PUBLICATIONS

- **A WAVELET BASED TEAGER ENERGY OPERATOR FOR SPIKE DETECTION IN MICROELECTRODE ARRAY RECORDINGS (IEEE TENCON 2009, SINGAPORE)**
  Nisseem Nabar, K. Rajgopal (IISc Bangalore)

  Abstract: Spike detection in neural recordings is the initial step in the creation of brain machine interfaces. The Teager energy operator (TEO) treats a spike as an increase in the `local' energy and detects this increase. The performance of TEO in detecting action potential spikes suffers due to its sensitivity to the frequency of spikes in the presence of noise which is present in microelectrode array (MEA) recordings. The multi-resolution TEO (mTEO) method overcomes this shortcoming of the TEO by tuning the parameter *'k'* to an optimal value *'m'* so as to match to frequency of the spike. In this paper, we present an algorithm for the mTEO using the multi-resolution structure of wavelets along with inbuilt low pass filtering of the sub-band signals. The algorithm is efficient and can be implemented for real-time processing of neural signals for spike detection. The performance of the algorithm is tested on a simulated neural signal with 10 spike templates obtained from MIT EEG Lab. The background noise is modeled as a colored Gaussian random process. Using the noise standard deviation and autocorrelation functions obtained from recorded data, background noise was simulated by an autoregressive (AR (5)) filter. The simulations show a spike detection accuracy of 90% and above with less than 5% false positives at an SNR of 2.35 dB as compared to 80% accuracy and 10% false positives reported on simulated neural signals.
  Key Take away: Used a non-linear energy measure to detect spiking activity in noisy neuronal recordings.

- **SPIKE DETECTION IN MICRO ELECTRODE ARRAY RECORDINGS USING WAVELET DENOISING AND THRESHOLDING**
  (International Conference on Advanced Data Analysis, Business Analytics and Intelligence, IIM AHMEDABAD, 2009)
  Nisseem Nabar, K. Rajgopal (IISc Bangalore)

  Abstract: Brain Machine Interfaces can be used to restore functions lost through injury or disease. The use of Micro Electrode Arrays is an invasive method of acquiring neural signals which can then be used as control signals. The first requirement for such a use is to extract time-stamped spike trains from the MEA recordings. For use in BMI applications, this extraction needs to be real time and computationally less expensive. We propose an algorithm based on wavelet denoising and thresholding of the denoised signal. Wavelets provide localization in both time and frequency domains and the ability to analyze signals at different resolutions. Appropriate thresholding of wavelet coefficients followed by reconstruction provides a less noisy version of the input signal. The algorithm proposed is tested on simulated data whose parameters have been decided from actual MEA recordings. It is found to be real-time and has variable memory requirements which make it ideal for BMI applications. Detection accuracy of

90% with false positives of less than 5% is achieved as compared to detection accuracy of 80% with false positives of 10% shown in literature (Kim and Kim, 2003).
Key Take away: Used wavelets to improve the strength of the spiking signal as compared to the noise to improve detection.

- **RECONFIGURABLE IMPLEMENTATION OF MULTILEVELWAVELET BASED IMAGE DENOISING (IEE VIE 2006, BANGALORE)**
  Jonathan Joshi[a], **Nisseem Nabar[a]**, Parul Batra[b] and Rohan A.[a] ([a]- K.J. Somaiya College of Engineering, Mumbai; [b]- Netaji Subhash Institute of Technology, Delhi)

  Abstract: An FPGA system for denoising images based on the statistical modeling of wavelet coefficients is presented. The basic algorithm calls for approximating the noisy wavelet coefficients based on observing their local neighbourhood. The architecture for the lifting based wavelet transform followed by the windowing technique for neighbourhood observation has been implemented keeping real time applications in the picture. The architecture has regular data flow and is adaptable to arbitrary image sizes. The wavelet used is the Daubechies' 9/7 biorthogonal wavelet. This paper highlights the advantages of using a higher level of the wavelet transform with the aspect of hardware optimization and better denoising with respect to certain modules of the implementation. The PSNR results for different test images have been presented along with the hardware results.
  Key Take away: Improved FPGA architecture for real time wavelet methods of improving Signal-to-Noise ratio of images. Added to previous work to improve hardware design & performance.

- **RECONFIGURABLE IMPLEMENTATION OF WAVELET BASED IMAGE DENOISING (IEEE MWSCAS 2006, PUERTO RICO)**
  Jonathan Joshi[a], **Nisseem Nabar[a]**, Parul Batra[b] ([a]- K.J. Somaiya College of Engineering, Mumbai; [b]- Netaji Subhash Institute of Technology, Delhi)

  Abstract: A reconfigurable system for denoising images based on the statistical modeling of wavelet coefficients is presented. The basic algorithm calls for approximating the noisy wavelet coefficients based on observing their local neighbourhood. The architecture for the lifting based wavelet transform followed by the windowing technique for neighbourhood observation has been implemented keeping real time applications in the picture. The architecture has regular data flow and is adaptable to arbitrary image sizes. The wavelet used is the Daubechies' 9/7 biorthogonal wavelet. The PSNR results for different test images have been presented along with hardware and timing results.
  Key Takeaway: Real time hardware implementation for using 'lifting' algorithm to improve signal to noise ratio in image which will help in transmission and storage.