MATLAB EXPO 2018

Designing and Testing Voice Interfaces through Microphone Array Modeling, Audio Prototyping, and Text Analytics

Vidya Viswanathan

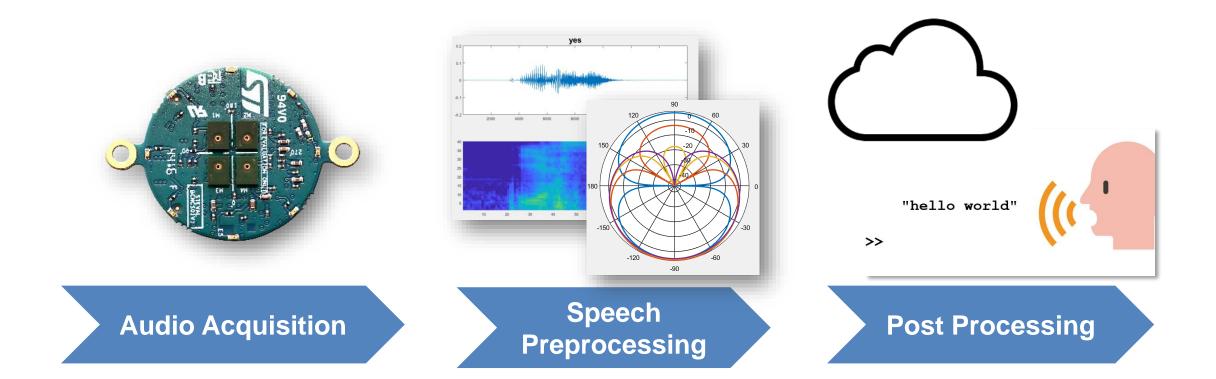


What Device Is This?

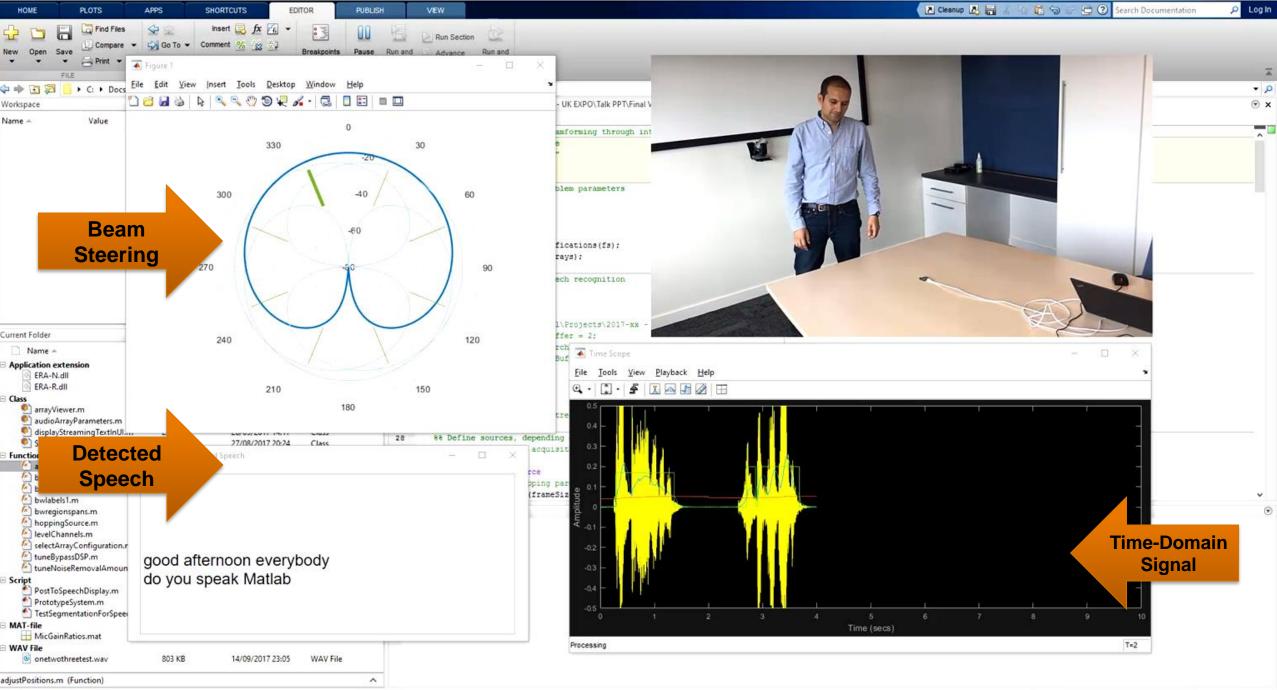




Overview of the System



A MATLAB R20176 PLOTS APPS



- Busy

script

D.

×

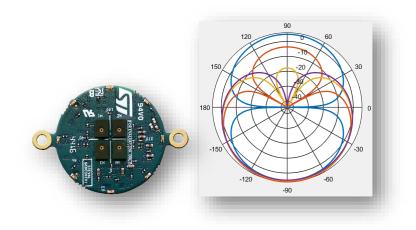


How Can I...

1. Design a voice interface?

2. Validate if my voice interface can work in real-life scenarios?

3. Test the performance of my system?







served in round bowls"

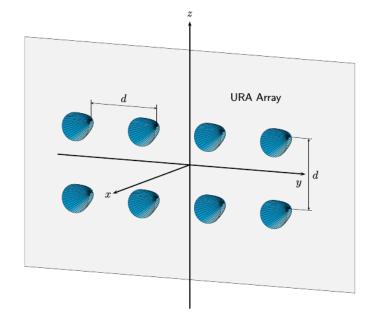
Guessed

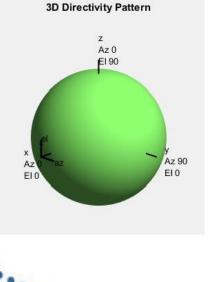
"the birth canal we sl "a large size in stock "blue the sheet to the "it's easy to tell the "these days a chicken "rice is often served



Choice of Microphones







- Single Microphone
 - Fixed directivity in a given direction
 - Noise cancellation is nontrivial

- Array of Microphones
 - Can control the directivity for a specific direction
 - Noise cancellation is easier

📣 MathWorks[®]

Microphone Array Geometries ULA Array URA Array UCA Array Phase center Element boresight Phase center Element boresight Uniform Rectangular Array **Uniform Linear Array Uniform Circular Array**

and many more...

