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Exploratory Study of Kohonen Network for Human Health State Classification

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***Abstract*— Kohonen Network is an unsupervised learning which forms clusters from patterns that share common features and group similar patterns together. This network are commonly uses grids of artificial neurons which connected to all the inputs. This paper presents an exploratory study of Kohonen Neural Network to classify human health state. Neural Connection tool is used to generate the result based on Kohonen learning algorithm. Procedural steps are provided to assist the implementation of the Kohonen Network. The result shows that side 2 is more appropriate for this problem with efficient learning rate 1.0. It gives good distribution for training and test patterns. Study to the variation of dataset's size will be considered in the near future to evaluate the performance of the network.**

***Keywords*— Clustering, Kohonen Neural Network, Body fat, Health state.**

I. INTRODUCTION

Neural network (NN) has successfully proven to present good achievement in prediction and classification task in data mining [1] - [4]. A Neural Network encompasses a unified network of simple processing units (neurons). The neurons function independently, and in parallel. NNs also evaluate many competing hypotheses simultaneously. Thus, NN is beneficial for the recognition of patterns [5] - [6] from huge amounts of data. This is supported with the ability of NN to work with high computation rates and solves several hypotheses in parallel.

NN requires training to identify patterns from the problem domain [5] The training phase of NNs can be either supervised or unsupervised. Supervised training involves both the input pattern and the correct classification of the input pattern [5]; [7]. While, the unsupervised training works with the input pattern without the corresponding labels or output [8]. Supervised networks are usually used for solving recognition and generalization problems. While, unsupervised networks are used for clustering a set of input data. Common examples of unsupervised learning algorithms are k-means for clustering problems, and Apriori algorithm for association rule learning problems [8] – [9].

This paper describes the utilization of Kohonen neural network which is a type of unsupervised learning network in an experiment to predict men's health state based on their body fat percentage. Particularly, Kohonen network is selected to realize the capability of the network in healthcare application domain. The experiment is conducted to classify the body health state by body fat percentage of 252 men based on their body mass index and various bodies circumference measurements. In clinical practice, public health uses body mass index (BMI; in kg/m2) as initial indicator to screen people's health state. BMI guidelines assumes that the body mass is closely associated with body fatness and consequent morbidity and mortality [11] – [12]. However, some individuals who are overweight are not overfat. While, people with normal range BMIs have a high percentage of their body weight as fat. These misclassified persons are uncommon relative to the population [13]. Hence in this study, body fat percentage is used as an indicator to predict the health state. A number or research also has been conducted which uses machine learning, and neural network method to predict the health states [14] – [16].

In the remaining of the paper, the use of Kohonen Network was formalized as a classification model for the simulation. Section II provides related work of this study. Data acquisition and preparation for training is discussed in Section III. The paper ends with computational experiments and associated conclusions.

II. RELATED WORK

This section describes the study on body fat which is the research area study and the Kohonen Network as well.

A. Body Fat

Human health is usually associated with bodily function and absence of disease. The health state is achieved with a balance integration of spirit, mind and body. Physical health is mainly consisting of three components [9] – [10] which are bodily function and absence of disease; psychological health; and social health. All the component complements each other to complete health. Various reading resource of health suggest people to assess their health, i.e. to evaluate their percentage of body fat [17]. This is because fat is primarily used to describe obesity. Excessive amount of fat may endanger to human as bioenergetics mechanisms become inefficient. Table I list standard body fat percent ranges [18].

Methods for determining body fat percentage include: hydrostatic weighing; skinfold caliper; electrical impedance; infrared measurement; Body Mass Index; and circumference measuring. The percentage of body fat for an individual can be estimated from body density. Two components of body are consisting of lean tissue and fat tissue.

TABLE I
STANDARD BODY FAT RANGES

Body Fat	Low	Optimal	Moderate	High	Dangerous
Women	< 15%	15 – 25%	26 – 30%	31 – 35%	> 35%
Men	< 10%	10 – 20%	21 – 25%	26 – 30%	> 30%

Let us have
D = body density,
W = body weight.
A = proportion of lean tissue,
B = proportion of fat tissue (A+B = 1),
a = density of lean tissue, and
b = density of fat tissue

and,
$$\begin{aligned} D &= weight/volume \\ &= W/\,[lean\ tissue\ volume\ +\ fat\ tissue\ volume] \\ &= W/\,[A * W/a\ +\ B * W/b] \\ &= 1/\,[(A/a)\ +\ (B/b)] \end{aligned}$$

Body fast estimation is calculated using estimates $a = 1.10\ gm/cm^3$ and $b = 0.90\ gm/cm^3$ body fat estimation is calculated [19].

$$Percentage\ of\ body\ fat\ =\ 457/D - 414.2.$$

B. Kohonen Self Organizing Map

The Kohonen neural network is an unsupervised learning and differs [6] from the feed forward back propagation neural network. This network does not use any activation function or bias weight [20]. Output from the Kohonen neural network does not consist of the output of several neurons [21].

