CCECE 2003

Signal Classification through Multifractal Analysis and Complex Domain Neural Networks

V. Cheung, K. Cannons, W. Kinsner, and J. Pear*

Department of Electrical & Computer Engineering

Signal and Data Compression Laboratory

*Department of Psychology

University of Manitoba, Winnipeg, Manitoba, Canada

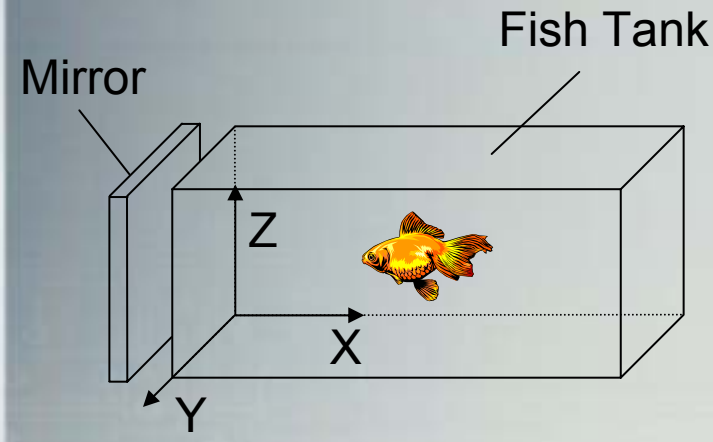
Outline

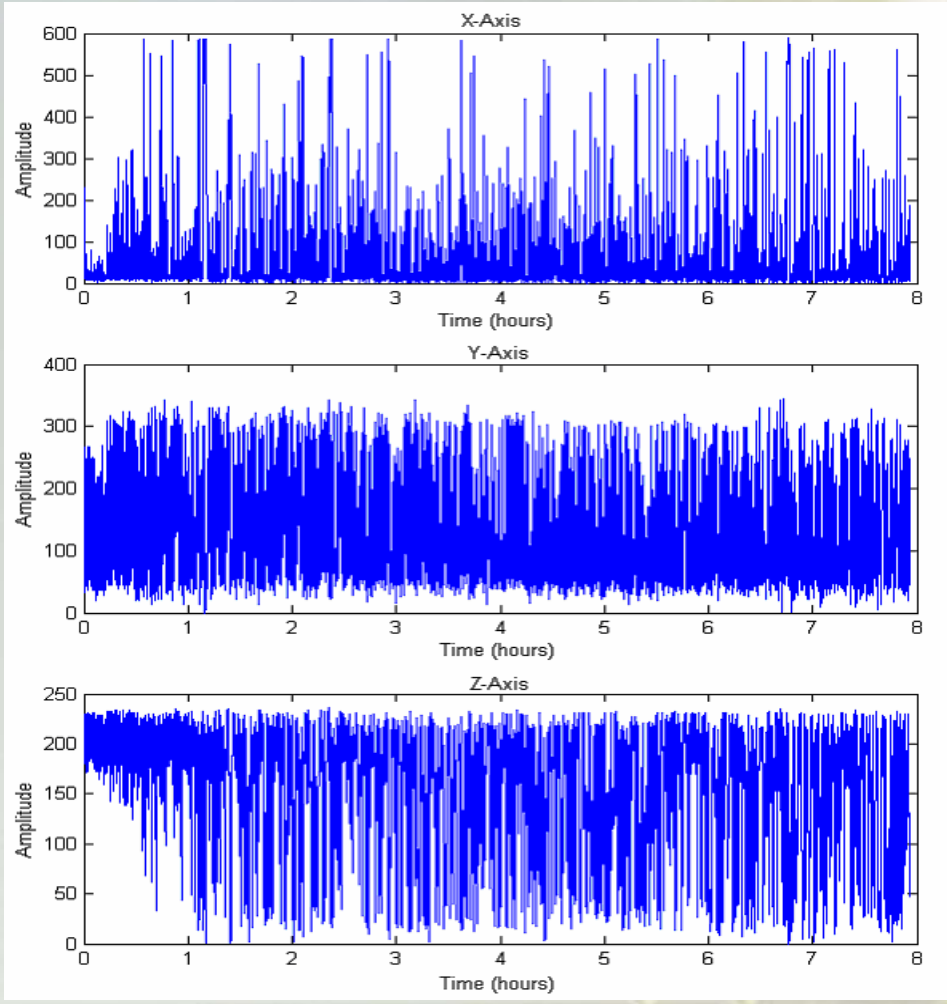
- Introduction
- Background
  - Variance fractal dimension trajectory
  - Kohonen self-organizing feature map
  - Probabilistic neural network
  - Complex domain neural network
- Experimental Results and Discussion
- Conclusion