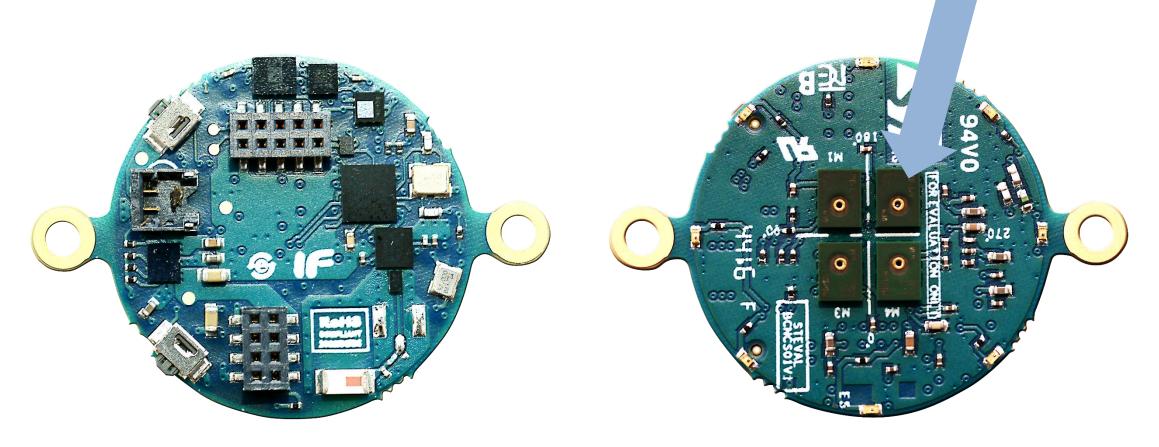
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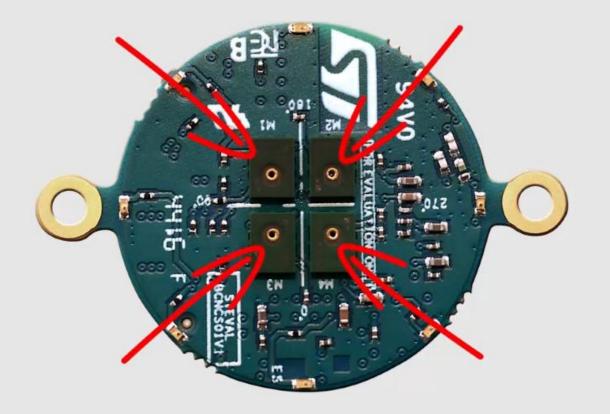


Design a Microphone Array System ...starting from a given array hardware

4x MEMS Microphones

BlueCoin from ST Microelectronics





4 microphones



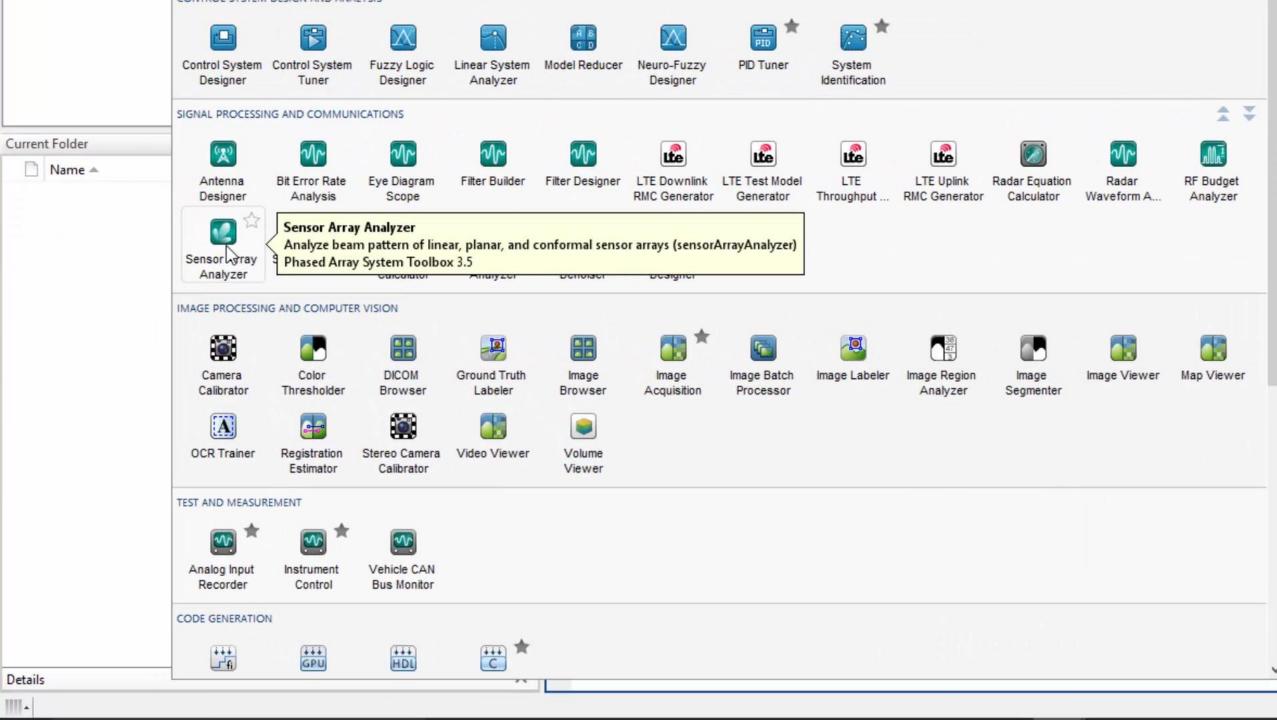
Microphone Array Design- Where to Start?

