A Novel Algorithm for the Reduction of Irregular Noise in Corrupted Speech Signals

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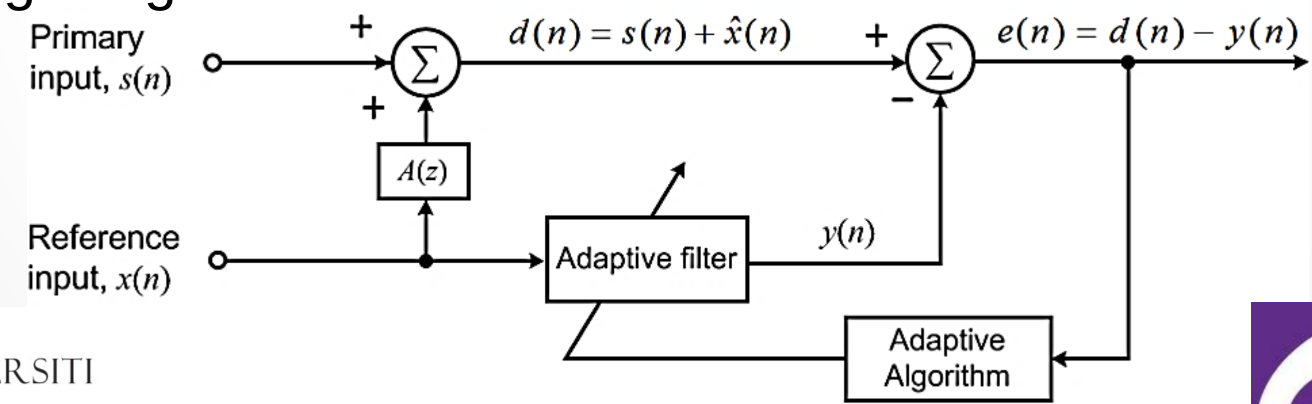
INTRODUCTION

- Noise cancellation using an adaptive filter offers lower costs and more practical in noise suppression such as the two-sensor Adaptive Noise Canceller (ANC)
  - One or more sensors of ANC are located at a vicinity of a noisy area where the signal is weak by the reference input sensor(s)
  - Using adaptive algorithm to control the coefficients of a digital filter.
  - The adaptive filter filters out the noise and improves the quality of target signal.



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- The choice of an adaptive algorithm is based on its convergence speed and computational power.
- The Least Mean Square (LMS) algorithm is common for most adaptive filters but it becomes very slow for ill conditioned input signals.
- The Recursive Least Square (RLS) and the Affine Projection (AP) algorithms showed best performances in convergence but has increased computational burden.
- Most existing literatures went too complex, merely theoretical and non-applicable in real-time
- Therefore, a smart noise cancellation system is proposed based on a selective mechanism that can be switched to apply several adaptive algorithms by measuring the characteristics of the noise signal

PROPOSED PROCEDURE

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EIGENVALUE SPREAD

- Calculation of eigenvalue spread is used for the proposed system to select appropriate algorithm in eliminating noise from regular/irregular noisy signals.
- The eigenvalue spread is determined from autocorrelation matrix **R**,

$$\mathbf{R} = E\left[\mathbf{n}(k)\mathbf{n}^H(k)\right] = \begin{bmatrix} E\left[|n_0(k)|^2\right] & E\left[n_0(k)n_1^*(k)\right] & \cdots & E\left[n_0(k)n_M^*(k)\right] \\ E\left[n_1(k)n_0^*(k)\right] & E\left[|n_1(k)|^2\right] & \cdots & E\left[n_1(k)n_M^*(k)\right] \\ \vdots & \vdots & \ddots & \vdots \\ E\left[n_M(k)n_0^*(k)\right] & E\left[n_M(k)n_1^*(k)\right] & \cdots & E\left[|n_M(k)|^2\right] \end{bmatrix}$$

