The Bottom-up approach is quite the opposite method of the top-down approach. In simple words it first identifies key points separately in an image and then groups them into poses. Actually it uses the graph clustering algorithm in its approach. This method for multiple person pose estimation has been widely used in most of the research papers[11]. In summary the bottom-up approach has been a popular method for detecting the multiple person pose estimation. And most of the researchers have found various ways to increase the efficiency and accuracy.

In the Hybrid approach both top-down and bottom-up methods are combined. An example of this work or the approach is mask RCNN based method, in which the object detection is used cleverly to detect the people, whereas the bottom-up method is used for the human pose estimation. One of the advantages of the hybrid approach is in its robustness of the top-down method which is used to detect the people in a given image and to estimate the poses. It delivers a fine grained accuracy of the bottom-up method, but it is very expensive.

A Multi stage approach repetitiously fines the pose estimates. The integral regression networks can be considered as the example of the multi stage approach which is used to refine the extraction of the keypoints. [12] Tracking the people in a given image, the models are classified into a single or multi pose estimation. The researchers have been carried out in a single person pose estimation with good results. But even though multi-person human pose estimation gained good attention, the challenges still exist.

The challenges come from the position of each person in image, visibility of joints, apparel they wear. This article includes the Dark Pose: Distribution - Aware Coordinate Representation for Human Pose Estimation, occNet: Human Pose Estimation for Real-World Crowded Scenarios, CFA: Cascade Feature Aggregation for Human Pose Estimation, HRNet: Deep High - Resolution Representation Learning for Human Pose Estimation, Simple Baselines for Human Pose Estimation and Tracking, CPN: Cascaded Pyramid Network for Multi-Person Pose Estimation, Realtime Multi-Person 2D Pose Estimation Using Part Affinity Fields.

It comes with the two common approaches in Pose Estimation in which the two methods are employed in estimating the pose of individuals in an image. The methods are namely Top down approach and Bottom up approach.

The results of some of the research [13] demonstrate that these 2D pose estimation models that are easy to use for remote rehabilitation purposes, can be compared with the 3DMA in an analysis. These outcomes are stronger in flexion and extension of the body muscles. However these outcomes are based on small selected movements.

The continued development of the human body pose estimation methods provide an exciting potential for the quantitative assessment of the human movement kinematics. And the human body pose estimation algorithms directly addresses a widespread problem of low cost, easy use, and accessibility to the technologies which enable human pose tracking in virtual environments namely home, clinic, schools, offices, playgrounds and other places. It mentions that the limitations of the pose estimation are the limited data, capture errors, positional errors, and recording devices. In addition to this the application of pose estimation in human health and performance provided the information about the clinical motor assessment in adult neurological conditions.

The clinical assessments result in the outcome measures which are critical to motor rehabilitation in adults with the severe neurologic conditions or the symptoms. These measures are typical to capture the patient's status at a point in time or to monitor their motor function. The Applications of Pose Estimations in Health and Performance across the Lifespan mentions that there are several different algorithms for the human body pose estimation. Namely OpenPose, DeepLabCut, DeepPose, DeeperCut, AlphaPose, Arttrack and many others. For instance , a commonly used algorithm is the human pertaining to OpenPose which works on the landmarks of the body, feet, hands, and the face.

The robot arm[14] which is designed on the basis of mediapipe and opencv is different because it works in real time without any delay. AI based methods are applied to detect the hand gestures. The Accuracy was measured by testing the robotic arm under multiple conditions. The finger movements, color and the distance have been considered for measuring the accuracy of the arm about 96%. The software frameworks include Arduino IDE along with the Arduino Nano using the C language, Pycharm IDE for image capturing and processing. Mediapipe and OpenCV libraries were used to develop the robotic arm. Using the landmarks of the hand the mediapipe splits the gestures of the hands into two parts: Palm detection and key points landmark detection.

3. Proposed System Methodology:

The HPE (Human pose estimation) is a basic task in the computer vision field which involves locating the landmarks or the key body points in an image or a video. An accurate and efficient human pose estimation is very important for various applications, which includes face recognition, gesture recognition, and human - computer interaction. In this study, we propose a robust approach for a single person pose estimation using Mediapipe, OpenCV, a widely adopted computer vision libraries.

Our approach is to leverage the power of Media Pipe and OpenCV's pre-trained deep learning models, in particular the Open Pose model, to detect and extract the landmarks or the key body points. We utilize the tensorflow, mediapipe, opencv altogether to extract the features and predict the landmarks accurately.

