Grenze International Journal of Engineering and Technology, July Issue

Artificial Intelligent Physiotherapy

Shalini Singh[1], Sonal Khule[2], Shubham Wakhare[3], and Vedant Yadav[4]
[1]Sinhgad Academy of Engineering, Pune, India
Email: shalinisingh10799@gmail.com
[2-4]Sinhgad Academy of Engineering, Pune, India
Email: {sonaldkhule, Shubham.c.w}@gmail.com, {vedant.y}@outlook.com

***Abstract*—Physiotherapy is the trending medication for curing bones related injuries and pain. In many cases, due to sudden jerks or accidents, the patient might suffer from severe pain. Therefore, it is the miracle medication for curing patients. Our aim here is to build a framework using Artificial Intelligence and Machine Learning for providing patients with a digitalized system for physiotherapy. Even though various computer- aided assessment of physiotherapy rehabilitation exist still recent approaches for computer aided monitoring and performance lack versatility and robustness. In our approach we have come up with proposition of an application which will record patient's physiotherapy exercises and also it will provide personalized advice based on user performance for refinement of therapy. By using OpenPose Library, our system will detect angle between the joints and depending upon the range of motion it will guide patient in accomplishing physiotherapy at home. It will also suggest patients about different physio-exercises. With the help of OpenPose it is possible to render the patient's images or real-time video.**

***Index Terms*— Physiotherapy, Artificial Intelligence, Machine Learning, OpenPose, Rendering.**

I. INTRODUCTION

A. Motivation

Physiotherapists often work with other health professionals to meet individual's health care needs. These days demands of physiotherapist are increasing but there is a lack of supply. Also, there are many benefits of physiotherapy which includes avoiding surgery, improved mobility and development, management of age related problem and improved balance. With increase in demand of physiotherapy its demand at home is also rising. But we cannot deny the fact there are some advantages of physiotherapy at home. At home better health outcomes are observed when a person is surrounded by people with whom they feel connected and at home they feel positive. Also, it is observed that at home healing is done faster.

It is observed that technology in the field of medical has been proven very beneficial. Varied amount of applications are being developed which are making life of doctors as well as patients easier. Technologies such as virtual reality, artificial intelligence and machine learning are among the most popular one in Medical applications. Exo-skeleton is one of them which is use for arms, legs and hands videogames that motivate patients to move and motivates them to improve.

With the help of applications like these medical technology therapists are getting tools they need to give the kind of care and support which is required by the patients in need. It is also decreasing workloads from the

Grenze ID: 01.GIJET.6.2.504

therapists and providing them means to treat more patients than before. Therefore, advancement of technology in medical with the help of cutting edge technology inspired us to develop a system which will be changing the lives of therapists as well as patients everywhere.

B. Problem Statement

People might have injured joints and cannot use their limbs to their full extent, such as after a fall, a stroke, or an accident. There is a need to develop an application to distinguish normal person and affected person using artificial intelligence and machine learning to provide the need of physiotherapy to the affected people. We are proposing an idea of an automated system which will track human range of motion while tracking physiotherapy exercises of patient.

C. *Background*

In recent years with increase in treatment of injury, physical strength, functioning of body and overall movement of body with involvement of science of movement of body rather than involvement of drugs and surgery has evolved need of physiotherapy. With increase in physical activity the demand of physiotherapy has increased. As well as it has increased the requirement of rehabilitation centers and demand of physiotherapists. Technology in the field of medical is now acting as supporting system of workload on physiotherapists.

Artificial Intelligence is technically defined as the development of technology which is used to perform technology operations which require involvement of human intelligence. Recently Artificial intelligence is playing major role in advancement of technology. Machine learning is one of the key component of artificial intelligence and it provides us with the ability of both supervised and unsupervised learning for training our model. Also, there are copious amount of model provided by machine learning which can be used for better training and prediction of our system. AI technology today can be in different forms such as software programs as well as hardware interface to develop a system which is capable of learning from their own datasets. In our project AI with machine learning can be used for posture detection and then assessment of patients.