Here, $\mathbf{n}^H(k)$ is the Hermitian transpose of input $\mathbf{n}(k)$

- The eigenvalues are calculated from the characteristic equation of $\mathbf{R}$

$$\det(\mathbf{R} - \lambda_j \mathbf{I}) = 0$$

- Here, $\mathbf{I}$ is the identity matrix and the eigenvalues λ_j is given by

$$\lambda_j = \begin{bmatrix} \lambda_1 & & & 0 \\ & \lambda_2 & & \\ & & \ddots & \\ 0 & & & \lambda_M \end{bmatrix}$$

where, λ_1, λ_2,..., λ_M are the eigenvalue elements of $\mathbf{R}$

- The eigenvalue spread of R is then calculated as

$$s(\mathbf{R}) = \frac{\max(\lambda_j)}{\min(\lambda_j)}$$

← maximum eigenvalue of $\mathbf{R}$

← minimum eigenvalue of $\mathbf{R}$

- Using the measurement of $s(\mathbf{R})$, the selection mechanism of appropriate adaptive algorithm is set

SELECTION MECHANISM

- The adaptive algorithms used are the Least Mean Square (LMS), the Recursive Least Square (RLS) and the Affine Projection (AP) algorithms.
- Algorithm application conditions :
  - o LMS – low eigenvalue spread
  - o RLS – large eigenvalue spread is very large
  - o AP – between 2 conditions above
- The AP would reduce colored noise with low projection order, similar to the Normalized LMS with mild complexity
- SNC selects an adaptive algorithm intelligently based on a flag setting.

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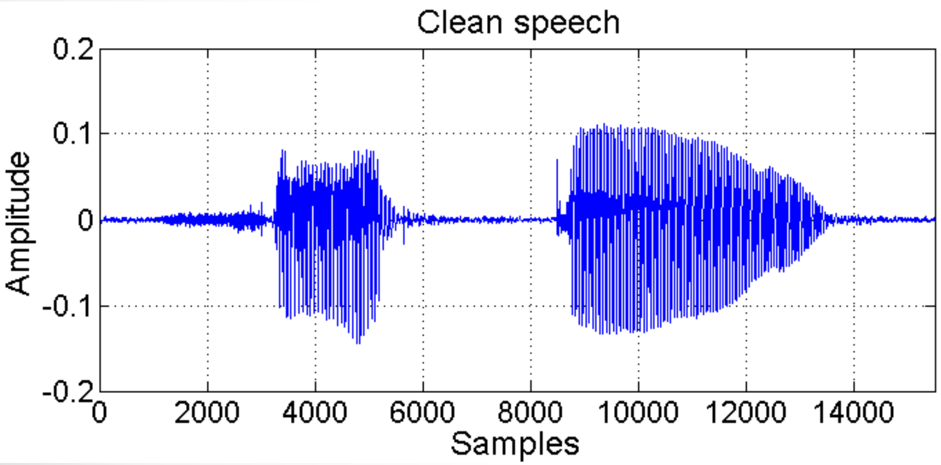
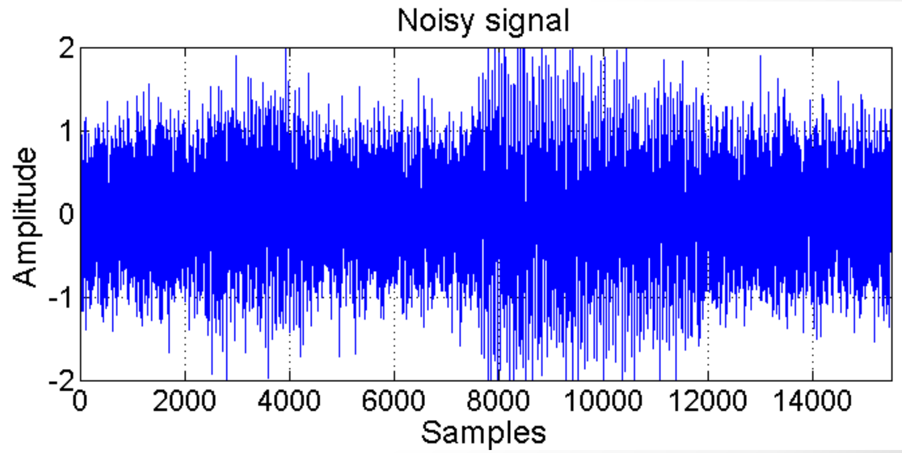
SIMULATION PROCEDURE