Introduction

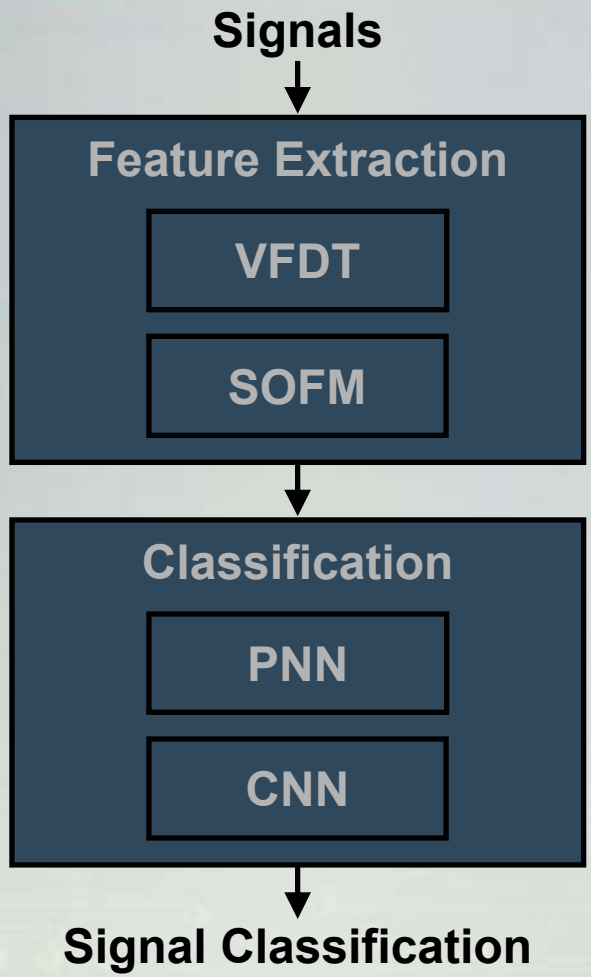
- Classification of signals that are:
  - Stochastic
  - Self-affine
  - Non-stationary
  - Multivariate
  - From non-linear systems
- Eg. multi-channel speech signals, multi-lead ECGs or EEGs