Open Pose is an open source library developed in C++ for the posture detection. It is used by importing open pose and later image is passed as NumPy matrices which is then converted to human key points. It is combination of Caffe, OpenCV, and OpenCL which is used for rendering of passed image. It is used in different fields such as hand gesture detection, Basketball games for prediction of basket throw and various other sports activities. It is also easier to use because of its capability to replace methods which involve high cost along with more equipment and time for processing.

II. LITERATURE SURVEY

Evolving technology has always been a great contribution in the field of Medical. With new technology we can see new approaches to solve problems faced in the field of medical. In our approach we took inspiration from previous work performed in the field of physiotherapy to contribute our idea. Different approaches have been used for advancement in the field of physiotherapy such as using inertial sensors, virtual reality etc.

For providing a deep learning framework for physical rehabilitation exercises, Min Xian [14] has proposed a computer aided system which evaluated patient's performance according to the data collected by a sensory system. Main components of the framework are the metrics which are used for performance evaluation. It is done on the basis of log-likelihood of Gaussian mixture model and encoding of low dimensional data representation obtained with a deep learning neural network. For validation of frameworks they have taken ten rehabilitation exercises.

David M Burns [13] along with his team mates has developed a system which deals with limitation of tools available for the proper measurement of adherence which occurs in the home setting of physiotherapy. Main goal of this research was to develop a measurement solution using smart watch. It can be used commercially to check and evaluate performance of shoulder physiotherapy which is performed at home. They used approach in which data of physiotherapy is collected by 6 axis inertial sensor. Data collected from the activity is then given to Activity recognition chain framework. ARC was designed with four supervised learning algorithms. It was validated using 5 fold cross validation. In main result it was observed that accuracy which was obtained using classification was above 94% and it was also observed that best performance was achieved using CRNN algorithm. Accuracy obtained by CRNN is 99.4 %.

In our approach for rendering of video obtained after physiotherapy we have used Open Pose library. Zhe Cao [4] has worked upon Real-time 2-D pose estimation using part affinity field. In this paper main objective was to obtain human 2D pose estimation where there was challenge of dealing with multiple people in images. This paper dealt with various challenges. First challenge was that an image can contain unknown number of people that can appear at any position or scale. Second problem that can arise because is interaction between people. Third problem can occur because of performance issue, as runtime complexity tends to increase with the increase in number of people in the image.

III. PROPOSED SYSTEM

Our proposed system consists of series of processing starting from recording of video at one end to evaluation of pose detected at the other end. Our proposed architecture consists of different stages such as video recording, pose detection, estimation of human key points and lastly evaluation of physiotherapy for betterment of therapy. Given below is the architecture of our system which includes pipeline of our proposed idea.

A. Uploading Recorded Video

Initial step for the patient who will be using our system will be to record video of the exercise patient will be performing. In recording of video we are providing complete flexibility to user. Patient will be given complete liberty to let them crop and to choose which video they want to upload. Once patient will be done recording and uploading video, next step will involve our posture detection library. Posture detection library will be used for rendering and generating human key points using Open pose which is built on C++ and includes Cafee, OpenCV, OpenCL and Cuda.

B. Posture Detection

Our proposed system consists of series of processing starting from recording of video at one end to evaluation of pose detected at the other end. Our proposed architecture consists of different stages such as video recording, pose detection, estimation of human key points and lastly evaluation of physiotherapy for betterment of therapy. Given below is the architecture of our system which includes pipeline of our proposed idea.

C. Scoring Function

In our system after we are done with the detection of key points then we execute our parser which uses key points as input. These set of key points is recorded in the form of x and y coordinates where x will represent frame of recorded video and y represents angle which is recorded. These set of inputs which we will get after posture detection will be then compared with already fed input key points of particular exercise performed by healthy person.

Later depending upon the values of current therapy key points and already fed key points error will be calculated. For calculation of scoring function we will take average of error which will be normalized to range between 0 and 1. After the calculation of score of therapy, current score will be then compared with previous score for evaluation of progress.

IV. WORKFLOW

In brief complete workflow of our project consists of steps of processing which will include uploading video of exercise, pose estimation, scoring function, result and sending of feedback to doctors for further suggestion. At the initial stage users will be expected to register and depending on the instructions of musculoskeletal exercises they will be required to record video of the exercise. At the later stage of processing pose estimation will be executed and it will be analyzed under the machine learning algorithms.