Array Design and Analysis



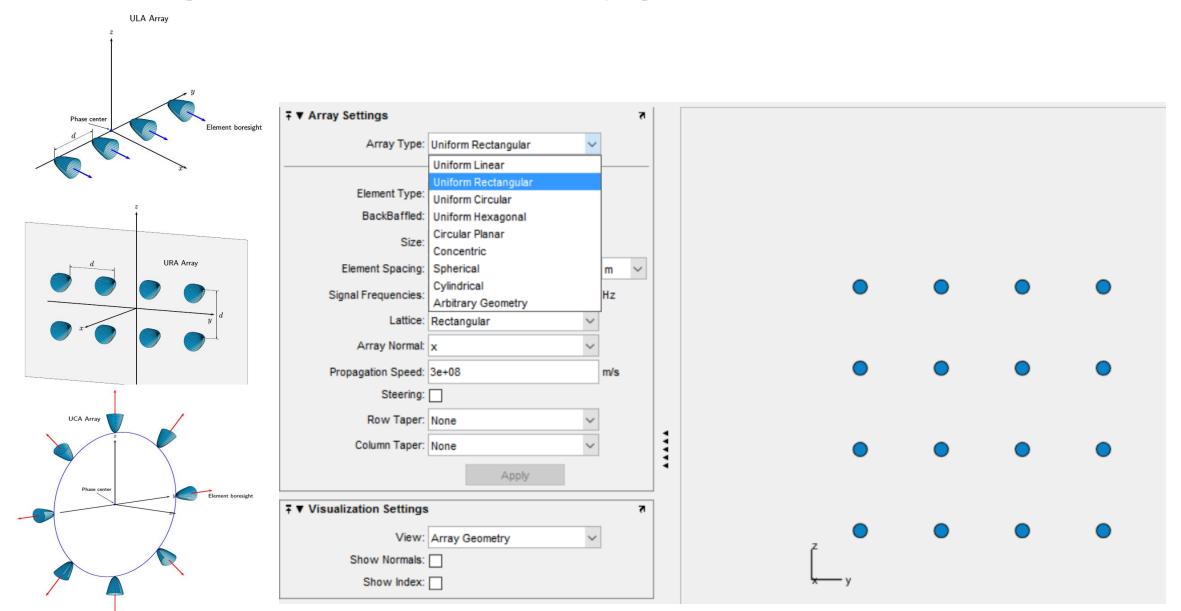
- Element definition
- Array geometry definition
- Array shading/tapers
- Array steering
- Radiation patterns in different forms

File Help								
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Parameters				- Visualizati	on			
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Cosine Power:	[1 1]							
Size:	[10 10]							
Element Spacing:	[500e-3 500e-3]		m 🔻					
Signal Frequencies:	300e+6		Hz			onse Pattern in u-v Hz steered at 0 Az		
Lattice:	Rectangular	•		1				
Propagation Speed:	300e+6		m/s	0.8				-10
Steering:	On	•		0.6 -				-20
Steering Angles:	[0; 0]		deg	0.4				-30
Row Shading:	Hamming	-		0.2				40
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Sidelobe Attenuation:	30		dB	-0.2				
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Array Span								
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Y-axis: Z-axis:		n n						
Total Number of Elements:	100							

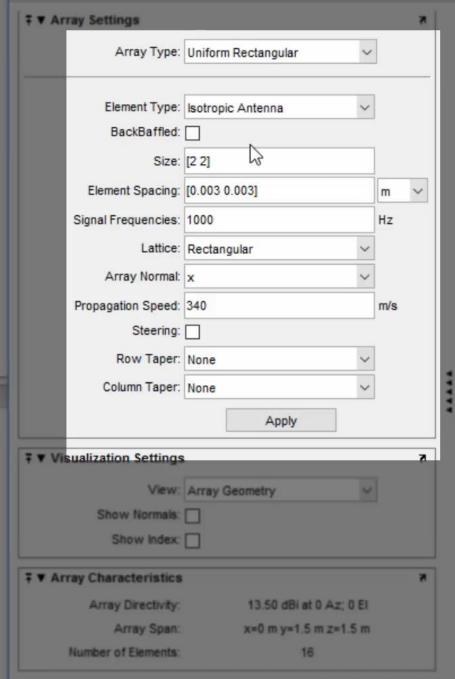


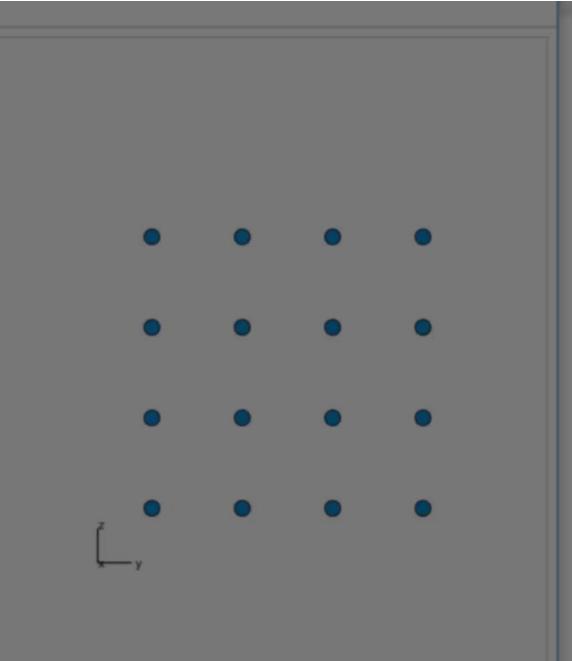


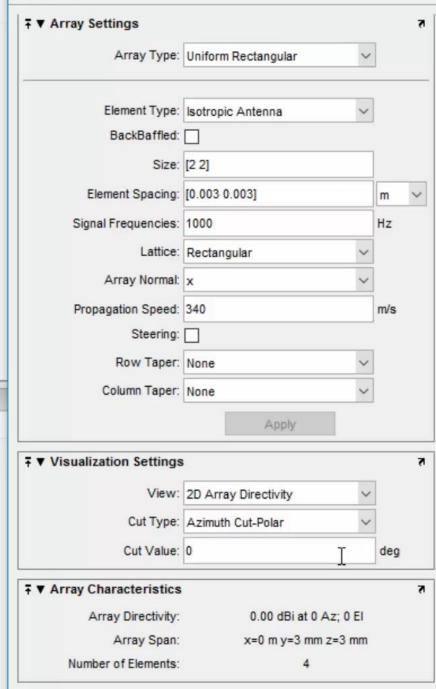
Choosing between different array geometries