Fish Dishabituation Signals





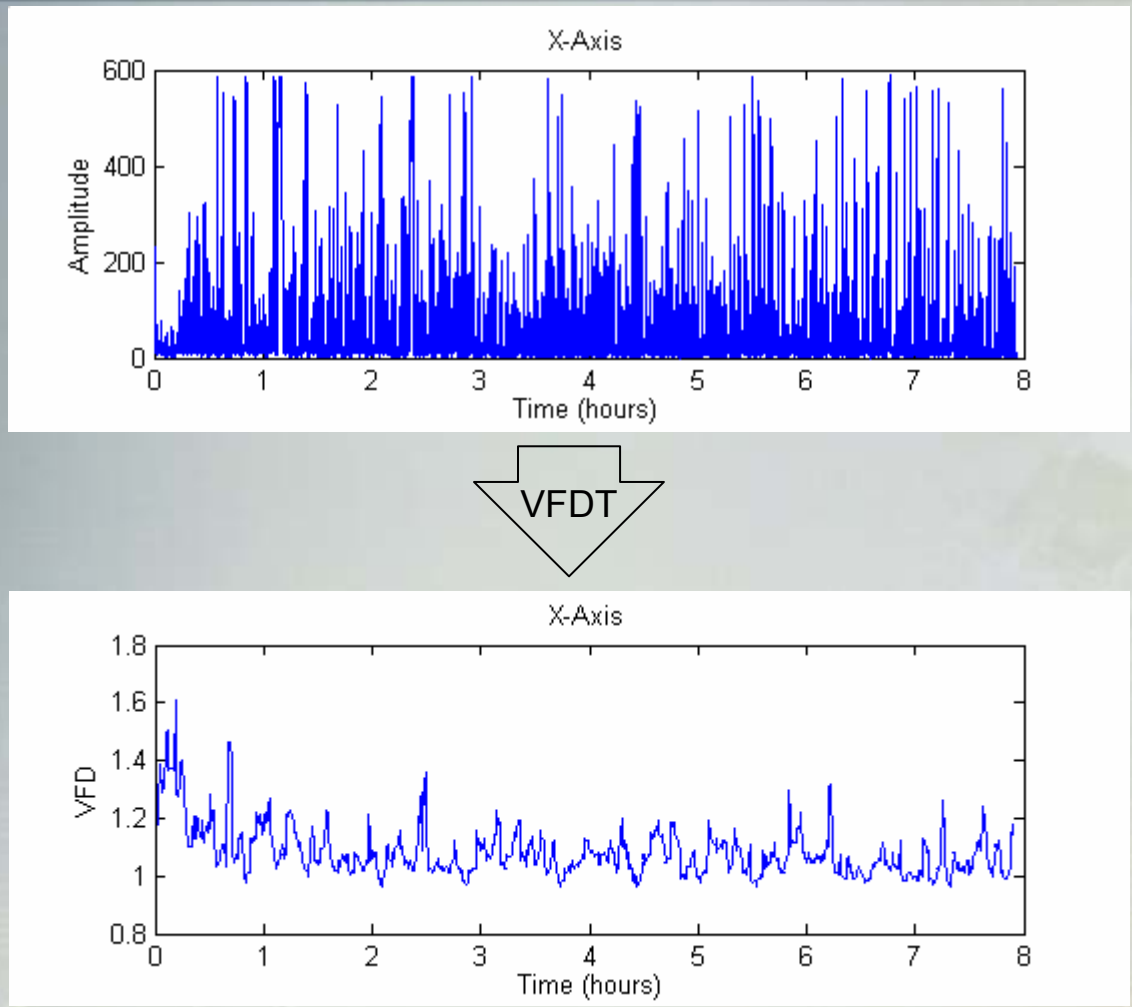
System Design



Variance Fractal Dimension Trajectory

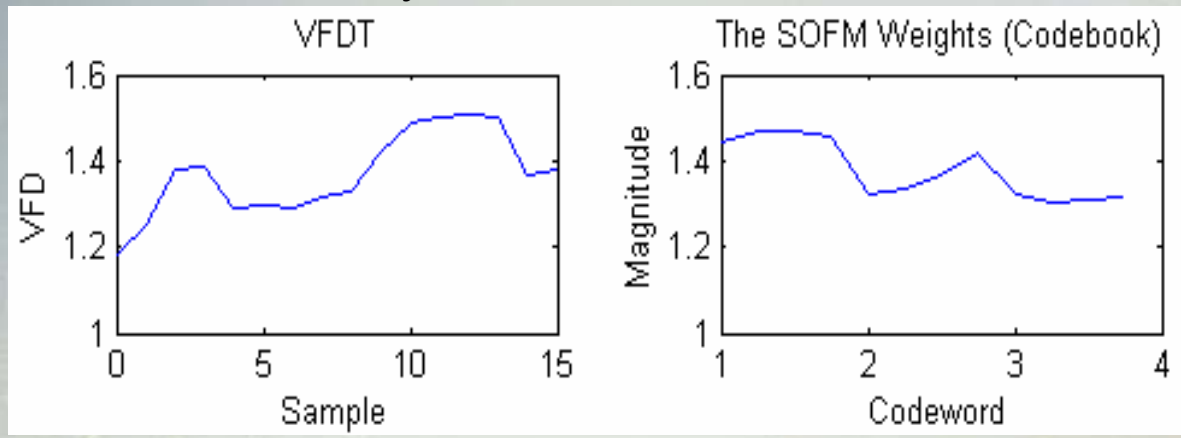
- Temporal multifractal characterization
  - Calculate the variance fractal dimension of a small segment of the signal in a sliding-window fashion over the entire signal [Kins94]
  - Reveals the underlying complexity of the signal
  - Provides a normalizing effect
- Advantages of the variance fractal dimension
  - Easy to compute
    - Measure the variance of amplitude increments at different scales
  - Can be computed in real-time

VFDT Plot


X-Axis
Amplitude
600
400
200
0
0
1
2
3
4
5
6
7
8
Time (hours)
VFDT
X-Axis
VFD
1.8
1.6
1.4
1.2
1
0.8
0
1
2
3
4
5
6
7
8
Time (hours)

Self-Organizing Feature Maps (SOFM)

- Topology-preserving neural networks using competitive unsupervised learning [Koho84]
- Two uses in this paper
  - Clustering
    - Aid in constructing the training and testing sets
  - Feature Extraction
    - Dimensionality reduction



