

# A Novel 3-Layer Soft Computing Integrated Technique ANFUS Based On Symptomatic Guidelines For Early Detection Of Sleep Disorders

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**Abstract**— Sleep assumes an indispensable part in life of human being to be casual and stress free from consistent day errands. However, some time, sleep gets disturbed by unordinary exercises and practices, because of which numerous sleep disorders emerge like Sleep Apnea, Insomnia, Parasomnia and Snoring. The different applications have been created in artificial intelligence domain for the finding of gawky practices which begins the interference in sleep nearby the backing of further new sleep disorders. This paper is based on a novel 3-layer soft computing method ANFUS which has been formulated for an early detection of the above said sleep disorders. In this methodology, artificial neural network (ANN) and fuzzy C-means (FCM) are integrated with support vector machine-one versus all (SVM-OVA). At layer-1, ANN is used to discover the relationship between collected patient records and disability factors of sleep disorders and the outcome is passed to FCM at layer-2 to define the boundaries of all overlapped disability factors. The result provided by FCM is utilized by SVM-OVA present at layer-3 to classify the sleep disorders. The outcome demonstrates that ANFUS integrated techniques provide an early detection of sleep disorders to help the patients to upgrade themselves from the various bad effects arising due to disrupted sleep, also known as sleep disorders.

**Keyword**- 3-Layer, Early detection, Sleep Disorders, Soft Computing

## I. INTRODUCTION

**“THE BEST WAY TO ESCAPE FROM REALITY IS TO SLEEP,  
THE BEST WAY TO IMAGINE SOMETHING IS TO SLEEP,  
AND THE BEST WAY TO WAKE UP IS TO SLEEP”**

Dalai Lama i.e., One of the famous head monks of Gelug School says that "Sleep is the best meditation" that is also a demand of every individual to cover up them to start the regular activities. It is a state where a person has lost its total consideration against the outer environment [3]. It is a stage, where all muscles are in calm state along with other sensual movements. An individual moves through many phases/stages at the time of its sleeping hours such as Wake, Non-Rapid Eye Movement (NREM) and Rapid Eye Movement (REM). On the other hand, at some point this sleep is hindered because of some humiliating practices, mental conditions related with it, otherwise called sleep disorders that further chop down the nature of sleep including dozing hours. The greater part of the parents is new to the characteristic of sleep disorders exasperating a ton of youngsters at the worldwide level. Sometime parents are unable to discriminate the sleeping arrangements of their children which become the major cause of suffering children from many side effects. It is finished up by the Toronto Star that the quantity of kids having lower evaluations in study are 6 to 9 times more noteworthy than others which are experiencing some sort of problems related to sleep [4].

Many intelligent techniques and systems have been adopted by researchers to detect sleep and the sleeping patterns including sleep disorders linked with them which produces some kind of disturbances in sleep. For the observation purpose, four sleep disorders are examined in this paper like sleep apnea, insomnia, parasomnia and snoring, in which sleep apnea [1] has an important aspect for over the top daytime drowsiness. It is very familiar among public, in which an individual goes through disrupted breathing in sleeping hours [2]. This disorder also puts a great effect on all regular activities due to the incompleteness of normal sleeping cycle. It also increases the risks of Type-2 diabetes, cardiovascular diseases as well as mortality rate from traffic accidents etc. Insomnia is also a sleep disorder in which an individual can't get snoozing or to stay unconscious according to its own particular desires. People suffered from insomnia are always complaining about the tiredness upon waking or even sometime people wake up too early in the morning. Parasomnia, an extremely prevalent sleep disorder is concerned with uncertain and unexpected moves, sentiments and perceptions. If there should arise an occurrence

of snoring, a sound is conveyed as a result of demoralized air improvement in the midst of breathing during the period of sleep. In like manner, there is a combination of other sleep disorders which put awful consequence for human body parts by fluctuates implies. A few sleep disorders are enough fit to thwart the physical, psychological, cognitive and motor functionality of human body. In typical life, not anybody make a fuss over the above said sleep disorders, likewise they don't know about the future impacts of these clutters on their body parts. With the progression of time, these sleep disorders turn out to be exceptionally lethal. Subsequently, an earlier detection of these sleep disorders is extremely vital undertaking to decrease the mortality component. Likewise, the motor function, cognitive, physio-psycho variables and parameters in light of PSG assume a basic part to analyse the sleep disorders.