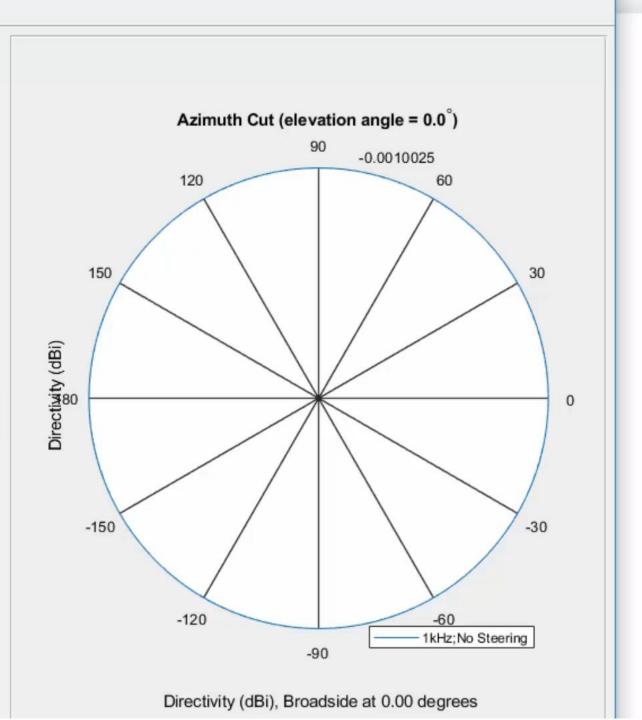
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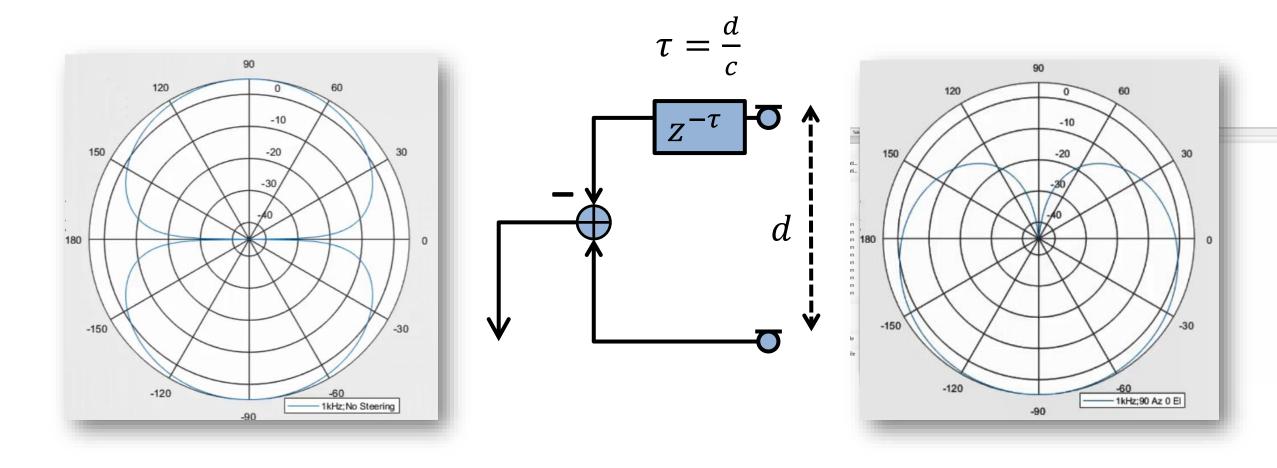


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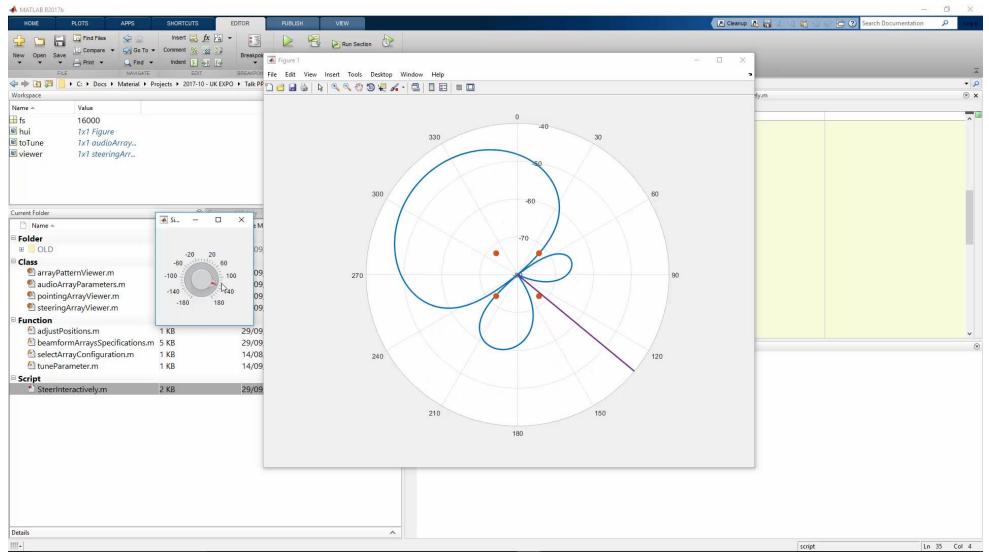
How do you get a Cardioid Pattern? Differential beamforming



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Beam Steering – Does this work?



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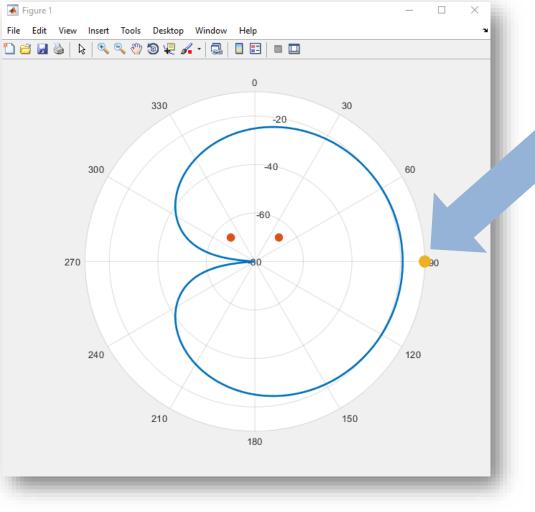


Variable Array Configuration

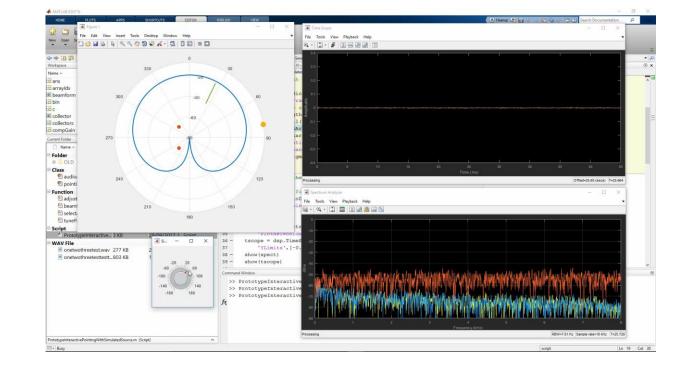
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Time Domain Simulation of an Array System



