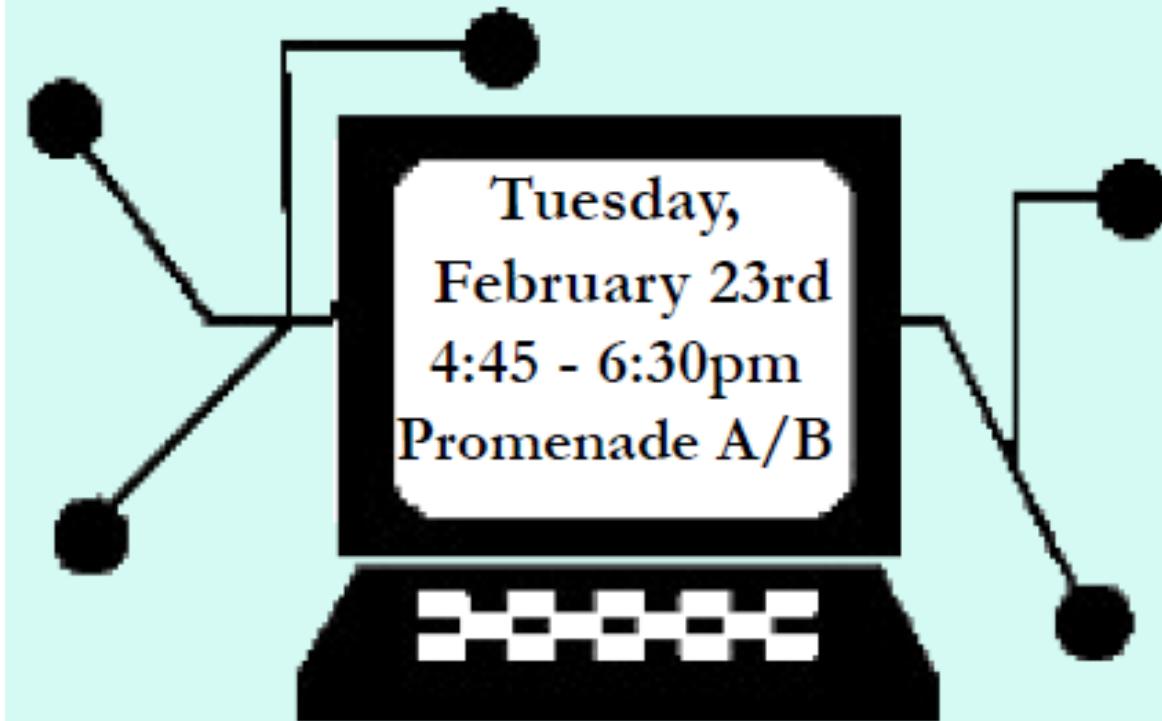


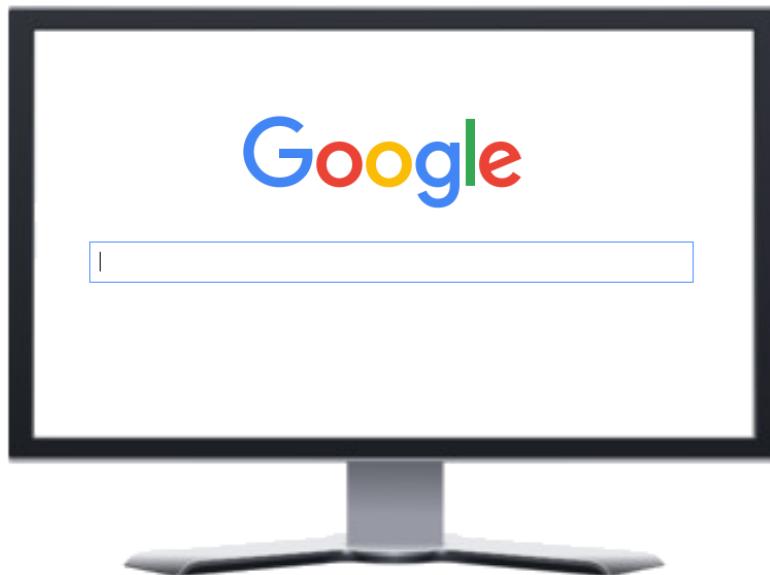
Research and Teaching Tools for MATLAB

A Community Discussion



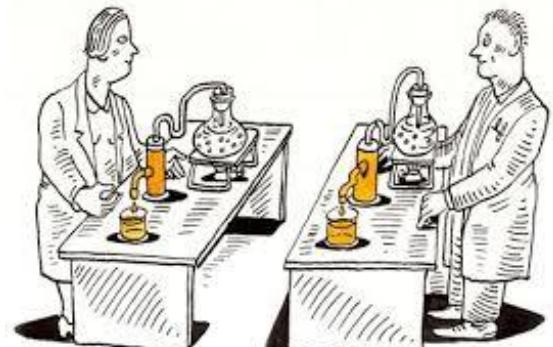
Purpose

What are the community needs for the efficient sharing of MATLAB tools and resources for research and teaching?



Why?

- Less duplication of effort across labs & teaching resources
- Rigor and reproducibility of research (new NIH requirement for grants)
- Improve learning experience for students
- Maybe have a more focused location for MATLAB research and teaching resources for the ARO community rather than Google



How?

- Talks to highlight how MATLAB is being used for research/teaching and what tools are available:
 - Michael Heinz
 - Ray Goldsworthy
 - Denis Drennan
 - Piotr Majdak
 - Laurel Carney

How?

- Lisa Kempler will share about what MATLAB has to offer for collaboration and promoting sharing of tools and resources
- Discussion on how to improve awareness/sharing of already available resources?

How?

Survey
(Please fill in once)

<http://tinyurl.com/ARO2016MATLABSurvey>



Comments/Questions/Ideas
(Fill in as many times as you like)

<http://tinyurl.com/ARO2016MATLABComments>



Research and Teaching tools for MATLAB

* Required

You are? *

Faculty/Academic Staff/Researcher
 Clinician
 Post-doc/Research Associate
 Student
 Other : _____

Do you use MATLAB?

Yes
 No

Research and Teaching Tools for MATLAB

Questions, comments, ideas (feel free to come back to this form and submit more responses throughout the session)

Add your questions, comments, ideas, etc. here

Your answer _____

Email (optional)

Your answer _____

SUBMIT

Uses of *MATLAB* for teaching and research in audiology and auditory neuroscience

Michael G. Heinz^{1,2}

¹ Dept. of Speech, Language, and Hearing Sciences
&

² Weldon School of Biomedical Engineering,
Purdue University, West Lafayette, IN, USA

Outline

- **Teaching**

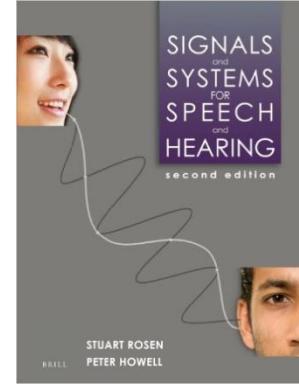
- *Audiology (AUD) students*
 - *Signal Processing for Hearing and Speech course*
- Undergraduate SLHS students
 - Hearing Science course
- Graduate BME students
 - Biomedical Signal Processing course

- **Research**

- AN models
- *Neural Spike train analyses – Correlograms*
- Data collection – NEL system

Teaching: Audiology (AUD) students,

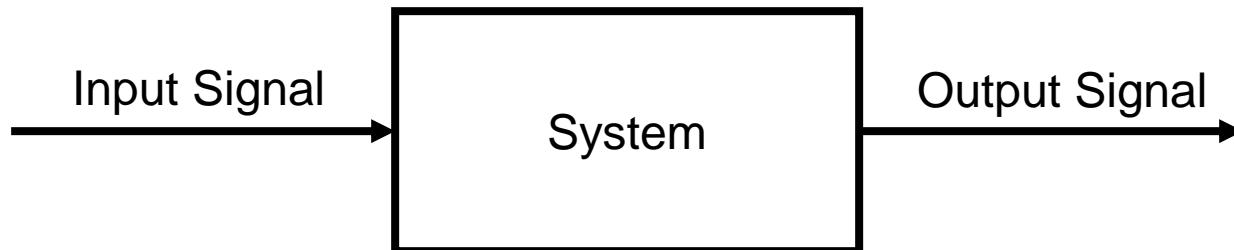
“Signal Processing for Hearing and Speech”



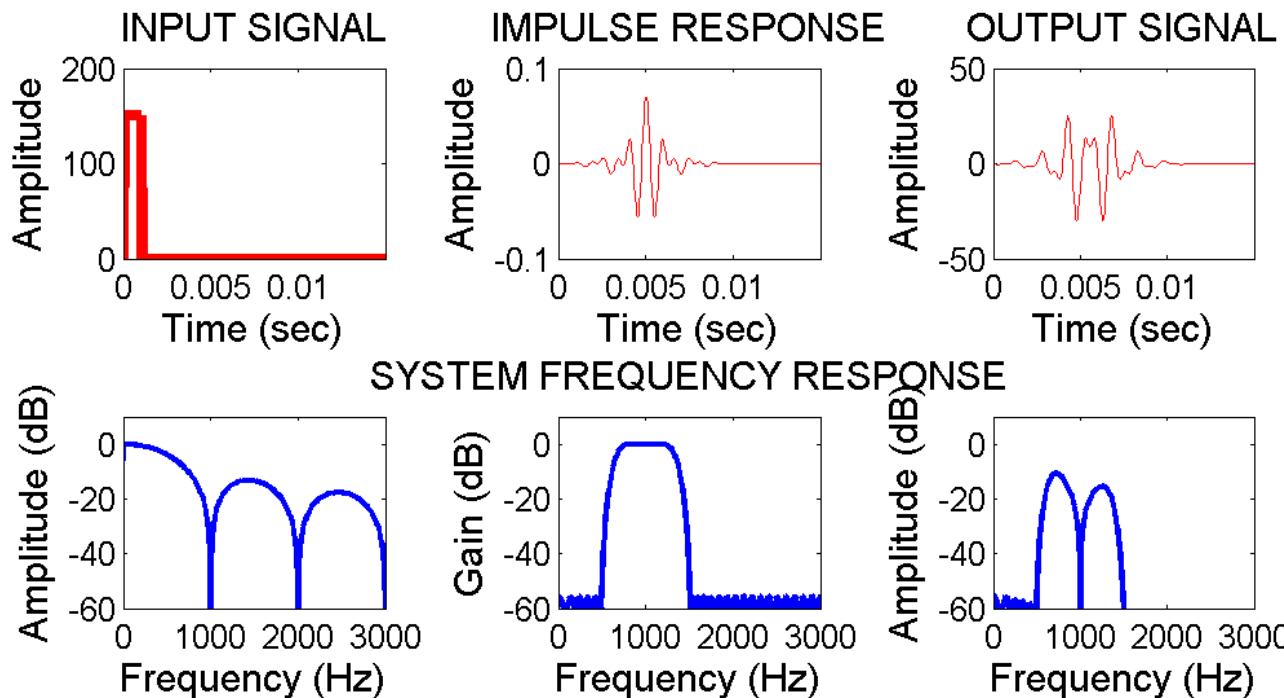
- **Based on Rosen and Howell Textbook**

- No equations, just figures conveying key concepts
- I developed MATLAB code for many of the core concepts in parallel with text chapters/figures
- Simple parameter changes allow students without MATLAB background to “explore” issues hands on and develop intuition beyond static text figures, e.g.,
 - Sinusoidal motion – unit circle
 - Time/frequency tradeoff (e.g., clicks, tones)
 - Linear vs log BWs,
 - Resolved/unresolved harmonics (effect of broadened BWs)
- Course toolbox of core functions (signal generation, Fourier analysis, filtering, ...)
- *ZIP file of course material shared with few colleagues*

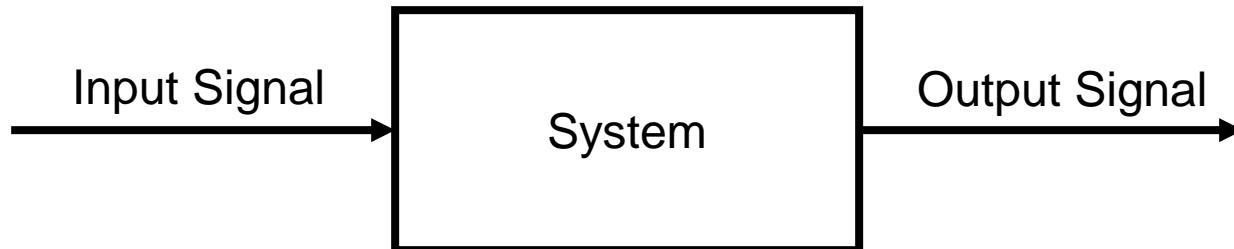
E.g., exploring click duration effects in characterizing a system



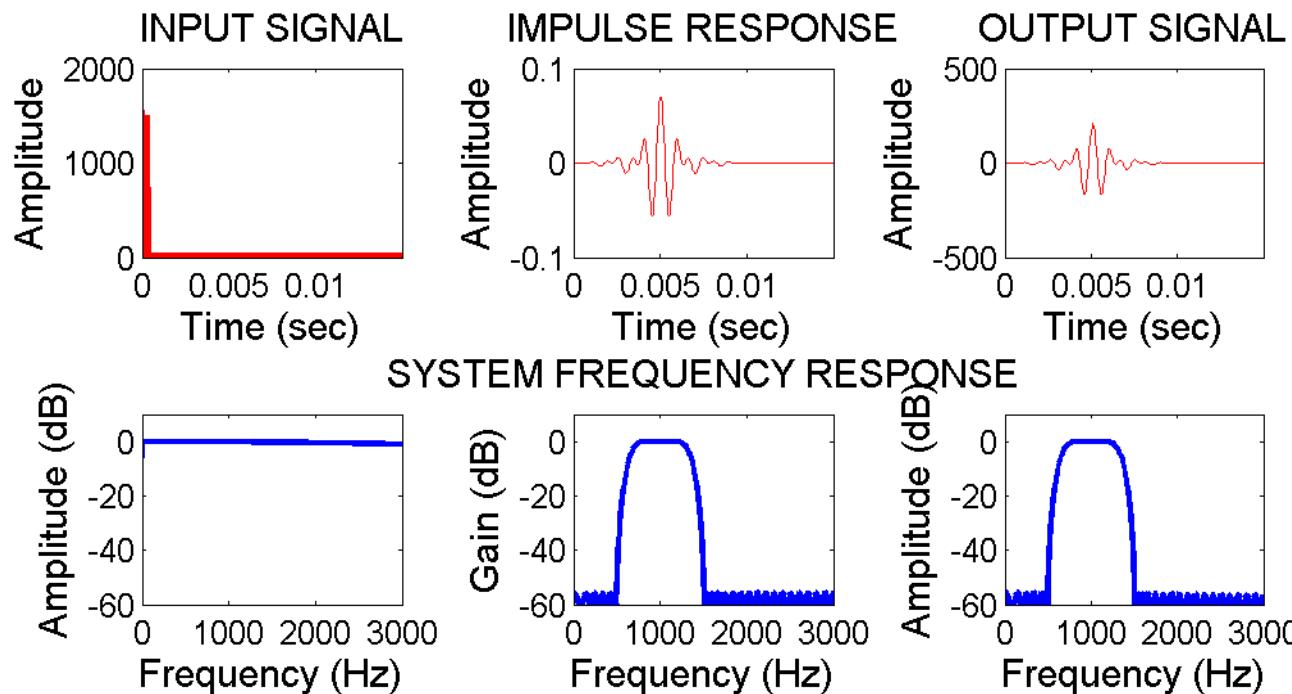
- MATLAB code using core functions from “course toolbox” (signal generation, filtering, Fourier analysis ...) allows simple parameter changes (click duration) to explore fundamental concepts in real applications (e.g., time/BW tradeoff)



