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

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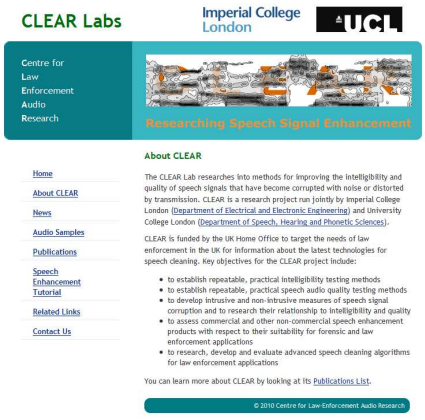
The CLEAR Project

- 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



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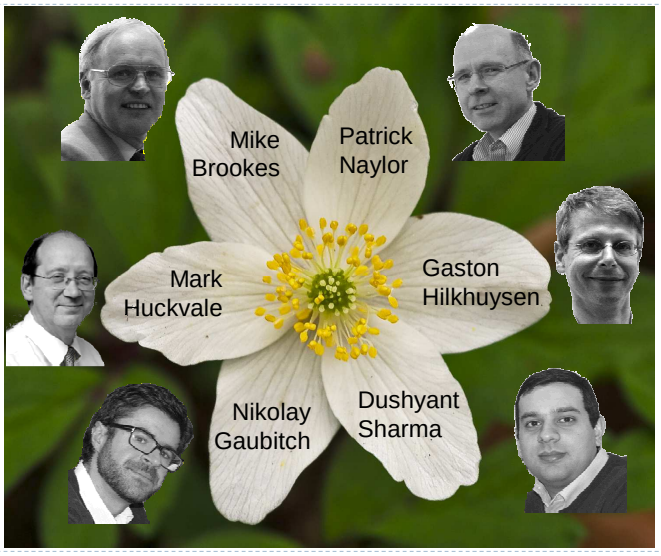
The CLEAR Team



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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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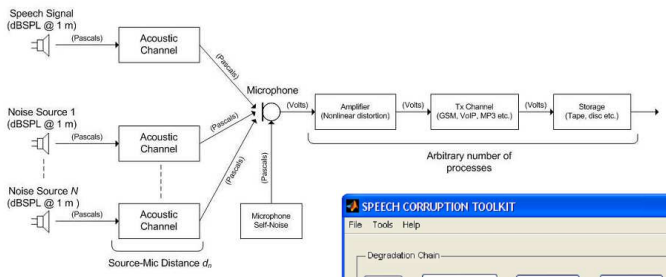
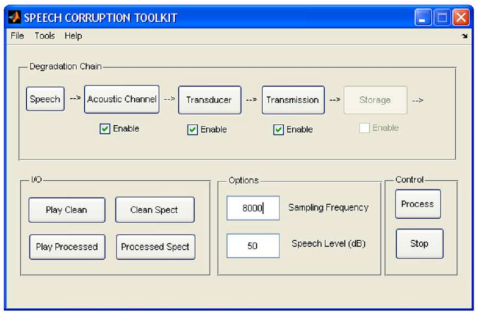
Measurement

Speech Corruption Toolkit





AUDIO!

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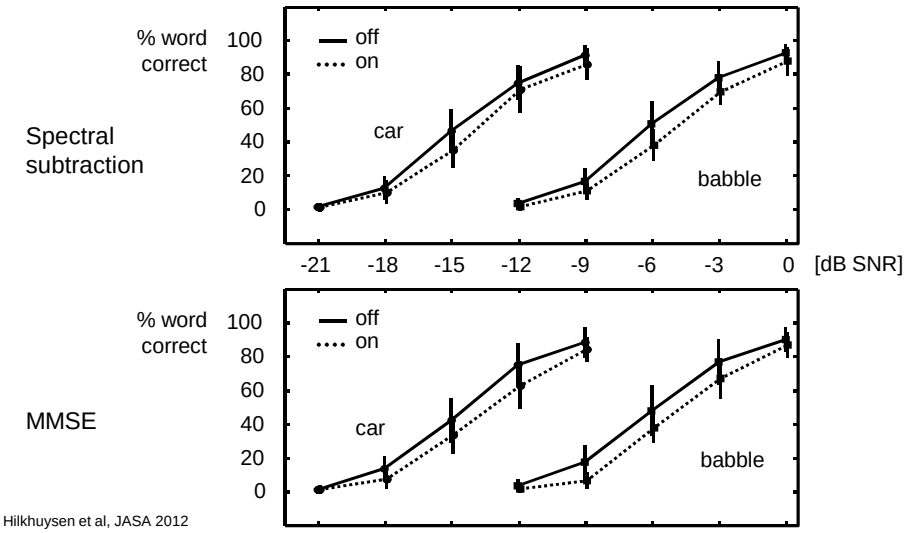
Noise Reduction Technology Evaluation