Sound source

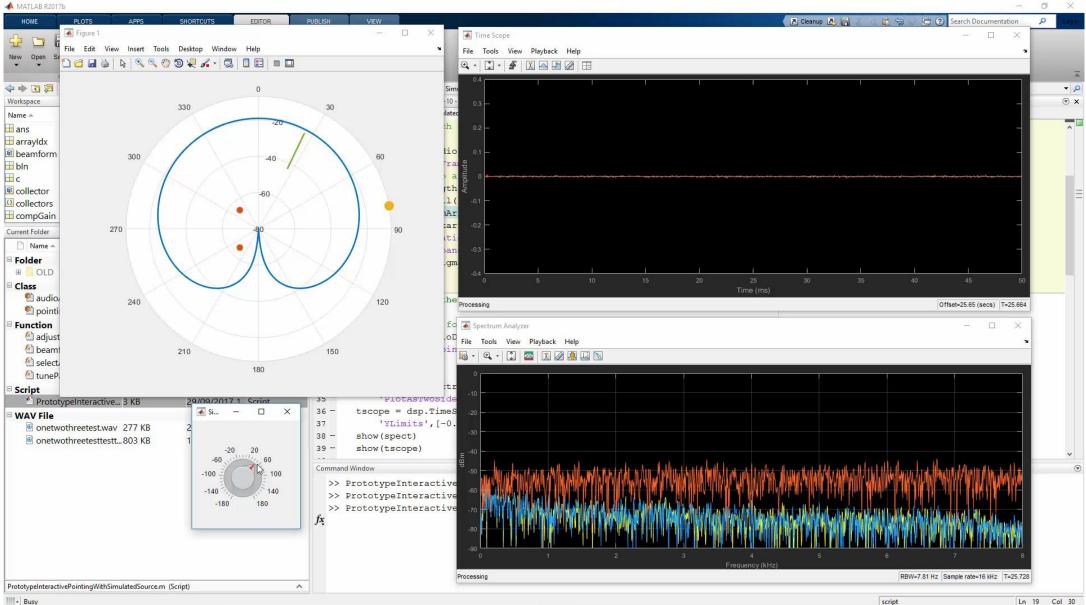


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Time Domain Simulation of an Array System







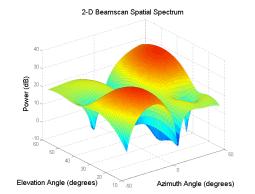
Direction of Arrival Estimation Phased Array System Toolbox

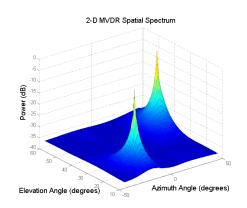
ULA

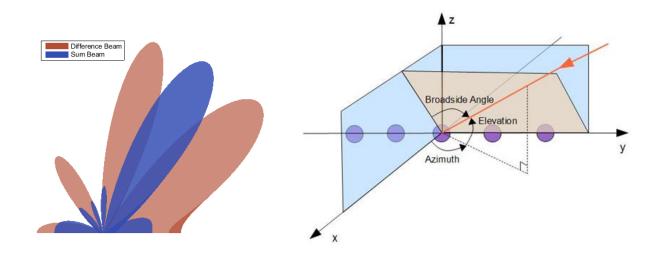
- Sum and difference monopulse
- Beamscan, MVDR (Capon)
- High resolution (ESPRIT, Root MUSIC, etc...)

URA

- Sum and difference monopulse
- Beamscan, MVDR (Capon)
- Conformal arrays
 - Beamscan
 - MVDR (Capon)







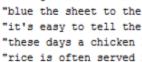


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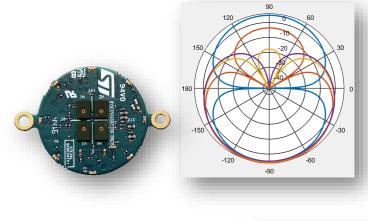


"the birth canal we sl

"a large size in stock

Guesse





True

slid on the smooth planks"

in stockings is hard to sell"

to the dark blue background"

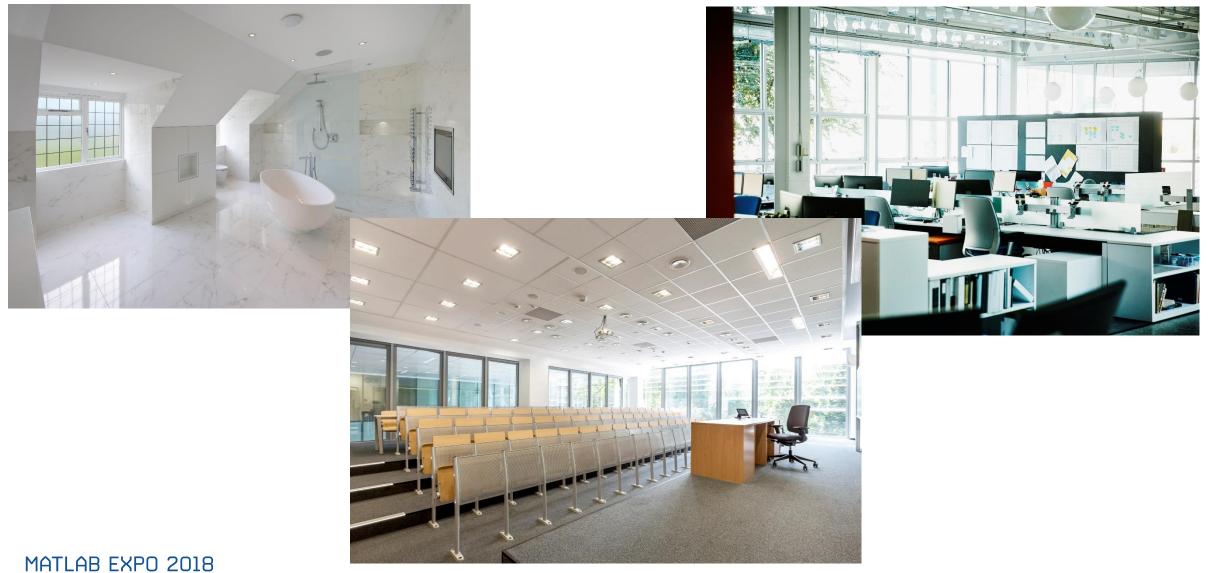
11 the depth of a well"

served in round bowls"

hicken leg is a rare dish"



Constrained Simulations vs. Real Life



22



Validating in Real-Life Scenarios

1. Including the Room Impulse Response

- Record the audio in a constrained environment
- Include the Room Impulse Response (RIR)
- Generate RIR
- Measure RIR
- 2. Live Acquisition
 - Connect a microphone array
 - Acquire speech signals live in a real-life environment