In our proposed system along with video, few extra inputs such as weight, height etc. will also be asked for accuracy of analysis. As we are going to consider range of motion for the analysis of physiotherapy therefore, there are different perspectives which are needed to consider in our model. Person with different weight have different joint angles and if not taken into account can result in inaccuracy of desired results.

Last stage of our model will present result in different format such as tabular or graphical representation of results. These reports will be then forwarded to doctors whom you need to consult, which will incorporate involvement of doctors in the process of your recovery. Inclusion of diet charts will also add as extras in our system because it is an important step in recovery of any patient with little bit of motivation and positivity.

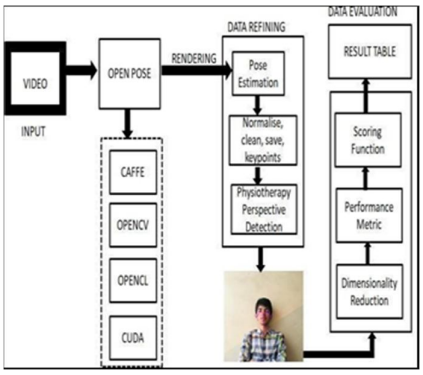


Figure 1. Workflow of the Model

V. SOLUTION

A. Image Rendering and calculation of angles

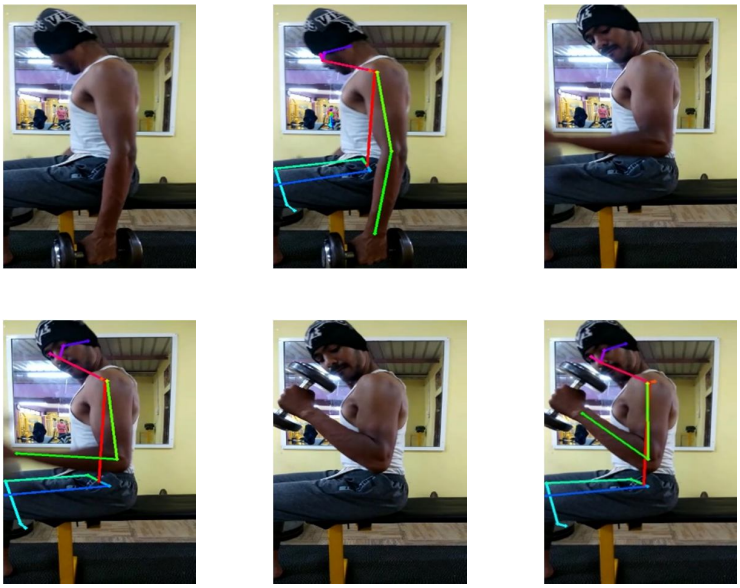


Figure 2. Rendered images of Bicep curl exercise

We have used Open Pose library for rendering of each frames of video uploaded by user. Open pose library helped us in finding out Co-ordinates of joints. To increase accuracy of finding out joints, it has included confidence value also. Confidence value along with x and y co-ordinates is used to determine probability of joints present at rendered key point. If value of n is greater than 0.50 then only presence of joint is considered at specific x and y coordinate. To optimize time complexity of rendering, we initially thought of compressing the image. But we observed that with decrease in quality of image, accuracy of representation of key points in rendered image also decreased. We also observed that there was no substantial difference in time complexity with respect to compression of image. After researching for various methods we finally decided to proceed with image of 720p h264 codec.

