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An Innovative Implementation of Corrective Yoga Posture Evaluation using embedded Wearable Device

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Abstract— **The most trending terminology of today's growing youth Stress. To overtake that stress many doctors and health experts advised to practice suitable yoga, pranayama, diet along with appropriate medicine. Due to which the number of yoga practitioners has been drastically increased. But when the result-oriented yoga exercise is concerned its accuracy and precision while doing proper yoga posture matters alot. Correct posture of yoga gives effective benefits to increase flexibility and muscle strength, improve the respiratory system and realises physiological effects in the body. After studying a comparative literature on different methodologies of posture recognition, we have developed an innovative system termed as smart assistive device for posture identification and its features extraction using machine learning algorithms in order to authenticate the correctness of the yoga- sans or yoga positions while practicing yoga. We have developed embedded wearable sensor-based device to acquire the time series data from sensors for different postures recognition. Based on trials conducted, a comparative remark of DT and ANN classifiers of machine learning in terms of accuracy, sensitivity, specificity and percent F-score are characterised**.

Keywords— Yoga, Posture Recognition, Smart Assistive Device, Machine Learning.

I. INTRODUCTION

Yoga's foundational ideas come from ancient Indian thought. A wide variety of contemporary yoga traditions (including Iyengar, Viniyoga, Sivananda, etc.) gives emphasis on different combinations of physical postures and exercises (asanas), breathing techniques (pranayama), states of deep relaxation (sushupti), and meditative practises designed to heighten one's awareness and lead to higher levels of consciousness (samadhi). People practised yoga as a therapeutic intervention, capitalising on the many psychological and physiological gains associated with its varied aspects during twentieth century. Asanas, or postures, are physical exercises that can improve a patient's flexibility, coordination, and strength; pranayama, or breathwork; and meditation, or mindfulness, can improve mental health by reducing stress and increasing self-awareness. In addition to these already mentioned benefits, it may also lower stress and blood pressure and boost resilience, mood, and metabolic control [7]. Our research work provides a solution for identifying the yoga postures using smart assistive wearable device. The structure of this paper is as follows. Proposed development of smart assistive device and system architecture for Intelligent Classification of Yoga Posture is discussed in section I, in section II, the classification model for Yoga Posture Recognition is deliberated. At last, in section III, experimental result evaluation is derived and in section IV the overall conclusion of the research analysis and references is presented.

I. PROPOSED DEVELOPMENT OF SMART ASSISTIVE DEVICE AND SYSTEM ARCHITECTURE

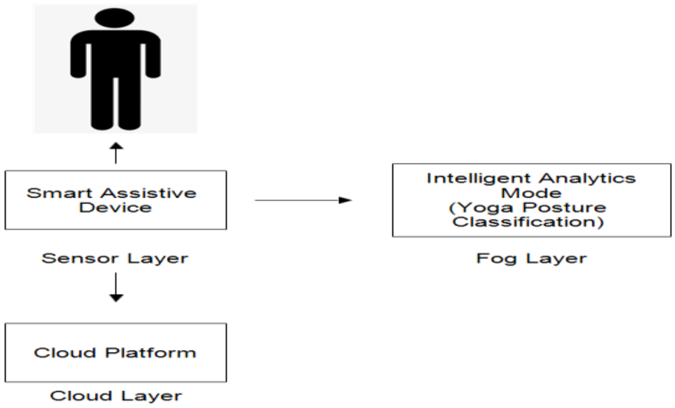

Fig 1: framework for Intelligent Classification of Yoga Posture using Smart Assistive Device

The intelligent yoga posture classification framework is as shown in above figure using suggested smart assistive device. It consists of three-layer approach, sensor layer, fog layer and cloud layer.
Sensor Layer: The smart assistive device which is wearable embedded device worn by user, deployed in sensor layer. It has flex sensor which continuously monitor the posture of user while performing the yoga position.

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Fog Layer: While intelligent analytics model is deployed in fog layer for yoga posture classification based on machine learning and signal processing approach.
Cloud Layer: The real time sensor data measurement of yoga postures can be observed in cloud layer which having storage platform and web dashboard platform for visualization.