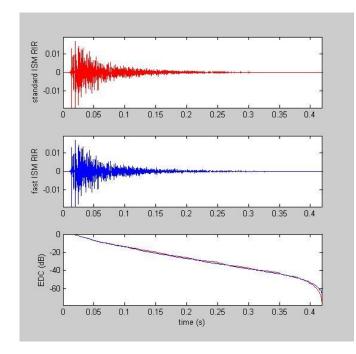


Integrating the Room Impulse Response

Room Impulse Response Simulation

Image Source Method (ISM) for simulation of Room Impulse Response (RIR) in small-room acoustics

Link to the code

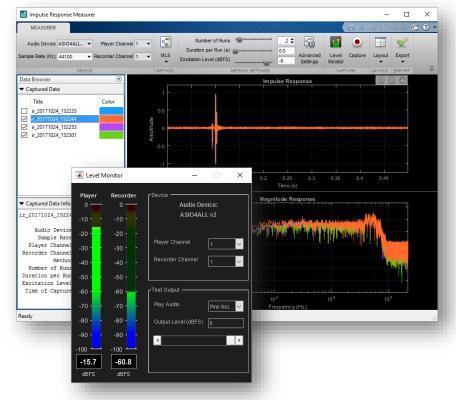


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Impulse Response Measurer App R2018a

Measure impulse and frequency responses of electrical and acoustic systems with:

- Maximum-Length Sequences (MLS)
- Exponentially Swept Sinusoids (ESS)





Live Acquisition from Hardware

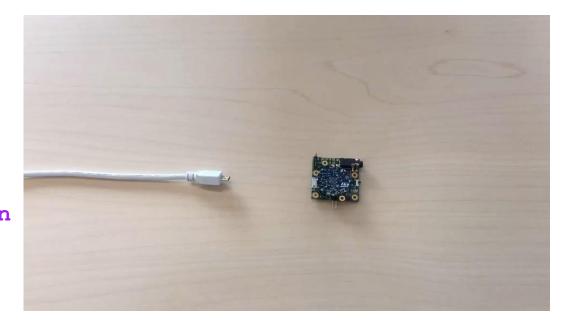
```
%% Live Audio Acquisition and Streaming
fs = 16000;
tscope = dsp.TimeScope('SampleRate',fs);
```

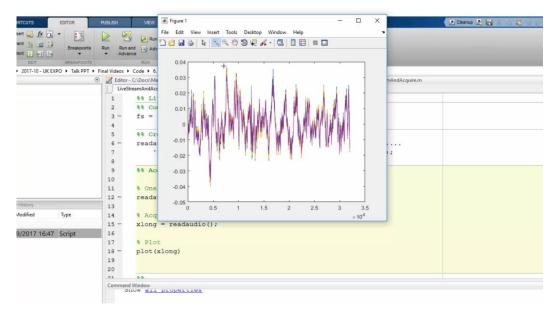
```
readaudio =
audioDeviceReader('SampleRate',fs,'NumChann
els',4,...
    'Device', 'Microphone (STM32 AUDIO
Streaming in FS Mode)');
% Set block duration
readaudio.SamplesPerFrame = 1024;
while isVisible(tscope)
    % Acquire live
    in = readaudio();
    % Visualize in real-time
    tscope(in);
```

end

release(readaudio)

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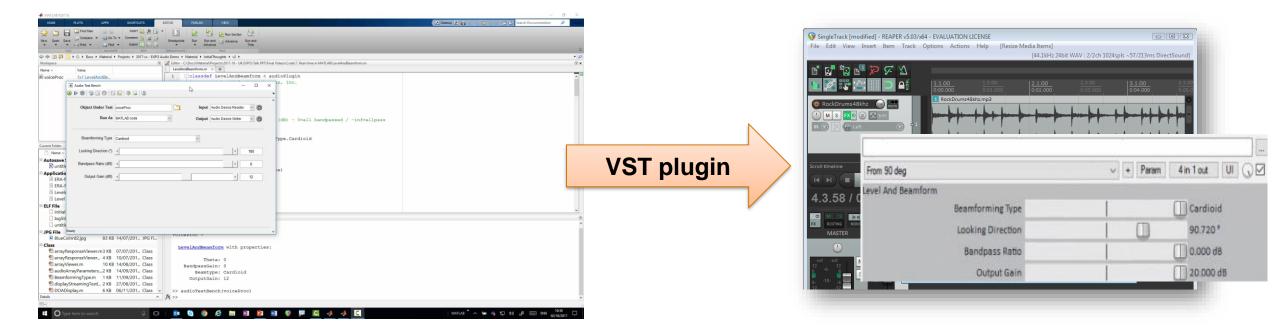
Creating Audio Testbench

MATLAB R2017b	承 Audio Test Bench					_		×
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Class BeamformingType.m LevelAndBeamform.m	Looking Direction (°)	4			Image: A start of the start	0		
	Bandpass Ratio (dB)	4			•	0		
	Output Gain (dB)	4			Image: A start of the start	12		
selectArrayConfiguration.m (Function)								
	Ready							~

- Debug your audio plugin
- Time and frequency domain visualization of your processing
- Option to bypass algorithm under test for interactive A/B testing



Reuse your design in Digital Audio Workstations Generating VST Plugins



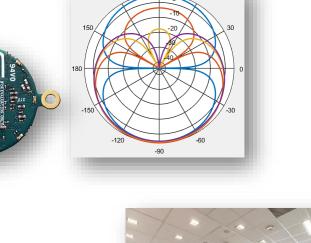


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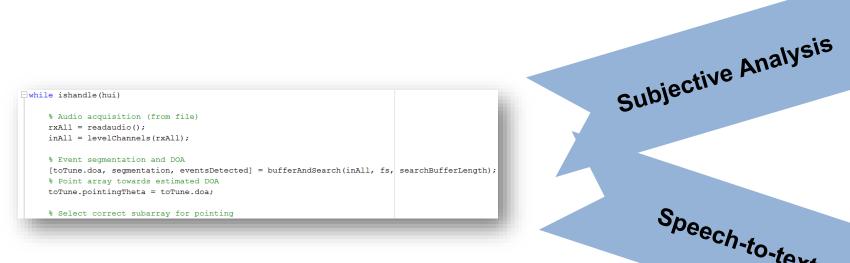
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	in stockings is hard to sell"	"a large siz
	to the dark blue background"	"blue the sh
1	ll the depth of a well"	"it's easy t
	hicken leg is a rare dish"	"these days
	served in round bowls"	"rice is oft

Guessed

"the birth canal we sl: "a large size in stock: "blue the sheet to the "it's easy to tell the "these days a chicken i "rice is often served i



How To Measure Performance?