Hilkhuysen et al, JASA 2012

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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
Product	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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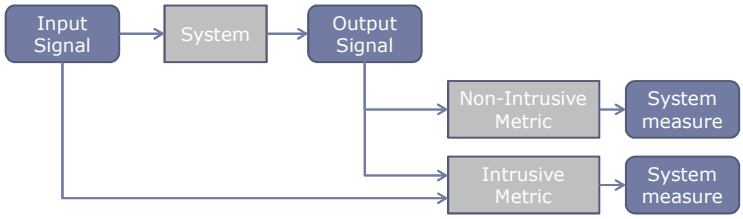
Modelling

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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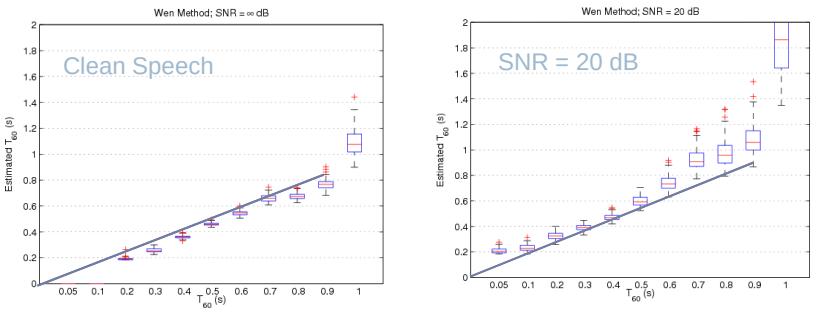
Example: T60 Estimation

- 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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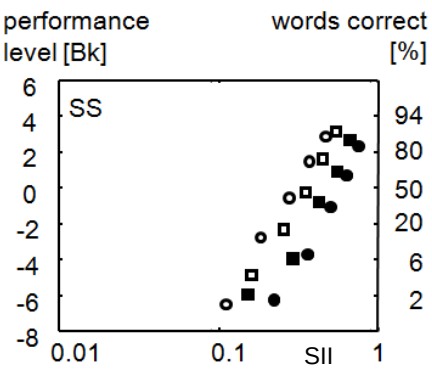
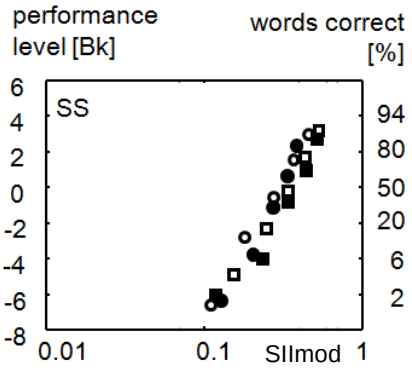
Intelligibility Modelling and Prediction

Speech Intelligibility Index



SII incorrectly predicts that NR improves intelligibility

SII from Envelope Modulations



SIImod provides a better, though still imperfect prediction

Hilkhuysen et al, in preparation

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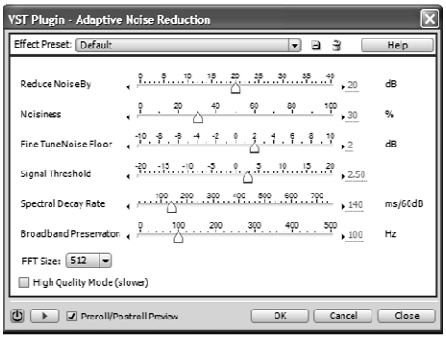
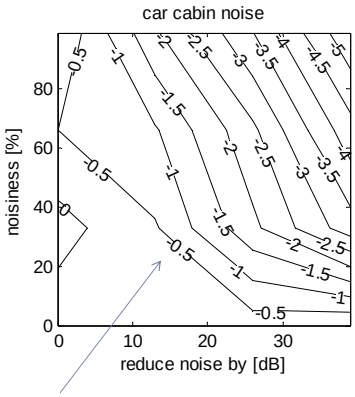
Enhancement