E.g., exploring click duration effects in characterizing a system

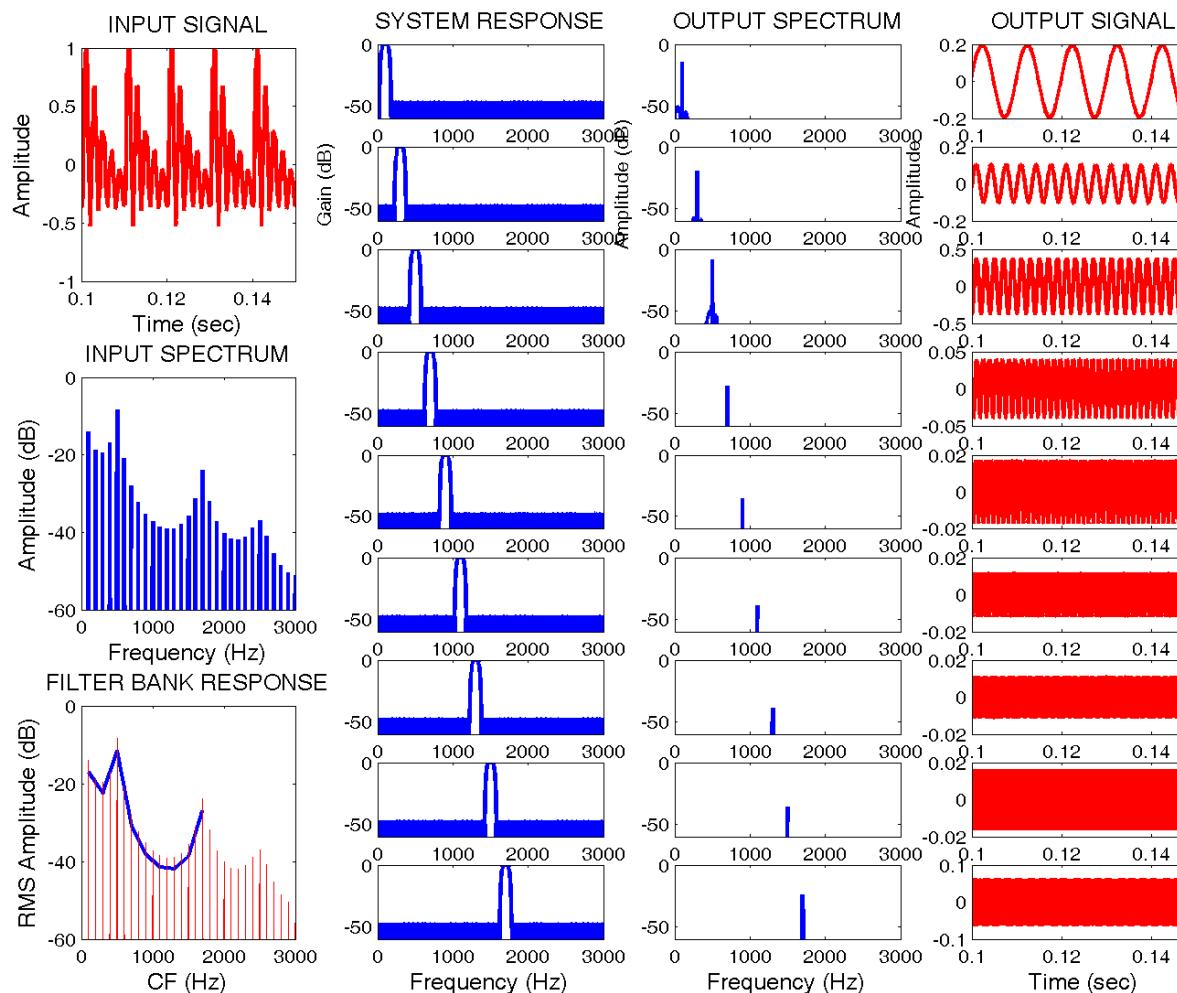


- MATLAB code using core functions from “course toolbox” (signal generation, filtering, Fourier analysis ...) allows simple parameter changes (click duration) to explore fundamental concepts in real applications (e.g., time/BW tradeoff)



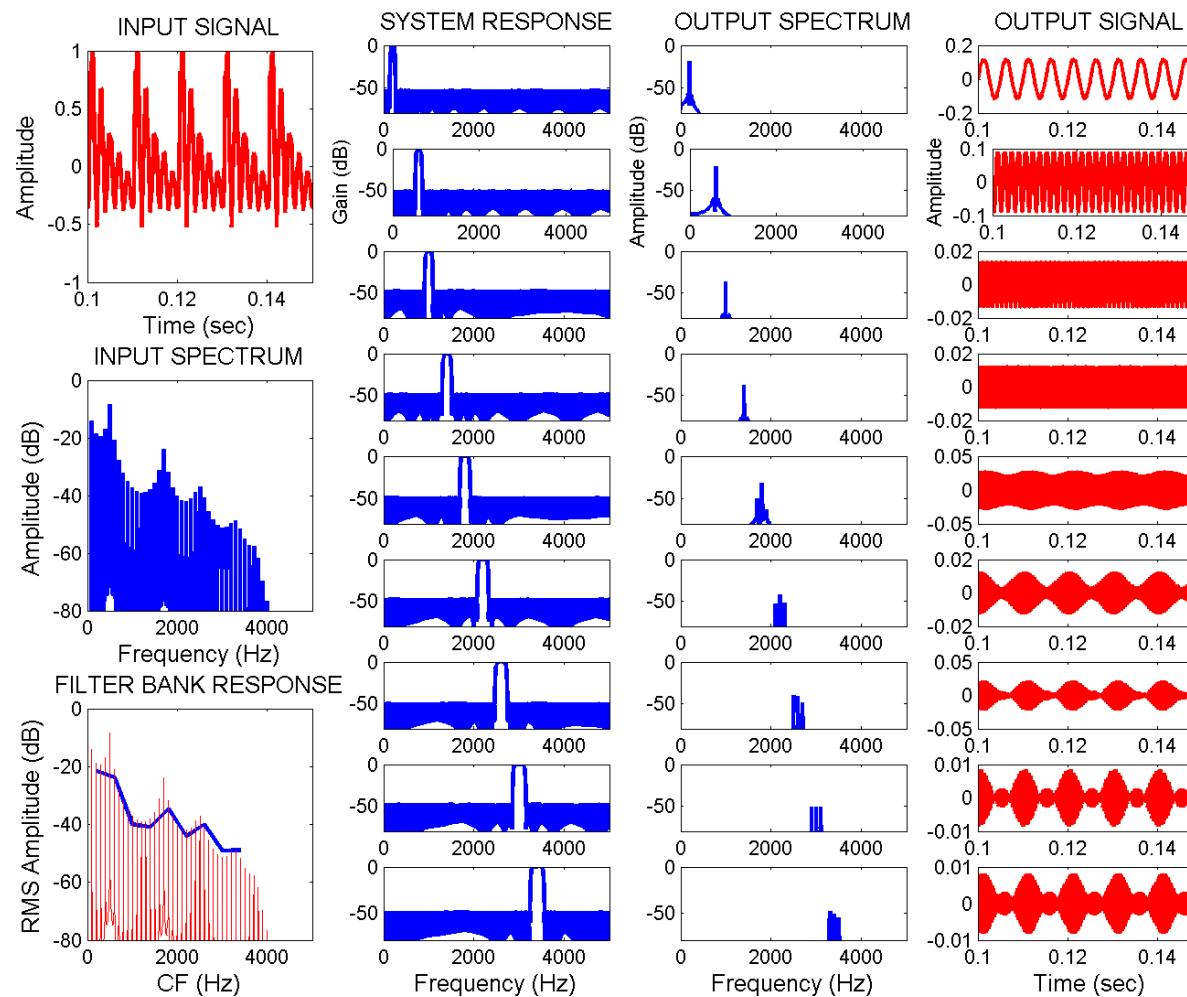
E.g., exploring effects of reduced frequency selectivity on harmonic resolvability

- Students have simple control of filter BWs (using “course-toolbox” functions) to explore filtering issues – linear vs logarithmic; broadening with hearing loss



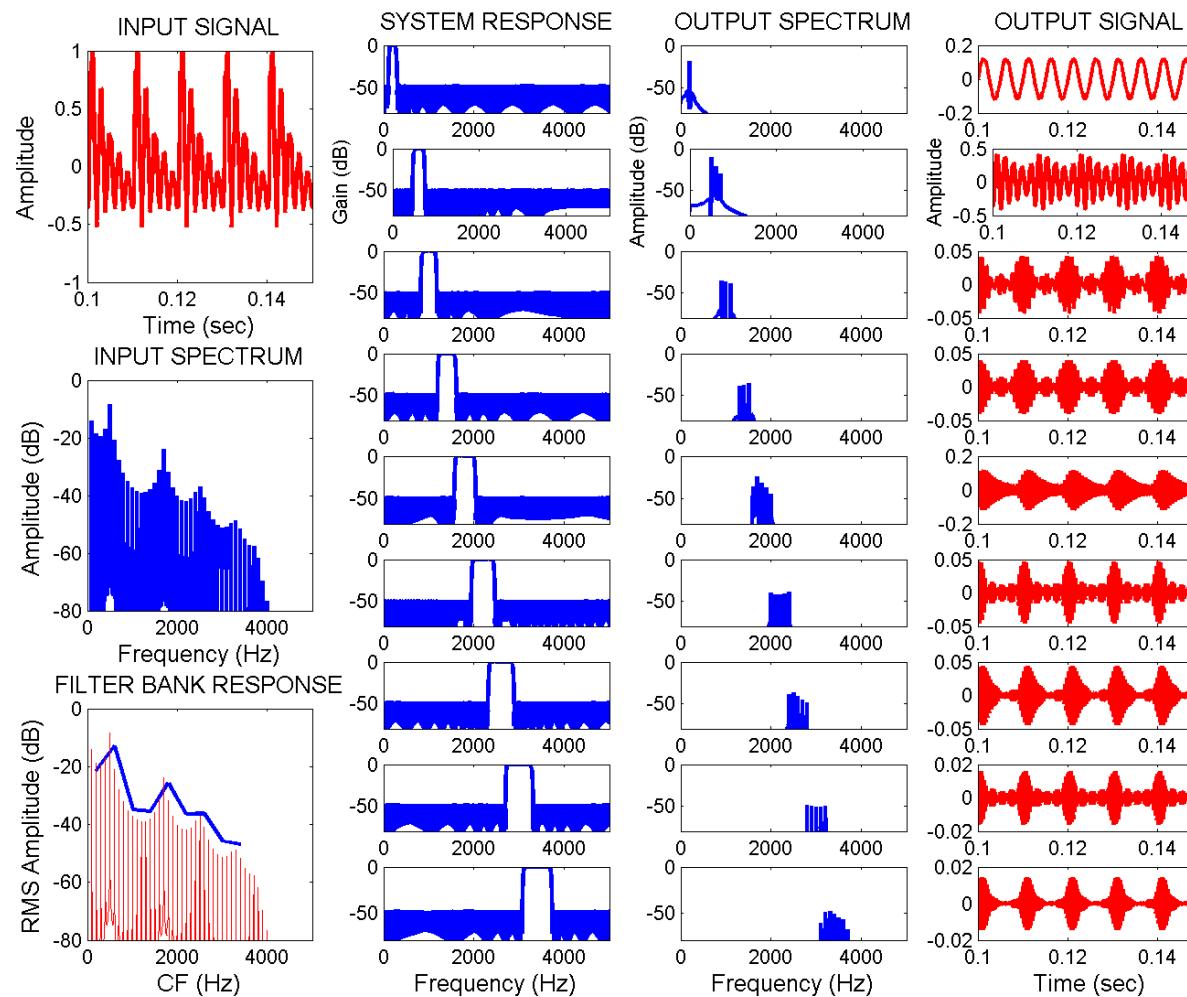
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E.g., exploring effects of reduced frequency selectivity on harmonic resolvability

- Students have simple control of filter BWs (using “course-toolbox” functions) to explore filtering issues – linear vs logarithmic; broadening with hearing loss



Outline

- **Teaching**

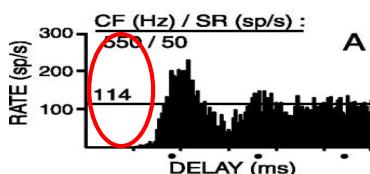
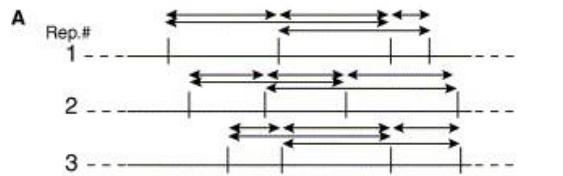
- *Audiology (AUD) students*
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 - Hearing Science course
- Graduate BME students
 - Biomedical Signal Processing course

- **Research**

- AN models (... Laurel)
- ***Neural Spike train analyses – Correlograms***
- Data collection – NEL system

Shuffled auto-correlograms provide an improved quantification of temporal structure in neural responses to arbitrary stimuli

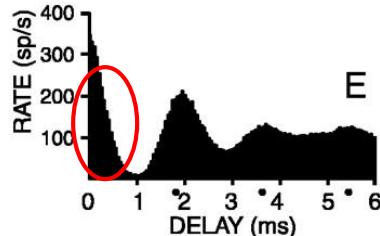
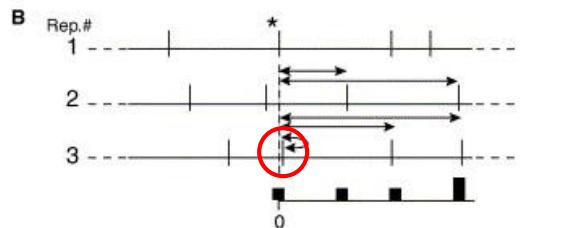
ALL-ORDER INTERSPIKE INTERVAL HISTOGRAMS (Ruggero, 1973)



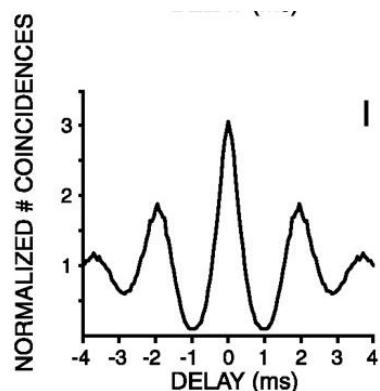
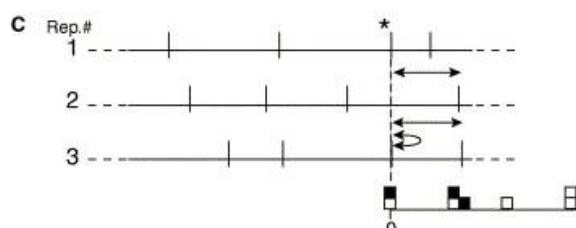
Response to broadband noise

SHUFFLED AUTOCORRELOGRAMS (SACs)

(Joris, 2003; Louage et al, 2004; Joris et al., 2006, ...)



Shuffling avoids refractory period

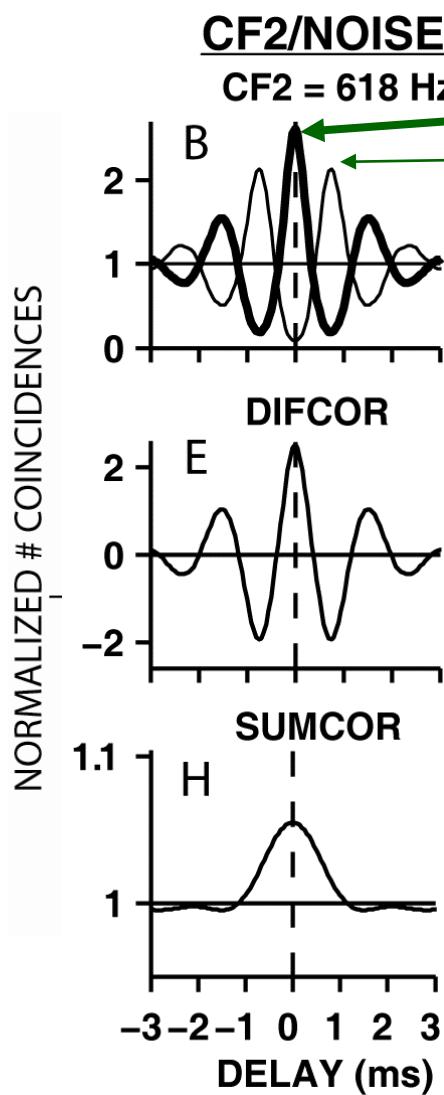


N² Smoothing

Normalized SAC:

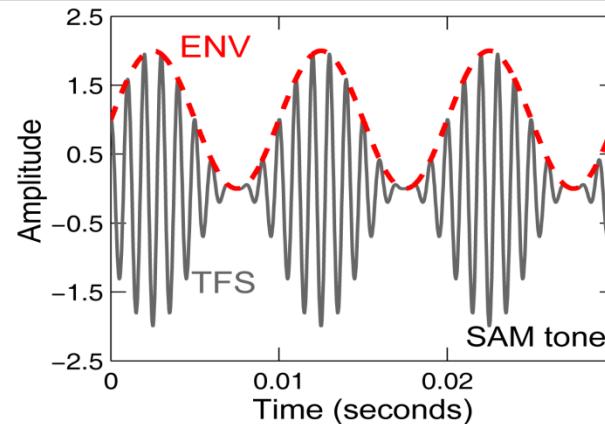
- 1 => No correlation
- > 1 ~ positive correlation
- < 1 ~ negative correlation
- Oscillations ~ CF
- Peak decay ~ BW

Temporal fine-structure (TFS) and envelope (ENV) coding can be separated via stimulus polarity inversion (Joris, 2003)