Output audio "sounds good"



"91.5% of spoken sentences correctly converted"

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	^{10-te} xt
True	Guessed
e slid on the smooth planks" in stockings is hard to sell" to the dark blue background" ll the depth of a well"	"the birth canal we sl: "a large size in stock: "blue the sheet to the "it's easy to tell the

"these days a chicken hicken leg is a rare dish" served in round bowls" "rice is often served



Test performance with speech-to-text services

- >> [samples, fs] = audioread('helloaudioPD.wav');
- >> soundsc(samples, fs)
- >> speechObject = speechClient('Google','languageCode','en-US');
- >> outInfo = speech2text(speech0bject, samples, fs);
- >> outInfo.TRANSCRIPT =

ans =

'hello audio product Developers'

>> outInfo.CONFIDENCE =

ans =

0.9385

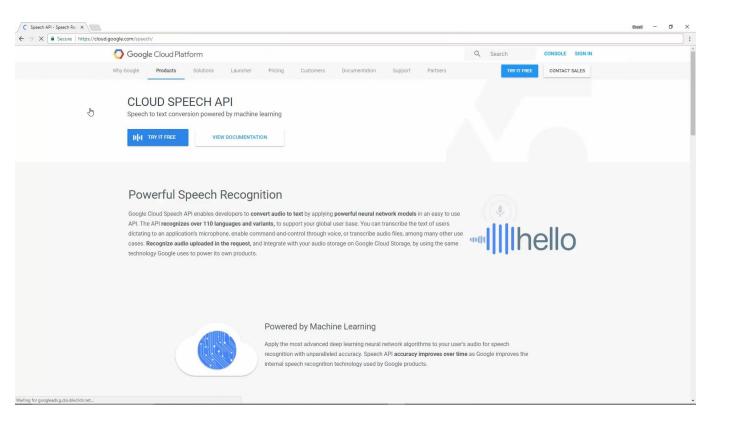
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						📣 MathWorks [,]
			while ishand	le(hui)	Cloud Servic	ces
			% Audio a	acquisition (from fi		
				readaudio(); levelChannels(rxAll)		
			% Event	segmentation and DOA	Connecting	
			[toTune.	doa, segmentation, e array towards estima	ventsDetected] = bufferAndSearch(inAll, fs, searchBufferLength);	
				pintingTheta = toTur	e.doa; Voice Interface	
			% Select	correct subarray fo	r pointing	
line in	antina data		% Sel	ect correct subarray	/ for pointing	
	oorting data					
int	o MATLAB					
					Speech to Text	
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	🖃 🔤 H1 Gab BlueCoin				True GuessedBaseline	ConfidenceBaselin
		231 KB		Size		
		217 KB lue 209 KB	Coin 231 KB			
		249 KB		eCoin	"the birch canoe slid on the smooth planks" "the birth canal we slid on the smooth planks"	0.74933
		269 KB	209 KB	231 KB	" a large size in stockings is hard to sell" "a large size in stockings is hard to sell"	0.9366
		251 KB	249 KB	217 KB	"glue the sheet to the dark blue background" "blue the sheet to the dark blue background"	0.95009
		253 KB 269 KB	269 KB	209 KB 249 KB	"its easy to tell the depth of a well" "it's easy to tell the depth of a well"	0.97403
		209 KB 277 KB	251 KB 253 KB	269 KB	"these days a chicken leg is a rare dish" "these days a chicken leg is a redfish"	0.86686
		269 KB	269 KB	251 KB	"rice is often served in round bowls" "rice is often served in rum balls"	0.95946
	🖃 🔤 H1 Gab BlueCoin		277 KB	253 KB	"the juice of lemons makes fine punch" "the cheese of lemons makes flying punch"	0.79089
		241 KB 7	269 KB	269 KB	"the box was thrown beside the parked truck" "the box was thrown beside the box truck"	0.82796
			Coin	277 KB	"the hogs were fed chopped corn and garbage" "the Hawks were fed chops corn and garbage"	0.81863
		239 KB 293 KB	241 KB 227 KB	269 KB eCoin	"four hours of steady work faced us" "A hours of study world fastest"	0 82947
		269 KB	239 KB	241 KB		
	ق б.wav	253 KB	293 KB	227 KB		
	🧃 7.wav	321 KB	269 KB	239 KB		
Spee	ch Dataset	245 KB 311 KB	253 KB	293 KB		
		287 KB	321 KB 245 KB	269 KB 253 KB		
	H1 Gab Headset		243 KB 311 KB	321 KB		
	1.wav	253 KB 🕜	287 KB	245 KB		31
	2.wav	263 KB lead	dset	311 KB		01



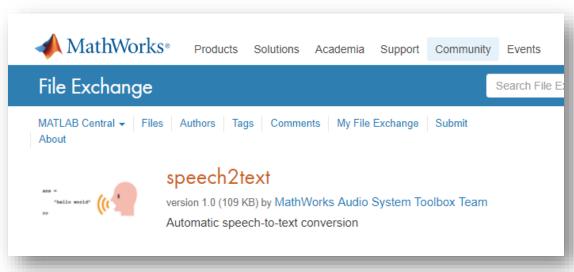
Connecting to Cloud Services for Speech Recognition

- Google[®] Speech API
- IBM[®] Watson Speech API
- Microsoft[®] Azure Speech API



Speech-To-Text – Access 3rd-party web services from MATLAB

- Automate content labelling of speech datasets
- Validate speech enhancement algorithms for transcription performance
- Run text analytics on auto-transcribed voice recordings
- Choice of
 - Google[®] Speech API
 - IBM[®] Watson Speech API
 - Microsoft[®] Azure Speech API
- Requires separate credentials for service provider of choice



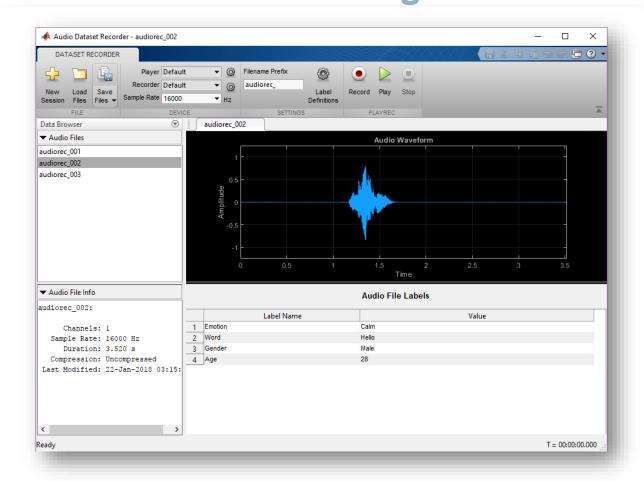
https://www.mathworks.com/matlabcentral/fileexchange/65266-speech2text