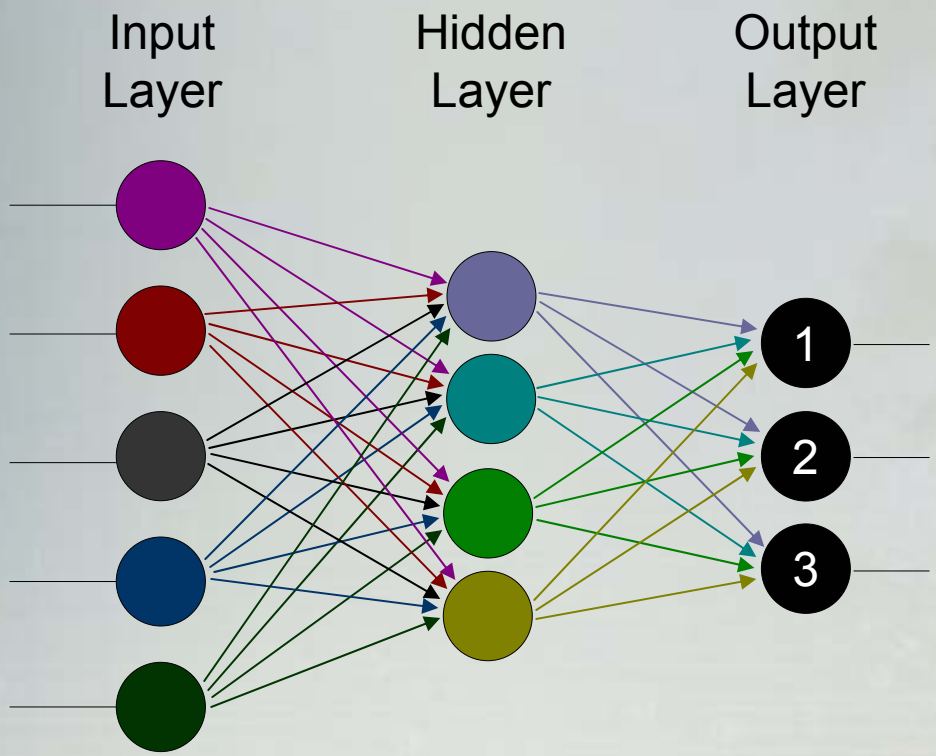
Probabilistic Neural Networks

- Neural network implementation of the Bayes optimal decision rule [Spec88]
  - eg. Spam filters
- Advantages
  - Asympotically Bayes optimal
    - Good classifiers
  - Trains orders of magnitude faster than other NNs
- Disadvantages
  - Slower execution than other NNs
  - Require large amounts of memory

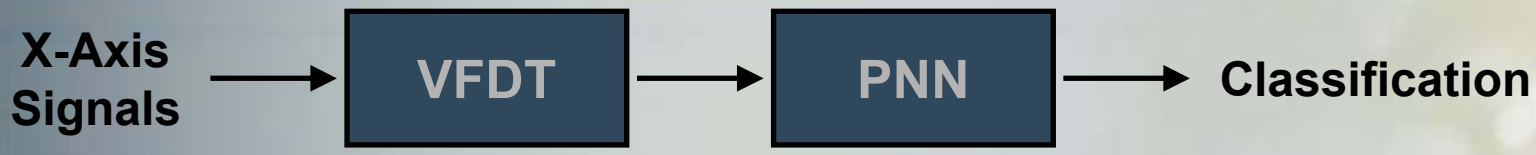
Complex Domain Neural Networks (CNN)

- **Advantages**
  - Works with inputs in their natural complex valued form
  - Faster training
  - Better generalization
- **Disadvantages**
  - More complexity
    - Convoluted partial derivatives involving complex analysis
- Ref: [Mast94]

