

Measurement, modelling and enhancement of the intelligibility of speech in noise at the Centre for Law-Enforcement Audio Research (CLEAR)

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The CLEAR Project

- ▶ Centre for Law-Enforcement Audio Research
 - ▶ Funded by UK Home Office
 - ▶ Joint Imperial College / University College London
 - ▶ Establish reliable techniques for testing the quality and intelligibility of speech signals after enhancement
 - ▶ Evaluate commercial products for speech enhancement
 - ▶ Develop predictive models of quality and intelligibility
 - ▶ Research new enhancement techniques

CLEAR Labs Imperial College London UCL

Centre for Law Enforcement Audio Research

Researching Speech Signal Enhancement

About CLEAR

The CLEAR Lab researches into methods for improving the intelligibility and quality of speech signals that have become corrupted with noise or distorted by transmission. CLEAR is a research project run jointly by Imperial College London (Department of Electrical and Electronic Engineering) and University College London (Department of Speech, Hearing and Phonetic Sciences).

CLEAR is funded by the UK Home Office to target the needs of law enforcement in the UK for information about the latest technologies for speech cleaning. Key objectives for the CLEAR project include:

- to establish repeatable, practical intelligibility testing methods
- to establish repeatable, practical speech audio quality testing methods
- to develop intrusive and non-intrusive measures of speech signal corruption and to research their relationship to intelligibility and quality
- to assess commercial and other non-commercial speech enhancement products with respect to their suitability for forensic and law enforcement applications
- to research, develop and evaluate advanced speech cleaning algorithms for law enforcement applications

You can learn more about CLEAR by looking at its [Publications List](#).

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www.clear-labs.com

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The CLEAR Team



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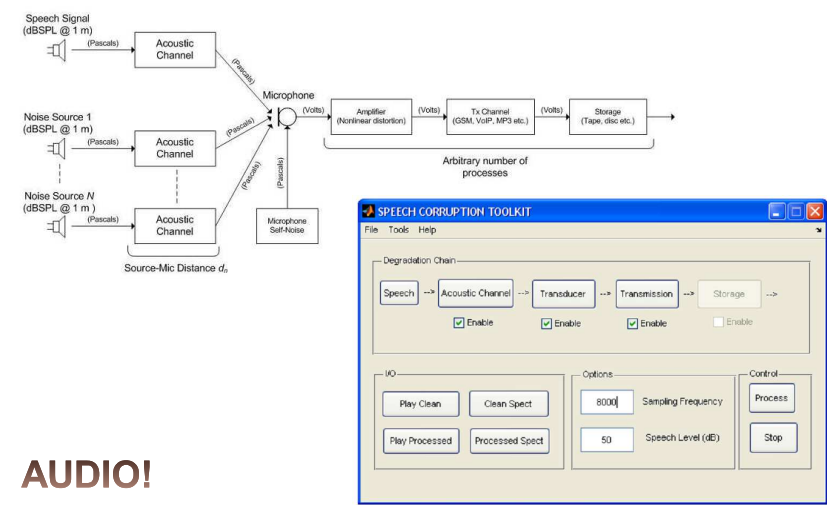
The CLEAR Approach

- ▶ **Measurement**
 - ▶ get a good understanding of how well existing systems work on a variety of signal types
- ▶ **Modelling**
 - ▶ build models which predict how well systems would work on specific signals
- ▶ **Enhancement**
 - ▶ choose the methods which we predict would have the best performance on a given signal
 - ▶ develop new methods based on improved understanding of speech perception in noise