- Target signal is a Malay utterance “SATU” sampled at 16 kHz
- Noisy speech subjected to several types of noises e.g. white, car, voice babble and pink noise
- The eigenvalue spread of the input noise signals are calculated using 125 data/frame with 60 frames each signal and is repeated to observe the changes in the noise signals





RESULTS & DISCUSSIONS

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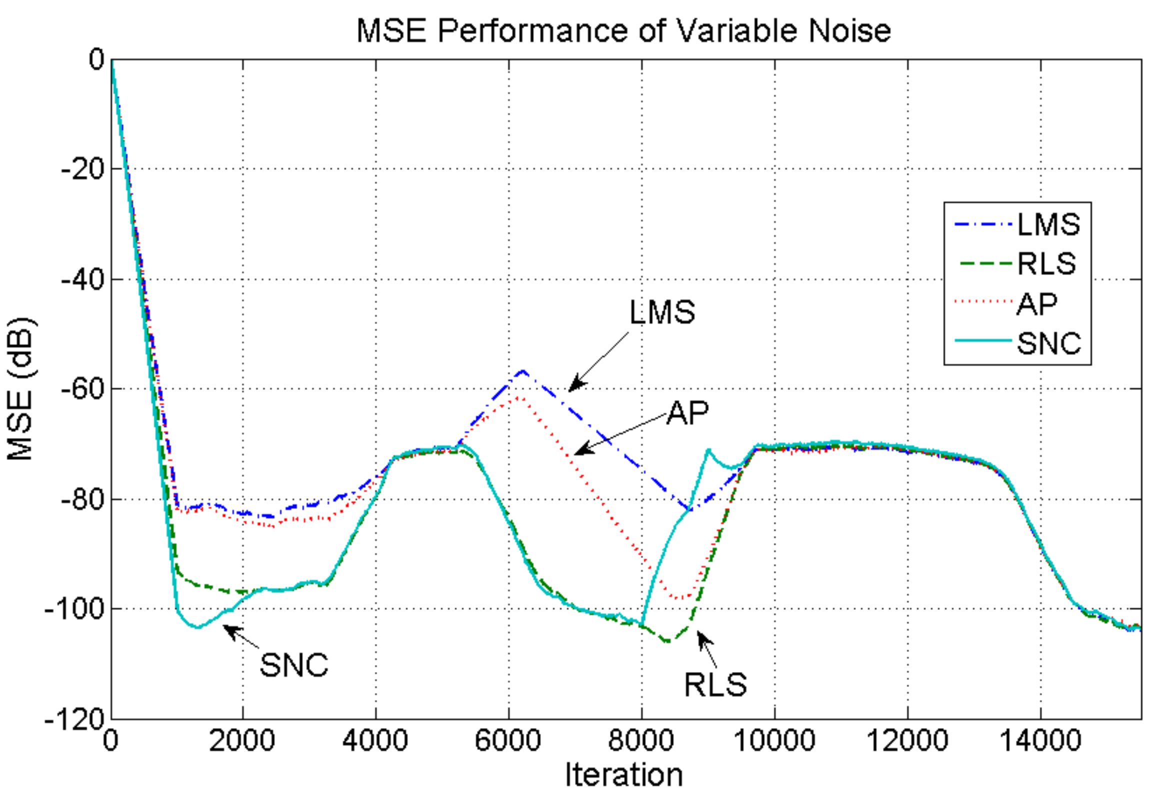
MSE PERFORMANCE

- MSE performance compared to other single algorithms
- At the beginning, the SNC convergence shows a similar behavior to that of the RLS
- Then, converges faster than others at the middle of the operation