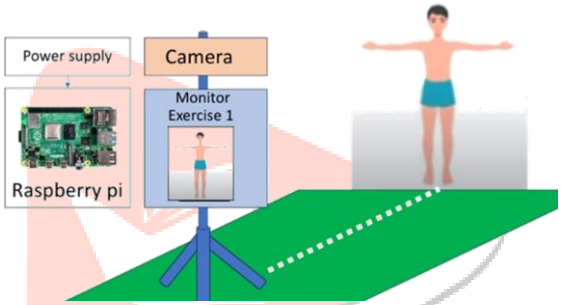


Fig.3.1: Schematic of reinforced physiotherapy equipment

The flow of the project would typically involve the following steps:

- The Equipment is switched on with the Power supply.
- The Physiotherapeutic patient stands in front of the equipment at a distance of 8 - 10 feet.
- The Command Prompt is given with the Python file.
- Tkinter GUI will be opened for the selection of the physiotherapeutic exercises as prescribed by the doctor.
- The camera module starts to Capture the movements of the patient.
- Landmarks of the person are extracted by the Mediapie.
- If the criteria for flexion and extinction of the targeted muscle is met the count increases.

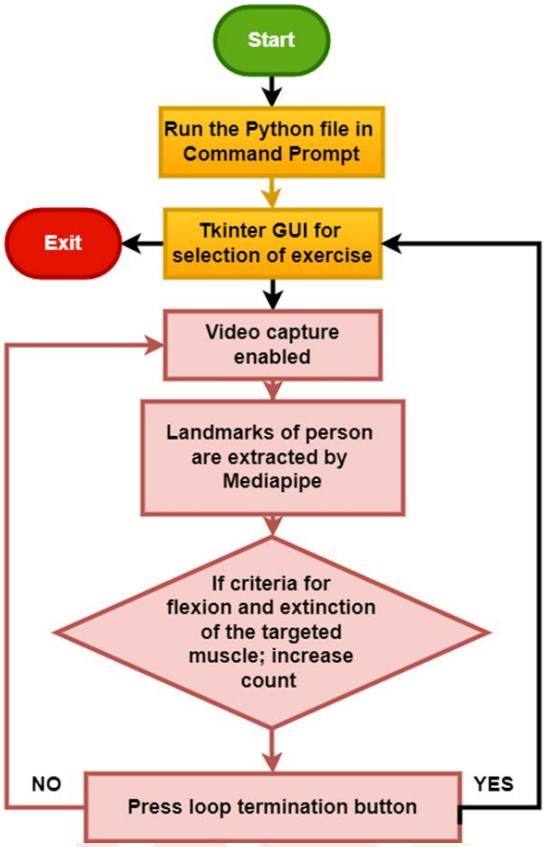
3.2 Selection of Components:

The system architecture of the project consists of several components that work together to achieve the desired functionality. The components are Raspberry Pi 4 Computer, Model, Consistent 17 Inch Led Monitor, Zebronics Camera Module, PiBox India for Raspberry

Pi 4 Case, Frontech Premium 2.0 Channel USB, Raspberry Pi 4 Usb Type C Power Adapter, SanDisk Ultra 64 GB Micro SDXC, Mouse, Keyboard.

These components are responsible for gathering information about the physiotherapeutic patient.

3.3 Design and Implementation:



To enhance the rehabilitation process, Design and implementation of stand-alone rehabilitation equipment using reinforced therapeutic exercises for improvement of targeted muscle strength.

It is an Innovative solution designed to integrate technology seamlessly into physiotherapy practices.
This project aims to bridge the gap between traditional physiotherapy methods and Technology-induced physiotherapy; providing patients a more engaging and effective rehabilitation experience.

