Novelty Detection by A Fast Feed-forward Neural Network- A Kernel Based Approach

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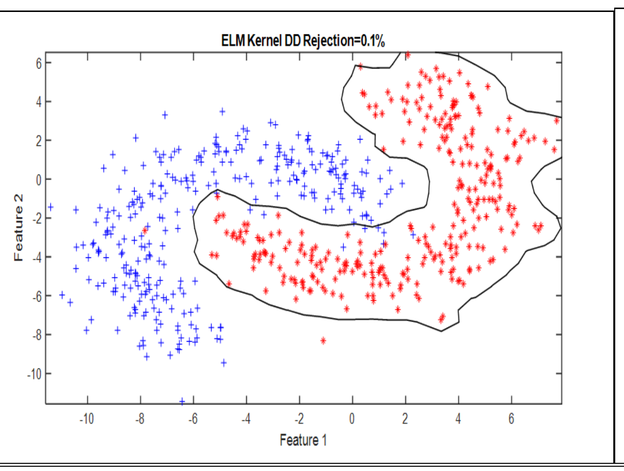
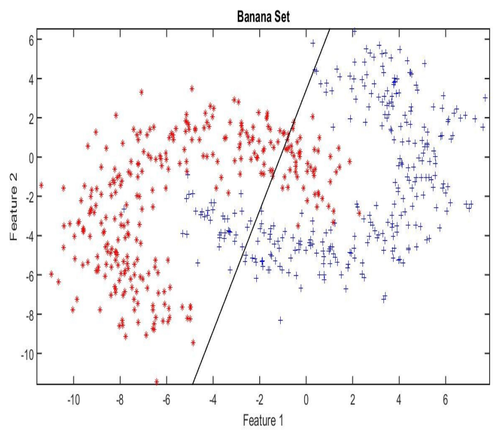
Objectives

- Develop a fast data descriptor, so that, it can handle **offline as well as online data** (i.e. Streaming Data) very efficiently.
- Develop one-class classifiers, which will support both type of feature mapping viz., Random and Kernel Feature Mapping.
- Develop One-class classifiers in such a way so that they yield outcomes in a single pass. Therefore, recently popular single feed-forward neural network, **Extreme Learning Machine (ELM)**, will used as a base classifiers to develop one-class classifiers.
- Develop one-class classifier for two types of framework viz., **Boundary based** and **Reconstruction based**.
- **Realized these classifiers on FPGA board to provide more speed up to the proposed data descriptors.**

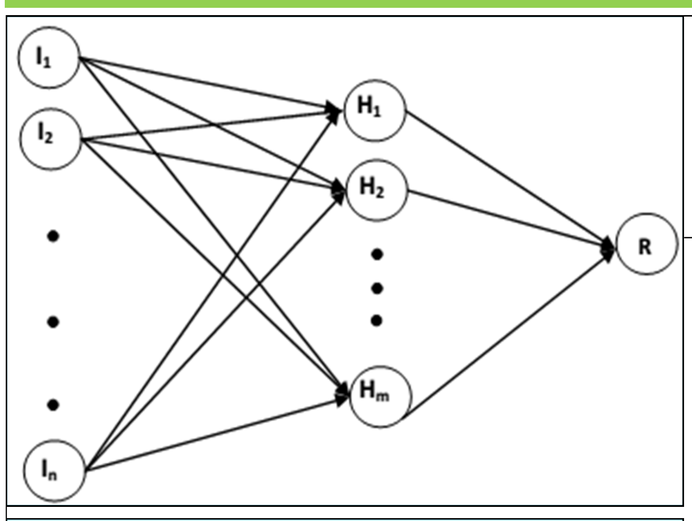
Binary-Class vs One-Class

- Construction of decision boundary by a **Binary Classifier** in such a way so it yields lowest classification error.
- **One-Class** constructs decision boundary in such a way so that it can describe the whole data, therefore, it is also **called as Data Descriptor (DD).** It has been mainly employed for **novelty or outlier detection.**





Architecture of the Proposed Offline One-Class Classifiers



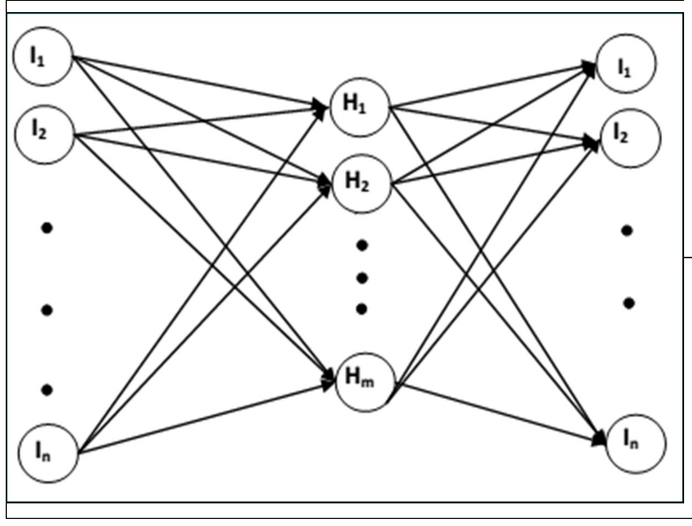
Boundary Based Approach: This is single node output architecture, which endeavor to approximate all samples at any real number R.