The Kohonen network or self-organizing map (SOM) [21] has to setup a structure of interconnected processing units which strive for the signal. The Kohonen network performs a mapping from a continuous input space to a discrete output space. The points close to each other in the input space are mapped to the same or neighbouring number of clusters in the output space. The basis of the Kohonen SOM network is soft competition among the number of clusters in the output spaces.

Kohonen neural network is a self-organizing mapping technique that allows to project multidimensional points to two dimensional networks [6]. There are two key concepts important in Kohonen network, competitive learning and self-organization [20]. Competitive learning finds a neuron that is most like to the input pattern, and the network modifies this neuron and its neighbourhood neurons to be even more similar to it.

Each node of the map is defined by a vector w_{ij} whose elements are adjusted during the training. The basic training algorithm is stated as follows:

Step 1: select an object from the training set find the node which is closest to the selected data (i.e. the distance between $w_{ij}$and the training data is a minimum)
Step 2: adjust the weight vectors of the closest node and the nodes around it in a way that the w_{ij}move towards the training data
Step 3: repeat from step 1 for a fixed number of repetitions

III. METHODOLOGY

The methodology followed in this study is first the acquisition and preparation of data, which need to be fed into the Neural Network. Then, Kohonen Neural Network tool was used to produce results. Afterwards these results were analysed to find out the pattern of clustering on the body health's conditions.

A. Data Acquisition

The dataset contains the categorical variables observed for fitting percentage of body fat to simple body measurements and has recorded for 252 men.

Variables uses in this dataset [13]; [28] are as follows:

Percent body fat using Brozek's equation, 457/Density - 414.2
Density (gm/cm^3)
Age (yrs)
Weight (lbs)
Height (inches)
Adiposity index = $Weight/Height$^2 $(kg/m$^2)
Fat Free Weight = $(1 - fraction\ of\ body\ fat) * Weight$, Brozek's formula (lbs)
Neck circumference (cm)
Chest circumference (cm)
Abdomen circumference (cm) "at the umbilicus and level with the iliac crest"
Hip circumference (cm)
Thigh circumference (cm)
Knee circumference (cm)
Ankle circumference (cm)
Extended biceps circumference (cm)
Forearm circumference (cm)
Wrist circumference (cm) "distal to the styloid processes"

The dataset has been distributed into class 1 and class 2 which correspond as follows

Class 1 = Men had a good health.
Class 2 = Men had a bad health.

TABLE II
HEALTH STATE CLASSIFICATION

Body Fat Percentage	**Health Condition**
< = 15 %	Good Health
> 15 %	Bad Health

```
12.6,10.708,23,154.25,67.75,23.7,134.9,36.2,93.1,85.2,94.5,59,37.
3,21.9,32,27.4, 17.1, Good
6.9,10.853,22,173.25,72.25,23.4,161.3,38.5,93.6,83,98.7,58.7,37.3
,23.4,30.5,28.9, 18.2, Good
24.6,10.414,22,154,66.25,24.7,116,34,95.8,87.9,99.2,59.6,38.9,24,
28.8,25.2,16.6, Bad
10.9,10.751,26,184.75,72.25,24.9,164.7,37.4,101.8,86.4,101.2,60.1
,37.3,22.8,32.4, 29.4,18.2, Good
27.8,1.034,24,184.25,71.25,25.6,133.1,34.4,97.3,100,101.9,63.2,42
.2,24,32.2, 27.7,17.7, Bad
20.6,10.502,24,210.25,74.75,26.5,167,39,104.5,94.4,107.8,66,42,25
.6,35.7,30.6, 18.8, Bad
19,10.549,26,181,69.75,26.2,146.6,36.4,105.1,90.7,100.3,58.4,38.3
,22.9,31.9,27.8, 17.7,Bad
12.8,10.704,25,176,72.5,23.6,153.6,37.8,99.6,88.5,97.1,60,39.4,23
.2,30.5,29,18.8, Good
```

Fig.1 Data Sample

B. Setting a Target

The classification for target setting is done based on the percentage of American men with percentage of body fat less than 15% [22], as stated in Table II. Men with body fat percentage less than or equal to 15 % are considered has a good health condition. Whereas men with body fat percentage greater than 15 % is considered in a bad health state.