Hence an incorporated procedure ANFUS is suggested in this paper to diagnose sleep disorders by using ANN, FCM and SVM-OVA. The database is acquired from various physicians consisting symptomatic guidelines and the polysomnography reports of various patients. A physician can declare the type of sleep disorder from the polysomnography report whether a patient is suffering from any of the sleep disorder or not. If unfortunately yes, then a patient can take relevant move to make control over that disorder. But, it is not possible for every individual to go through from the polysomnography due to its high cost factor and also, it is very time consuming and cumbersome process as it takes the entire night to analyse the patient. Hence, to overcome this problem, a symptomatic approach is used for the early detection of each sleep disorder which is also in the favour of every individual from the perspective of cost factor and time consumption. If the result goes in the favour of any sleep disorder then the patient can be recommended for the polysomnography by ANFUS, otherwise it is not mandatory to go through it.

The rest of the paper contains the consequent pieces. Fragment 2 oversees writing survey. Segment 3 is worried with gathering of data and methods got for this paper. In this manner, area 4 solidifies the synopsis of the achieved results and conclusion.

## II. LITERATURE REVIEW

ANN normally utilized for pattern identification and characterization [5, 25] includes an aggregation of perceptrons participated in layers by utilizing different associations and data controlling methodology in medicinal area. It has a versatile nature to modify its structural pattern amid its learning stage, in this way, utilized to explain true convoluted connections. The back propagation (BP) algorithm is mostly utilized as a part of ANN learning strategy which has been used by numerous specialists as a part of the identification and characterization of sleep apnea/hypopnea occasions, recognition of sleep wake stages [6, 7], recognition of REM sleep, sleep spindles [7], detection of sleep disordered breathing [8] and Classification of Obstructive sleep apnea [5] by achieving 88% accuracy. ANN has a couple focal points over knowledge based system in showing a reciprocal way to deal with rule based reasoning regarding learning representation that need quite a while to build such a framework from rule based methodology [9, 25]. ANN has an extremely alluring property for automated recognition which does not need any intricate grouping principles or complex area learning [10]. In spite of few advantages, ANN has also some disadvantages, as the association of NN is uncertain. From the prior information/learning used for the presentation reason can't be managed for better instatement of framework parameters and the decreasing of learning era [11, 19, 25].

Fuzzy set hypothesis assumes a fundamental part to manage the complexities in medical area while dealing with choices [12]. It is a sort of probabilistic rationale which manages thinking that is rough instead of steady and exact. Fuzzy rule based framework accomplished great results for a few samples, yet despite everything it needs to enhance its execution [13]. Mamdani-like fuzzy principles engages figuring out how to be actualized in kind of linguistic form, close to dialect comprehended by person which encourages information procurement, understandability and permits logical capacities [14]. It has various central focuses like as straightforward rearrangement of standard base or fuzzy sets, effortlessness of comprehension as a result of the region of yield in phonetic structure, easy to layout in light of less cost, acquisitions to allow conflicting sources of info, get in contact at persevering state in a lesser time interval. On the opposite side, fuzzy has moreover obstruction like as troublesome advancement of a model from a fuzzy system. The maximum accuracy achieved by using fuzzy logic is 87.05 % [15]. Marcos et al. proposed an assistant tool to diagnose the obstructive sleep apnea by using the radial basis function (RBF) network and compared the results by using three different classification methods like k-mean, FCM and orthogonal least squares. It was found that RBF-FCM provides the best classification accuracy by reducing the network complexity.