Calculate Error Value → Decision Function based on some threshold criteria → Target Class / Outlier Class

Minimization problem is defined for boundary based architecture:

$$Min.\ L : \frac{1}{2}\|\beta\|^2 + C\frac{1}{2}\|H\beta - R\|^2$$
$$S.T.\ \ h(x)\beta = R - E$$

Where, R = Any Real Number, C = Regularization parameter



Reconstruction Based Approach: This is just an autoencoder, which endeavor to reconstruct all input samples at output layer.

Calculate Error Value → Decision Function based on some threshold criteria → Target Class / Outlier Class

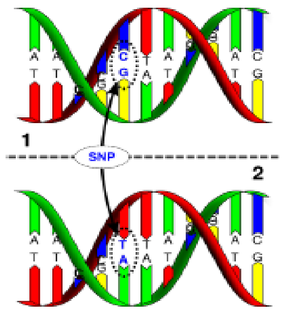
Minimization problem is defined for reconstruction based architecture:

$$Min.\ L : \frac{1}{2}\|\beta\|^2 + C\frac{1}{2}\|H\beta - X\|^2$$
$$S.T.\ \ h(x)\beta = X - E$$

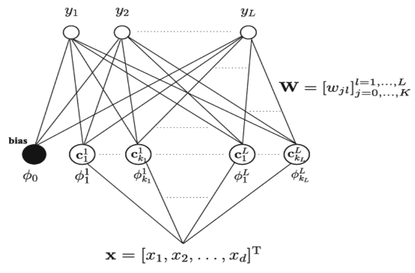
Where, X = Training Samples, C = Regularization parameter

Usage of Multi-Label Classifier for identifying Disease Resistant Genes in Soybean Genome (Future Scope)

- **Genes** are associated with **biological functions**.
- **Disease gene association:** Identifying which DNA variation are highly associated with a specific disease.
- **Single Nucleotide Polymorphisms (SNPs):** These are the most common form of DNA variations.
- SNPs are developed as a type of DNA molecular marker, and widely used in genetic research including genome mapping.
- **Functional Genomics:** Every gene can be associated with multiple biological function. Thus prediction of gene functional classes needs more than traditional machine learning algorithms.
- Multi class classification examples are associated with a single label, whereas **multi label classification** is a supervised classification task where each data instance may be associated with *multiple* class labels.