B. Classification of user using health status

After researching and studying various physio reports we concluded that range of motion of every body part varies with respect to health status of human. Therefore, it was necessary in our approach to classify users into different categories. For classification of users into different categories we used random forest classifier. Major categories in which users are divided are Normal, Overweight, Weak, Extremely weak, Obesity and Extreme Obesity. Our dataset consists of 500 users.

```
Primary arm: Left
nose: 709.722,709.722
neck: 648.993,648.993
lshoulder:
635.202,635.202
lelbow:
664.575,664.575
lwrist:
727.392,727.392
rshoulder:
664.671,664.671
relbow: 0.0,0.0
rwrist: 0.0,0.0
lhip: 631.363,631.363
lknee: 668.556,668.556
lankle: 0.0,0.0
rhip: 660.714,660.714
rknee: 623.522,623.522
rankle: 0.0,0.0
leye: 680.314,680.314
reye: 725.315,725.315
lear: 621.626,621.626
rear: 0.0,0.0
```

```
Primary arm: Left
nose: 711.649,711.649
neck: 650.896,650.896
lshoulder:
633.301,633.301
lelbow: 674.44,674.44
lwrist:
862.489,862.489
rshoulder:
668.574,668.574
relbow: 0.0,0.0
rwrist: 0.0,0.0
lhip: 674.429,674.429
lknee:
686.173,686.173
lankle: 0.0,0.0
rhip: 690.101,690.101
rknee: 0.0,0.0
rankle: 0.0,0.0
leye: 680.412,680.412
reye: 727.383,727.383
lear: 627.456,627.456
rear: 0.0,0.0
```

```
Primary arm: Left
nose: 713.702,713.702
neck: 652.923,652.923
lshoulder:
637.193,637.193
lelbow:
680.284,680.284
lwrist: 809.64,809.64
rshoulder:
670.54,670.54
relbow: 0.0,0.0
rwrist: 0.0,0.0
lhip: 641.132,641.132
lknee: 0.0,0.0
lankle: 0.0,0.0
rhip: 701.88,701.88
rknee: 0.0,0.0
rankle: 0.0,0.0
leye: 686.18,686.18
reye: 731.259,731.259
lear: 631.335,631.335
rear: 0.0,0.0
```

Figure 3. 18 key points of three frames

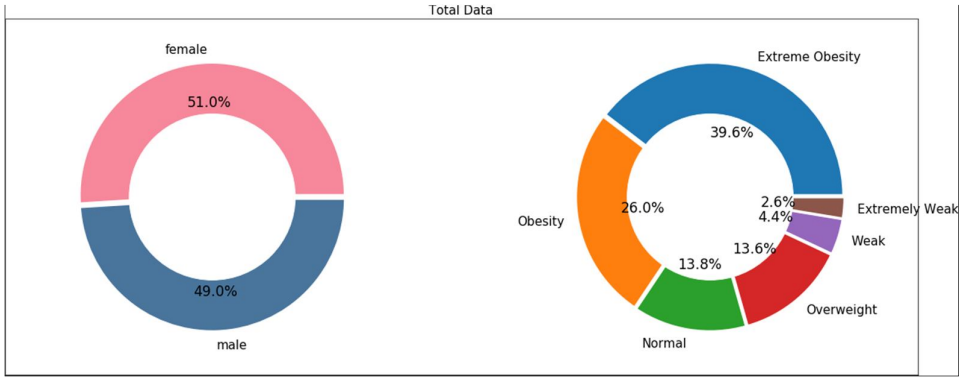


Figure 4. Categorization of user into different health status

In our classification approach for checking accuracy of our model using Random forest classifier, we also took into consideration number of decision trees required. Our model gave us 91% accuracy with 200 decision trees. Given below is graph of no of decision tress vs accuracy of model.

C. Comparison of curves using DTW

In previous stage of our work we calculated angles for each frame. Then at this stage of our work for performance analysis of exercise we will compare range of motion of healthy person with person who needs physiotherapy. For comparison of angles we will compare curves obtained by plotting angles of every frame. For exercise of bicep curls we took into consideration angle between forearm and upper arm and angle between torso and upper arm. Dynamic type warping (DTW) is an algorithm which is used to compare distance between two sequences of curves. Given below is result obtained after comparison of two curves.