SVM is a procedure based on machine learning prescribed by Vapnik in 1995. The key thought behind SVM is the improvement of an upgraded confining hyperplane. Because of its theory limit is used for deciding supervised classification, regression problems [16,18] and binary classification [16]errands containing segments of non-parametric associated bits of knowledge which increases the edge between the preparation set and decision boundary, can give a part as a quadratic advancement issue. SVM is a supervised learning model associated with entirely learning calculations to inspect data and perceive examples. To find a detaching hyper plane with maximal edge, it maps the data into a huge dimensional space [20]. The topside of SVM is that it can

fathom the issue of non-straight plan [16]. The kernel function is utilized to take care of the issue of inner estimation in high measurement, from now on, an incredible method for non-direct game plan. The portion capacity must be expert to accomplish the best order precision characterization accuracy for dark specimens. The characterization execution delivered by k-NN, probabilistic neural network and linear discriminant classifiers was less than SVM in case of testing data [17].

### III. MATERIAL AND METHODS

The below stream graph appeared in Fig. 1 speaks to the philosophy received in proposed work.

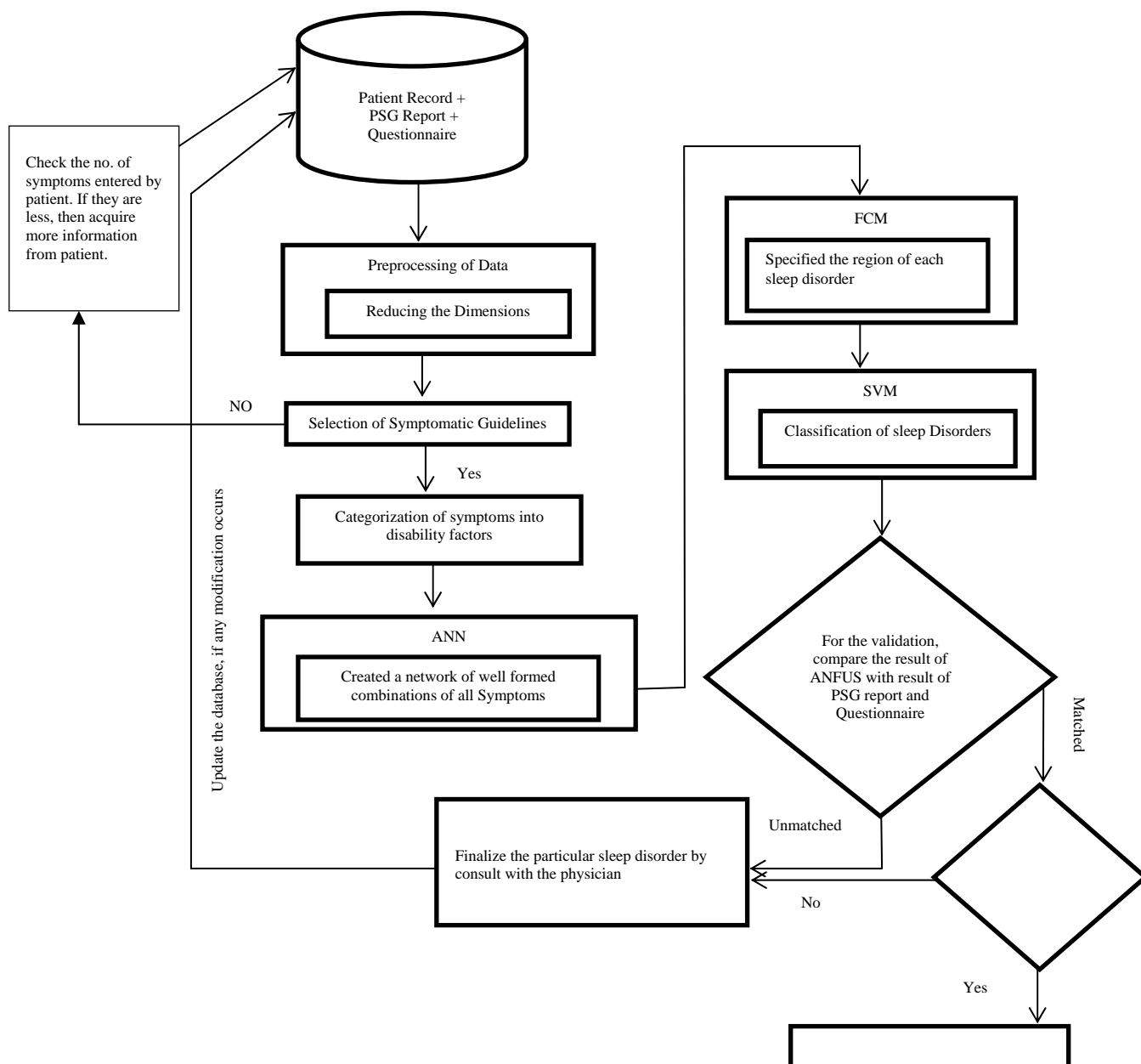


Fig. 1. Flow Chart of Proposed System (ANFUS)

#### A. Symptomatic Guidelines

The symptomatic records are separated into four sleep factors on the behalf of their presence in the corresponding disorder. The beneath said Table I delineates every one of the side effects taken together to analyse the sleep disorders which influence the distinctive human body parts by various aspects.

TABLE I. Symptoms of Sleep Disorders

Sleep Disorders	Symptoms
Sleep Apnea	High Blood Pressure (HB), Dry Throat (DT), Bedwetting (BW), Irregular Heart Rhythm (IHR), Breathing (BT), Headache (HD), Unusual Sleep Positions (US), Teeth Grinding/Clenching (TG/TC), Nightmare Choking (NC), Napping/Drowsiness (NP), Sleep Disturbances (SD), Daytime Sleepiness (DS), Night Awakening (NA), Moodiness (MD), Concentration Loss (CS), Forgetfulness (FG), Learning Problem (LP)
Insomnia	Dry Throat, Irregular Heart Rhythm, Eye Movement (EM), Disturbance, Daytime Sleepiness, Night Awakening, Moodiness, Tiredness (TD), Concentration Loss