C. Data Preparation

Data pre-processing is performed on raw data to prepare it for another processing procedure. This is to improve the overall quality of the patterns obtained from data mining process. There are several different tools and methods can be used for data pre-processing. For example, data cleaning is used to remove noise and correct inconsistency in the data. Data integration joins the data from multiple sources into a coherent data store. While, data transformation, such as normalization manipulates raw data to produce a single input [23]. Such techniques are appropriate to improve the accuracy and efficiency of mining algorithms. In this study, data normalization is performed based on maximum value and min-max methods.

D. Normalizing the Attributes

In the data normalization, each input contributes equally to the decision or prediction made by the network [23]. Data normalization concerns the attribute data in the scaled within a small specified range such as -1.0 to 1.0 or 0 to 0.0. These data pre-processing is applied in this experiment since the neural network tool using neural network back propagation algorithms to speed up the learning phase.

In this experiment, normalization [24] – [25] is performed using the following methods:

i. Maximum Value

In this method the maximum value in an attribute are identified and transform using the formula as follows:

$$new\_value = \frac{old\_value}{maximum\_value}$$

ii. Min-Max Normalization

This method performs a linear transformation on the original data, based on the formula as follows:

$$new\_value = \frac{old\_x - minimum\_x}{minimum\_x - maximum\_x}$$

All the data falls into range 0.0 to 1.0 after the data pre-processing.

E. The Kohonen Network

The initial weights in the Kohonen layer can be distributed in five ways. The random number seed used in distributing the weights can be established. This enable repetition in the experiments.

```
Small Random: The weights are set to small random
values between -0.1 and 0.1.
Random : The weights are set to random values between
-1 and 1.
From Data     : The weights are set by taking random
samples from within the input data set.
Small Grid    : The initial weights are distributed
in a small grid pattern.
Grid          : The initial weights are distributed
in a grid pattern.
```

Kohonen learning algorithm [26] - [27] is outlined as follows:

Start: Select at random n-dimensional weight vectors $\mathbf{w}_1, \mathbf{w}_2, \ldots, \mathbf{w}_m$ of the m computing units. Identify an initial radius r, a learning constant η, and a neighbourhood function ϕ.

Step 1: Select an input vector ξ using the desired probability distribution over the input space.

Step 2: Select the unit k with the maximum excitation (that is, for which the distance between $\mathbf{w}_i$ ad is minimal, $i = 1, \ldots, m$).

Step 3: Update weight vectors using neighbourhood function and the update rule

$$\mathbf{w}_i \leftarrow \mathbf{w}_i + \eta\phi(i,k)(\xi - \mathbf{w}_i), \text{ for } i = 1, \ldots, m.$$

Step 4: Stop, when the maximum number of iterations has been reached; otherwise modify η and ϕ as scheduled and continue with Step 1.

F. Experiment

The experiment is performed using Neural Connection software where data will be trained. This tool performs the training session with Kohonen Neural Network. Kohonen networks make the basic assumption that clusters, or classes, are formed from patterns that share common features and group similar patterns together. The architecture involves two elements. First the neural technique works on the set of inputs which is linked to an output. This process uses a supervised neural technique i.e. Multi-Layer Perceptron. Secondly, the type of output desired is selected. In this experiment, the Text Output is due to initial results would be examined using a cross tabulation matrix and a test data set. Data output then is needed to feed back the results into the database. The architecture of Kohonen Neural Network as illustrated in Fig. 2 and 3.