A. Proposed System architecture:

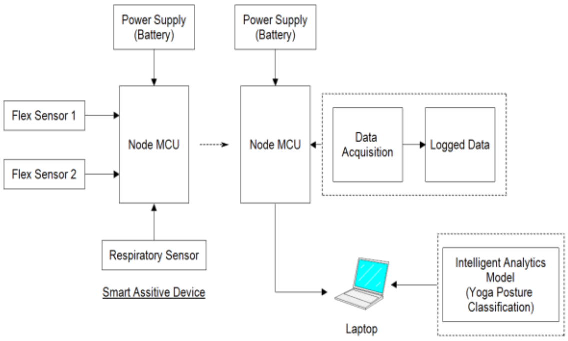

Fig 2: Proposed system architecture

The proposed prototype embedded device is based on master-slave communication platform. However, master device acts as acquisition device which further logged real time posture sensor data and forward it to cloud and fog layer for further analysis and interpretation of data. Also, slave device acts as sensing unit where it has Node MCU as main microcontroller unit interfaced with flex sensor which sense the posture of user while performing yoga position. Also, it has respiratory sensor which sense the quality of air breathing which can be used for further analysis of breathing after and before performing yoga position. The intelligent analytics model for yoga posture classification is performed using machine learning technique which is deployed in fog layer, which acquires sensor data from master node controller unit via internet of things (IoT). While laptop device is used as fog device for data analysis.
The Node MCU, ESP32, acts as main controller unit, is a low-cost, low-power microcontroller open source IoT platform with integrated Wi-Fi and Bluetooth. It has dual core processors that run at frequencies up to 240 MHz. A flex sensor is a kind of sensor which is used to measure the amount of defection otherwise bending. The designing of this sensor can be done by using materials like plastic and carbon. The carbon surface is arranged on a plastic strip as this strip is turned aside then the sensor's resistance will be changed. Thus, it is also named a bend sensor. As its varying resistance can be directly proportional to the quantity of turn thus it can also be employed like a goniometer. A respiratory sensor is a device that detects chest or abdominal expansion and contraction. It outputs a respiration waveform. Respiratory sensors can be wearable or environmental.

II. DEVELOPMENT OF CLASSIFICATION MODEL FOR YOGA POSTURE RECOGNITION

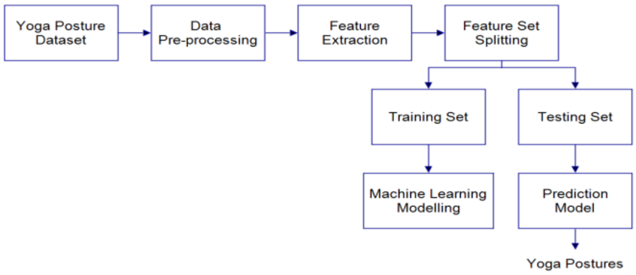

Fig 3: Proposed framework for classification of Yoga posture classification

A. Yoga Posture Dataset

We tried to collect as much as data of the most popular yoga postures performed by as many as volunteers. However, we could invite 20 volunteers, 10 males and 10 females, for the dataset collection because it was hard to find volunteers who can perform all or most of the yoga postures correctly. The average age of the volunteers was 31.5. All the volunteers were wearing T-shirts and pants with wearable device that we have developed. In addition, all volunteers were regularly practicing yoga before the time of the experiment, however, the few of the volunteers had never practiced yoga before.
Yoga poses for recognition are Shavasana, Balasana, Bhuijagasana, Tadasana, Uttanasana, Setu Bandha Sarvangasana, Anulom Vilom Pranayama during trials, we had collected 20 samples for each pose, 140 samples for each volunteer, and totally, 980 samples for all 7 volunteers. Each session is exported as .csv file upon recorded.