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Measurement

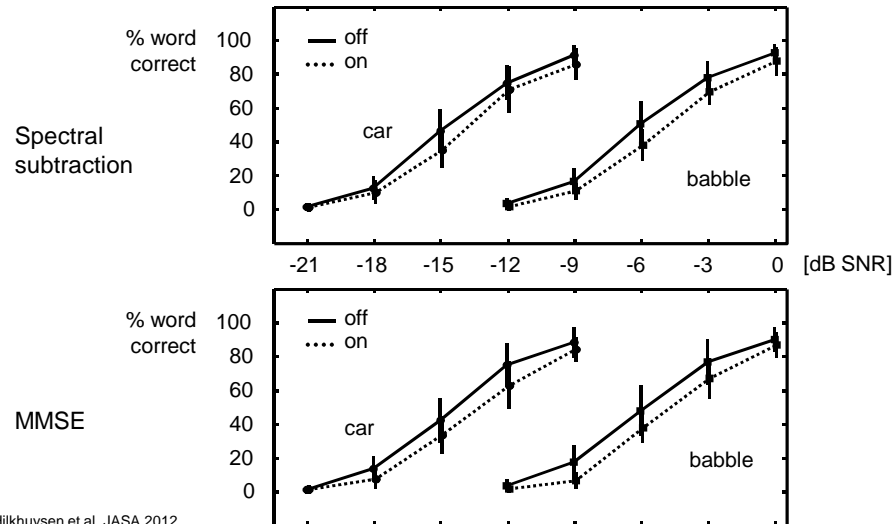
Speech Corruption Toolkit



AUDIO!

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Noise Reduction Technology Evaluation



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Commercial Systems Evaluation



- ▶ 12 modules from 5 commercial systems, up to 5 parameter settings per module
- ▶ 5 recording scenarios, each with/without CODEC
- ▶ Adaptive procedure for estimating SRT
- ▶ Closed response set task
- ▶ 2400 SRTs estimated, >900hrs of subject tests

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Commercial Systems Evaluation

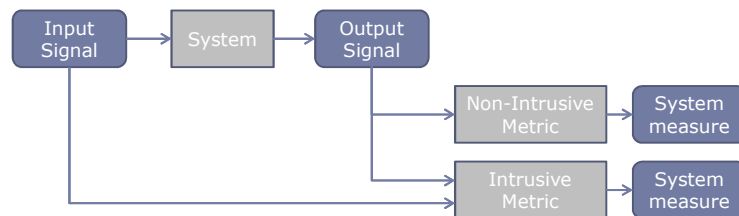
SRT shift (dB)		Scenario				
		S1	S2	S3	S4	S5
p r o d u c t	P1	-3.7	-3.4	-3.4	-3.4	-3.4
	P2	-1.3	0	0	0	0
	P3	-1.2	-3	-1.2	-1.2	-1.2
	P4	-1.6	-1.6	-1.6	-1.6	-1.6
	P5	-2.5	-1.6	-1.6	-1.6	-3
	P6	-2.3	-0.9	-0.9	-2.1	-0.9
	P7	-1.7	-1.7	-1.7	-1.7	-1.7
	P8	-3.3	-1.9	-1.9	-1.9	-1.9
	P9	-2.7	-2.7	-2.7	-2.7	-2.7
	P10	-3.8	-1.3	-1.3	-1.3	-1.3
	P11	-0.2	0	0	0	0

- ▶ All scenarios could be made better
 - ▶ SRT improved by up to 2.0 dB
- ▶ All scenarios could be made worse
 - ▶ SRT degraded by up to 3.8 dB
- ▶ No module consistently best
- ▶ No parameter settings consistently best

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Modelling

Estimation of Signal Properties

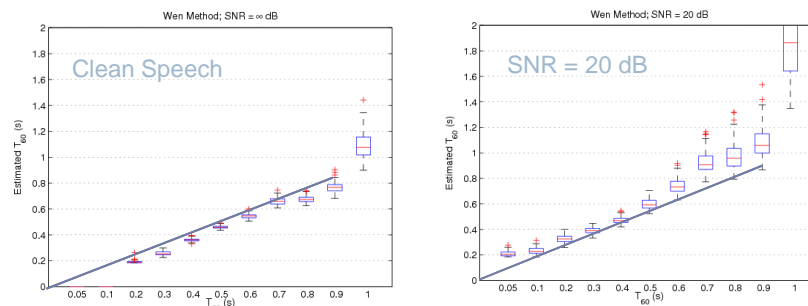


- ▶ Analyse signals to estimate nature of corruption:
 - ▶ Noise, SNR, Reverberation, Channel, CODEC
- ▶ Estimate intelligibility/quality of signal regions
 - ▶ Non-intrusive prediction of STOI
 - ▶ Non-intrusive prediction of PESQ