Shuffled correlograms

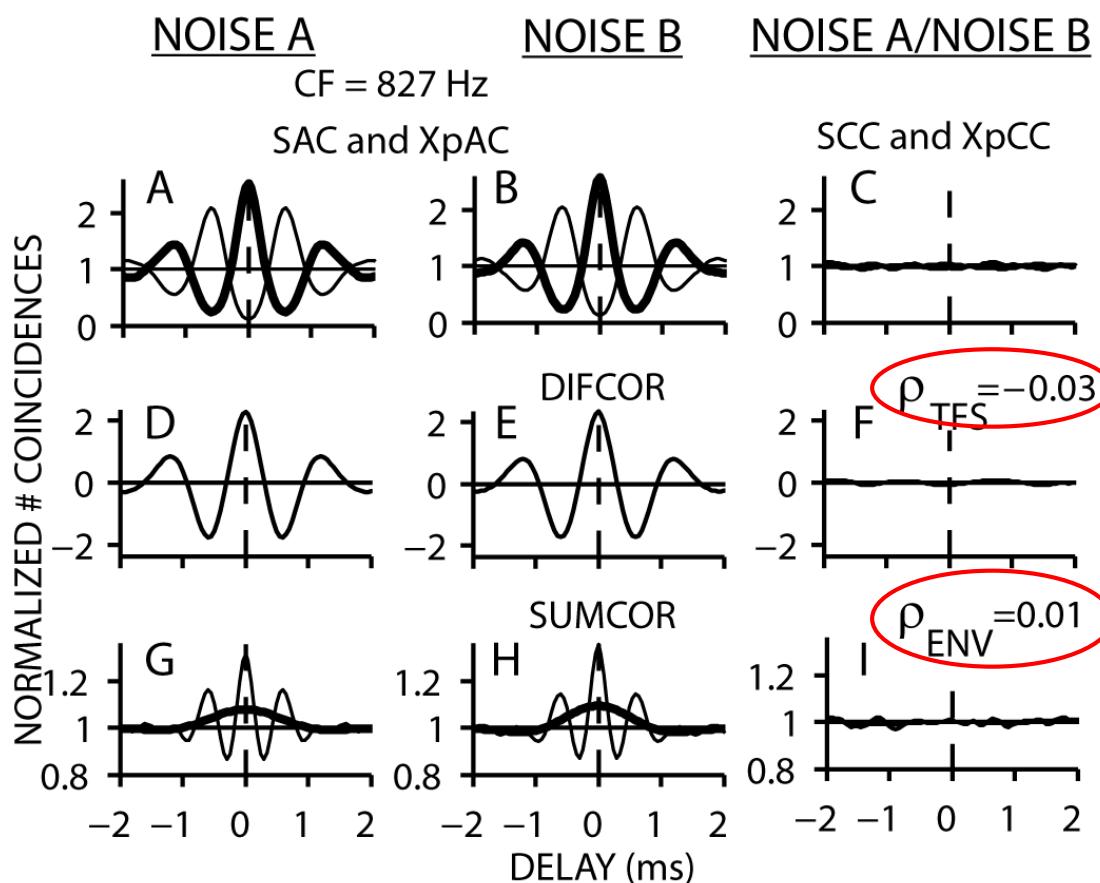
SAC (A+/A+);
XpAC (A+/A-)



DIFCOR = SAC – XpAC (isolates fine structure)
- peak height quantifies TFS coding strength

SUMCOR = $\frac{1}{2}$ (SAC + XpAC) [emphasizes envelope]
- peak height quantifies ENV coding strength

- Neural cross-correlation coefficients ($0 \leq \rho_{TFS} \leq 1$, Heinz and Swaminathan 2009)
 - Computed from neural spike times (model or animal data)
 - Used for:
 - Cross-stimulus comparisons of TFS or ENV coding (chimaeric speech)
 - Cross-CF comparisons (traveling wave delay estimates)
 - Relies on correlograms computation function in C for efficiency, run as MEX
 - ZIP file with MATLAB code shared with a number of colleagues:
 - basic AN model demo



Two uncorrelated noises

$$\rho_{AB} = \frac{\text{Cov}(A, B)}{\sqrt{\text{Var}(A) * \text{Var}(B)}}$$

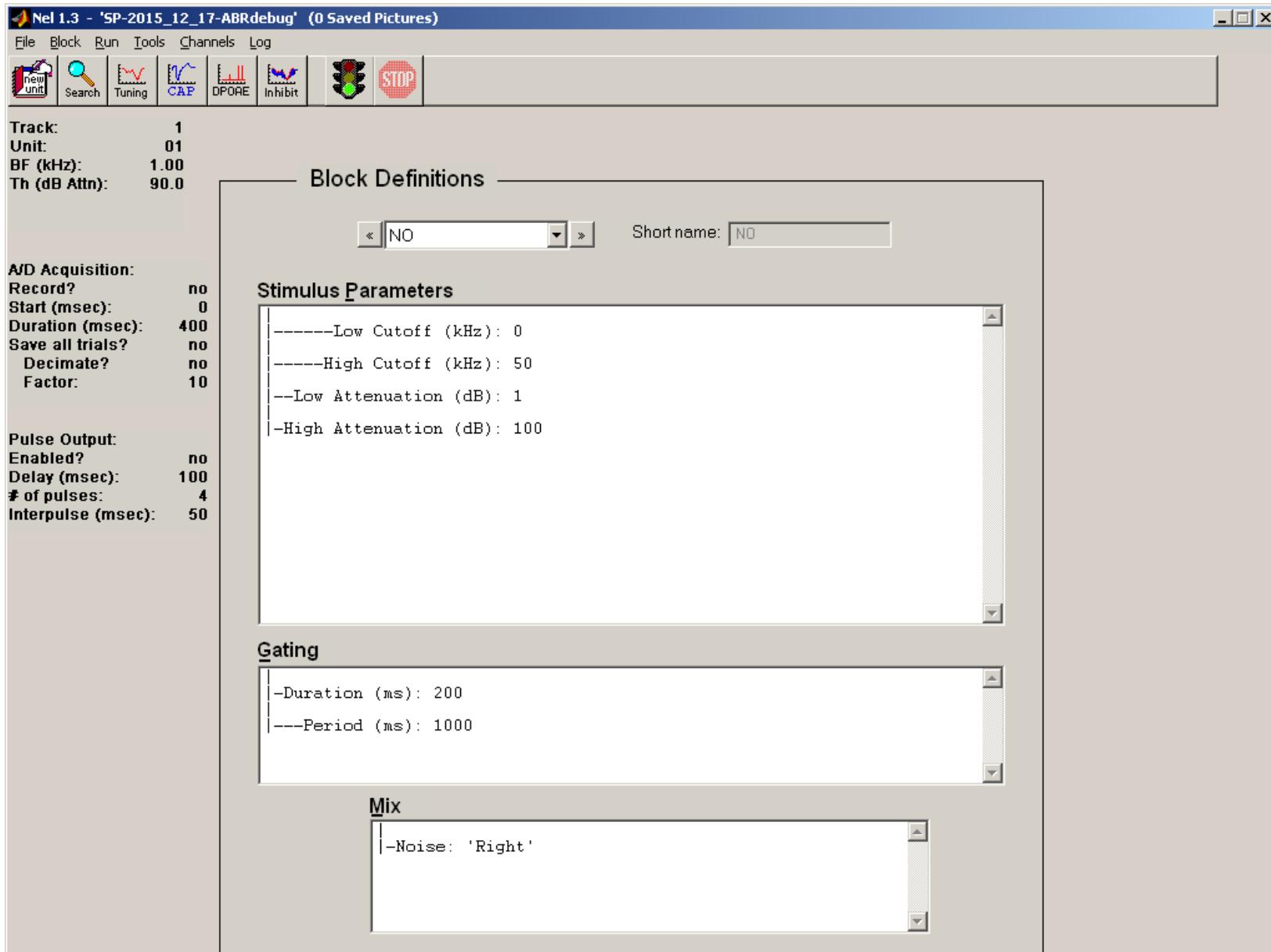
$$\rho_{TFS} = \frac{DC(AB)}{\sqrt{DC(A) * DC(B)}}$$

$$\rho_{ENV} = \frac{SC(AB)}{\sqrt{SC(A) * SC(B)}}$$

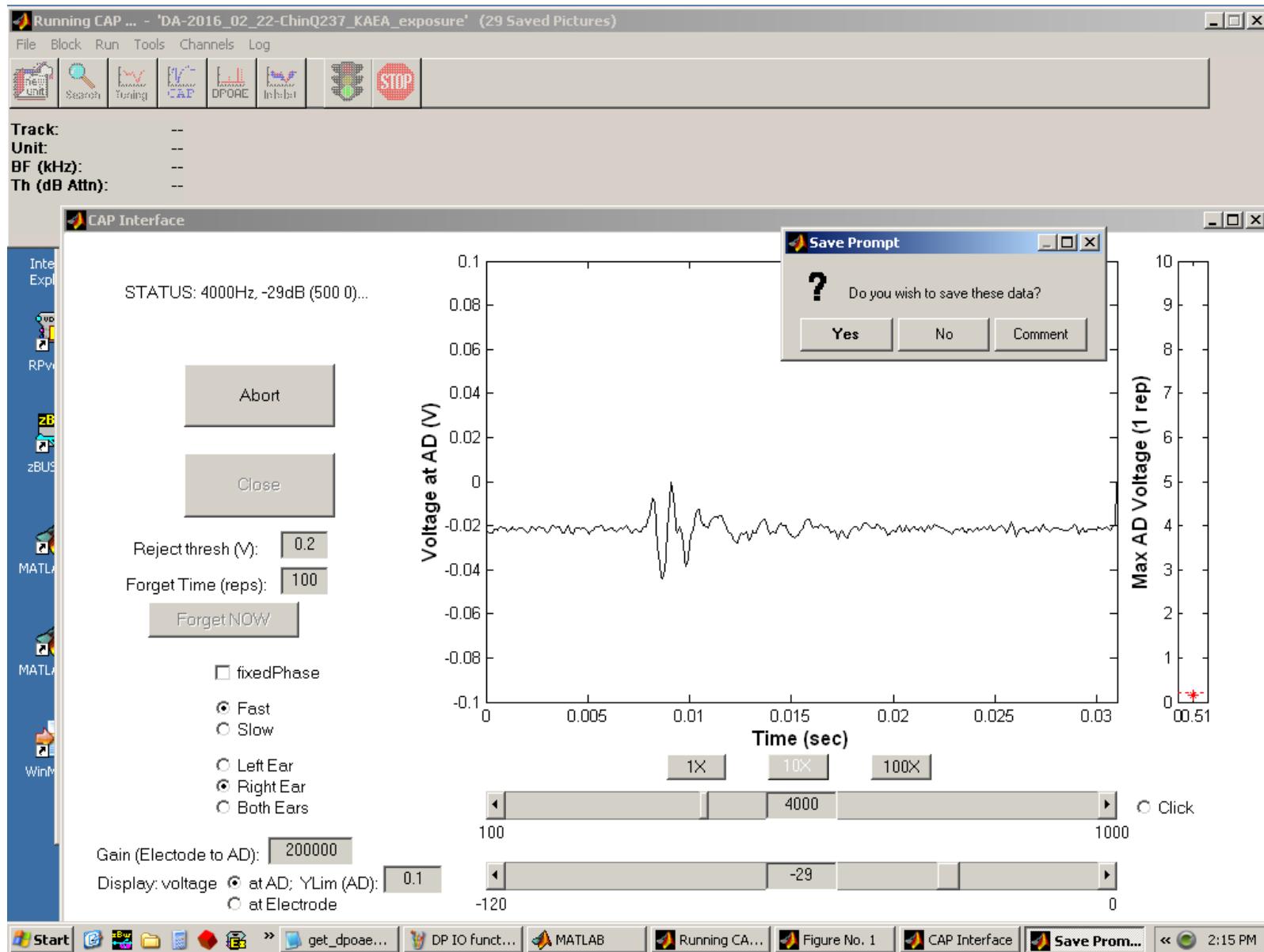
Outline

- Teaching
 - *Audiology (AUD) students*
 - *Signal Processing for Hearing and Speech course*
 - Undergraduate SLHS students
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- Research
 - AN models (... Laurel)
 - *Neural Spike train analyses – Correlograms*
 - **Data collection – NEL system**

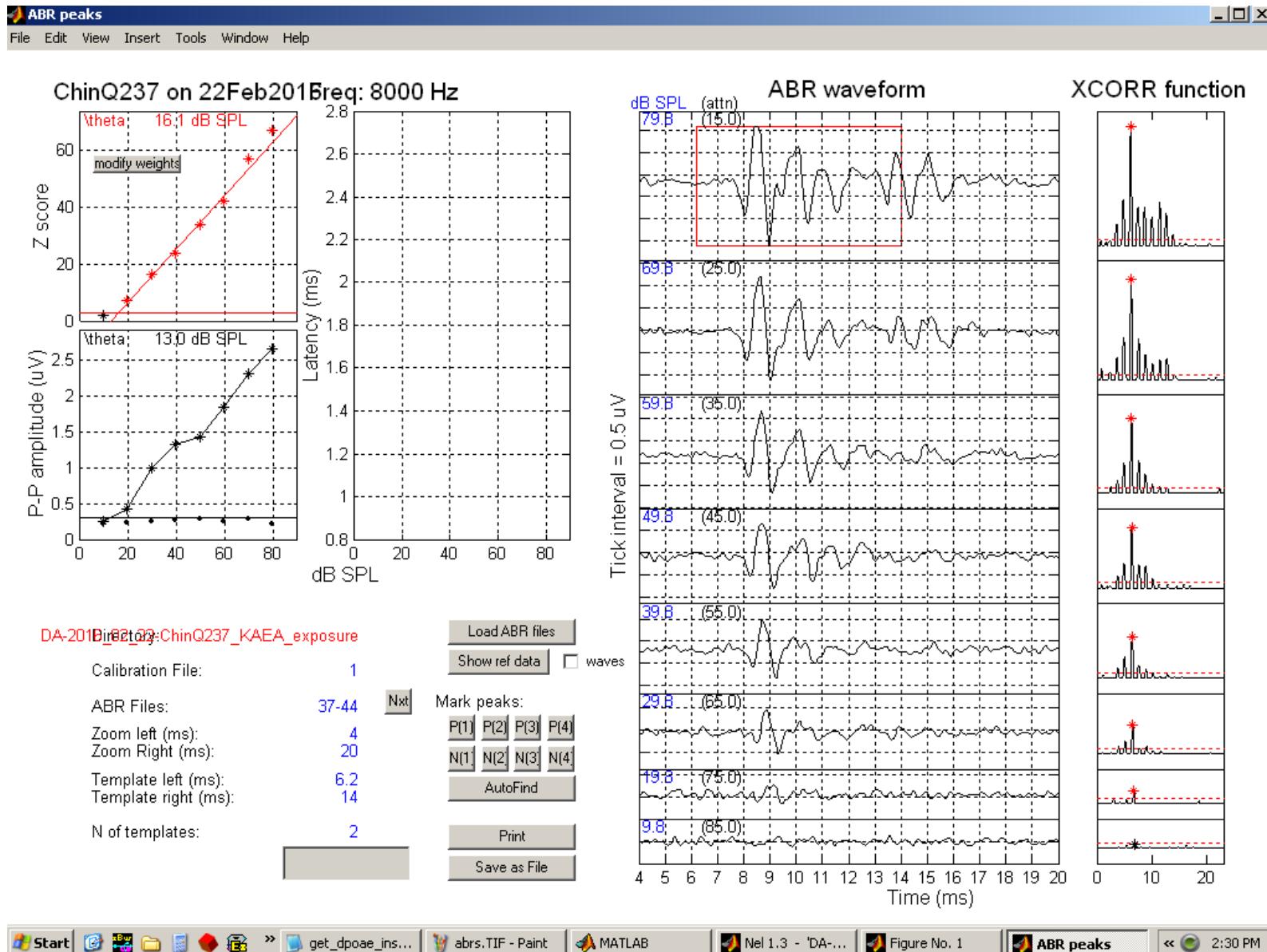
Neurophysiological Data Collection – “NEL” system (from Eric Young’s Lab)



Neurophysiological Data Collection – “NEL” system (from Eric Young’s Lab)



Neurophysiological Data Collection – “NEL” system (from Eric Young’s Lab)



Software Tools for Hearing Research

Ray Goldsworthy



USC University of
Southern California

Why Matlab?

- Strikes the right balance
 - Complete acoustic control
 - Community resources
 - Signal processing tools
 - Research interfaces

Speech Materials

Psychophysical
Procedures

Room Acoustics

Signal Processing

Research
Interfaces



Why ~Matlab?