Parasomnia	Bedwetting, Irregular Heart Rhythm, Unusual Sleep Positions, Teeth Grinding/Clenching, Eye Movement, Nightmare Choking, Sleep Disturbances
Snoring	High Blood Pressure, Dry Throat, Irregular Heart Rhythm, Breathing, Headache, Napping (Drowsiness), Daytime Sleepiness, Night Awakening, Learning Problem

**B. Questionnaire**

For validation of the result, a questionnaire has been acquired from various physicians which is already framed by them after consulting with patients as per the symptomatic guidelines from which all they are suffered. It also includes the PSG based parameters like AHI (apea-hypopnea index), BMI (Body Mass Index) and NC (Neck Circumference) to diagnose the sleep apnea and the other sleep disorders are diagnosed on the behalf of the questions as mentioned in the following Table II.

TABLE III. Questionnaire and PSG Parameters

Sleep Apnea	Insomnia	Parasomnia	Snoring
<ul style="list-style-type: none"> <li>• <b>PSG parameters</b></li> <li>AHI Value &lt;5- Normal &gt;5- Sleep Apnea</li> <li>BMI &lt;30- Normal &gt;30- Sleep Apnea</li> <li>NC &lt;43cm-Low Risk &gt;43cm-High Risk</li> </ul>	<ul style="list-style-type: none"> <li>• Do you have trouble falling sleep?</li> <li>• Do you feel sad, irritable or hopeless?</li> <li>• Do you kick legs in your sleep?</li> <li>• Do you have trouble staying asleep?</li> <li>• Do you use alcohol to help you sleep?</li> <li>• How much time usually taken to sleep?</li> <li>• Do you awaken in the morning naturally or using alarm?</li> </ul>	<ul style="list-style-type: none"> <li>• Do you have any unusual behaviours or movements during sleep?</li> <li>• Do you have any problem related to stop breathing, gasp or choking in your sleep?</li> <li>• How many times you rise to use toilet?</li> <li>• How you ever noticed the problem of teeth grinding/clenching in kids?</li> <li>• How many times your sleep frequently disturbed?</li> </ul>	<ul style="list-style-type: none"> <li>• Do you have problem related to blood pressure?</li> <li>• Do you ever suffered from any heart related problem?</li> <li>• Do you wake up with headache?</li> <li>• Do you find chock/struggle while breathing?</li> <li>• Have you ever noticed about toss and turn frequently during sleep?</li> <li>• Are you facing the problem of dry throat?</li> </ul>