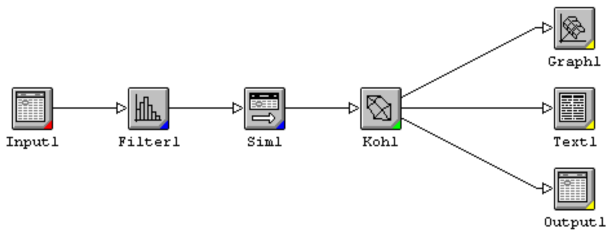

Fig. 2 The Kohonen Neural Network

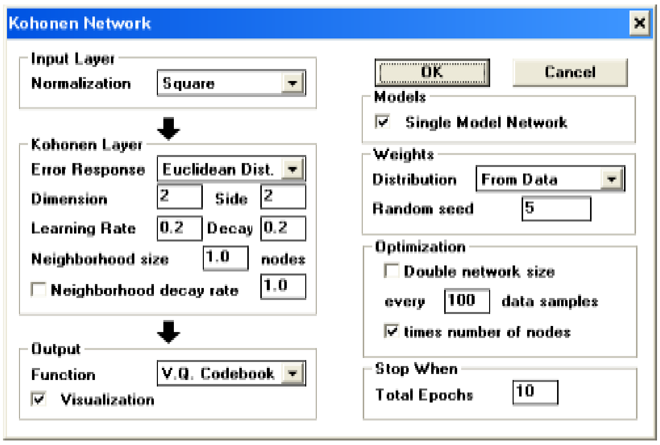

Fig. 3 The Kohonen Neural Network Setting

IV. Experiment and Results

In this experiment, the pattern of the clustering is affected by the learning rate. The experiment is carried out for side 2 which has 4 clusters ranges from 0 to 3, side 3 with 9 clusters ranges from 0 to 8 and side 4 clusters ranges from 0 to 15. Table III shows data distribution used in the experiment.

TABLE III
DATA DISTRIBUTION

	Train	Test
Data	202	25

The results for Kohonen training is shown in Table IV, V, and VI for Side 2, Side 3 and Side 4 respectively.

Side 2

Table IV shows the result of training and testing that the parameter and learning rate has been set up from 0.1 to 1.0. When the learning rate is set to more than 0.3 the percentage of training patterns in cluster 2 reduces from 16.83% (34/202) to 10.40% (21/202). For cluster 1, distribution pattern increased from 24.26% (49/202) to 29.70% (60/202). Meanwhile, data distribution pattern for pattern is same for learning rate 0.1 and 0.3 (21.78%) and decreased at 1 point at learning rate 0.3 to 0.5 (21.29%). At cluster 3, the pattern is decreased at learning rate 0.1 and distributed at same pattern from learning rate 0.2 to 0.4.

TABLE IV
SIDE 2

Side 2																				
Learning Rate	0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
Cluster	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test
0	34	2	21	0	21	0	61	10	76	9	48	4	48	5	1	0	1	0	1	0
1	49	8	60	10	61	10	21	8	21	6	1	0	1	0	78	10	47	4	105	13
2	44	6	44	8	43	8	43	8	43	6	104	14	49	8	121	15	105	13	49	8
3	73	9	77	8	77	8	77	8	62	10	49	7	104	12	2	0	49	8	47	4
Subtotal	202	25	202	25	202	25	202	25	202	25	202	25	202	25	202	25	202	25	202	25
Total	227		227		227		227		227		227		227		227		227		227	

Based on the distribution of training and testing patterns in each cluster, the learning rate 0.1 produces well distributed patterns. Therefore, learning rate 0.1 is the best learning that gives good distribution for training and test patterns.

To analyse the effect of learning rate on the distribution on training or test pattern, the result exhibited in Table IV are summarised in the Fig 4.

The distribution on training pattern has a same number until the learning rate achieved 0.5, particularly for cluster 2 as shown in Fig. 4. This pattern is also observed for the cluster 3 where data are distributed with same number until learning rate is 0.4 for both training and test data.

For the test pattern at least 1 of the cluster does not have any test pattern in them. However, the learning rate 0.1 indicates that the test pattern falls into cluster 0 to 3. Since the number of test pattern is very small, it's not sufficient to allocate the patterns evenly into each cluster. Thus, it's concluded that side 2 is more suitable for this problem based on data distribution in Table IV