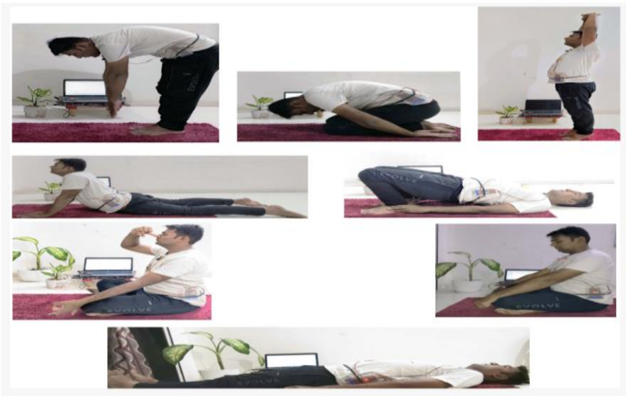

Fig 4: Samples of Yogasanas for classification of Yoga posture

B. Data preprocessing

Data processing is collecting raw data and translating it into usable information. The raw data is collected, filtered, sorted, processed, analyzed, stored, and then presented in a readable format. It is usually performed in a step-by-step process. Data preparation or data cleaning is the process of sorting and filtering the raw data to remove unnecessary and inaccurate data. Raw data is checked for errors, duplication, miscalculations, or missing data and transformed into a suitable form for further analysis and processing. This ensures that only the highest quality data is fed into the processing unit

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C. Feature Extraction

Time Domain Features - Mean absolute value (MAV), waveform length (WL), zero crossings (ZC), slope sign changes (SSC), RMS, and standard deviation.Frequency Domain Features - Skewness, mean frequency, and kurtosis.

D. Feature Splitting

The train-test split is used to estimate the performance of machine learning algorithms that are applicable for prediction-based algorithms. This method is a fast and easy procedure to perform such that we can compare our own machine learning model results to machine results. By default, the Test set is split into 30 % of actual data and the training set is split into 70% of the actual data. We need to split a dataset into train and test sets to evaluate how well our machine learning model performs. The train set is used to fit the model, and the statistics of the train set are known. The second set is called the test data set, this set is solely used for predictions.

E. Machine Learning Classification Modelling

four machine learning classifiers used to give below:

1. Support Vector Machine (SVM)

In a support vector machine (SVM) model, the various categories are projected onto a multidimensional hyperplane. To reduce the error as much as possible, SVM will generate the hyperplane through a series of iterations. SVM's end purpose is to categorise datasets into groups such that a maximum marginal hyperplane (MMH) may be discovered

A normal vector, or the direction perpendicular to a hyperplane, is denoted by the vector W. The parameter b in the equation stands for the hyperplane's distance along the normal vector w from the origin. To train our model, we have access to a collection of input feature vectors X and theirassociated class labels Y, which make up our training dataset.

2. Decision Tree (DT):

Decision Tree is a machine learning based tree-structured classifier, where each node in a decision tree represents a feature in a dataset, while the branches indicate the decision rules and the leaf nodes reflect the results. Using inferred decision rules from the data characteristics, the objective is to develop a model that can predict the value of a target variable. This method relies heavily on a concept called "Entropy."

3. Random Decision Forest (RDF)

To increase prediction accuracy and keep over-fitting in check, a random forest averages the results of many decision tree classifiers that have been individually trained on different subsamples of the dataset. The output of a random forest is predicted not by a single decision tree, but rather by averaging the forecasts of many individual trees. More trees in the forest mean more reliable results and less chance of overfitting. The following diagram illustrates how the Random Forest method functions.

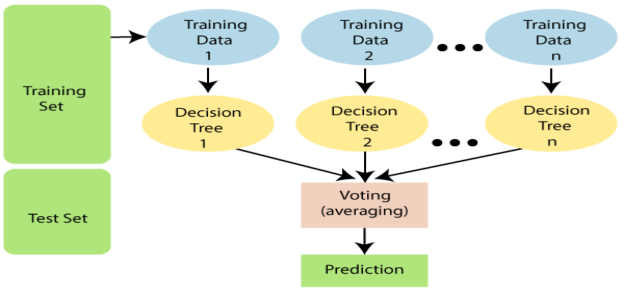

Fig 5 : Working of the Random Forest algorithm

4. ARTIFICIAL NEURAL NETWORK (ANN)

A feed forward artificial neural network, a multilayer perceptron (MLP) produces a set of outputs given a set of inputs. To define an MLP, we may say that it has several layers of input nodes coupled as a directed graph between the input and output layers. When training an MLP network, backpropagation is used. Multi-layer perceptron learning is depicted in the following image.