- Wearable algorithms
 - Longitudinal studies
 - Real environments
 - At-home training

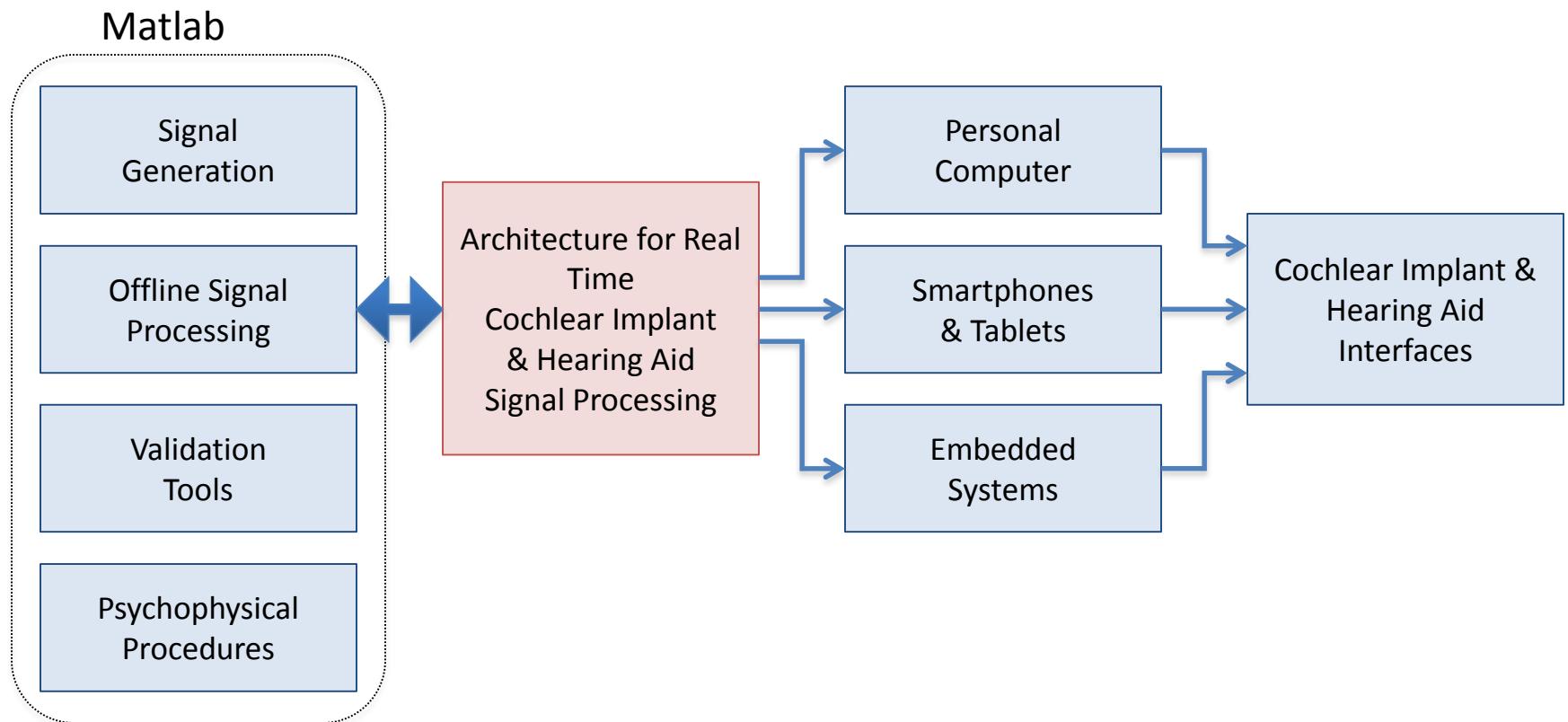
Speech Materials
& Psychophysical
Procedures

Real
World

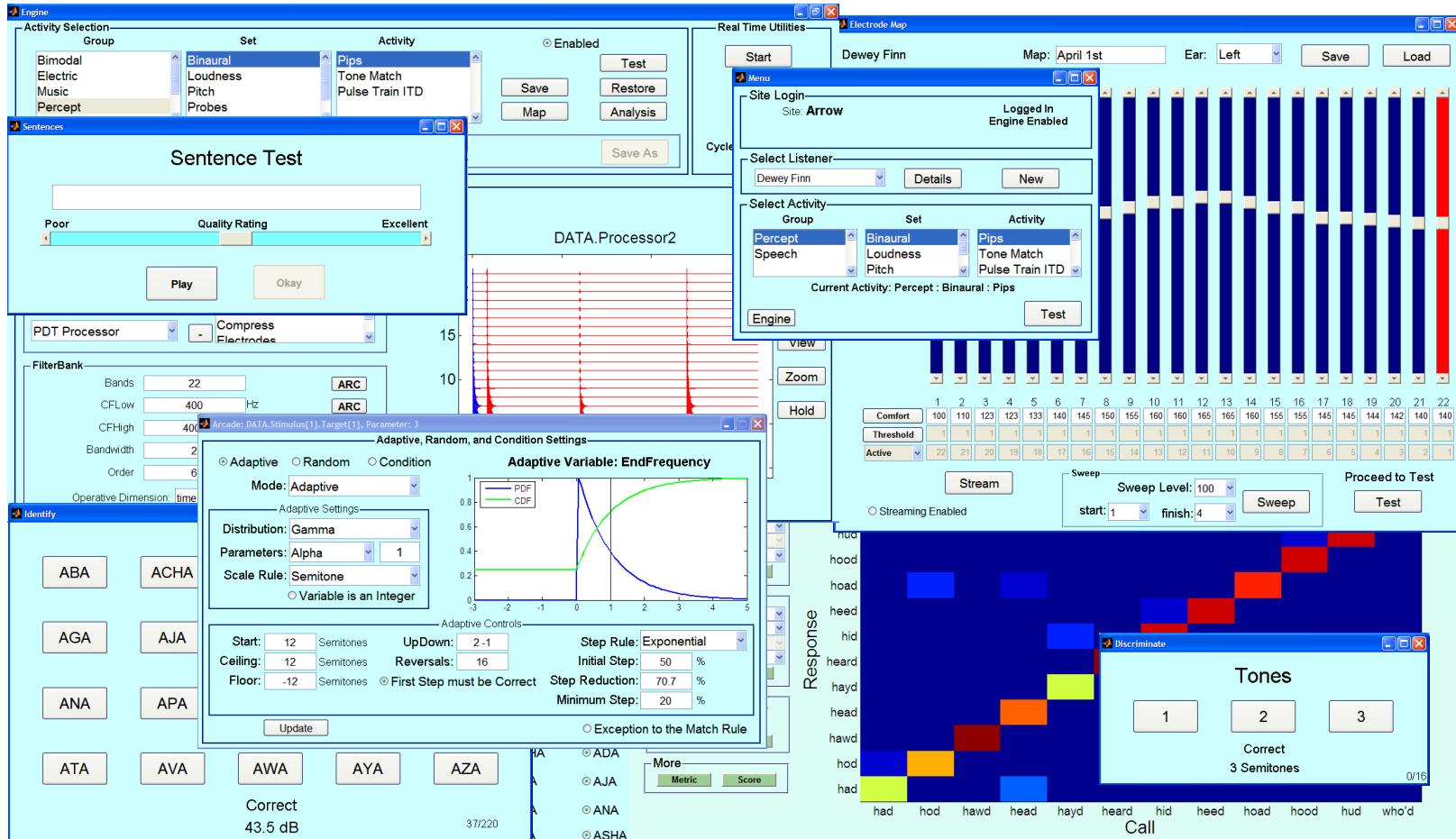
Signal Processing
on Research
Interfaces



Comprehensive System



Open Design Matlab Tools



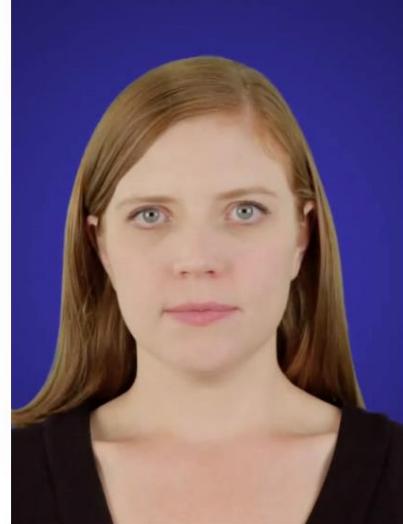
Percept, a MATLAB toolbox for cochlear implant and hearing aid research.

Open Design Web Tools

teamhearing.org

Modified Rhyme Test

| | | |
|------|------|------|
| bent | dent | rent |
| sent | tent | went |



Click on the word that you heard.

repeat

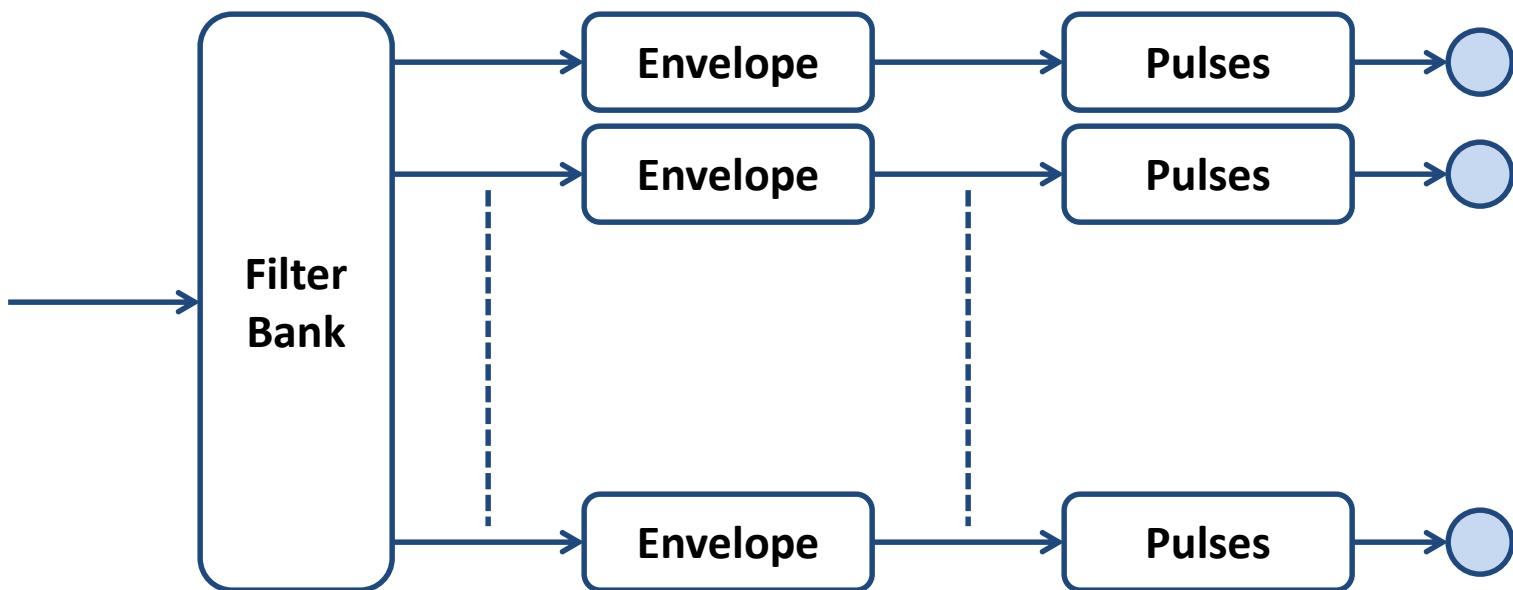
Score: ●●●●●●●●



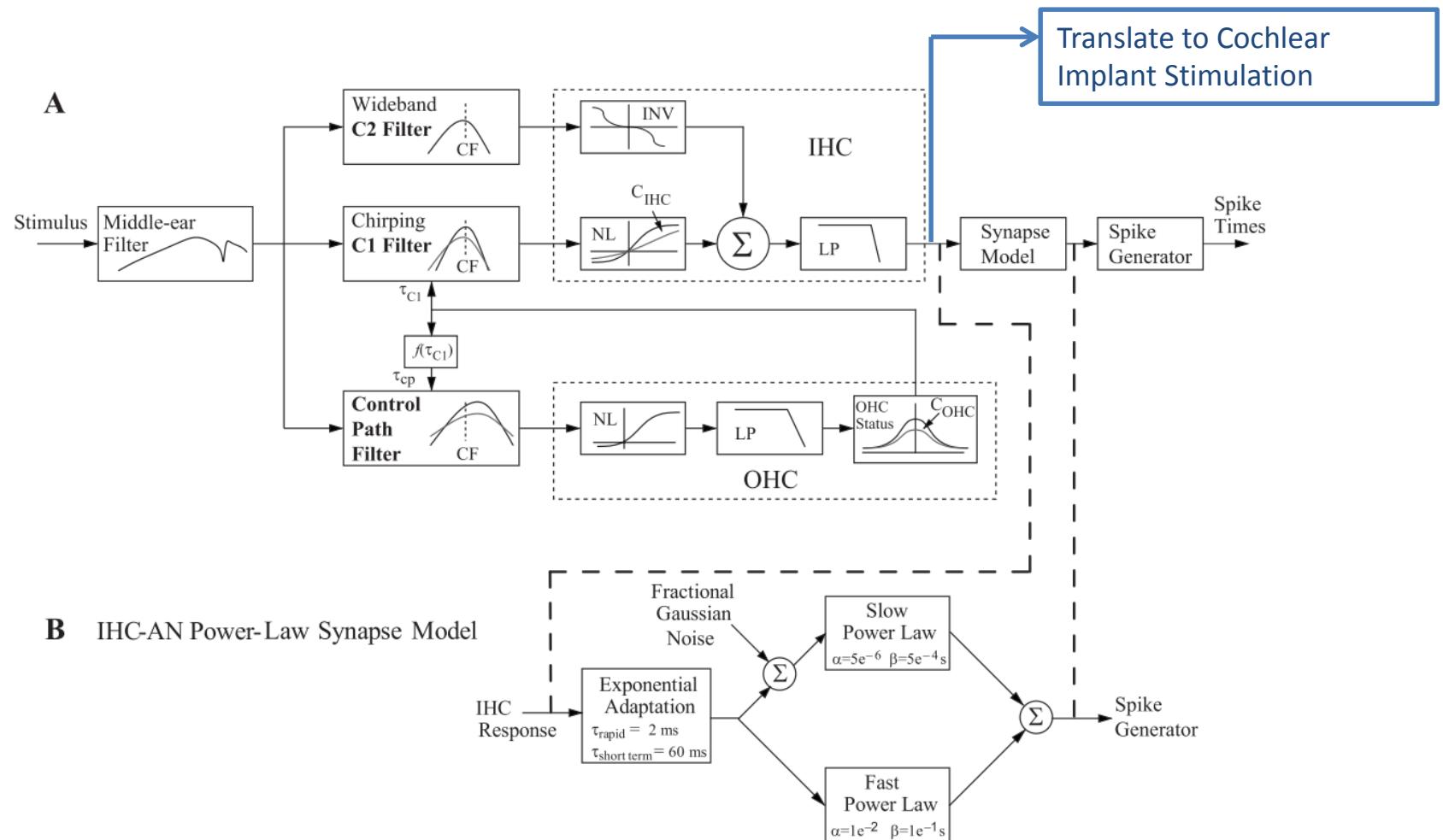
Example Usage

*Adaptive Filtering Based on Auditory
Models*

Basic Signal Processing for Cochlear Implants



Auditory Periphery Model

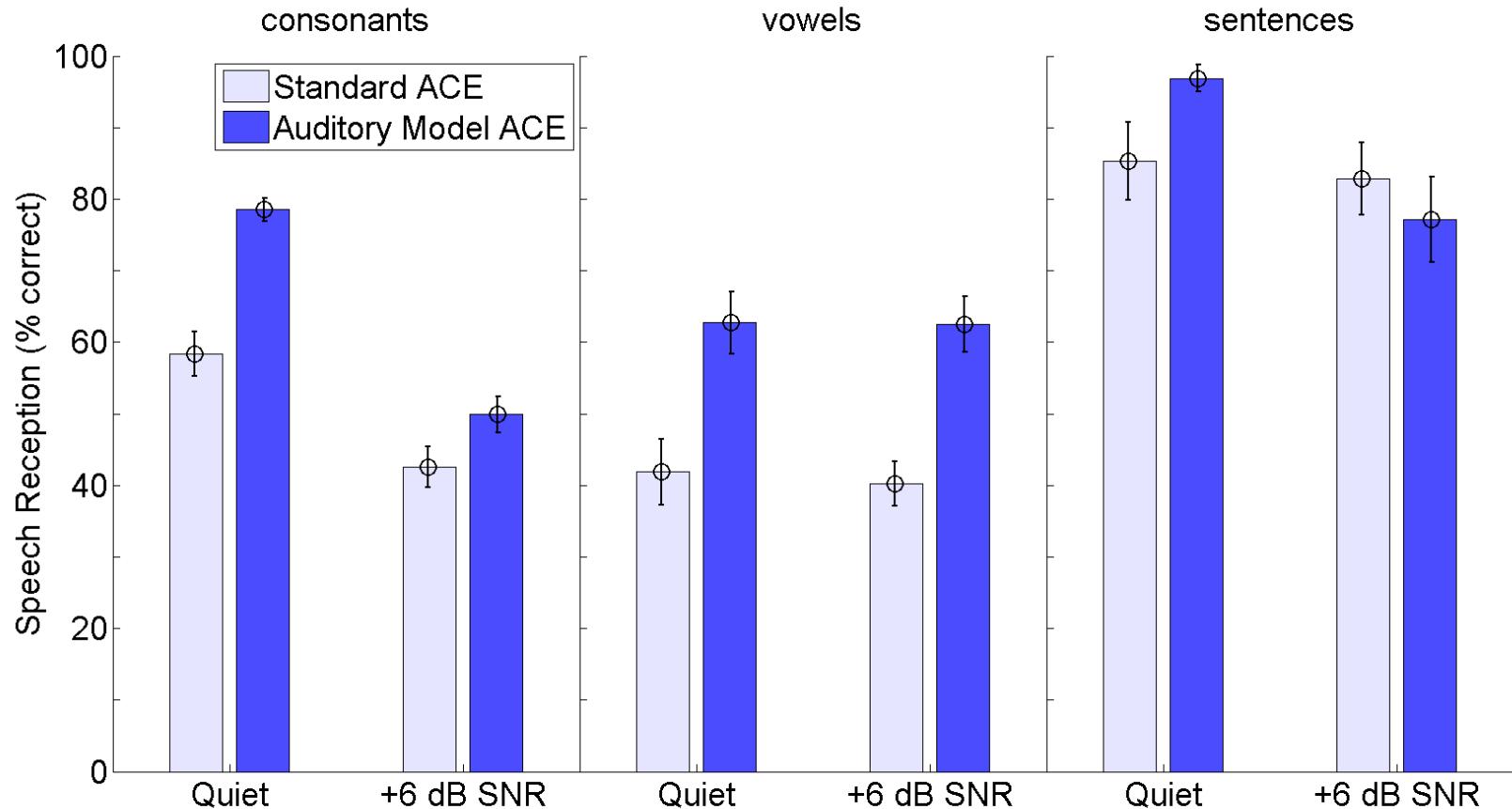


Zilany *et al.*, 2009

Study: Initial Assessment

- 5 adult cochlear implant users tested
- Comparison of Standard and Auditory-Model implant processing
- Strategies delivered via research interface in laboratory setting
- Speech reception in quiet and noise measured using consonant, vowel, and sentence materials

