Analysis of Noise Emitted From Electrical Machines by Clustering Method

[1]Sen Tirtharaj, [2]Kar Amitava and [3]Banerjee Debamalya
[1]Dept. of E.E, Asansol Engineering College
tirtha.bitm@gmail.com
[2]Dept. of CA, Asansol Engineering College
karamitava@gmail.com
[3]Dept. of Production Engg, Jadavpur University
debamalya_banerjee@yahoo.co.uk

ABSTRACT

This paper refers to a study of noise, emitted from different electrical machines (AC & DC) as noise is very noticeable and physically harmful to human beings. This study has been conducted in an electrical machines laboratory. Different noise parameters such as LAeq (equivalent continuous A-weighted sound level), LAE (sound exposure level), LAV (average sound level) and TWA (Time weighted average level) are taken by a precision noise dosimeter (Model-4444). Clustering method is applied for analyzing high and low noise variables for identical noise producing machines. Clustering is a popular non-directed learning data mining technique for partitioning a dataset into a set of clusters (i.e. segmentation). Although many clustering algorithms may be applied, but none of them may be superior on all datasets, and so it is never clear which algorithm and which parameter settings are the most appropriate for a given dataset. Our dataset is based on the different sound parameters mentioned above. We have applied graph based clustering method (Zahn's algorithm) for analyzing this. Zahn's algorithm first constructs a minimal spanning tree and then deletes the inconsistent edges i.e. the edges which are too long as compared to the other edges, to form clusters. For the construction of the minimal spanning tree we have used the Prim's algorithm. The result implies grouping of similar noise producing machines. In the first iteration there were two clusters. The second iteration resulted to three clusters. We have shown up to third iteration which resulted to the formation of four clusters of machines producing four identical levels of noise.

Key words: Noise Dose, Graph-based clustering, partitioning data, minimum spanning tree, inconsistent edges

INTRODUCTION

Clustering algorithms are used to cluster a number of objects. But in this paper it is used for the first time to cluster machines making similar levels of noises. First let us know something about noises.

Noise is calculated in the dB scale taking the sound pressure level (Lp in decibels), the formula used: $Lp = 20\log(P/P_0)$, Where P is the root mean square (rms) sound pressure and P_0 is the reference sound pressure (0.00002 N-m-2). Noise dose may be given in terms of a value relative to unity or 100% of an "acceptable" amount of noise. Different parameters related to noise dose are L_{Aeq} (Equivalent continuous A-weighted sound level), L_{AV} (Average sound level), L_{AE} (Sound exposure level), TWA (Time weighted average) etc. L_{Aeq} is the constant sound level that, in a given time period would convey the same sound energy as the actual time varying A-weighted sound level. LAE is defined as that level which lasting for one second has the same acoustic energy as a given noise event lasting for a period of time T. LAV is defined as the total energy averaged over the total time. TWA is the noise that is weighted over a certain amount of time such as 8 hours (for machine noise).

Noise dose readings has been taken from a paper named "**Noise Dose Emitted from Different Electrical Machines Compared**" by **Tirtharaj Sen, Pijush Kanti Bhattacharjee, Debamalya Banerjee, Bijan Sarkar published on International Journal of Soft Computing and Engineering (IJSCE), Volume-1, Issue-4, September 2011.** The data taken is given below:-

Table 1: Noise parameters for various electrical machines

Elec. M/C/ Noise Para.	**L_{Aeq} (dB)**	**L_{AE} (dB)**	**L_{AV} (dB)**	**TWA (dB)**
DC Shunt Motor	82.2	111.9	81.8	56.9
Wound Rotor Induction Motor	84.5	113.9	84.5	59.3
Squirrel Cage Induction Motor	78.3	107.7	70.6	85.4
Single Phase Induction Motor	73.0	88.7	0	0
Synchronous Motor	77.1	106.7	0	0
DC Generator	86.6	115.9	86.4	61.0

CLASSIFICATION OF MACHINES

The availability of data shows that all the machines have four types of measurement. So the data from each machine can be plotted in a four dimensional graph as a scatter diagram with the axes measuring LAeq (equivalent continuous A-weighted sound level), LAE (sound exposure level), LAV (average sound level) and TWA (Time weighted average level). It is a four-dimensional scatter diagram, it cannot be shown graphically. Let us represent

A = DC Shunt Motor
B = Wound Rotor Induction Motor
C = Squirrel Cage Induction Motor
D = Single Phase Induction Motor
E = Synchronous Motor
F = DC Generator

Table 1A: Noise parameters for various electrical machines

M/C	L_{Aeq}	L_{AE}	L_{AV}	TWA
A	**82.2**	**111.9**	**81.8**	**56.9**
B	**84.5**	**113.9**	**84.5**	**59.3**
C	**78.3**	**107.7**	**70.6**	**85.4**
D	**73**	**88.7**	**0**	**0**
E	**77.1**	**106.7**	**0**	**0**
F	**86.6**	**115.9**	**86.4**	**61**

Each of these A, B, C, D, E, F has four dimensions. The logical distance between each of these machine from the other is calculated.