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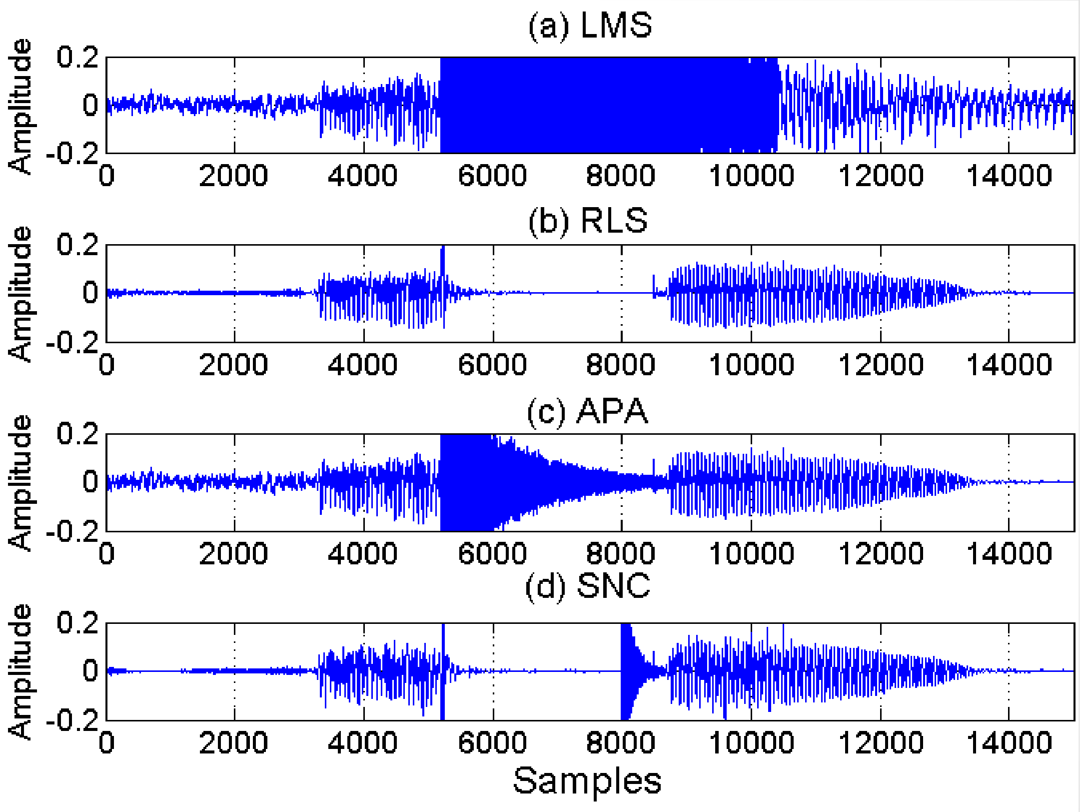
OUTPUT SIGNAL

- The figure shows the processed speech using different algorithms to control the adaptation process
- SNC showed capability of computing different algorithm when the noise properties changed



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COMPUTATIONAL COMPLEXITY

- Calculations are made using parameters in the simulations, filter length N = 32 and projection order for AP, M = 4
- The proposed system has nearly 65% reduction to that of the RLS

Algorithm	Computational Complexity		
	Additions	Multiplication	Calculation
LMS	$2N+1$	$2N+1$	65
RLS	$3N^2+11N+9$	$3N^2+7N+9$	3305
AP	$(M^2+2M)N+M^3+M^2-M$	$(M^2+2M)N+M^3+M^2$	848
SNC	$\frac{3N^2+15N+12}{3}$	$\frac{3N^2+11N+11}{3}$	1145

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CONCLUSION

- The paper proposed a novel noise canceller based on measurement of eigenvalue spread
- Capable to remove regular and irregular noise by applying an appropriate algorithm
- The convergence performance of proposed system outperformed that of other algorithms
- Computational complexity is reduced almost 65% of the RLS algorithm
- This study can be extended to include more variants of existing algorithms