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			while ishan	dle(hui)	Cloud Servi	Ces
				<pre>acquisition (from readaudio();</pre>	file)	
				levelChannels(rxA		
				segmentation and .doa, segmentation		
			% Point	array towards est		
			toTune.	pointingTheta = to	^{mated DOA} Voice Interface	
			% Selec	t correct subarray	for pointing	
. .			s Se	lect correct suba	ray for pointing	
Imp	porting data		1.1.1			
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		209 KB 249 KB	231 KB 217 KB	ueCoin	"the birch canoe slid on the smooth planks" "the birth canal we slid on the smooth planks"	0.74933
		249 KB 269 KB	217 KB 209 KB	231 KB	" a large size in stockings is hard to sell" "a large size in stockings is hard to sell"	0.9366
		203 KB	209 KB 249 KB	217 KB	"glue the sheet to the dark blue background" "blue the sheet to the dark blue background"	0.95009
		253 KB	249 KB	209 KB		0.97403
		269 KB	209 KB	249 KB	"its easy to tell the depth of a well" "it's easy to tell the depth of a well"	
		277 KB	253 KB	269 KB	"these days a chicken leg is a rare dish" "these days a chicken leg is a redfish"	0.86686
	i 10.wav	269 KB	269 KB	251 KB	"rice is often served in round bowls" "rice is often served in rum balls"	0.95946
	🖃 🔤 H1 Gab BlueCoin		277 KB	253 KB	"the juice of lemons makes fine punch" "the cheese of lemons makes flying punch"	0.79089
	i.wav	241 KB 🕜	269 KB	269 KB	"the box was thrown beside the parked truck" "the box was thrown beside the box truck"	0.82796
			eCoin	277 KB	"the hogs were fed chopped corn and garbage" "the Hawks were fed chops corn and garbage"	0.81863
		239 KB	241 KB	269 KB	"four hours of steady work faced us" "A hours of study world fastest"	0.82947
	J.wav	293 KB		ueCoin	THE COURT OF STREAM WARS LEADED OF "A DAMPY AT STRATE WARDAR STREET"	
		269 KB	239 KB	241 KB		
		253 KB	293 KB	227 KB		
Cnad		321 KB 245 KB	269 KB	239 KB 293 KB		
Spee	ch Dataset	245 KB 311 KB	253 KB	269 KB		
		287 KB	321 KB 245 KB	253 KB		
	H1 Gab Headset	LOTIND	245 KB 311 KB	321 KB		
		253 KB /	287 KB	245 KB		2 4
		263 KB lea	207 ND	311 KB		34
	2.wdv	200 KD 168	adset	STEND		



Building a small speech dataset quickly Example: an App with automated content labelling*

Play
H1 Gab BlueCoin Close
the birch canoe slid on the smoo
the birch canoe slid on the smoo glue the sheet to the dark blue b
its easy to tell the depth of a well these days a chicken leg is a rar rice is often served in round bow
the juice of lemons makes fine p the box was thrown beside the p the hogs were fed chopped corn
four hours of steady work faced a large size in stockings is hard
BlueCoin beta

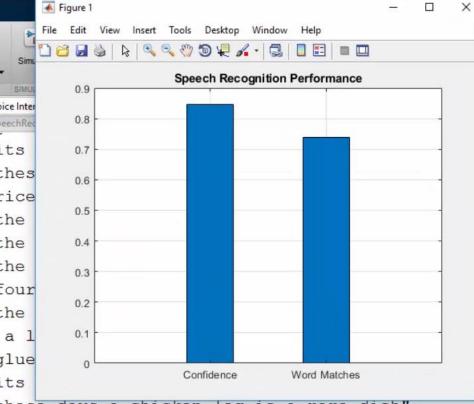


*See also Dataset Recorder App prototype in example "Record Audio Datasets" (From R2018a in Audio System Toolbox)

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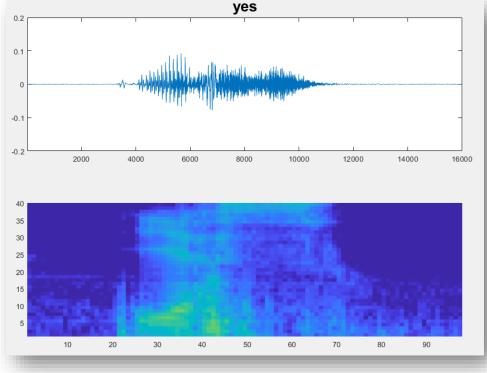
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Speech Command Recognition with Deep Learning (New Example)

- Train a Convolutional Neural Network (CNN) to recognize speech commands
- Work with <u>Google's speech command dataset</u>
- Leverage helper code for:
 - Reading and managing large datasets (New audio datastore prototype)
 - Transforming 1D signals into 2D images via perceptually-aware spectrograms (New auditory spectrogram prototype)
- Prototype trained network in real-time on live audio
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To Learn More about Deep Learning with MATLAB

Demystifying Deep Learning 14:30–15:15

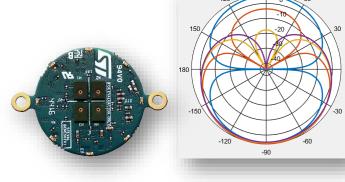
Deep learning can achieve state-of-the-art accuracy for many tasks considered algorithmically unsolvable using traditional machine learning, including classifying objects in a scene or recognizing optimal paths in an environment. Gain practical knowledge of the domain of deep learning and discover new MATLAB[®] features that simplify these tasks and eliminate the low-level programming. From prototype to production, you'll see demonstrations on building and training neural networks and hear a discussion on automatically converting a model to CUDA[®] to run natively on GPUs.



Dr. Amod Anandkumar, Senior Team Lead, MathWorks India



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Audio System Toolbox Live Acquisition from hardware

Leveraging Audio Plugins for performance improvement

Test the performance of my system?Using Cloud Services for Speech RecognitionCreating your own speech dataset

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"the birth canal we sl "a large size in stock "blue the sheet to the "it's easy to tell the "these days a chicken "rice is often served





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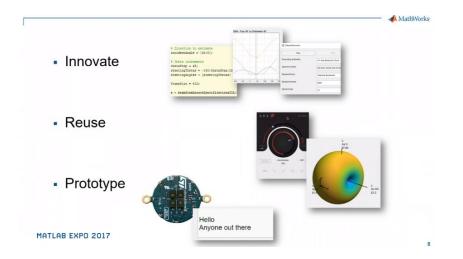


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