Preliminary Results



Conclusions

- Growing body of academic toolboxes for hearing research
- Clear articulation of academic and research goals is an important next step
- Need for real-time signal processing architecture for wearable devices



The multivariate temporal response function (mTRF) toolbox: a MATLAB toolbox for relating neural signals to continuous stimuli

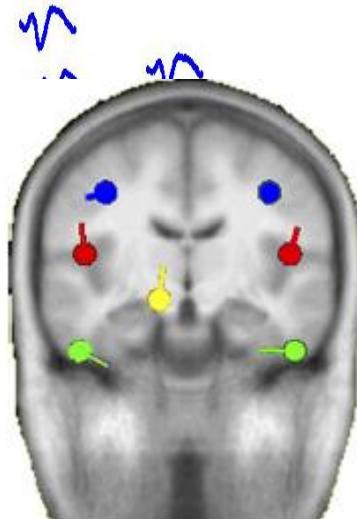
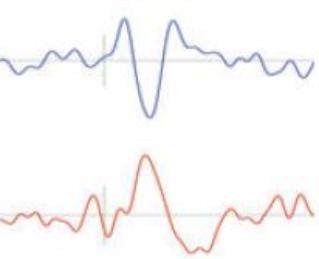
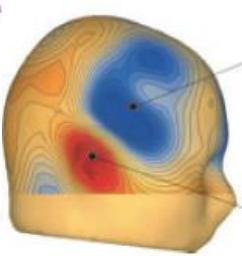
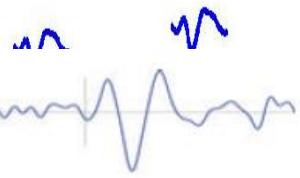
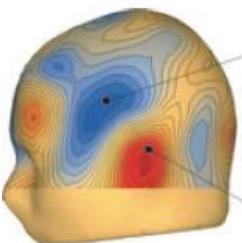
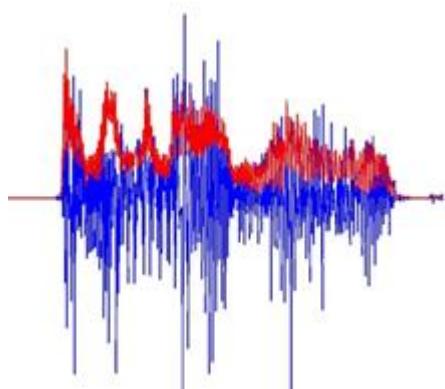
Denis Drennan

Lalor Lab, Trinity College Dublin



Forward Encoding

Amplitude Envelope
Continuous Stimuli



Neural Data

EEG Recordings



128 Electrodes



$$x(t)$$

*

$$\omega(\tau)$$

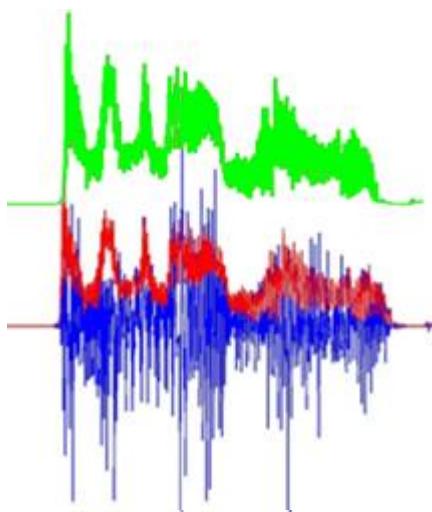
TRF

$$= y(t)$$

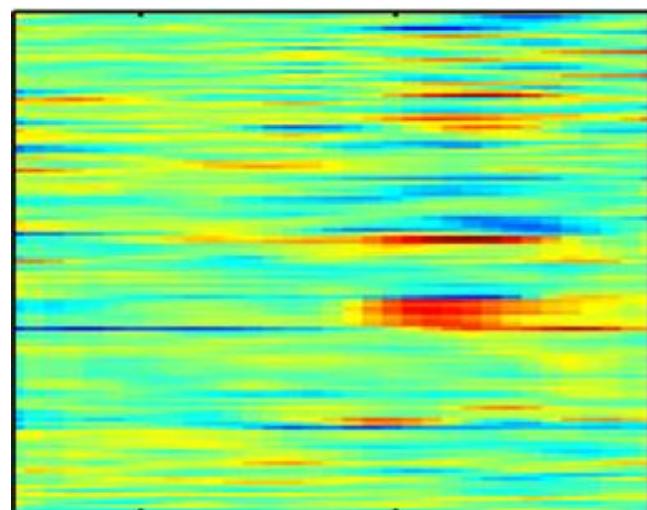


Backward Decoding

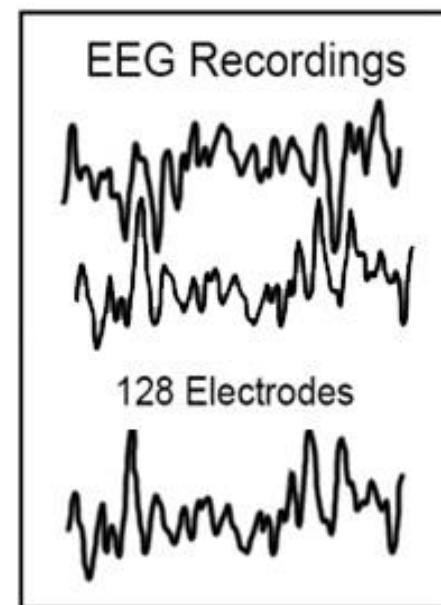
Stimulus Reconstruction



Decoder



Neural Data



$$x(t) =$$

$$g(\tau, n)$$

mTRF

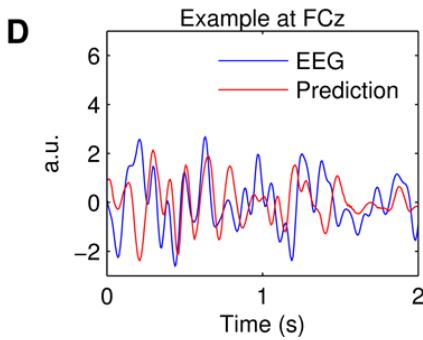
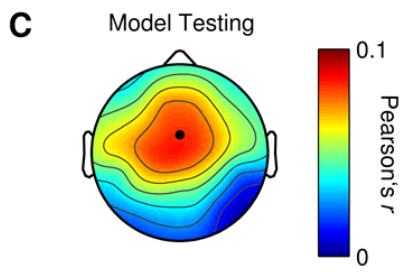
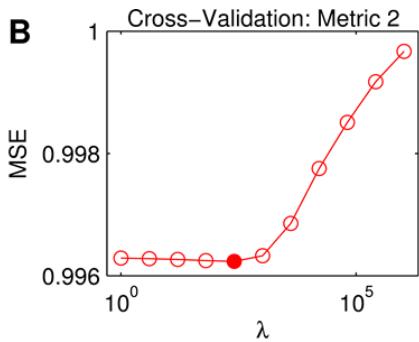
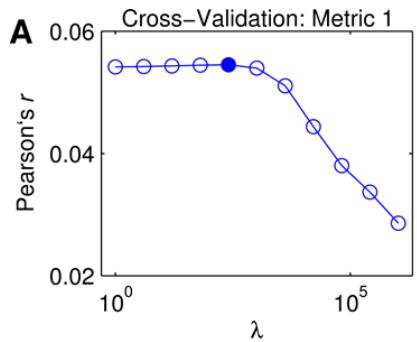
*

$$y(t)$$

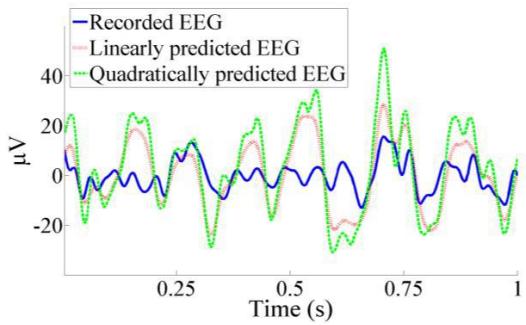
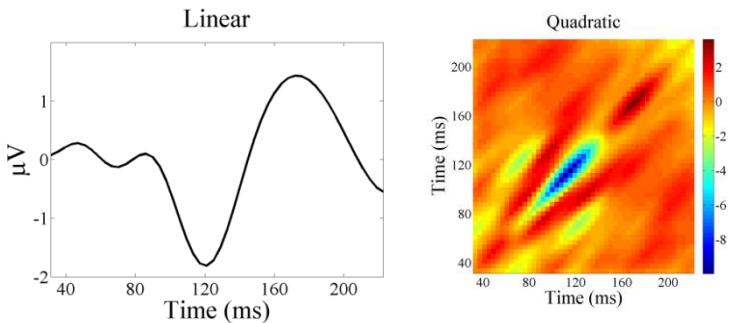


Optimization and Prediction

Examples



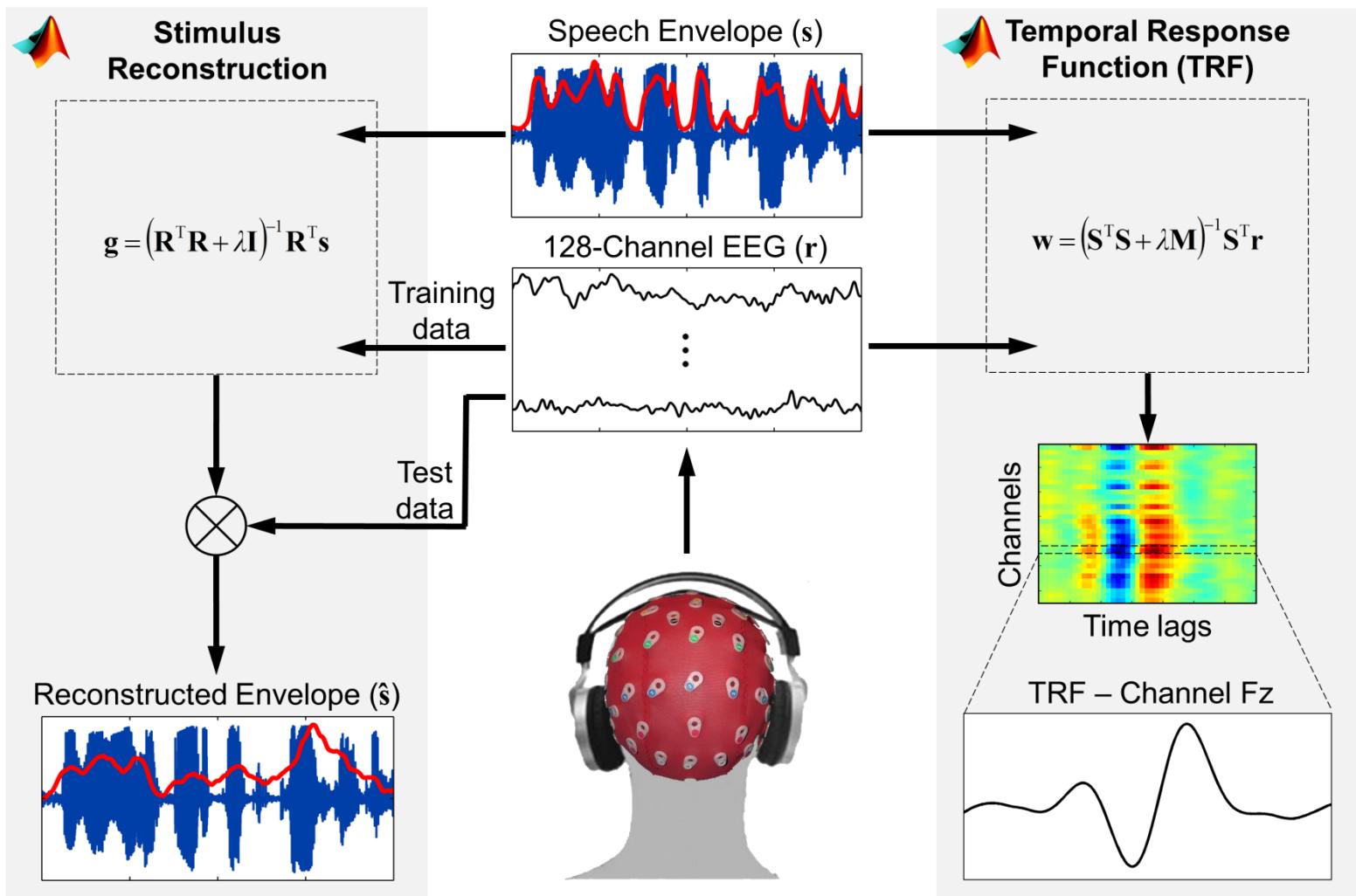
Previous Work



Power et al., EMBC, 2011



Experimental Procedure & Analysis

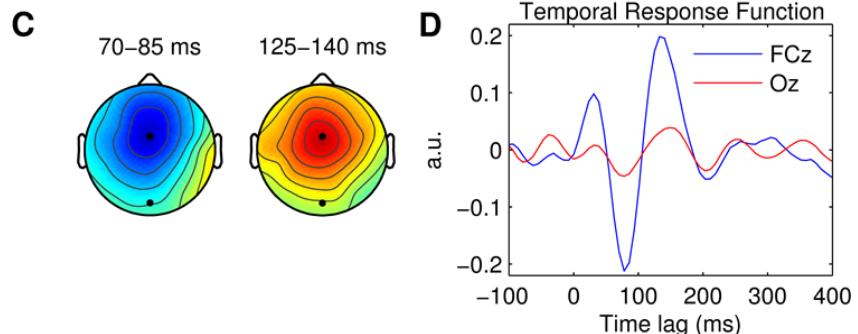
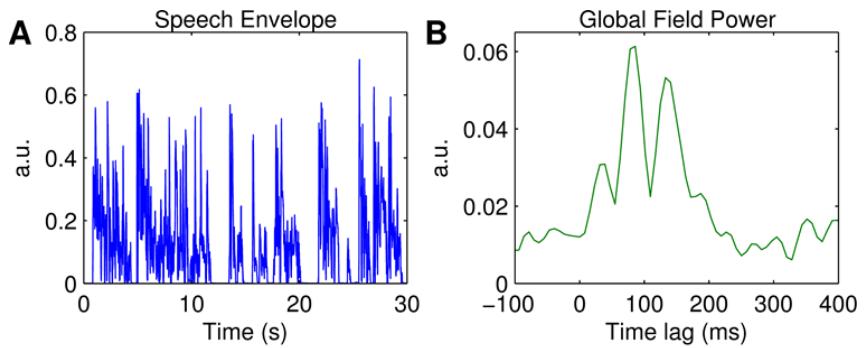




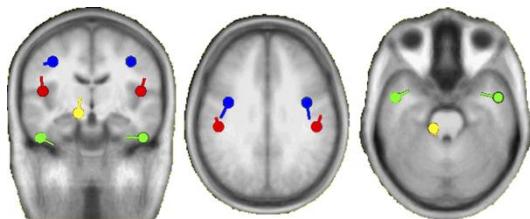
Univariate TRF Estimation

(Forward Encoding)