**C. Processing of Data**

For the examination, an aggregate of 366 patient records are gathered from various physicians. Every one of the symptoms are sorted into four disability areas in light of their effect on the different human body parts like physical structure, psychological, cognitive and motor functions [22] of an individual are showed up in the Table III. The whole notation is meant as '0' and '1'. Here "0" speaks to that specific side effects are not connected with the endorsed sickness and "1" implies the vicinity of that manifestation in underlined disorder [21]. A sum of 41 symptoms is considered to be as input variables for the whole examination. Each one of these symptoms are normalized and categorized into 19 symptoms (removal of redundancy) based on their characteristics such as four symptoms TG/TC, EM, NC and NP lead towards the arrangement of motor function disability. Likewise the other remaining symptoms are categorized which lead towards the other disabilities factors.

To diminish the multifaceted nature or to lessen the dimension of 19 symptoms, a recipe is prepared based on an index value (INV) doled out to all side effects on the reason of their importance in the specific disorder and the binary values (SMT) assembled from the manifestations of various patients. The aggregate sum of the augmentation of  $SMT_i * INV_i$  will create different qualities as indicated by various sleep disorders. The beneath said formula is passed to ANN to find out the particular values of all disability factors by using the training data set.

$$Disease\ DISI = \sum(SMT_i * INV_i) \tag{1}$$

Here,  $SMT_i$  = Binary values of symptoms,

$INV_i$  = Index number of symptoms

Now, due the uncertainty problem in ANN, there is a need to normalize the data so that it would be distributed among the entire range. Now, these 19 input variables are converted into 4 input variables (MF, PSY, CO and PY) that are depicted in following Table III.

TABLE IIIII. Disability Factors associated with Sleep Disorders

Sleep Disorders	Motor Function Disability (MF)				Psychological Disability (PSY)					Cognitive Disability (CO)			Physical Disability (PY)						
	TG/TC	E M	N C	N P	S D	D S	T D	N A	M D	C S	F G	L P	H B	D T	B W	I H R	B T	H D	U S
Sleep Apnea	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
Insomnia	0	1	0	0	1	1	1	1	1	1	0	0	0	1	0	1	0	0	0
Parasomnia	1	1	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	1	
Snoring	0	0	0	1	0	1	0	1	0	0	0	1	1	1	0	1	1	1	0

To check the normalization of data, Table IV, V is formulated in which mean and standard deviation (St. DEV) is computed. Each of the sample training input data is subtracted with the corresponding mean value mentioned in Table IV and then divided the output with their respective standard deviation value. Now, if the value is negative then it indicates that the cell does not belong to the corresponding distributed column as shown in Table VI.

TABLE IVV. Sample Input Data

MFD	PSD	CD	PHD
0.933333	0.580645	0.857143	0.929134
0.533333	0.806452	0.714286	0.850394
0.133333	1.032258	0.571429	0.771654
0.533333	0.258065	0	0.322835
0.133333	0.290323	0.142857	0.519685
0.066667	0.258065	0.285714	0.291339

TABLE V. Mean and Standard Deviation

Disbilty Factors	MEAN	St. DEV	MIN	MAX
MFD	0.374222	0.315692	0	0.93333
PSD	0.553978	0.280596	0	1
CD	0.299048	0.314003	0	1
PHD	0.478215	0.325773	0.06	1

TABLE VI. Normalization of Data

MFD	PSD	CD	PHD
1.745776	0.103837	1.798648	1.364901
0.480722	0.917487	1.341365	1.125277
0.78433	1.731136	0.884081	0.885652
0.480722	1.05852	-0.94505	0.48021
0.78433	-0.94228	0.48777	0.118854
-0.99517	1.05852	-0.03049	-0.57606

**D. Technology Used**

1) *ANN*: For this paper, ANN was trained with feed forward back propagation (FFBP) algorithm. From the literary works, it has been found that BP algorithm is widely utilized and gives better answers [26]. Subsequently, it is utilized to discover the relation between symptomatic guidelines and the disability factors covering all the possible combinations. A total of 4 ANN is used like first ANN covering the relation between four symptoms (TG/TC, EM, NC and NP) and motor function disability factor. Likewise, other combinations are made among the rest of the symptoms and disability factors. The selecting patient records were utilized to provide training and testing of ANN. As the symptomatic guidelines are now categorized into the disability factors, so number of input nodes of ANN is equivalent to the number of disability factors and now ANN provides the whole combinations which are possible with the four disability factors. The following are the parameters on the behalf of which ANN is trained [24].