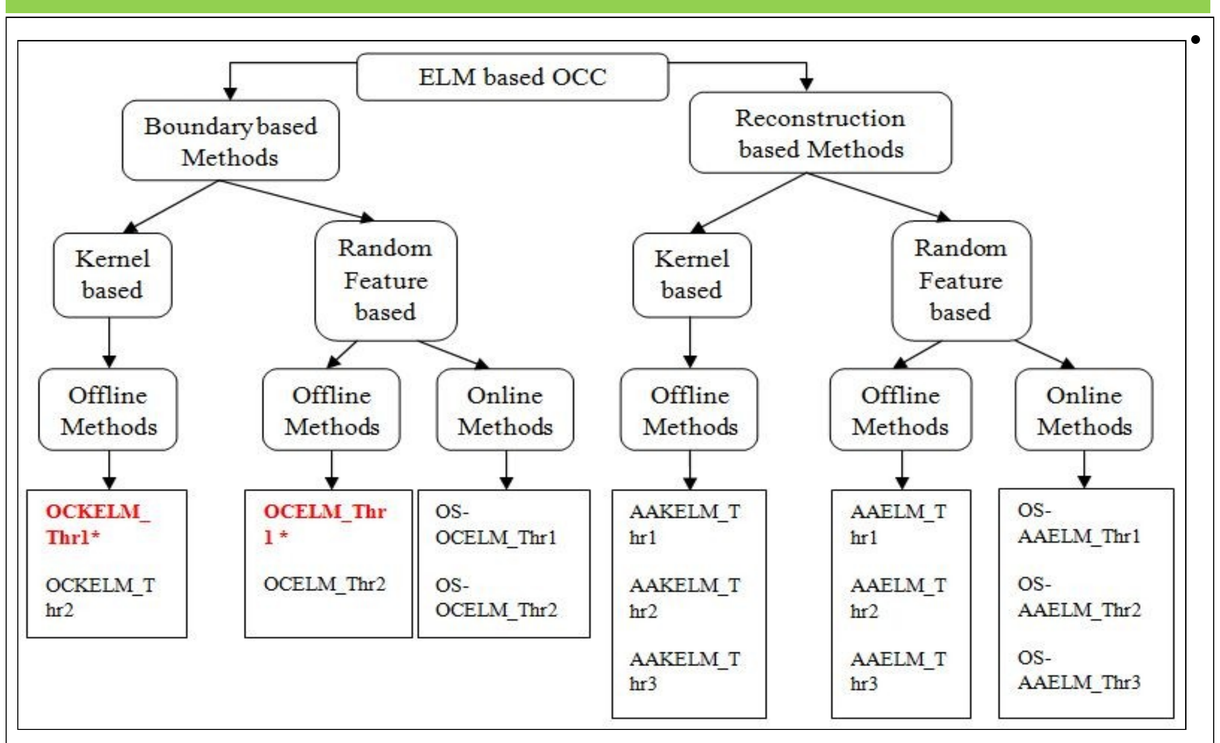


X_1	X_2	X_3	X_4	X_5	C_1	C_2	C_3	C_4	$Y \subseteq \mathcal{Y}$
3.2	1.4	4.7	7.5	3.7	1	0	0	1	$\{\lambda_1, \lambda_4\}$
2.8	6.3	1.6	4.7	2.7	0	0	1	1	$\{\lambda_3, \lambda_4\}$
7.7	6.2	4.1	3.3	7.7	1	0	0	1	$\{\lambda_1, \lambda_4\}$
9.2	0.4	2.8	0.5	3.9	0	1	0	0	$\{\lambda_2\}$
5.5	5.3	4.9	0.6	6.6	1	1	1	0	$\{\lambda_1, \lambda_2, \lambda_3\}$



Architecture of ML-RBF Neural Network. [*M.L.Zhang, 2009*]

Proposed One-Class Classifiers (ELM-2015 & Neurocomputing)

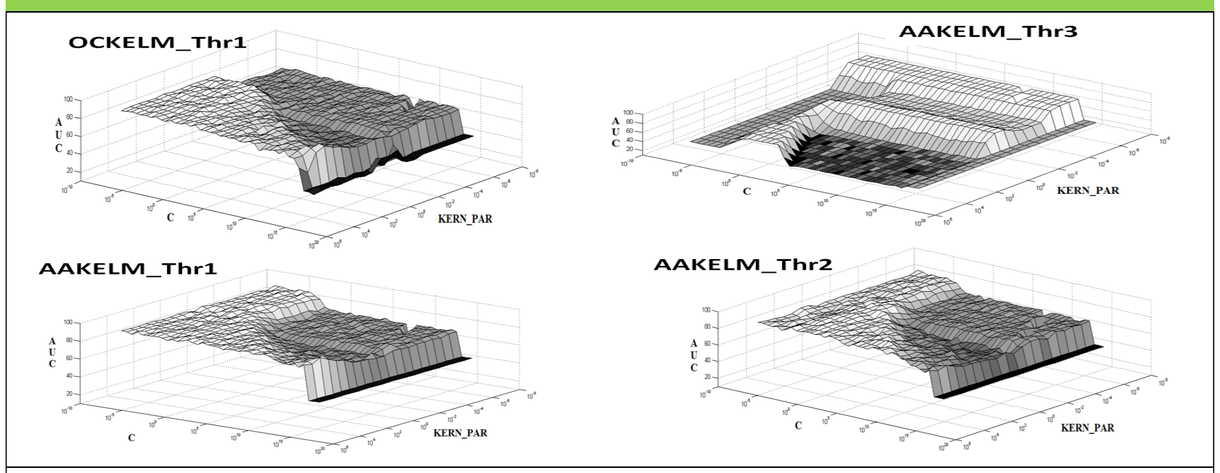


C. Gautam, A. Tiwari and Q. Leng, "*On The Construction of Extreme Learning Machine for Online and Offline One Class Classifier - An Expanded Toolbox*". Extended version of ELM-2015 paper (**Selected in conference to submit it for Journal**), **Neurocomputing (ELSEVIER) (Accepted), 2016, Impact Factor: 2.392 (SCI Indexed).**