$AB = \sqrt{(82.2-84.5)^2 + (111.9-113.9)^2 + (81.8-84.5)^2 + (56.9-59.3)^2} = 4.72 \approx 5$

Similarly we calculate AC, AD, AE, AF, BC, BD, BE, BF, CD, CE, CF, DE, DF AND EF. The value thus calculated is given below:-

Table 2: The edges with their weights of the complete graph

Edges	Weights	Edges	Weights
AC	**31**	**AB**	**5**
BC	**31**	**AD**	**103**
BD	**107**	**AE**	**100**
CD	**113**	**BE**	**104**
CE	**111**	**BF**	**4**
DE	**18**	**CF**	**31**
DF	**110**	**AF**	**9**
EF	**107**		

The graph thus obtained is complete with all the edges having weights calculated.

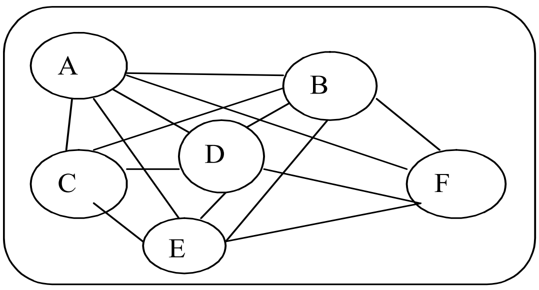

Fig 1: Complete graph drawn from logical distance of all machines

From the complete graph, minimum spanning tree is constructed using the Prim's algorithm.

Table 3: PRIM'S algorithm converts the complete graph in minimum spanning tree

From/To	A	B	C	D	E	F
A	0	5	31	103	100	9
B	*5*	0	31	107	104	4
C	31	*31*	0	113	111	31
D	103	107	113	0	18	110
E	*100*	104	111	*18*	0	107
F	9	*4*	31	110	107	0

The minimum spanning tree is thus drawn

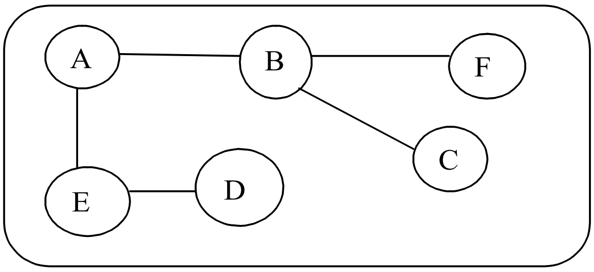

Fig 2: Minimum spanning tree drawn from the complete graph

The mean and standard deviation of the edges are calculated and from these the z value of each is calculated of the weights.

z = (edge weight – mean)/ standard deviation

The edges of the Minimum Spanning Tree, along with their weights, their mean, their standard deviation and their z value are given as under:-

Table 3a: The edges of minimum spanning tree their mean and their standard deviation

Edges	Weights	z value
AB	5	-0.674483
AE	100	1.718022
BC	31	-0.018019
BF	4	-0.696229
DE	18	-0.329254
μ	31.5603	
σ	39.7838	

Now, Zahn's algorithm states that the inconsistent edge i.e. the edge having the z-value greater than one. The edge AE has z-value 1.718. So AE is removed.

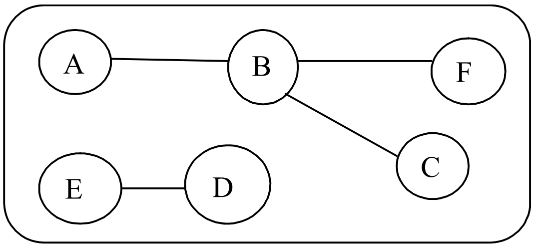

Fig 3: Cluster formed as a result of deletion of edge AE

Now there are two clusters – ABCF and DE. Again, the mean and the standard deviation and the corresponding z-value of the remaining edges are calculated. These are given as under:-

Table 4: The edges of minimum spanning tree their mean and their standard deviation after 2nd iteration

Edges	Weights	z value
AB	**5**	**-0.71334**
BC	**31**	**1.29563**
BF	**4**	**-0.7799**
DE	**18**	**0.34316**
μ	**14.5**	
σ	**12.8**	

In the second iteration BC has the greatest z-value. So BC is removed.

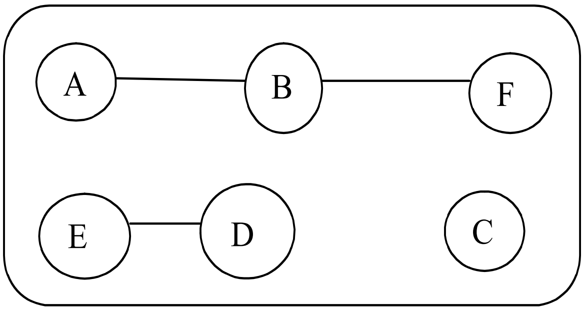

Fig 4: cluster formed as a result of deletion of edge BC

The cluster then becomes ABF, DE and C. Again, the mean and the standard deviation and the corresponding z-value of the remaining edges are calculated. These are given as under:-

Table 5: The edges of minimum spanning tree their mean and their standard deviation after 3rd iteration

Edges	Weights	z value
AB	5	-0.52116
BF	4	-0.62667
DE	18	1.153785
µ	9	
σ	8.191	

In the second iteration DE has the greatest z-value. So it is removed.