No. of iterations:- 152

Learning Rate:- 0.001 to 0.4

Network Type:- FFBP

Training Function:- TRAINBR

Transfer Function:- TRANSIG

The following Fig. 2 depicts the representation of ANN with respect to all disability factors. From the Fig. I, it can be seen that 4 neurons are used at input layer, 10 neurons at hidden layer and 1 neuron at output layer which is used for motor function disability. Likewise, all ANN representations are displayed corresponding to other disability factors having different number of neurons at each layer. All these circumstances empower the efficient learning as it was discovered by fluctuating estimations of root mean square error that is a halting criteria while providing training and testing of ANN [24].

2) *FCM*: FCM is a type of clustering in which every information point can have a place with more than one group or partition. The outcome obtained from ANN was in overlapped form and to define the boundaries of all disability factors with respect to each sleep disorder, FCM is utilized. It works by allocating membership to every data point relating toward every cluster center on the premise of separation between the cluster center and the information point. Progressively the information is close to the cluster center more is its membership towards the specific cluster center. Plainly, summation of membership of every information point ought to be equivalent to one. After every iteration, membership and cluster center are redesigned.

TABLE IV. Normalization of Data

No. Of Iterations (Decision on Area Selection)
Iteration 1, fcn value = 107.674994
Iteration 2, fcn value = 80.554022
Iteration 3, fcn value = 74.367618
Iteration 4, fcn value = 58.998631
Iteration 5, fcn value = 43.590371
Iteration 6, fcn value = 20.246484
Iteration 7, fcn value = 5.176535
Iteration 8, fcn value = 4.621905
Iteration 9, fcn value = 4.621720
Iteration 10, fcn value = 4.621720

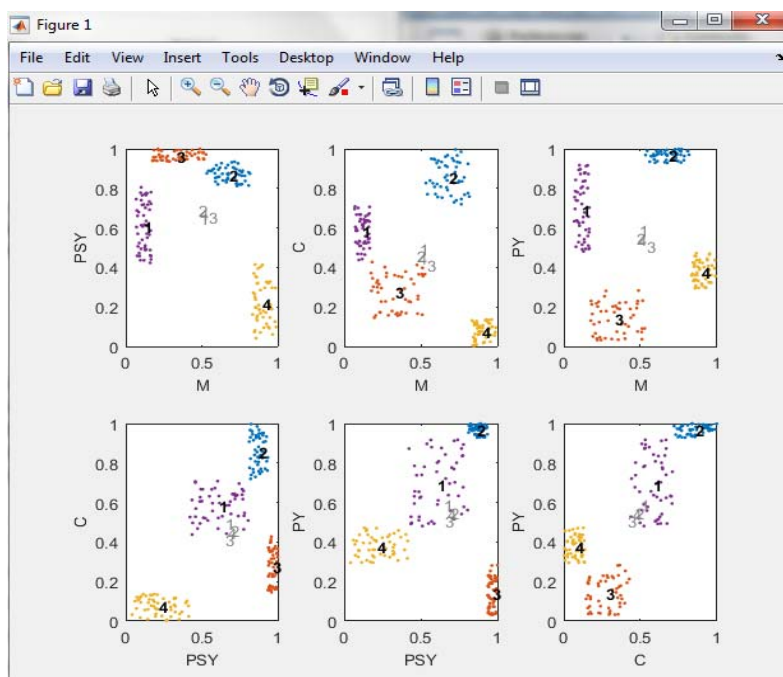


Fig. 2. Results obtained from FCM Classifiers

3) *SVM-OVA*: It has ability to minimize both basic and empirical risk provoking better speculation for new data request. The essential favourable position of SVM is the settlement of non-linear classification issues and having no requirement of speed clasp for narrowing model [5, 9]. To solve the inner product calculation, kernel function is used. Henceforth, it is a great technique used for non-linear classification.