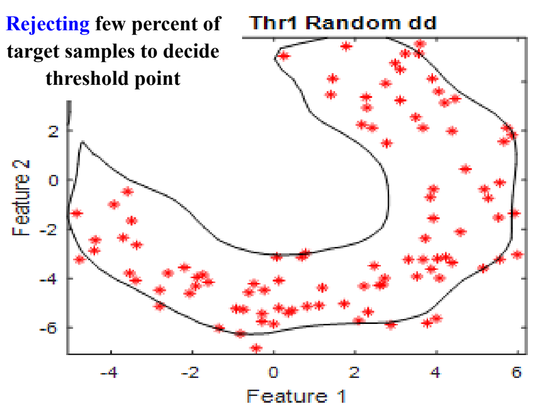
•**C. Gautam** and A. Tiwari, *"On The Construction of Extreme Learning Machine for One Class Classifier"*. In Proceedings of **6th ELM-2015** (**Springer**), Hangzhou, China, vol. 6, pp. 447-461, December, 2015. **(Travel Grant Fully Funded by Department of Science and Technology, Govt. of India)**

•C. Gautam, A. Tiwari and S. Ravindran, "*Construction of Multi-class Classifiers by Extreme Learning Machine Based One -Class Classifiers*". (**Paper Accepted in IJCNN-2016**) (**IEEE Computational Intelligence Society Conference, Rank A**).

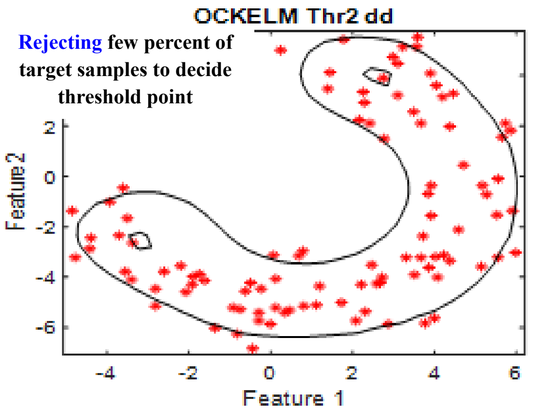
Behaviour and Performance of Different Threshold Criteria and Speed-UP Factor



Rejecting few percent of target samples to decide threshold point

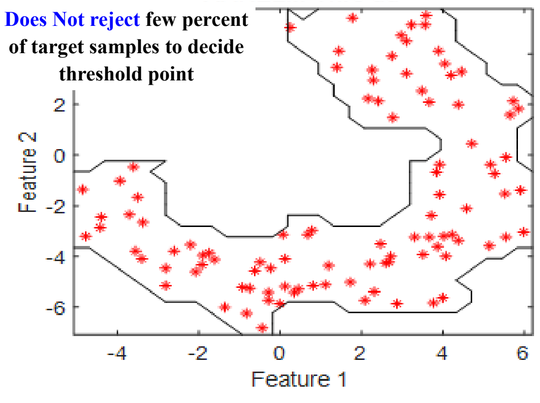


Rejecting few percent of target samples to decide threshold point



Time Consumed During Training →	Abalone	Arrhythima	Breast cancer	Diabetese
Svdd	31.36	0.41	0.76	2.26
autoenc_dd	58.14	732.04	12.22	32.53
OCKELM_Thr1	0.48	0.07	0.06	0.10
OCKELM_Thr2	0.50	0.07	0.07	0.10
AAKELM_Thr1	0.49	0.08	0.07	0.16
AAKELM_Thr2	0.52	0.08	0.07	0.14
AAKELM_Thr3	0.57	0.16	0.07	0.11
OCELM_Thr1	0.51	0.15	0.09	0.14
OCELM_Thr2	0.54	0.15	0.09	0.14
AAELM_Thr1	0.56	0.16	0.09	0.13
AAELM_Thr2	0.56	0.16	0.09	0.14
AAELM_Thr3	0.57	0.23	0.09	0.17

Does Not reject few percent of target samples to decide threshold point



Conclusion

- **100 to 1000 times faster** than traditional one class classifiers like back-propagation based autoencoder neural network data description etc.
- Proposed one class classifiers for **Online Sequential** learning, so, it can handle streaming data (no need to train from scratch). All proposed classifiers work for both type of feature mapping i.e. Random and Kernel feature mapping.
- As, ELM based one-class classifiers are based on single pass only, so, it **can be easily implemented on hardware** compared to traditional one-class classifiers. Even, **ELM has been already implemented on hardware for Multi-class classifiers (Implemented on FPGA and CPLD board using VHDL)** and we are planning to implement it for one-class classifiers.
- **Overall, contributed a MATLAB Toolbox** for many offline and online One-class Classification methods Novelty/Outlier Detector), which would be very useful for the research community.