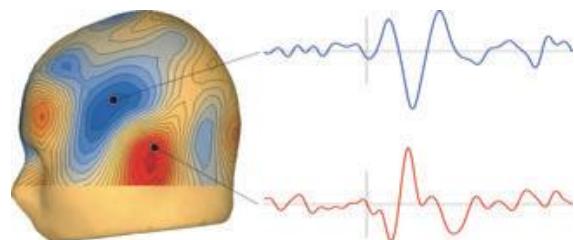
Examples



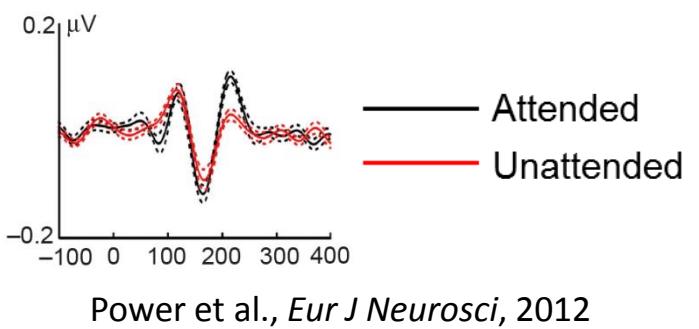
Previous Work



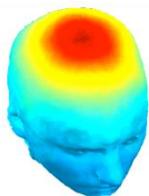
Lalor et al., *J Neurophysiol*, 2009



Lalor & Foxe, *Eur J Neurosci*, 2010



Power et al., *Eur J Neurosci*, 2012

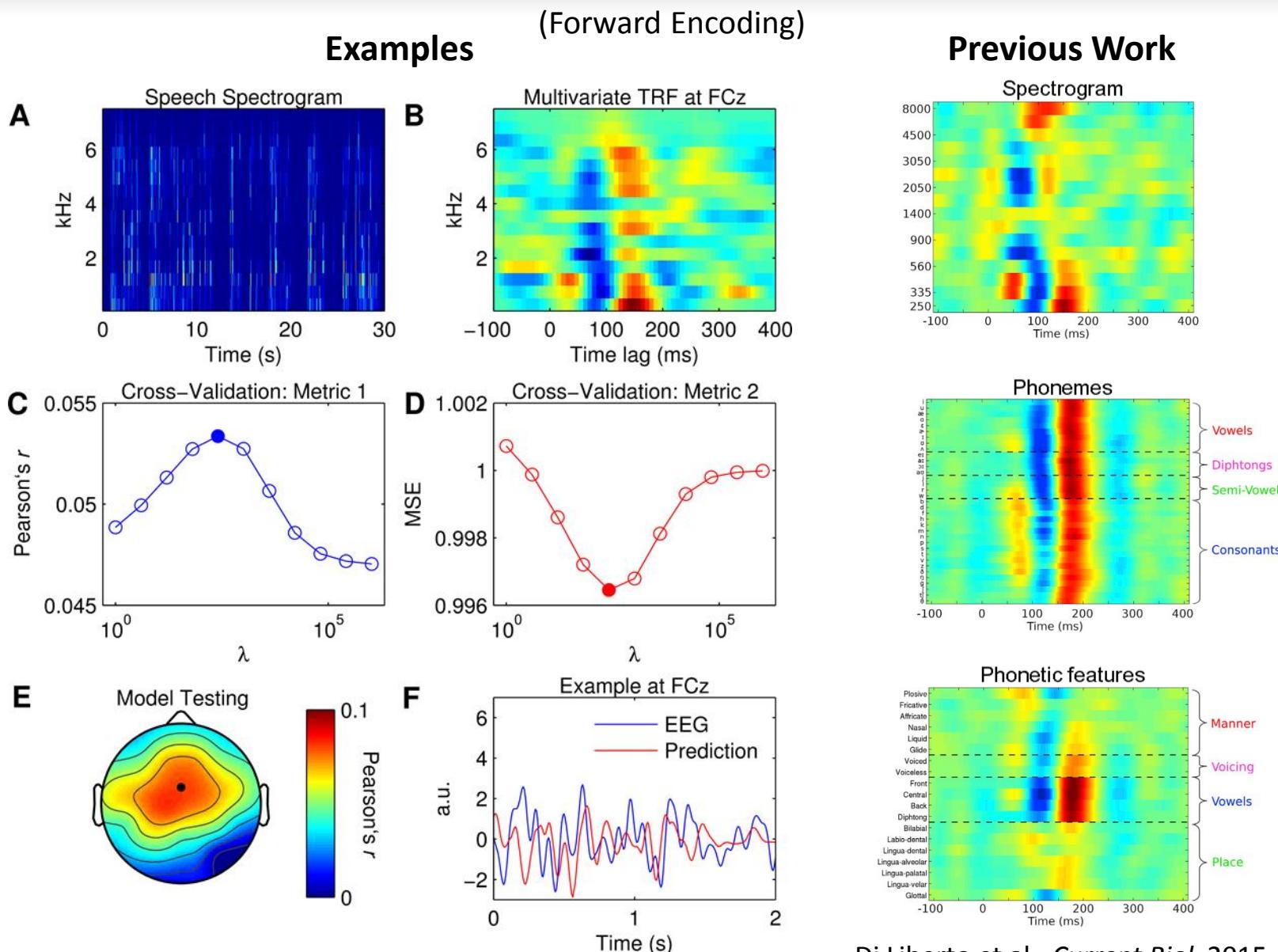


EEGLAB

<http://sccn.ucsd.edu/eeglab/>



Multivariate TRF Estimation

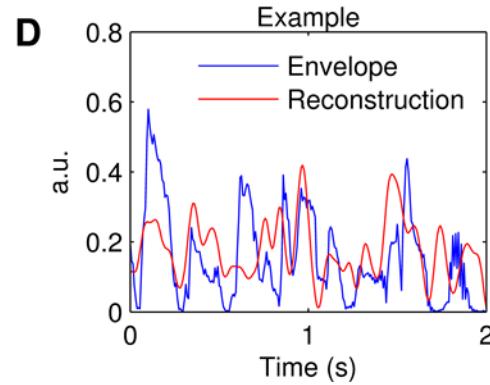
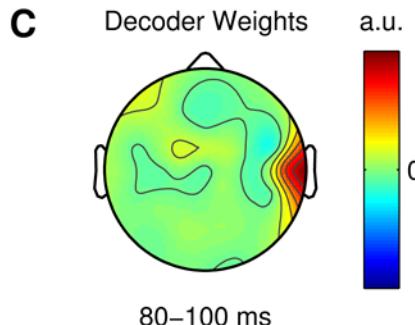
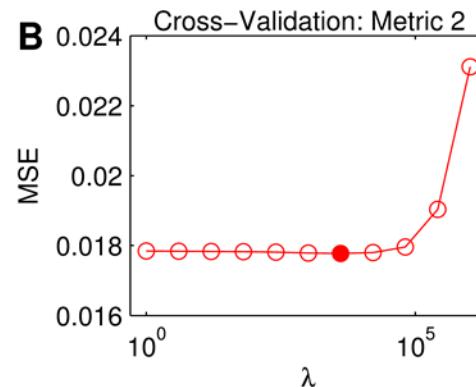
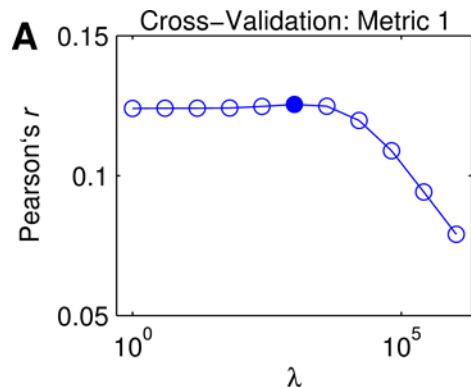




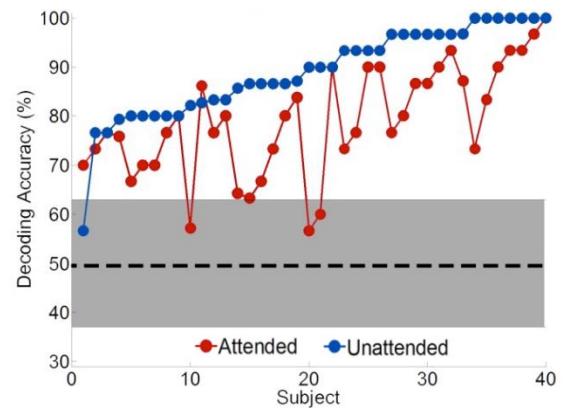
Multivariate Stimulus Reconstruction

(Backward Decoding)

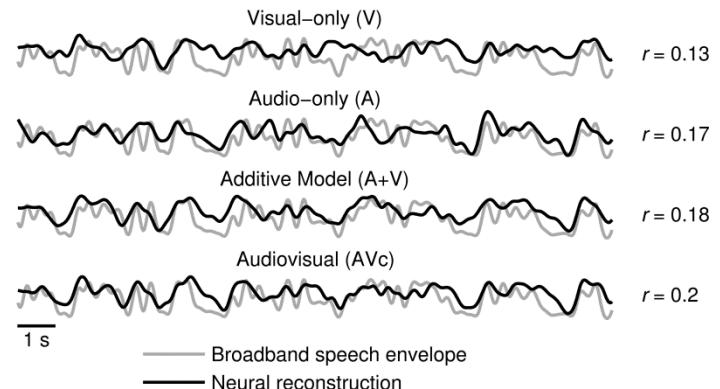
Examples



Previous Work



O'Sullivan et al., *Cereb Cortex*, 2015



Crosse et al., *J Neurosci*, 2015



mTRF Toolbox Functions

| Function | Inputs | Outputs | Details |
|--------------|--|--|--|
| mTRFtrain | STIM– stimulus (time × feats) RESP– response (time × chans) FS– sampling rate (Hz) DIR– mapping direction (forward==1, backward==−1) START– start time lag (ms) FIN– finish time lag (ms) LAMBDA– ridge parameter | MODEL– stimulus-response mapping (forward = feats × lags × chans, backward = chans × lags × feats) T– time lags (ms) CONST– regression constant | Performs multivariate ridge regression on stimulus STIM and response RESP to solve for stimulus-response mapping function MODEL. Time lags should be set in milliseconds between START and FIN and sampling rate FS should be in Hertz. Pass in DIR==1 to map forwards or DIR==−1 to map backwards. Regularisation is controlled using the ridge parameter LAMBDA. |
| mTRFpredict | STIM– stimulus (time × feats) RESP– response (time × chans) MODEL– stimulus-response mapping (forward: feats × lags × chans, backward: chans × lags × feats) FS– sampling rate (Hz) DIR– mapping direction (forward==1, backward==−1) START– start time lag (ms) FIN– finish time lag (ms) CONST– regression constant | PRED– prediction (forward: time × chans, backward: time × feats) RHO– correlation coefficient PVAL– correlation <i>p</i> -value MSE– mean squared error | Predicts outcome PRED of convolving stimulus STIM (or response RESP) with stimulus-response mapping function MODEL. Pass in DIR==1 to predict RESP or DIR==−1 to predict STIM. Returns correlation coefficient RHO between PRED and STIM (or RESP), corresponding <i>p</i> -value PVAL and mean squared error MSE. |
| mTRFcrossval | STIM– stimulus trials [cell{1,trials}(time × feats)] RESP– response trials [cell{1,trials}(time × chans)] FS– sampling rate (Hz) DIR– mapping direction (forward==1, backward==−1) START– start time lag (ms) FIN– finish time lag (ms) LAMBDA– ridge parameter values | RHO– correlation coefficient PVAL– correlation <i>p</i> -value MSE– mean squared error PRED– prediction [forward: cell{1,trials}(time × chans), backward: cell{1,trials}(time × feats)] MODEL– stimulus-response mapping (forward = feats × lags × chans, backward = chans × lags × feats) | Performs leave-one-out cross-validation on stimulus trials STIM and response trials RESP for range of ridge values LAMBDA. Validation measures returned include correlation coefficient RHO, corresponding <i>p</i> -value PVAL and mean squared error MSE. Time lags T should be set in milliseconds between START and FIN and sampling rate FS should be in Hertz. Pass in DIR==0 to map forwards or DIR==1 to map backwards. Returns predicted signals PRED and stimulus-response mapping function MODEL. |
| lagGen | X–vector or matrix of time series data (forward: time × feats, backward: time × chans) LAGS–vector of time lags (samples) | XLAG–matrix of lagged time series data (forward: time × lags*feats, backward: time × lags*chans) | Returns matrix XLAG containing lagged time series of X for range of time lags given by vector LAGS. If X is multivariate, LAGGEN will concatenate features for each lag along the columns of XLAG. |



History of mTRF Toolbox

- This toolbox had its beginnings at the Telluride Neuromorphic Cognition Workshop in 2012
- ***Applications for this year now open!!***
[\(https://neuromorphs.net/nm/wiki/2016\)](https://neuromorphs.net/nm/wiki/2016)
- This workshop continues to produce novel approaches and progress is being made towards a broader toolbox incorporating other machine learning approaches for relating naturalistic stimuli to multivariate neural data



Where can you find mTRF Toolbox?

Sourceforge: <https://sourceforge.net/projects/aespa>

or

Lab website: <http://lalorlab.net>

The screenshot shows the SourceForge project page for 'mTRF Toolbox'. The top navigation bar includes links for 'Search', 'Browse', 'Enterprise', 'Blog', 'Deals', 'Help', 'Log In', and 'Join'. Below the navigation is a 'SOLUTION CENTERS' section with 'Go Parallel' and 'Resources' links. The main content area displays the 'mTRF Toolbox' project details. It features a large image titled 'On Brains, Computers and Cocktail Parties' showing a brain, a laptop, and a person. Below this are two small figures: one showing a TRF graph (Time Response Function) and another showing a response function heatmap. On the left, there's a summary bar with 'Add a Review', '6 Downloads (This Week)', 'Last Update: 2015-10-03', and social sharing buttons for Twitter, Google+, and Facebook. A prominent green 'Download' button offers 'mTRF_1.3.zip'. To the right, there are sections for 'Recommended Projects' (listing 'MPC-HC: Media Player Classic Home ...', 'OpenStim', and 'Apache OpenOffice') and 'Top Searches' (listing 'arabic speech matlab emg'). A 'Report inappropriate content' link is at the bottom.

mickcrosse@gmail.com

edlalor@tcd.ie

ÖAW

AUSTRIAN
ACADEMY OF
SCIENCES



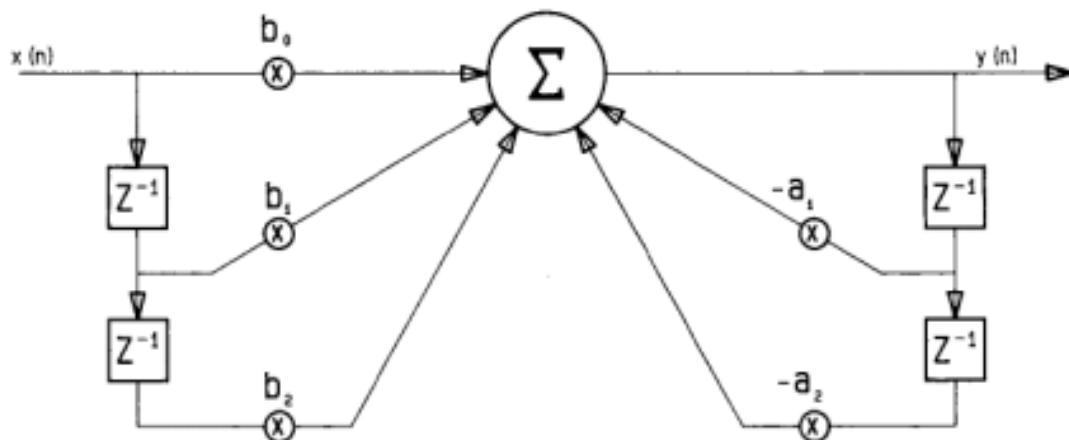
Piotr Majdak

Teaching and Toolboxes

ARO 2016, San Diego, USA

- Working with Matlab since 1999
- Teaching:
 - Algorithms in computer music and acoustics (since 2002)
 - Audio engineering (since 2014)
- Research:
 - Spatial hearing (NH and CI listeners)
 - Acoustic measurements

- Coding, from the scratch



$$\begin{aligned}y(n) = & b_0 x(n) + b_1 x(n-1) + b_2 x(n-2) \\& -a_1 y(n-1) - a_2 y(n-2)\end{aligned}$$

- Coding, from the scratch

```
function out=biquad_lp(in,fc,d,fs)

% biquad_lp      - low pass filter, canonical bi-quad form
% out=biquad_lp(in,fc,d,[fs])
%
% Implementation of low pass biquad filter in canonical form.
%
% input parameters:
% in:   input signal
% fc:   cut-off frequency [Hz]
% d:    damping factor
% fs:   sampling frequency
```

- Coding, from the scratch

```
function out=biquad_lp(in,fc,d,fs)
...
    % calculate all coefficients
F=1/tan(pi*fc/fs);
b0=1/(1+2*d*F+F*F);
b1=2*b0;
b2=b0;
a1=2*b0*(1-F*F);
a2=b0*(1-2*d*F+F*F);
    % initialize vectors
len=length(in)+2;    % get the length + overhead
y=zeros(len,1);        % define y and x
x=zeros(len,1);
x(3:len)=in;          % merge to: zeros . in . zeros
    % main loop
for n=3:len
    y(n)=b0*x(n)+b1*x(n-1)+b2*x(n-2)-a1*y(n-1)-a2*y(n-2);
end
    % set the output
out=y(3:end);
```

- Coding, from the scratch
- Goal: Students being able to code new stuff
- Advantage: students being able to code
- Disadvantage: takes time
- Work around:
 - basics in exercises
 - more interesting things in theory lectures with many examples

- **Teaching:** Tools to simplify often used processes:
 - **spect:** plot a spectrum in context of audio engineering:
 - `spect (fft(my_time_signal)) ;`
 - `spect (my_complex_valued_spectrum) ;`
 - **etc:** calculate the logarithmic energy-time curve
 - **expsweep:** create an exponential frequency sweep
 - **sysid_basic:** basic system identification for audio devices
 - Download: <http://piotr.majdak.com>

- **SOFA API:** handling of HRTFs and BRIRs
 - implements the spatially oriented format for acoustics (**SOFA**, AES standard since last May)
 - load/save SOFA files
 - plot/analyze SOFA objects
 - spatialize sounds
 - relies on netcdf (standard library in Matlab)
 - Resources: <http://www.sofaconventions.org/>

- Auditory modeling toolbox (**AMT**):
 - Collection of auditory models (currently 22 models)
 - Auditory periphery: Outer/middle/inner ear, auditory nerve
 - Monaural and binaural masking effects
 - Spatial effects like lateralization, localization, distance estimation, speaker recognition
 - Speech perception and speech reception in rooms

- Auditory modeling toolbox (AMT):
 - Collection of auditory models (currently 22 models)
 - Focus on reproducibility of research data and algorithms

Background

Figure 9 in original publication
(Langendijk and Bronkhorst, 2002):

AMT: exp_langendijk2002('fig9')