D. Evaluation of progress

In our model for progress evaluation we developed a score function which will be calculated on the basis of DTW algorithm. Results which we got from DTW algorithm were long in range. Therefore to confine our

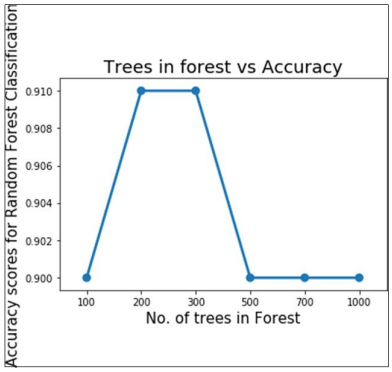
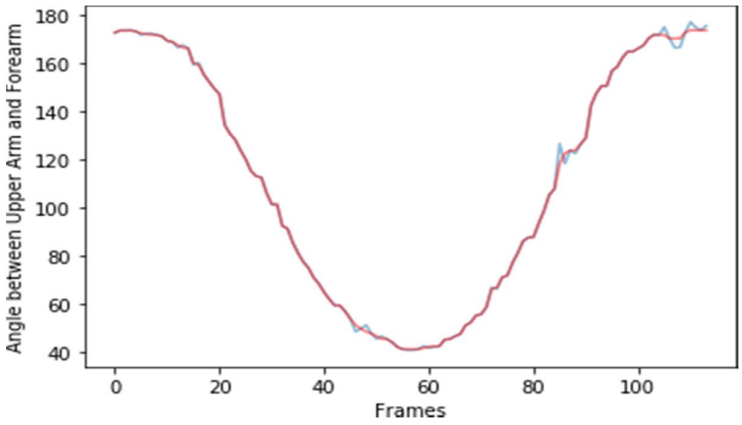
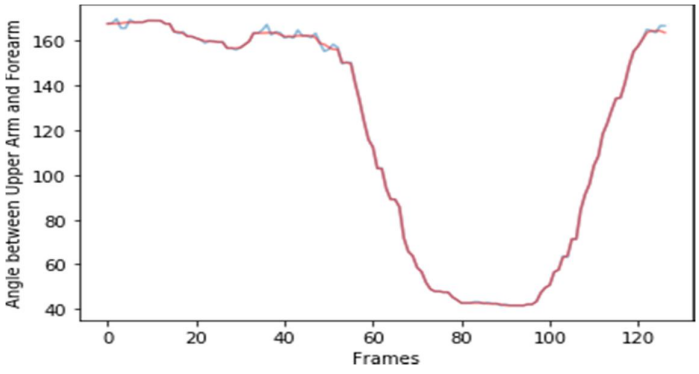


Figure 5. Accuracy scores for Random Forest Classification




```
Minimum Angle between Upper Arm and Forearm:40.74
Range of angle between Forearm and upperarm: 136.50999704877233
```

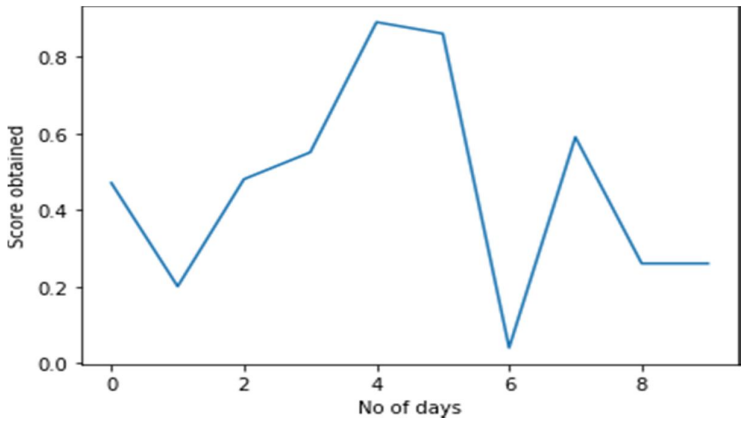
Figure 6. Curve obtained for healthy person




```
Minimum Angle between Upper Arm and Forearm:41.56
Range of angle between Forearm and upperarm: 128.26308161698847
```

Figure 7. Curve obtained for person who needs physiotherapy

range of values from 0 to 1 we used normalization techniques. If score obtained is greater than 0.75 then performance of exercise is good. If score is between 0.5 and 0.75 then performance is average. If score is less than 0.5 then performance is poor and requires hard work. Progress curve is plotted at the end to give clear picture of exercise progress for duration of time.




```
Your average performance score at present is:0.46
Your Performance is not impressive. You need to work hard next time
```