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Example: T60 Estimation

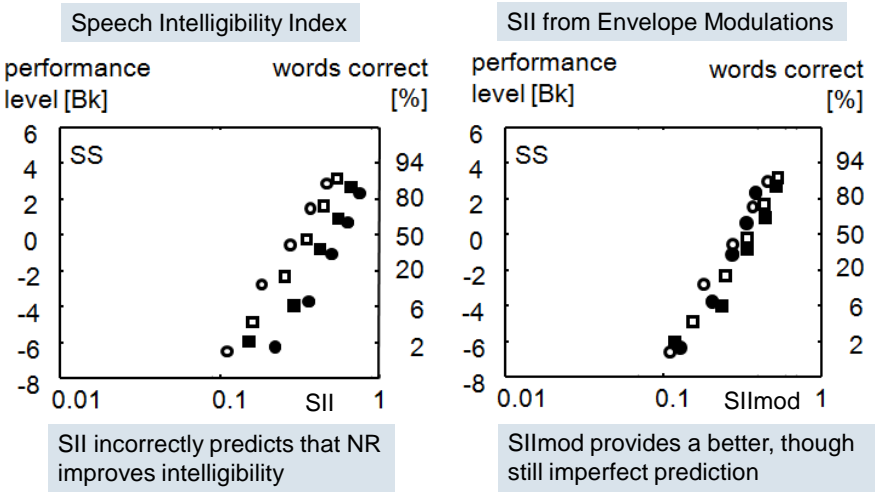
- ▶ T60 = Reverberation time = time for energy to decay by 60 dB
- ▶ Estimate by looking at peak decay rates in speech
- ▶ Excellent results in clean speech (SNR > 20 dB)
- ▶ T60 is overestimated in very reverberant or noisy conditions



Gaubitch et al, 2012

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Intelligibility Modelling and Prediction



Hilkhuyzen et al, in preparation

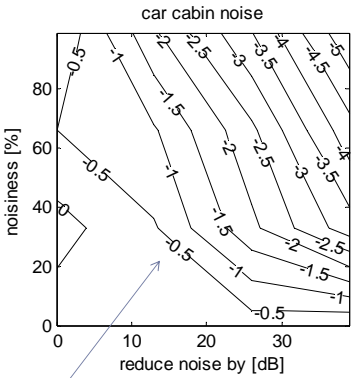
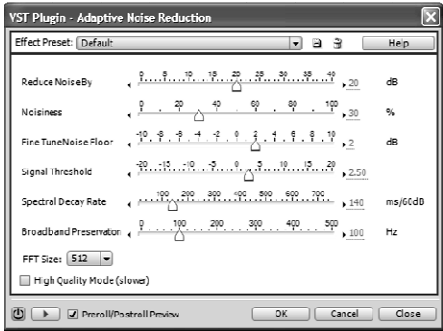
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Enhancement

Optimising use of commercial system

Adobe Audition Noise Reduction

Change in intelligibility



Hilkuysen & Huckvale
AES Audio Forensics 2010

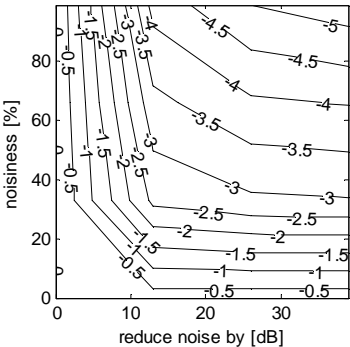
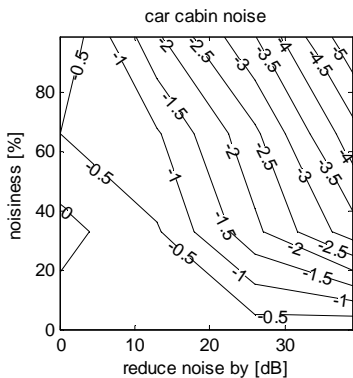
Change measured in log odds ratio
(-1 = double errors for same # correct)

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Optimising use of commercial system