CNN Architecture



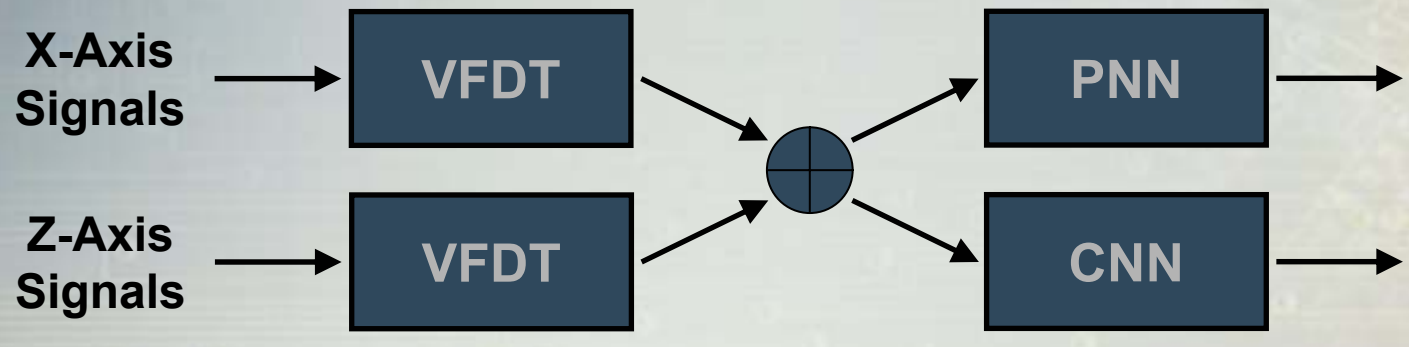
Experiment #1



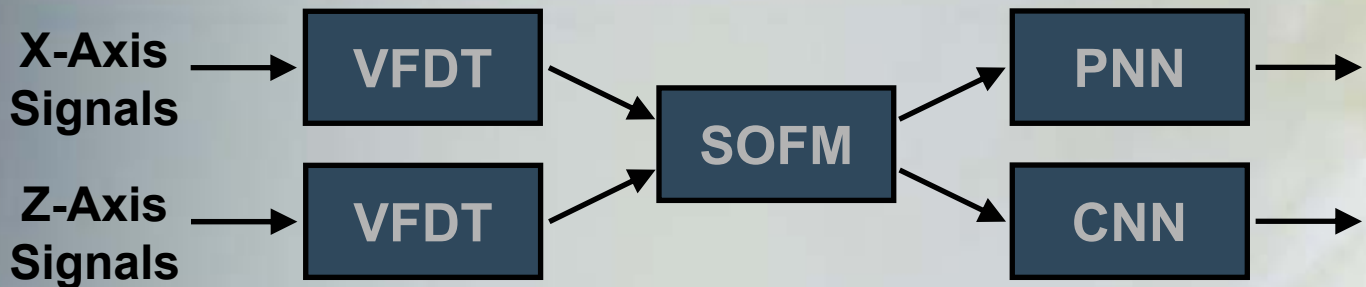
		Experimental				Correct Class. Rate
		1	2	3	4	
Expected	1	**24**	0	0	0	100.00%
	2	3	**135**	4	4	92.47%
	3	0	12	**111**	65	59.04%
	4	0	23	70	**93**	50.00%
Average Correct Classification Rate: 66.73%						
95% Confidence Interval: [62.77%, 70.69%]						

Experimental Results Summary

Signal	Classifier	Classification Rate (%)				Average Rate (%)
		1	2	3	4	
X	PNN	100	92	59	50	67
Z	PNN	63	29	47	91	58
X & Z	PNN	100	95	84	95	91
X & Z	CNN	96	87	80	91	87



SOFM Feature Extraction



Signal	Classifier	Average Rate (%)	
		VFDT	+ SOFM
X	PNN	67	66
Z	PNN	58	61
X & Z	PNN	91	88
X & Z	CNN	87	85

Conclusions

- A system capable of classifying self-affine, stochastic, non-stationary, multivariate signals originating from non-linear processes was developed
- Feature extraction involving variance fractal dimensions and self-organizing feature maps shown to be effective
- Probabilistic neural networks and complex domain neural networks shown to be capable of performing the desired classification

Acknowledgements

- Natural Sciences and Engineering Research Council (NSERC) of Canada
- University of Manitoba

References

[ChCa03] V. Cheung and K. Cannons, *Signal Classification through Multifractal Analysis and Neural Networks*. BSc Thesis. Dept. of Electrical and Computer Engineering, University of Manitoba, Winnipeg, MB, 106 pp., 2003.

[Kins94] W. Kinsner, "Batch and real-time computation of a fractal dimension based on variance of a time series," Technical Report, DEL94-6; UofM; June 15, 1994, (v+17) 22 pp.

[Koho84] T. Kohonen, Self-Organization and Associative Memory. Berlin: Springer-Verlag, 1984.

[Mast94] T. Masters, *Signal and Image Processing with Neural Networks: A C++ Sourcebook*. New York, NY: John Wiley & Sons, Inc., 1994.

[Spec88] D.F. Specht, "Probabilistic neural networks for classification, mapping, or associative memory", *IEEE International Conference on Neural Networks*, vol. 1, pp. 525-532, July 1988.