The Standalone Reinforced Physiotherapy Equipment (RPE) is an innovative solution designed to revolutionize physiotherapy practices through the integration of advanced technology concepts and safety features
This Equipment is particularly designed for 4 exercises namely:

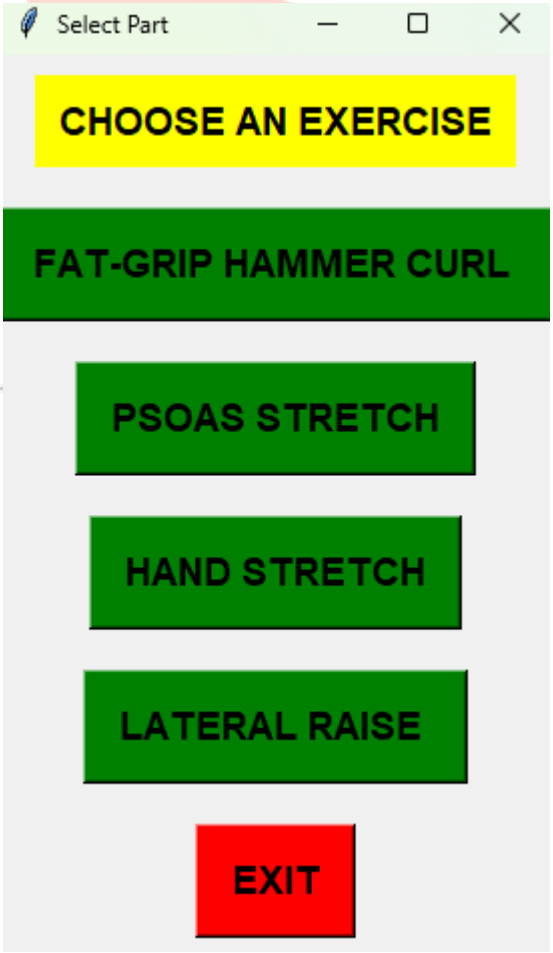
1. Fat Grip Hammer Curl
2. Psoas Stretch
3. Hand Stretch
4. Lateral Raise

When the Python file is executed in the command prompt the Tkinter GUI appears with the menu of the exercises that the patient wants to perform. The Physiotherapeutic patient has to choose one exercise which he has to perform and start doing the exercise in front of the equipment at a distance of 8 - 10 feet from the Display Module.

The menu in this equipment comes with the four exercises. These exercises are designed with the help of Mediapipe and OpenCV Python Libraries. The selected exercises focus on the targeted muscles of the Physiotherapeutic patient and enhance the reliability of the patient.

This promotes the movement in the patient and causes the person to gain physical health by the movement of flexion and extension of the targeted muscles. The equipment comes with the number of repetitions of the exercises the physiotherapeutic patient performing. It monitors the movement of the patient and counts the repetitions of the hands and legs or the body parts.

3.3.2 Proposed Exercises



1. Fat Grip Hammer Curl:
This exercise will increase the strength of our grip. It stimulates the muscle fibers in our hands, fingers and forearms. The flexion and extension of the arms helps the patient to build the upper and lower arm muscles which are brachialis and brachioradialis.

This enhances the stronger grip for pulling and other strength and power movements. This improves the muscle development in the forearms. These also indirectly contribute to muscle strength gains in the biceps and triceps.

2. Psoas Stretch:

Stretching the Psoas muscles can help the patient relieve tension, improve the posture, and reduce the risk of developing pain in lower back, hips and legs. The flexion and extension of the psoas muscles improves the mobility of the knee.

Psoas muscles along with the iliacus muscle, makes up the iliopsoas unit which is very important or essential for correct standing or sitting.Sitting for a long period of time can cause the psoas muscles to become tight. An easy stretch can help prevent or treat tightness of the psoas muscles.

3. Hand Stretch:

The Hand Stretching helps in improving the blood flow, reducing risk of injury, easing pain and stiffness and increasing flexibility. It helps us to lengthen our muscles and tendons in hands and in wrists.

It improves the flexibility of the hand muscles and results in the better performance of our physical activities.

4. Lateral Raise:

The Lateral raises are extraordinary exercises for muscle building and strength in the shoulder and upper back. This exercise improves the core muscles and stabilizes us.

The defined shoulders can be achieved by doing the Lateral raises. It strengthens the muscles situated in the shoulders and upper back muscles of the body. It results in the enhancement of the shoulder movement.

3.4 Software Libraries:

A. Media Pipe:

It is an open - source framework which is used to build the pipelines in order to perform the computer vision inference over data such as audio or video. It was developed by Google which provides tools and libraries for the AI and Machine Learning Applications.

It provides easy to use abstractions and flexible tools on top of tensor flow. The Mediapipe framework is a low level component which is used to build one of the efficient on-device machine learning pipelines.

It helps with the rapid prototyping of pipelines with artificial intelligence models. It deploys computer vision applications into demos.

B. OpenCV:

The OpenCV is used for image processing and computer vision tasks. It is one of the open source libraries which performs tasks like detecting the face, and tracking the objects and detecting landmarks and much more.