Observed

Predicted



Hilkuysen & Huckvale
AES Audio Forensics 2010

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Blind channel estimation

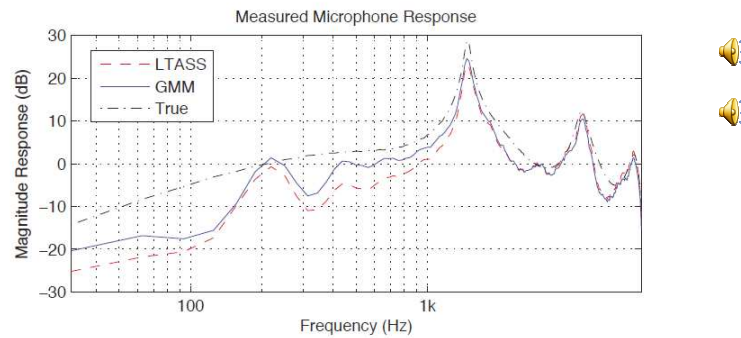


Figure 5: Estimates of a measured microphone response in the noise-free case. The WSD is 5.5 dB with LTASS based estimation and 2.9 dB with GMM based estimation.

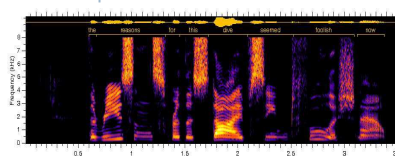
Gaubitch et al, 2011

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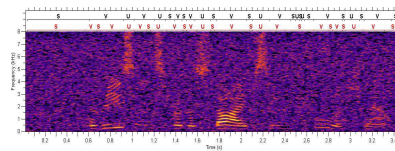
Binary Masks

- ▶ Noise-robust pitch estimation (PEFAC)
- ▶ HMM segmentation into Voiced/Unvoiced/Silent
 - ▶ inputs are voiced and sibilant detector outputs
 - ▶ imposes temporal continuity
- ▶ Mask generation:
 - ▶ Voiced: 10 harmonics
 - ▶ Unvoiced: Estimated sibilant freqs
 - ▶ Silent: None
 - ▶ Add original at -20 dB
- ▶ Segmentation good
 - ▶ 80% @ 0 dB SNR
- ▶ Working on improved mask generation

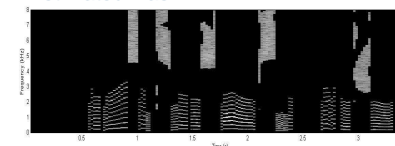
Clean Speech



SNR = 0 dB white noise



Estimated Mask

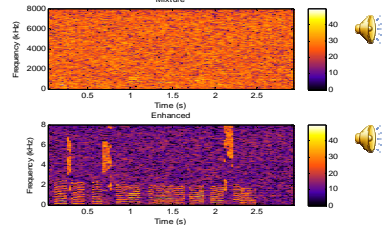


Gonzales and Brookes, 2011

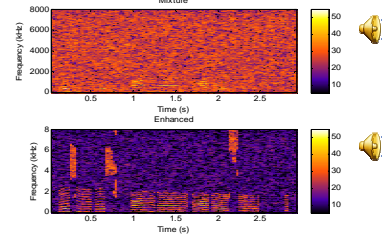
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Binary Mask Examples

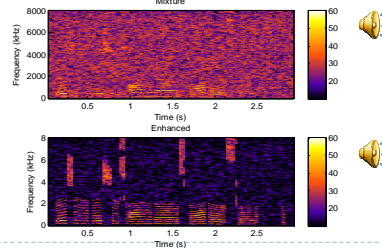
SNR = -10 dB



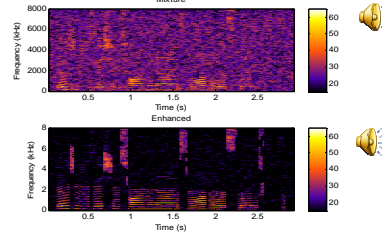
SNR = -5 dB



SNR = 0 dB



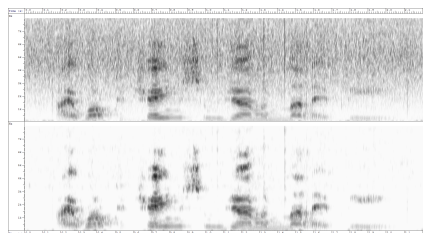
SNR = 5 dB



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Conclusions

- ▶ The CLEAR Project seeks to advance the science of speech signal enhancement through application of models based on quantitative measurement.
- ▶ Contact us for more information
- ▶ Visit www.clear-labs.com for publications



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