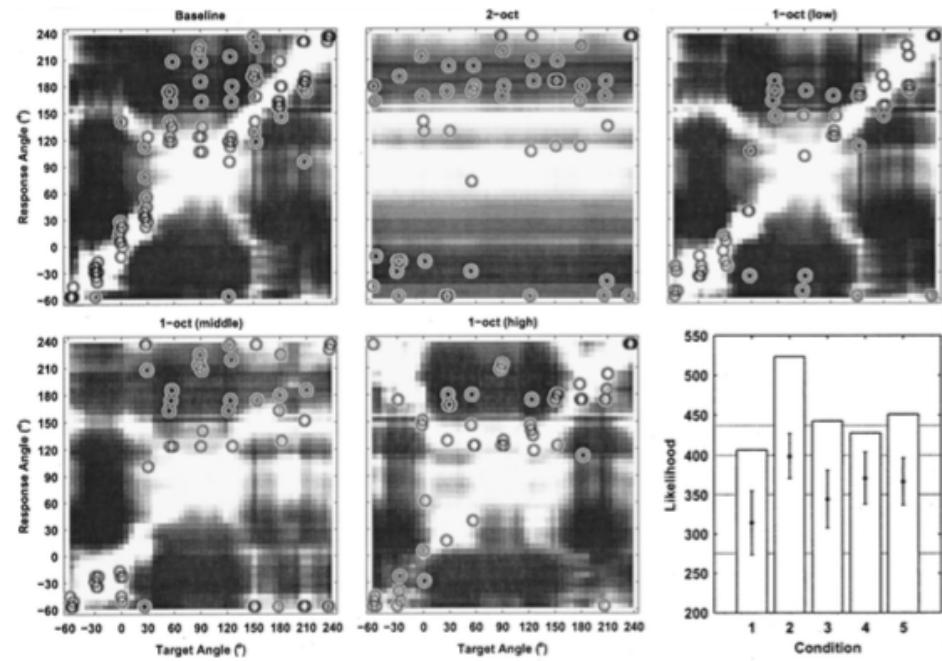
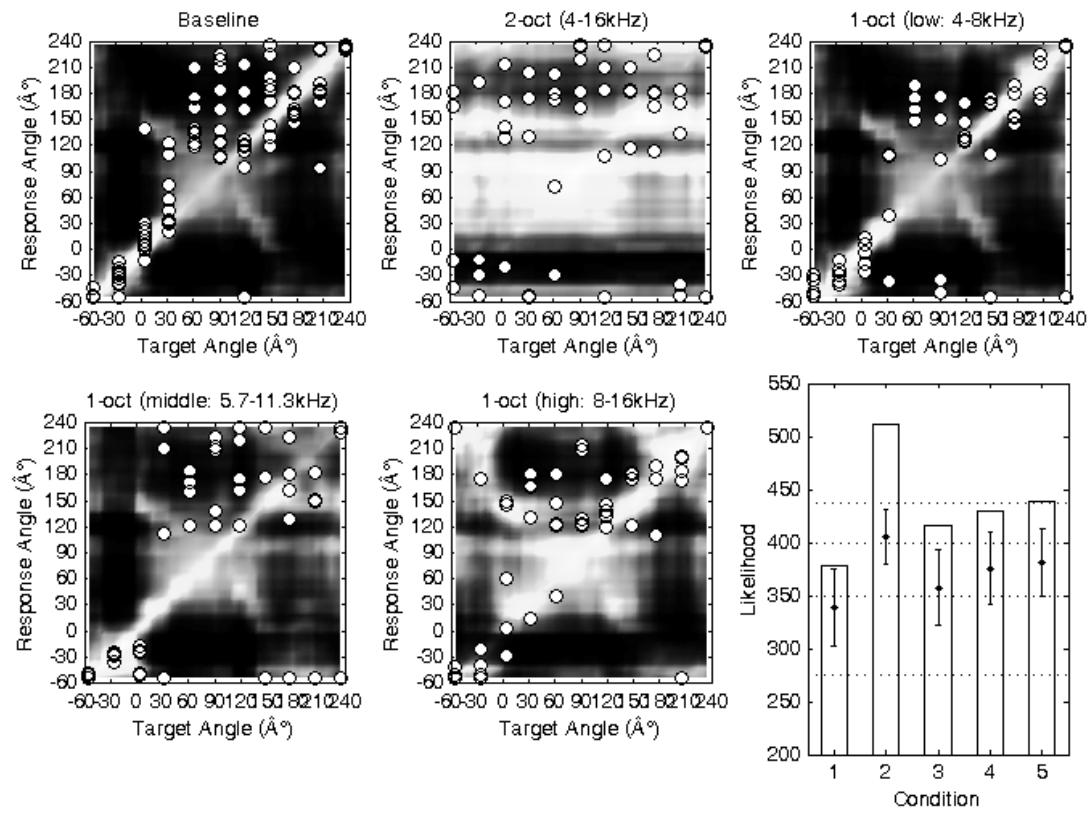


FIG. 9. Same as Fig. 7, but now showing the data of listener P3.



- Auditory modeling toolbox (AMT):
 - Collection of auditory models (currently 22 models)
 - Focus on reproducibility of research data and algorithms
 - Includes a repository of data and signals (>6 GB)
 - Download of auxiliary data on demand
 - Download of pre-calculated results
 - Caching calculated results

- Auditory modeling toolbox (AMT):
 - Collection of auditory models (currently 22 models)
 - Focus on reproducibility of research data and algorithms
 - Includes a repository of data and signals (>6 GB)
 - Integrates/relies on other toolboxes/systems:
 - the **SOFA** API for HRTFs
 - the sound field synthesis toolbox (**SFS**, Wierstorf and Spors)
 - the large time-frequency analysis toolbox (**LTFT**, Soendergaard et al.) for time-frequency signal processing
 - MEX files (compiling C and C++ files)
 - Python

- Auditory modeling toolbox (AMT):
 - Collection of auditory models (currently 22 models)
 - Focus on reproducibility of research data and algorithms
 - Includes a repository with data and signals (>6 GB)
 - Integrates/relies on other toolboxes/systems
 - Implements documentation directly in the header
 - Compiles to PHP for a website
 - Compiles to clean .M files for Matlab's help system

- Auditory modeling toolbox (AMT):
 - Collection of auditory models (currently 22 models)
 - Focus on reproducibility of research data and algorithms
 - Includes a repository with data and signals (>6 GB)
 - Integrates/relies on other toolboxes/systems
 - Implements documentation directly in the header
 - Still in development (alpha status; changes may affect backward compatibility):
 - Download version: 0.9.7
 - Plan for 2016: release of version 1.0

- Teaching material: <http://piotr.majdak.com>
- SOFA API (HRTFs):
 - Download: <http://sourceforge.net/projects/sofacoustics>
 - Sources: <https://github.com/sofacoustics/sofa>
 - Documentation and files: <http://www.sofaconventions.org/>
- The AMT:
 - Download: <http://sourceforge.net/projects/amtoolbox>
 - Documentation: <http://amtoolbox.sourceforge.net/>

Experiences Sharing Auditory Models in Matlab

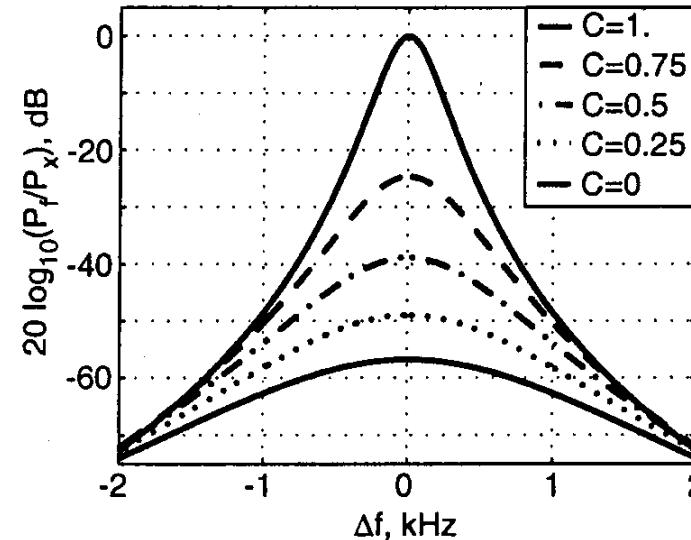
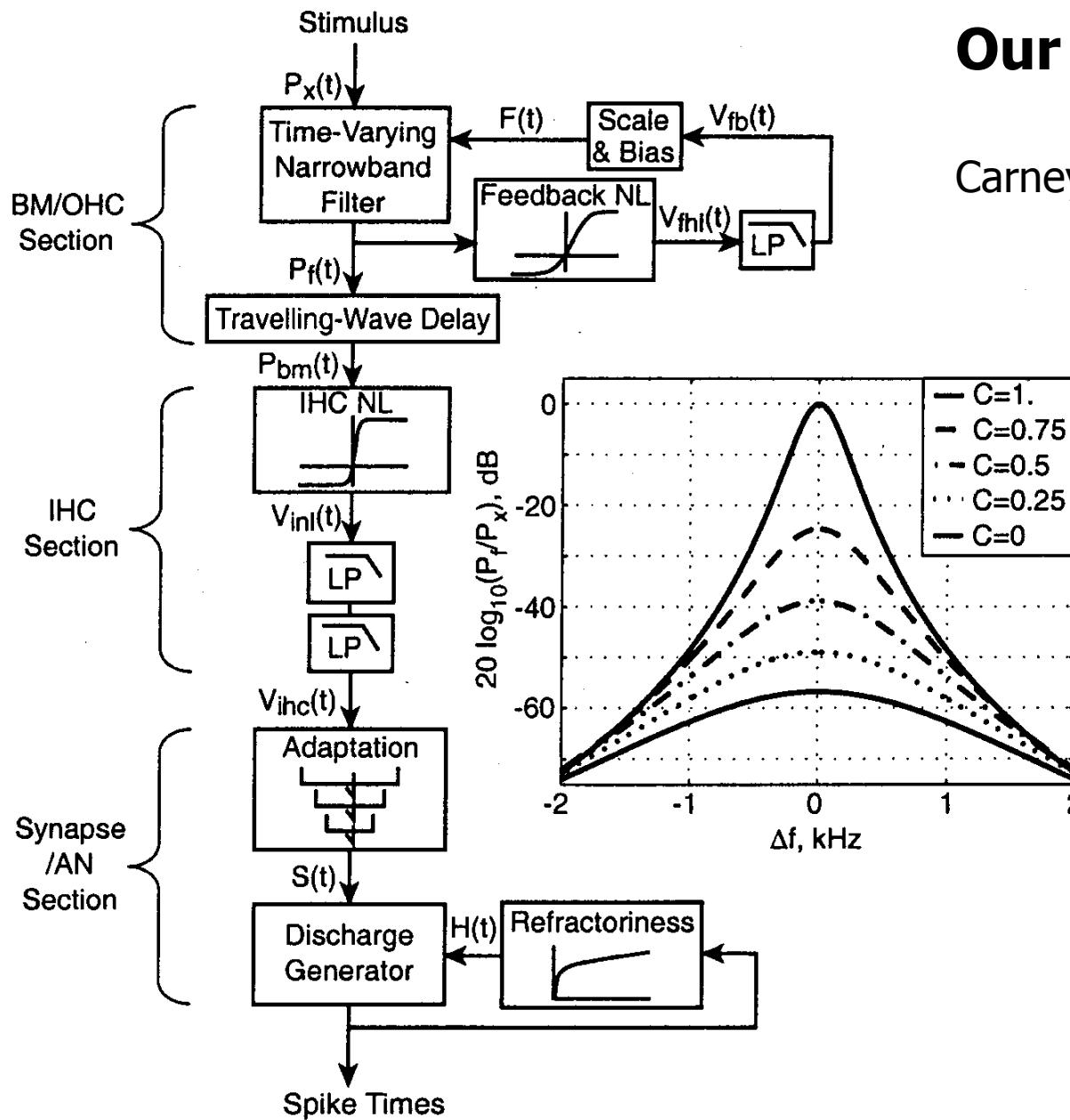
Laurel Carney

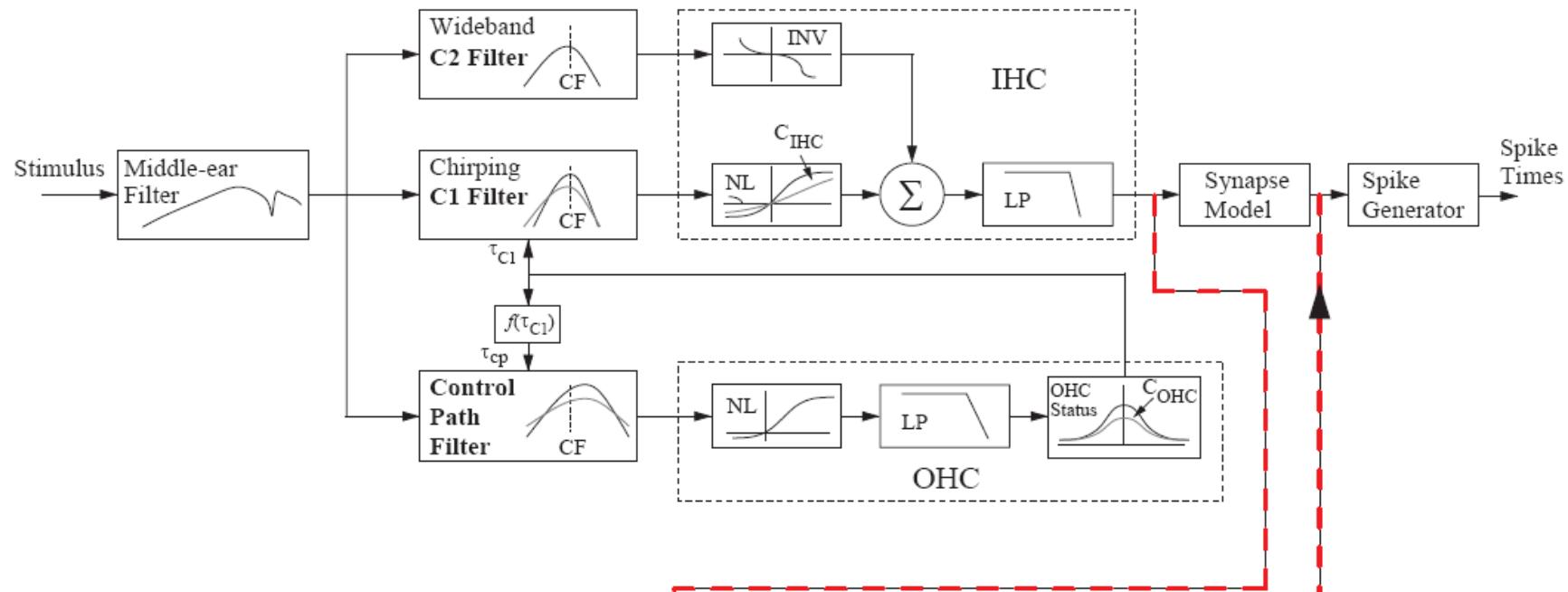
University of Rochester

[https://www.urmc.rochester.edu/labs/Carney-Lab/publications/auditory-
models.cfm](https://www.urmc.rochester.edu/labs/Carney-Lab/publications/auditory-models.cfm)

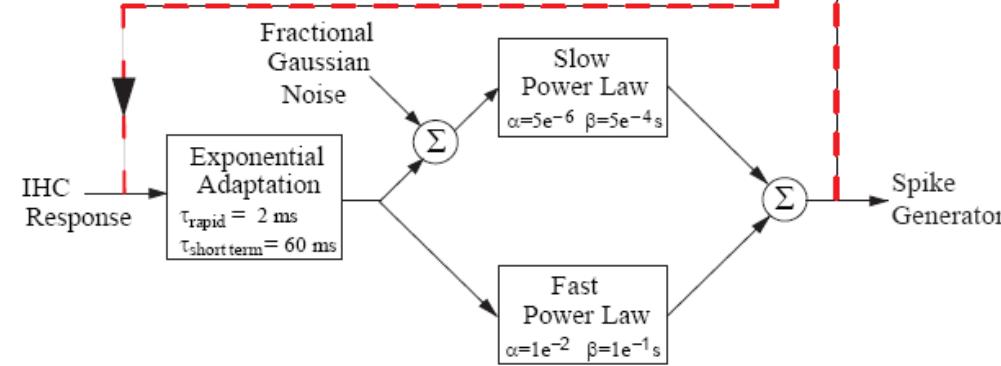
Our first effort to share code:

Carney, 1993 - Written in C (from Fortran)
1st shared via floppy disk





IHC-AN Synapse Model



Zilany et al, 2009, 2014 – most recent version of AN model

What has worked?

- Make code freely and easily available –
 - Post it (rather than having users request it personally)
 - Readme file
 - Readable code (no professional programmers!)
 - “anmodel_test.m” – simple sample m-file that runs simulation & plots response
- (Try to) Share only Published models
 - Post models & papers together
- Have faith in evolution!
 - (If it were up to me alone, the code would be in BASIC!)
 - Matlab is a good solution today, but our students will decide on the next gen....