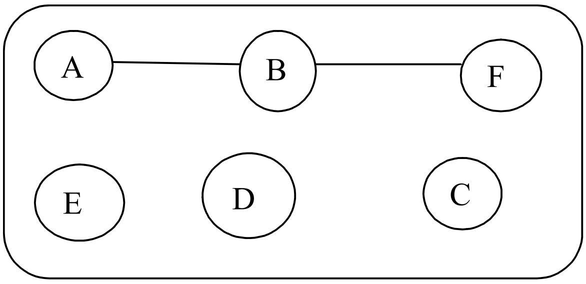

Fig 5: cluster formed as a result of deletion of edge DE

The cluster then becomes ABF, D, E and C. Again, the mean and the standard deviation and the corresponding z-value of the remaining edges are calculated. These are given as under:-

Table 6: The edges of minimum spanning tree their mean and their standard deviation after 4th iteration

Edges	Weights	z value
AB	5	0.71087
BF	4	-0.73
µ	4.3	
σ	0.61177	

Now, all the z-value is less than one. So iteration stops here. The final clusters are ABF, D, E and C.

This implies that the machines DC Shunt Motor, Wound Rotor Induction Motor and DC Generator produce similar levels of noises. The other three motors – Squirrel Cage Induction Motor, Single Phase Induction Motor and Synchronous Motor produce levels of noises each of which are different from the other.

CONCLUSIONS

Classification of machine is done on the basis of machines producing similar levels of noises. We have used Prim's algorithm to convert a complete graph to minimum spanning tree and then Zahn's algorithm which leads to clustering of machines. The entire data is taken from another paper which was written as a result of a detailed experiment in an electrical laboratory. So basically we dealt with secondary data. Our result may be of particular importance to the laboratory where the experiments were conducted. The laboratory may go for detailed inspection. It may lead to replacement of faulty part of the machines thereby reducing the different noise levels thereby decreasing noise related environmental pollution. Noise is very irritating for the workers and sometimes it leads to reduction of the workers' productivity. Reduction of noise may thus increase the productivity of the workers.

RELEVANCE OF THE WORK

Electrical machines are in various industrial operations like drilling, cutting, milling etc. where mainly three-phase induction motors are used. Zahn's algorithm may be effectively used for identifying noise exposure from electrical machines which leads to better, healthy and ergonomically less-noise environment for the workers.

REFERENCES

1. S John Peter & S P Victor (2010). A Novel Algorithm for Informative Meta Similarity Clusters Using Minimum SpanningTree. *International Journal of Computer Science and Information Security*, **8 (1).**
2. T. Asano, B. Bhattacharya, M. Keil and F.Yao. "Clustering Algorithms based on minimum and maximum spanning trees". In Proceedings of the 4th Annual Symposium on Computational Geometry,Pages 252-257, 1988.
3. Anil K. Jain, Richard C. Dubes "Algorithm for Clustering Data" Michigan State University, Prentice Hall, Englewood Cliffs, New Jersey 07632.1988.
4. H. Gabow, T. Spencer and R. Rajan. " Efficient algorithms for finding minimum spanning trees in undirected and directed graphs". Combinatorica, 6(2):109-122, 1986.
5. D. Karger, P. Klein and R.Tarjan. "A randomized linear-time algorithm to find minimum spanning trees". Journal of the ACM, 42(2):321-328, 1995.
6. J. Kruskal. "On the shortest spanning subtree and the travelling salesman problem". In Proceedings of the American Mathematical Society, Pages 48-50, 1956.
7. R. Prim. "Shortest connection networks and some generalization". Bell systems Technical Journal,36:1389-1401, 1957.
8. C. Zahn. "Graph-theoretical methods for detecting and describing gestalt clusters". IEEE Transactions on Computers, C-20:68-86, 1971.

9. Goelzer B, Hansen CH., Sehrndt G (2001). Occupational Exposure to Noise: Evaluation, Prevention and Control. Publication Series from the Federal Institute for Occupational Safety and Health, Document published on behalf of the World Health Organization, (Dortmund, Berlin).
10. Michel P, Girard S.A, Simard M, Larocque R. Leroux T, Turcotte F (2008). Accident Analysis and Prevention J. Elevier 40, 1644 1652.
11. Pancholy M,. Chhapgar AF, and Singhal SP (1967). Noise Survey in Calcutta, J. Sci. Ind. Res. 26, 314–316.
12. Roy B, Santra SC, Chandra S, and Mitra B (1984), Traffic Noise Level in Calcutta, Sci. Cult. 50, 62–64.