Figure 8. Progress curve

VI. Conclusions

Our approach will be an end to end computer vision application which will be using pose estimation technique and visual geometry to provide personalize feedback on fitness exercise. We are using Machine learning because it has potential to involve physiotherapy practice through human level diagnostic, decision making and measurement. We are also using a function to score which will map the performance metric into movement quality scores and to generate metrics score for repetitions of exercises. We use output of pose estimation with the help of open pose to evaluate physiotherapy videos to evaluate exercise through human pose key points. We will be using this to for assessing and improvement of rehabilitation exercise.
In future scope we can also add a chat bot system which will solve the issue of reluctant nature of patients toward physiotherapy. Mostly patient's don't see improvement in therapy because there are some set of exercises which are needed to be performed with strict discipline. Most of the patients don't follow regularity in their therapy. Therefore, this chat bot system will be using cognitive therapy for understanding of psychology of patients for faster healing of them and to maintain regularity. It will also be able to keep track of their routines and it will chat with them on regular basis for collecting more data for processing of psychology. Thus we will be able to make a system which will not only be providing support for physiotherapy but it will also help in maintaining emotional stability of the human for healing.

References

[1] Nijeweme-d'Hollosy WO, van Velsen LS, Poel M, Groothuis-Oudshoorn CG, Soer R & Hermens H. Evaluation of three machine learning models for self-referral decision support on low back pain in primary care. International journal of medical informatics. 2018; 110, 31-41. doi: 10.1016/j.ijmedinf.2017.11.010.

[2] Masato Nakai, Yoshihiko Tsunoda, Hisashi Hayashi, Hideki Murakoshi, Prediction of Basketball Free Throw Shooting by Open- Pose, School of Industrial Technology, Advanced Institute of Indus- trial Technology 1-10-40, Higashiooi, Shinagawa-Ku, Tokyo, 140- 0011, Japan, October, 2018

[3] López-Solà M, Woo CW, Pujol J, Deus J, Harrison BJ, Monfort J & Wager TD. Towards a neurophysiological signature for fibromyalgia. Pain. 2017, 158(1): 34-47.

[4] Zhe Cao, Student Member, IEEE, Gines Hidalgo, Student Member, IEEE, Tomas Simon, Shih-En Wei, and Yaser Sheikh, OpenPose: Realtime Multi- Person 2D Pose Estimation using Part Affinity Fields, 30 May 2019.

[5] Christopher Tack, Artificial intelligence and machine learning — applications in musculoskeletal physiotherapy, Guy's and St Thomas' NHS Foundation Trust, Guy's Hospital, Great Maze Pond, SE1 9RT, London, UK, 2019.

[6] Kianifar R, Lee A, Raina S & Kulić D. Automated Assessment of Dynamic Knee Valgus and Risk of Knee Injury During the Single Leg Squat. IEEE journal of translational engineering in health and medicine. 2017; 5(2100213): 1-13. doi: 10.1109/JTEHM.2017.2736559.
[7] Yalin Liao, Aleksandar Vakanski, Member, IEEE, and Min Xian1, A Deep Learning Framework for Assessing Physical Rehabilitation Exercises, 30 Jan 2019
[8] Sumaira Ghazal, Umar S. Khan, Human Posture Classification Using Skeleton Information, National University of Sciences and Technology, H- 12, Islamabad, Pakistan,2018
[9] Gin´es Hidalgo Mart´ınez, OpenPose: Whole-Body Pose Estimation, April 2019
[10] Sen Qiao,Yilin Wang,Jian Li,Real-Time Human Gesture Grading Based on OpenPose,2017
[11] Junchen Shen, Yanlin Luo, Zhongke Wu, Yun Tian, Qingqiong Deng, CUDA-based real-time hand gesture interaction and visualization for CT volume dataset using leap motion,Springer-Verlag Berlin Heidelberg 2016
[12] Ashinsky BG, Bouhrara M, Coletta CE, Lehallier B, Urish KL, Lin, PC, & Spencer RG. Predicting early symptomatic osteoarthritis in human knees using Machine learning classification. Journal of Orthopaedic Research. 2017.
[13] Burns D, Leung N, Hardisty M, Whyne C, Henry P & McLachlin S. Shoulder Physiotherapy Exercise Recognition.
[14] Min Xian, A Deep Learning Framework for Assessing Physical Rehabilitation Exercises.