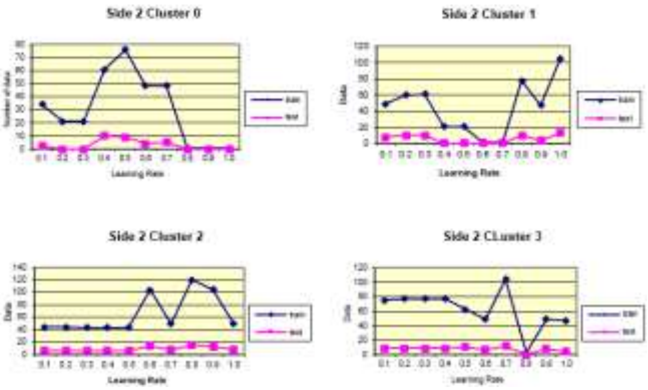

Fig. 4 Side 2 Cluster's Graph

TABLE V
SIDE 3

Side 3																				
Learning Rate	0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
Cluster	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test
0	2	0	0	0	1	0	1	0	1	0	30	0	2	0	2	0	1	0	81	9
1	36	5	19	5	32	3	31	2	2	0	2	3	37	8	34	7	2	0	36	9
2	31	7	35	4	37	6	37	3	35	3	31	3	32	4	38	3	36	7	1	0
3	23	3	38	4	2	0	2	0	2	0	34	4	32	4	28	3	3	0	45	6
4	18	0	19	2	2	0	2	0	32	2	1	0	1	0	1	0	61	6	2	0
5	11	2	13	2	17	2	21	2	38	2	34	0	41	4	61	9	34	7	31	1
6	40	2	40	5	35	3	35	3	35	3	2	0	41	5	44	6	30	1	2	3
7	39	3	24	5	38	3	38	0	37	0	31	2	2	0	2	0	47	6	1	0
8	17	3	17	4	25	4	25	3	24	3	38	2	2	0	1	0	1	0	25	3
Subtotal	202	25	202	25	202	25	202	25	202	25	202	25	202	25	202	25	202	25	202	25
Total	227		227		227		227		227		227		227		227		227		227	

Table V illustrates the distribution pattern for side 3. We observed that cluster 0 for side 3 has the smallest number of data distributed in both test and training. For learning rate 0.2, there is no distribution data for both test and training pattern. The data is distributed almost well for the cluster 1 to 8 in learning rate 0.1. The effect of learning rate on the distribution on training or test pattern are illustrated in Table V.

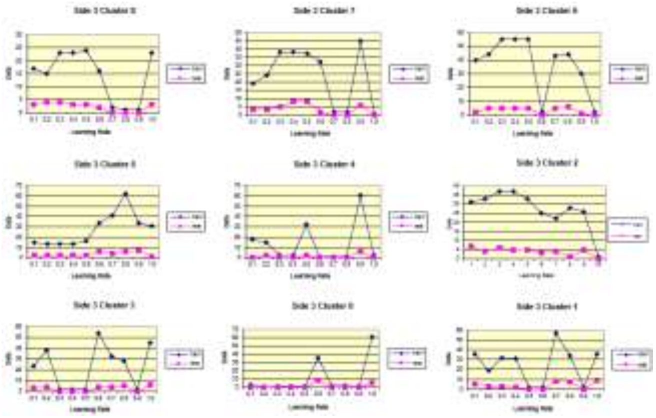

Fig 5. Side 3 Cluster's Graph

Refer to the Fig 5, the train and test for cluster 0 is distributed in 0 and 1. When the learning rate is at 0.3 the distribution of data is heavier in cluster 0 to cluster 4 compared to cluster 5 to 8. For the test pattern at least 1 of the cluster does not have any test pattern in them. However, the learning rate 0.1 indicates that the test pattern falls into cluster 0 to 3. Since the number of test pattern is very small, it's not sufficient to allocate the patterns evenly into each cluster.

For cluster 5, the distribution is increased in parallel of learning rate despite decrease at learning rate 0.8. For cluster 6 the distribution decreased when the learning rate is 0.6. The rest of the clusters do not exhibit a regular pattern.

Table IV depicts the data distribution for side 4. The distribution pattern for cluster 0 is only 1 for train and 0 for test allocate from learning rate 0.1 to 0.6. For cluster 13 and 14, the distribution decreased when learning rate 0.2 and has a same pattern until learning rate 0.6.