Optimising use of commercial system

Adobe Audition Noise Reduction



Change in intelligibility



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

Hilkhuysen & Huckvale
AES Audio Forensics 2010

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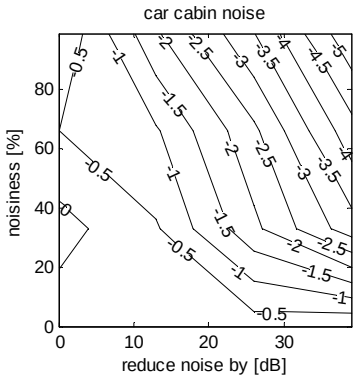
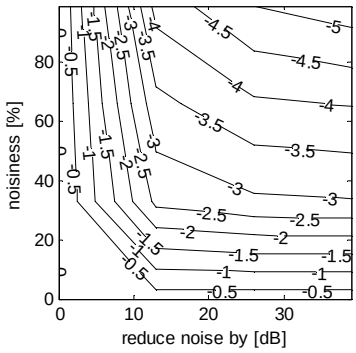
Optimising use of commercial system

Observed



Predicted



Hilkhuysen & Huckvale
AES Audio Forensics 2010

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Blind channel estimation

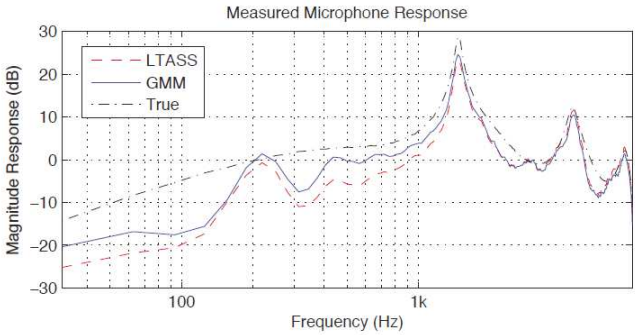

Figure 5: Estimates of a measured microphone response in the noise-free case. The WSD is 5.5 dB with LTASS based estimation and 2.9 dB with GMM based estimation.

Gaubitch et al, 2011

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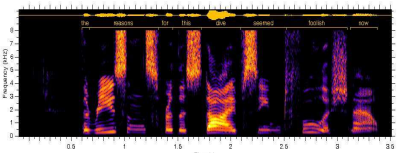
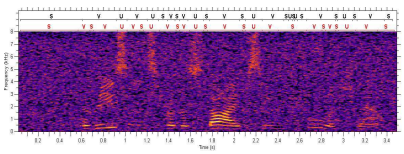
Binary Masks

- 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

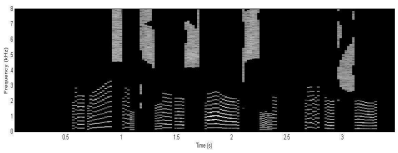
Clean Speech



SNR = 0 dB white noise



Estimated Mask



Gonzales and Brookes, 2011

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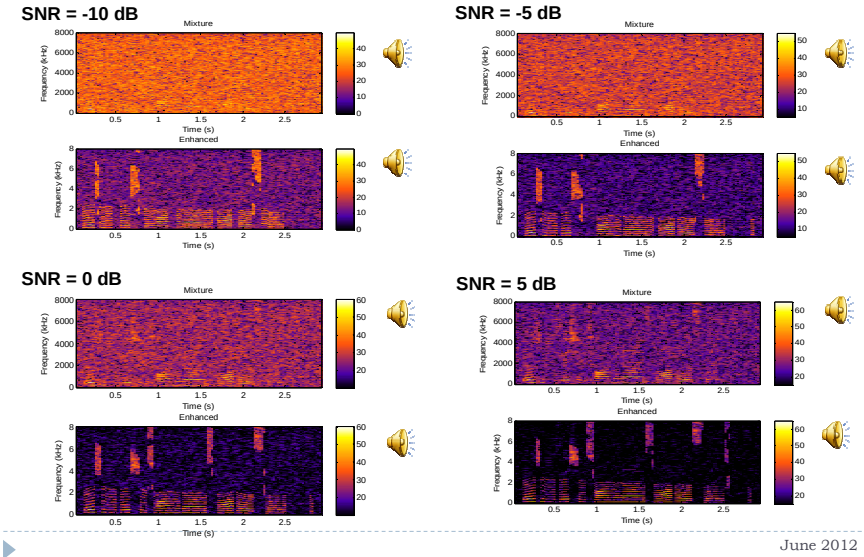
Binary Mask Examples



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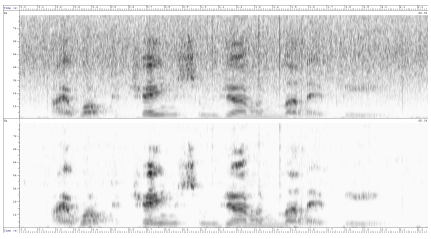
Conclusions

- The CLEAR Project seeks to advance the science of speech signal enhancement through application of models based on quantitative measurement.



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