# GAUSSIAN MIXTURE MODEL BASED NON-ADDITIVE FUZZY SYSTEMS

By


**NISHCHAL KUMAR VERMA**

**Department of Electrical Engineering**


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Gaussian mixture model

# CERTIFICATE

This is to certify that the thesis entitled **"Generalized Mixture Model based Non-additive Fuzzy Systems"** being submitted by **Mr. Nishchal Kumar Verma** for the award of the degree of the **Doctor of Philosophy** in the Department of Electrical Engineering, Indian Institute of Technology, Delhi is a record of bonafide research work he has carried out under my supervision. The results contained in this thesis have not been submitted to any other Institute or University for the award of any degree or diploma.

**(Prof. Madasu Hanmandlu)**
Department of Electrical Engineering,
Indian Institute of Technology, Delhi
Hauz Khas, New Delhi-110016
INDIA

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# Abstract

In many realistic applications, the assumption of independence among inputs does not hold good. The thesis is therefore concerned with the fuzzy modeling by taking into account the interaction among the inputs as well as dynamics of the system. To address this problem, the non-additive fuzzy system is proposed using the framework of Gaussian Mixture Model (GMM) in the Generalized Fuzzy Model, where the Sugeno's $\lambda$-measure enters into the model to account for the interaction.

In the next study, we are bent upon devising an efficient non-additive fuzzy system using Q-measure by replacing Sugeno's $\lambda$-measure for the purpose of reducing the computational burden of the algorithm. Our attention is then turned on to further simplification by resorting the estimation of fuzzy measures from covariance matrices in GMM. This makes the model simpler as there is no need of learning the fuzzy measures from the data.

Enthused by the success in the non-additive fuzzy modeling, we focus on tackling the dynamic behavior of the fuzzy systems by embedding the state information into them using Hidden Markov Model (HMM). Incorporation of HMM into the fuzzy model is found to give encouraging results for the dynamic systems. All of our algorithms have been validated on the two bench mark applications (Box and Jenkins gas furnace data and Industrial Dryers data) and two real data applications (the Earth's magnetic field and Electric load demand of Indian utility).

Finally we have tried to concentrate on the quality of the clusters that constitute the fuzzy rules in order to improve the efficiency and performance of the resulting model and this has been achieved by developing "Improved Mountain Clustering (IMC)" technique.

The quality of the clusters is judged by the entropy function. The IMC is then implemented on Industrial Dryers data as well as on the segmentation of different color images. This clustering technique is found to be computationally efficient as compared to the well known and commonly used clustering algorithms like K-Means, FCM, Modified Mountain clustering, EM clustering algorithms. Though IMC has been developed to replace EM clustering but all along EM clustering is used in GMM as it provides the membership functions directly.

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