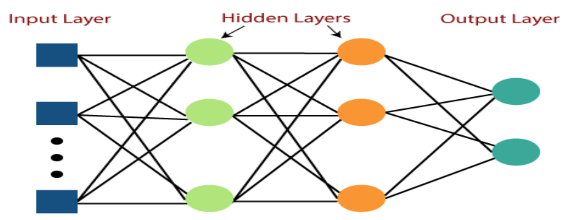

Fig 6: Layer representation of MLP

5. Algorithm Steps:

Input – Flex sensor's data from wearable device for each yoga posture
Output – Yoga Posture Recognition
Procedure Step1: Sensor data acquisition from wearable device Step2: Pre-process the sensed signals for noise removal Step3: Apply feature extraction based on time and frequency domain features Step4: Dataset splitting of signals into train and test signals Step5: Extract train features and labels from dataset to train the model Step6: By initializing the hyperparameters for SVM, DT, RDF and ANN, create the model Step7: Train and validate the all-machine learning models Step8: Store trained model, if validation is satisfactory Step9: Load test feature data and apply on step2 and step 3 Step10: Predict the test feature signals to get yoga posture type

Table I: Algorithm Steps.

III. EXPERIMENTAL RESULT

A. Experimental Setup

The proposed model provided in this paper uses the various machine learning model to detect correct yoga postures. This experiment has been performed using NVIDIA GeForce GTX-1080 GPU and Intel i5 CPU. While training and test datasets consist of numerous ups and downs in accuracy until the several hyperparameter tuning. Additionally, proposed approach was carried out to validate the performance of the model in which the dataset was split into training and validation data in the ratio of 70:30. The training and validation sets were mutually exclusive.

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A. Performance Evaluation Parameters

Accuracy, sensitivity, specificity, and f-score are used to assess performance within the context of the confusion matrix.

$Accuracy = (TP+TN)/(TP+TN+FP+FN)$

Sensitivity = $TP/(TP+FN)$

$Specificity = TN/(TN+FP)$

F-score = $TP/TP+0.5(FP+FN)$

were, TP – true positive, TN – true negative, FP – false positive, FN – false negative

B. Result Evaluation

Classifiers	Training Time (sec)	Testing Time (sec)
SVM	64.2	22.8
DT	69.5	27.1
RDF	68.4	19.7
ANN	76.2	25.9

Table 2: Comparative Analysis of Different Classifiers

Classifiers	Accuracy (%)	Sensitivity (%)	Specificity (%)	F-score (%)
SVM	86.44	90.05	86.44	87.14
DT	81.35	81.84	81.35	81.29
RDF	94.91	95.61	94.91	94.90
ANN	91.52	91.82	91.52	91.48

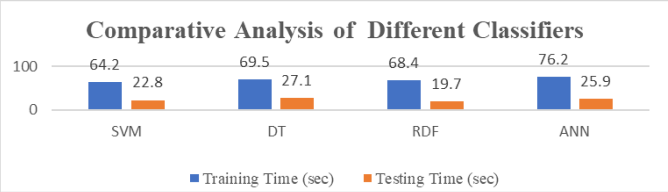

Fig.7: Graphical representation on Comparative Analysis of Different Classifiers

Table 3: Classifiers Parameter's Estimation

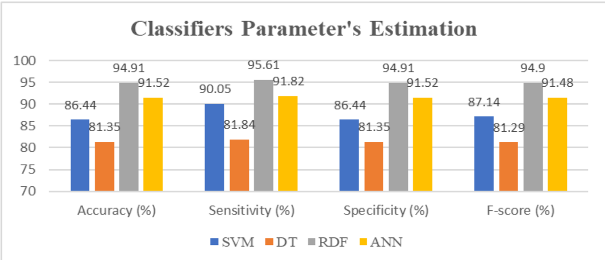

Fig8 : Graphical representation on Classifiers Parameter's Estimation

B. CONCLUSION

Yoga is being part of routine human life nowadays. This fact develops a curiosity for yoga posture identification and effective research in this domain. It has been found that the use of pose detection tools can help practitioners to do yoga with more precision. Due to the difficulty of detecting posture in real time and the limited availability of datasets, posture recognition is a difficult task. The advantages of yoga are suggested by these evaluations in a variety of contexts, but additional research is needed to draw firm conclusions. Small, low-quality trials with several instances of bias characterize most studies on yoga for a variety of diseases. In this research we have developed and implement the prototype model for posture recognition. Based on trials conducted, several parameters are characterised using machine learning algorithms. We get a comparative remark of DT and ANN classifiers in terms of accuracy, sensitivity, specificity and percent F-score. This work presents the initial model creation and assessment of yoga posture categorization. Since the underlying psychophysiological explanation is plausible, it is suggested that more research be conducted in this area.

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