After deciding the boundaries of all disability factors with respect to each sleep disorder by fuzzy c-mean, the input values are passed to SVM classifier for the classification. The fundamental confinement of SVM is of arranging the outcomes in two aggregates as it were. To beat this impediment, one of the traditional methodology OVA is utilized by executing the structure of SVM on each disorder one by one. For this, one class considers positive having appropriate group number and another with negative worth relating to whatever remains of the classes. Fundamentally, SVM is a supervised learning system which acknowledges a perceived arrangement of input data, responses and endeavors to develop a predictor model which produces sensible expectations for the gathering to new information as demonstrated as follows. For preparing the classifier the following equation is utilized.

$$z = \sum W_k f(Sv_i, v) + b \tag{2}$$

Where,  $kf$  is a kernel function uses an optimization method to recognize support vectors  $sv_i$ , weights  $w_i$  and bias  $b$  which are utilized to classify vectors  $v$ . In [23], authors implemented the soft computing method based on SVM-OVA to classify the sleep disorders.

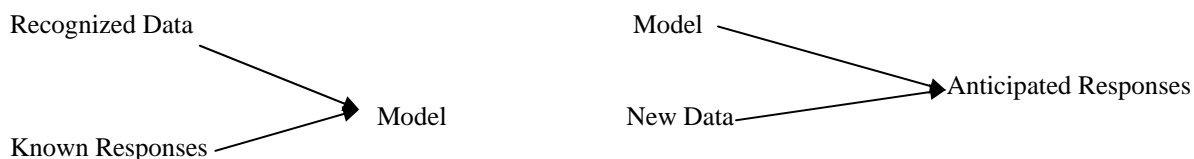


Fig. 3. Methodology Adopted by SVM-OVA

After providing training to SVM, four different structures are created corresponding to sleep disorders which are then passed to SVM classifiers for testing with 21 new input data which yields the result as shown in the accompanying Table VI. It is plainly portrayed from the following table that each structure classifies the sleep disorder with respect to the actual output having the same disorder value. In the table, 1 stands for sleep apnea, 2 for insomnia, 3 for parasomnia and 4 for snoring. The accuracy of the trained classifier is calculated by the following formula which provides 92.4% accurate results.

TABLE VIVII. SVM-OVA Output Phase

Struct-SA	Struct-IN	Struct-PR	Struct-SN	Actual Output
1	-1	-1	-1	1
-1	-1	-1	-1	1
1	-1	-1	-1	1
-1	2	-1	-1	2
-1	2	-1	-1	2
-1	2	-1	-1	2
-1	-1	3	-1	3
-1	-1	3	-1	3
-1	-1	3	-1	3
-1	-1	-1	4	4
-1	-1	-1	4	4
-1	-1	-1	4	4

$$\begin{aligned}
 \text{Accuracy} &= (\text{Total correct records} / \text{Total number of checking records}) * 100 \\
 &= (61/66) * 100 \\
 &= 92.4
 \end{aligned}$$

#### IV. RESULTS AND DISCUSSION

In this paper an effort is made for the early detection of sleep disorders primarily focused on sleep apnea, insomnia, parasomnia and snoring. For this, a novel 3-layer soft computing based an integrated technique ANFUS is proposed based on the symptomatic guidelines and compared the result with the PSG parameter and questionnaire acquired from the physicians. It is found that the results obtained from ANFUS are almost similar to the PSG parameters. Hence, it can be a best approach for the early detection of sleep disorders because for every individual it is not possible to go through from the PSG procedure due to its high cost factor. Moreover, it is also a time consuming and cumbersome process. Therefore, ANFUS can be utilized as an indicator to diagnose itself for the above said sleep disorders. If any individual finds himself to be suffering from any sleep disorder after the diagnosis form ANFUS only then he needs to go through form the process of PSG.

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