TABLE VI
SIDE 4

Learning Rate	0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
Cluster	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test
0	1	0	1	0	1	0	1	0	1	0	1	0	16	2	13	1	7	0	1	0
1	9	0	9	2	13	0	3	0	9	2	37	2	2	0	2	0	2	0	2	0
2	29	0	16	0	11	0	9	1	17	4	9	2	2	0	2	0	11	1	10	0
3	13	1	11	4	15	2	18	1	9	2	16	5	11	4	22	2	22	2	47	2
4	7	1	1	0	5	0	5	0	17	1	14	1	25		18	4	14	1	18	1
5	30	2	11	2	19	2	13	2	5	0	8	0	15	2	23	2	37	2	30	1
6	21	1	43	1	18	2	18	2	21	0	15	1	25	2	17	3	29	4	1	0
7	4	1	41	1	9	5	14	1	26	2	11	6	27	4	33	4	2	0	14	5
8	11	1	22	5	22	0	18	0	19	2	17	6	17	5	28	1	39	2	39	6
9	28	2	15	5	16	3	9	3	12	4	15	3	26	2	13	4	30	4	25	1
10	14	1	17	1	17	1	17	1	3	0	1	0	1	0	3	0	39	1	7	0
11	17	2	13	5	19	4	27	4	30	1	18	1	7	0	7	0	14	2	30	1
12	15	1	10	1	14	2	18	1	30	1	12	1	16	3	12	3	1	0	24	1
13	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
14	9	1	1	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0
15	20	2	21	2	15	0	10	0	11	4	17	0	17	3	18	1	1	0	9	1
subtotal	202	25	202	25	202	25	202	25	202	25	202	25	202	25	202	25	202	25	202	25
total	227		227		227		227		227		227		227		227		227		227	

To analyse the effect of learning rate on the distribution on training or test pattern, the result exhibited in Table VI are summarised in the following graph.

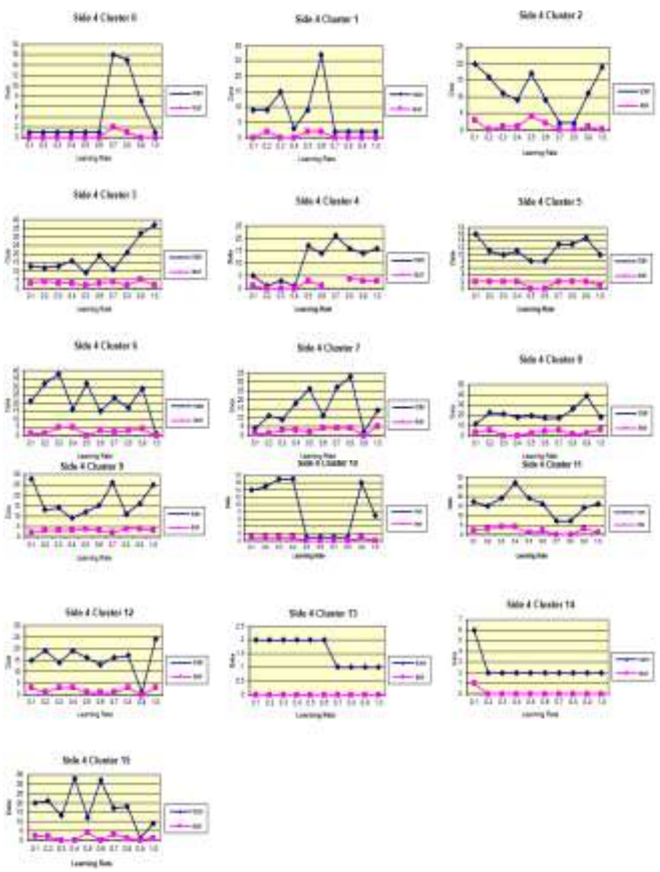

Fig. 6 Side 4 Cluster's Graph

Based Fig. 6, the distribution on training pattern for cluster 0 is same from learning rate 0.1 to 0.6. For cluster 1, the distribution of data is heavily at learning rate 0.6, given a biggest number of data from the other learning rate.

For cluster 2, the pattern is decreased accordingly from learning rate 0.1 to 0.4. The data distribution pattern for cluster 5 and 8 gives a well pattern in this side 4 experiment.

For cluster 3, the distribution was increase according to the learning rate increments.

Cluster 5 in side 4 has well distributed pattern since the data were allocate almost same in all learning rates.

For cluster 13, there are no distributions data fall for all learning rate in test. While in cluster 14, the distribution is decreased at learning rate 0.2 before the remains learning rate distribute the same pattern to the end.

Based on the distribution of data in Table IV, V and VI, it's concluded that side 2 with 4 clusters is more fitted for this problem. Side 3 and 4 presents irregular patterns.

V. Conclusions

A Kohonen neural network contains only two levels. The network is presented with an input pattern that is given to the input layer. This input pattern must be normalized to numbers in the range between -1 and 1. The output from this neural network will be one single winning output neuron. This study presents the use of Kohonen neural network to classify health state based on body fat percentage. From experiment, side 2 shows appropriate results while predicting health's state. Experimental steps explain in this work may assist the use of Kohonen network for unsupervised prediction. Study to the variation of dataset's size will be considered in the near future to see the performance of the network.

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