11th AIAA/CEAS Aeroacoustics Conference (26th AIAA Aeroacoustics Conference)
23 - 25 May 2005, Monterey, California

AIAA 2005-2961

Extensions of DAMAS and Benefits and Limitations of Deconvolution in Beamforming

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The DAMAS deconvolution algorithm represents a breakthrough in phased array imaging for aeroacoustics, potentially eliminating sidelobles and array resolution effects from beamform maps. DAMAS is an iterative non-negative least squares solver. The original algorithm is too slow and lacks an explicit regularization method to prevent noise amplification. Two extensions are proposed, DAMAS2 and DAMAS3. DAMAS2 provides a dramatic speedup of each iteration and adds regularization by a low pass filter. DAMAS3 also provides fast iterations, and additionally, reduces the required number of iterations. It uses a different regularization technique from DAMAS2, and is partially based on the Wiener filter. Both DAMAS2 and DAMAS3 restrict the point spread function to a translationally-invariant, convolutional, form. This is a common assumption in optics and radio astronomy, but may be a serious limitation in aeroacoustic beamforming. This limitation is addressed with a change of variables from (x,y,z) to a new set, (u,v,w). The concepts taken together, along with appropriate array design, may permit practical 3D beamforming in aeroacoustics.

Nomenclature

$\vec{x}$	=	3D source locations
$\langle\ \rangle$	=	Time average, for both time domain processing and sums of STFT signals.
STFT	=	Short Time Fourier Transform.
$s(\vec{x}', j)$	=	Narrowband source strength at location $\vec{x}'$ and time block j.
$\vec{C}(\vec{x}')$	=	Narrowband array response vector for a source at $\vec{x}'$.
$\vec{w}(\vec{x})$	=	Narrowband array weighting vector to steer to $\vec{x}$.
$b(\vec{x})$	=	Beamform map value for the grid point $\vec{x}$.
$\dagger$	=	Hermitian conjugate; complex conjugate transpose.
$q(\vec{x})$	=	Power-type acoustic source strength at $\vec{x}$.
$psf\ (\vec{x},\vec{x}')$	=	Point spread function connecting a source at $\vec{x}'$ to an image point $\vec{x}$.
$psf\ (\vec{x}-\vec{x}')$	=	Shift-invariant or "convolutional" psf.
$\vec{k}$	=	Spatial frequency in FFT-based image processing.
$p(\vec{k}), b(\vec{k}), q(\vec{k})$	=	psf, beamform map, and source strength in the spatial frequency domain.
$\vec{X}$	=	The values of the source strengths over a grid, stacked on a vector.
$\vec{Y}$	=	The values of a beamform map, stacked on a vector.
A	=	A matrix form of the psf, as expressed in $\vec{Y} = A\vec{X}$
γ	=	Regularization parameter for the Weiner filter.
$\vec{\mu} = (a, b, 0)$	=	The location of a microphone in the array.
(u, v, w)	=	Beamforming coordinates transformed to make the psf approximately convolutional.

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