It plays an important role in real time operation which is crucial in today's systems. With this we can even read an image, enhance an image, detect an object in the image and much more.

This library can be used for face recognition, image analysis, object detection, etc. The abbreviation of OpenCV is Open Computer Vision Library. It gives real time optimized Computer Vision tools. It enhances the real time monitoring of the objects and persons.

4. RESULTS

The design of RPE is successful and the developed software code for Fat-Grip Hammer curl, Psoas stretch, Hand stretch and Lateral Raise exercises to strengthen the Biceps bronchi and Psoas muscles located at the Arm and Leg respectively are successfully demonstrated.

However, the dynamic changes in the position of the practitioner pose a challenge in the successful measurement of counts. This may be avoided by improving the computational efficiency and structured instructions to the practitioner.

Fig. 4.1.1 Result of Fat-Grip Hammer Curl exercise captured through RPE.

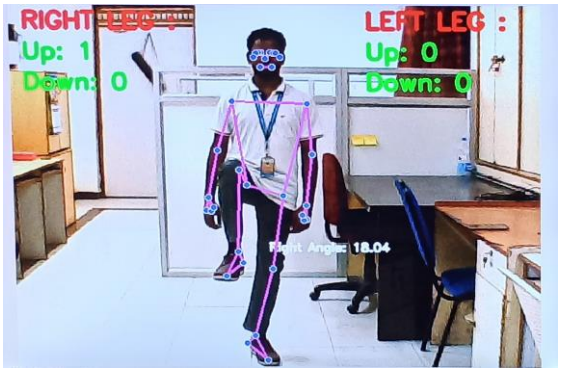


Fig.4.1.2 Result of Psoas stretch exercise captured

through RPE, Right and left leg psoas strength count displayed on screen and feedback to the practitioner.

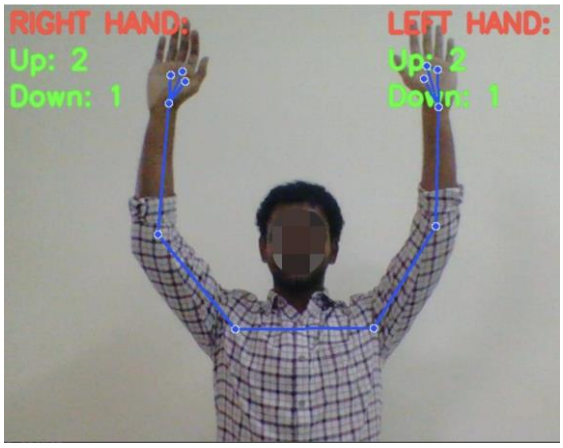


Fig 4.1.3 Result of Hand Stretch exercise captured through RPE, Right and left hand stretch count displayed on screen and feedback to the practitioner.

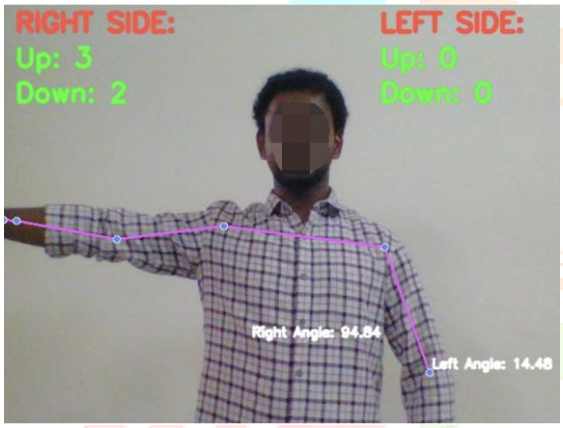


Fig 4.1.4 Result of Lateral Raise exercise captured through RPE, Right arm raise count displayed on screen and feedback to the practitioner.

5. Conclusion

This Standalone Reinforced Physiotherapy Equipment represents a new way of approach to rehabilitation, emphasizing personalized, technology-driven, safety features, and user-friendly design, it aims to revolutionize physiotherapy, providing an effective and engaging path to recovery. This equipment fills the gap between the physiotherapeutic patient and the doctor. The Fat- Grip Hammer Curl, Psoas Stretch, Hand Stretch and Lateral Raise exercises developed in this equipment provides the patients to train their targeted muscles. This study shows that there is a chance that the healthcare field can advance with computer vision based technology.

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7. Author's Note

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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