What's New? ***UR EAR***

Visualizing Population responses
of AN fibers and
Amplitude-Modulation Tuned
Cells in Inferior Colliculus

Students:

Natalia Galant

Braden Maxwell

Danika Teverovsky

Thomas Varner

Existing AN & IC models

Matlab Tool, to be posted soon

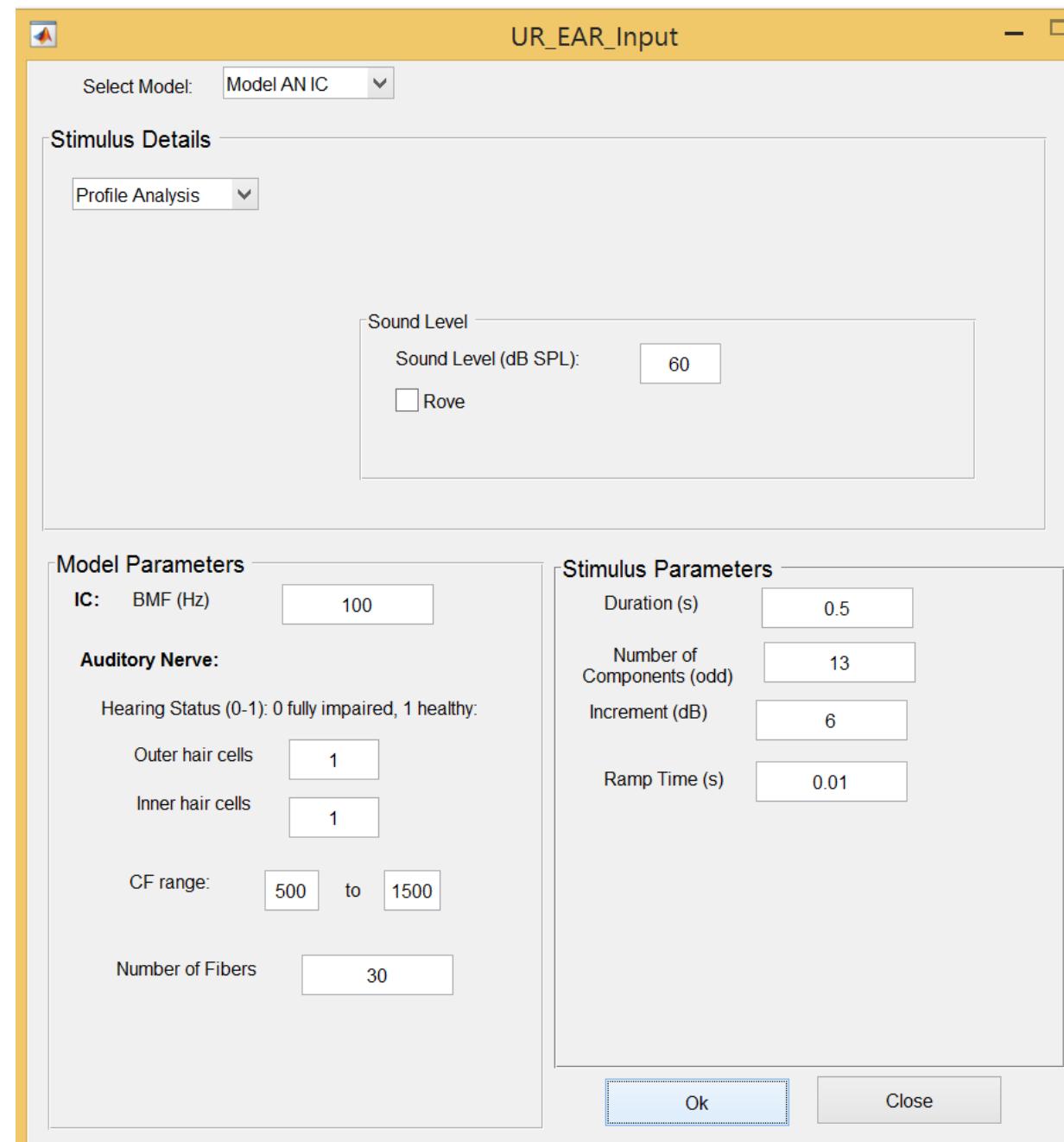
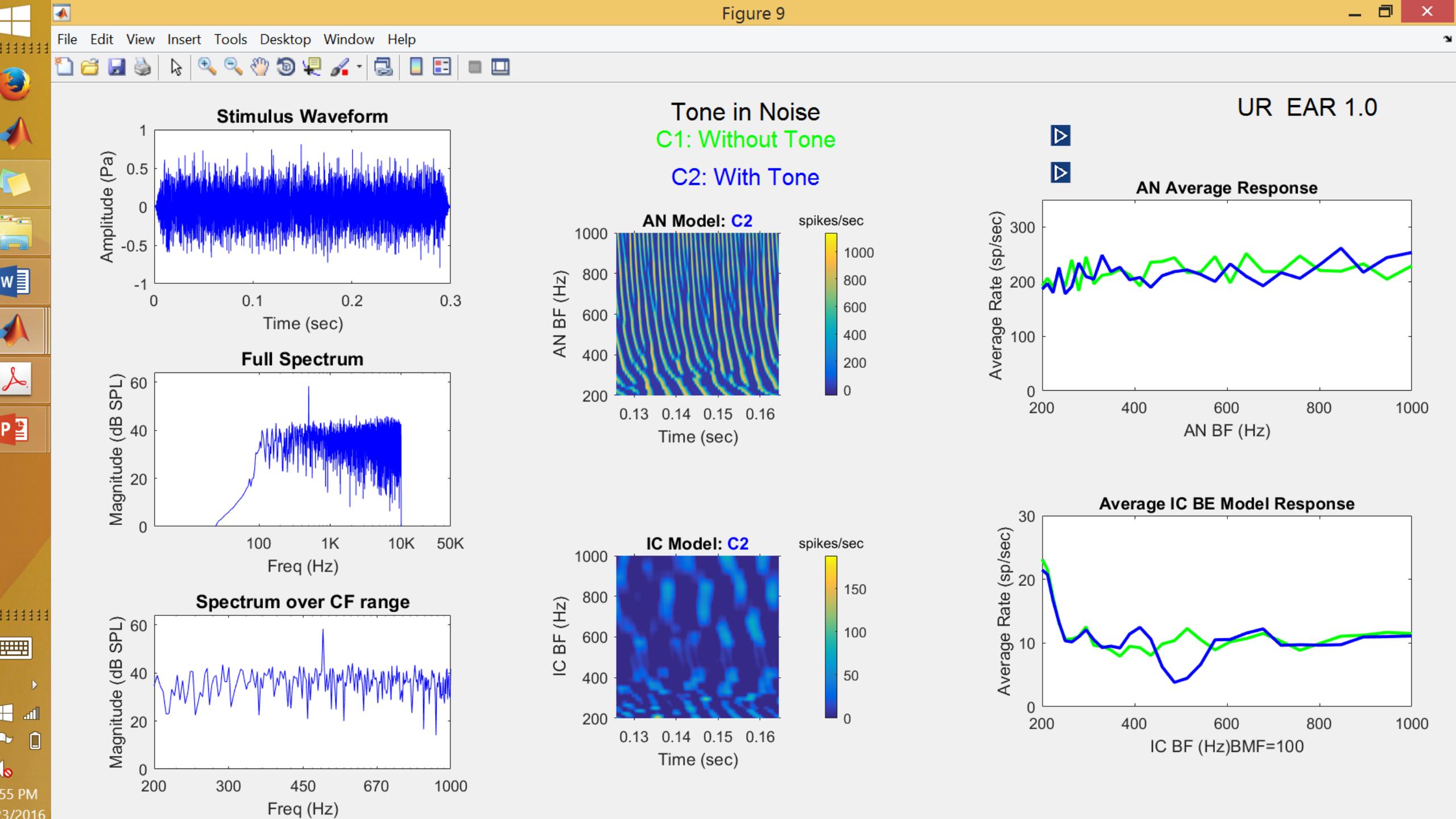


Figure 9



Speaking MATLAB – Implanting Community Best Practices



Lisa Kempler, MATLAB Community Strategist
lisak@mathworks.com
ARO Winter Meeting
February 23, 2016



Lots of Code!!! Multiple Repositories . . .

GitHub

Explore Features Enterprise Pricing

Search

language:matlab

38,000

We've found 37,919 repository results

Repositories 37,919

Code

MATLAB CENTRAL

File Exchange

Answers

Newsgroup

Link Exchange

Blogs

Trendy

Cody

Contest

MathWorks.com

File Exchange

Files

Authors

Tags

Comments

My File Exchange

Submit a File

Search Files

Advanced Search

Search all Support

Sort By: Date Updated (Newest - Oldest)

26,000



1 - 50 of 25648

GalaxyModel by Haihona



The Grad Student Legacy: Unfinished Code



Source:
Photo, concept
[Ian Foster's](#)
[EC AHM talk](#)

Lots of Audiology, Speech Code: Is it Vetted? Discoverable?

“Speech” Code on File Exchange

331

The screenshot shows a list of 331 MATLAB code submissions related to speech processing. Each entry includes a thumbnail, the file name, a brief description, ratings, comments, downloads, and a link to the code. A red box highlights the top submission: "Theme from Super Mario Brothers Song" by James Humes.

| File Name | Description | Ratings | Comments | Downloads |
|--|---|------------|-------------|-------------------------|
| Theme from Super Mario Brothers Song | plays the Super Mario Brothers theme song. (audio processing, video processing, music) | 43 Ratings | 34 Comments | 159 Downloads (30 Days) |
| matlab code for automatic speech recognition | sayed | 11 Ratings | 17 Comments | 147 Downloads (30 Days) |
| Silence removal in speech signals | A simple method for silence removal in speech streams (signal processing, speech analysis, audio) | 4 Ratings | 6 Comments | 144 Downloads (30 Days) |
| Speaker Recognition Biometric System Matlab Code | Simple and Effective Source Code For for Speaker Identification Based On Neural Networks (auto speaker recognit..., automatic voice ident..., matlab biometric) | 3 Ratings | 6 Comments | 140 Downloads (30 Days) |
| Gabor filter | Generates Gabor filters using bandwidth, aspect ratio, phase, wavelength and angle as parameters. (gabor filter, image processing, gabor filtergabor_exa...) | 12 Ratings | 14 Comments | 125 Downloads (30 Days) |
| Pitch Determination Algorithm | Extract pitch of speech signal based on subharmonic-to-harmonic ratio (audio processing, video processing, pitch) | 21 Ratings | 17 Comments | 123 Downloads (30 Days) |

GitHub: “Speech”, Audio, Signal Processing Code

164

The screenshot shows GitHub search results for repositories related to speech, audio, and signal processing. The first search query is "language:matlab speech", resulting in 164 repositories. The second query is "language:matlab audio", resulting in 208 repositories. The third query is "language:matlab signal processing", resulting in 178 repositories. Each search result shows the number of repositories, code, issues, and users.

| Search Query | Repositories | Code | Issues | Users |
|-----------------------------------|--------------|--------|--------|--------|
| language:matlab speech | 164 | 15,535 | 100 | Matlab |
| language:matlab audio | 208 | 15,535 | 100 | Matlab |
| language:matlab signal processing | 178 | 27,498 | 87 | Matlab |

208

178

mariannux/ecg-kit

A Matlab toolbox for cardiovascular signal processing

Updated 3 hours ago

NOCIONS/letswave6

Letswave 6 - Matlab EEG signal processing toolbox

Updated 16 days ago

kaustubhcs/Digital-Signal-Processing

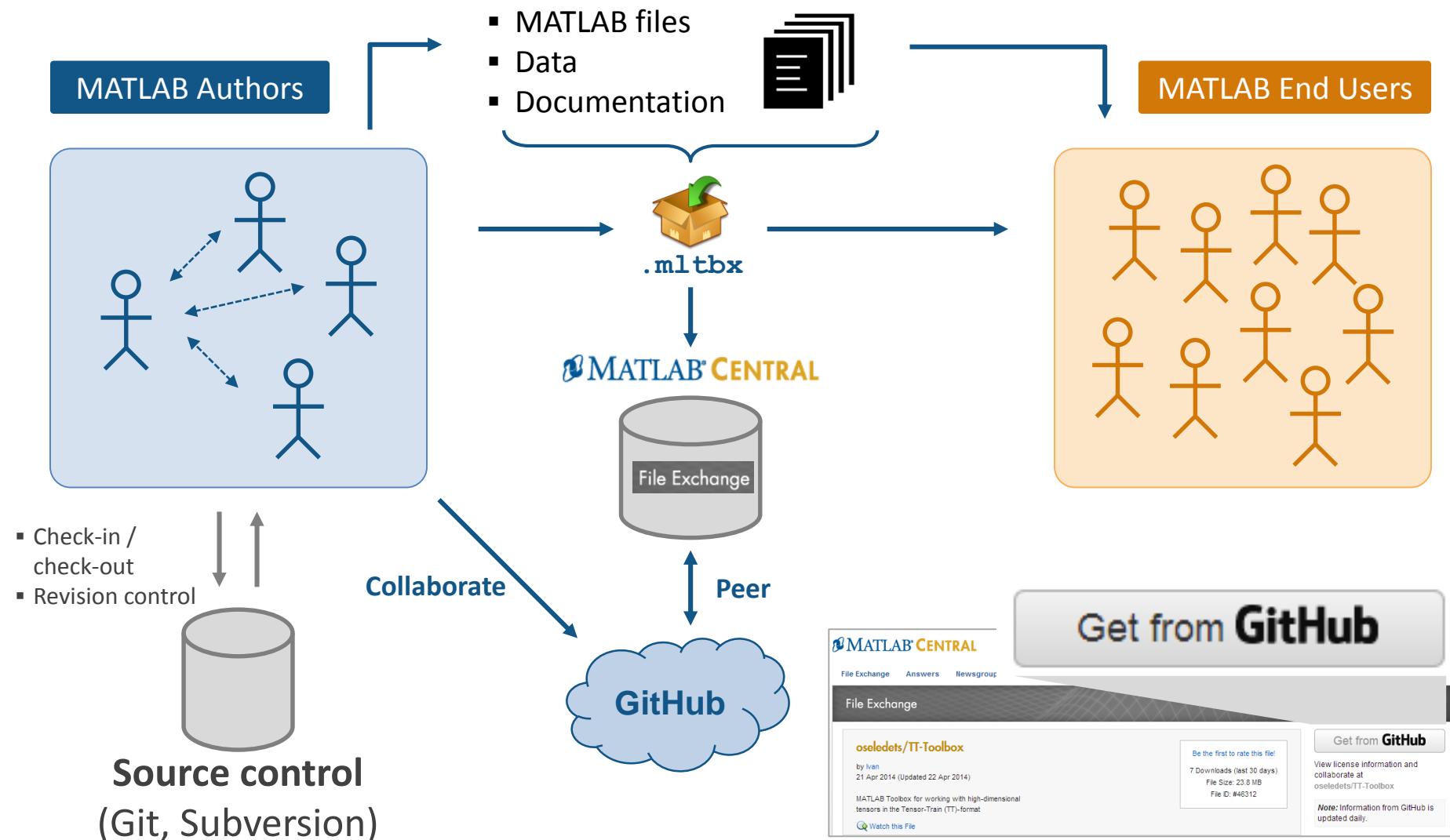
~KTB

Updated on Sep 11, 2015

Why Share Tools in Public Repositories?

- Conservation of Resources (Reuse)
- Collaboration
- Measure Value (Downloads, Rating)
- Helps you be organized and accountable!

Managing & Sharing MATLAB Code





SPM



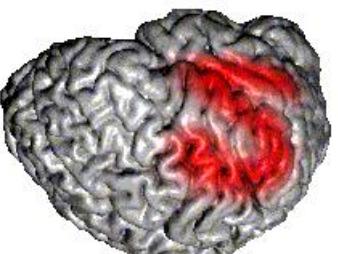
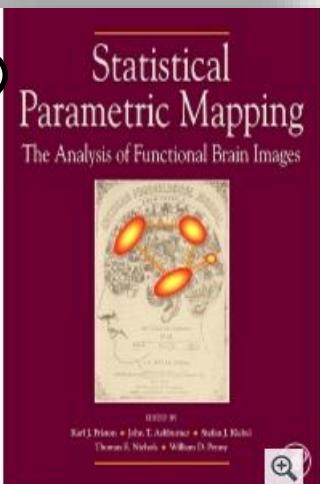
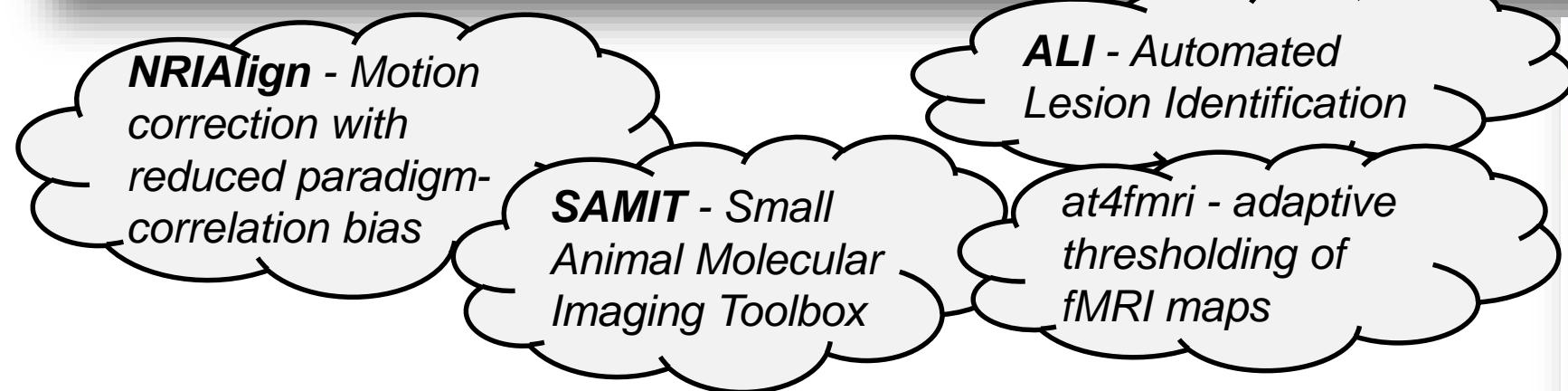
By members & collaborators of the Wellcome Trust Centre for Neuroimaging
[Introduction](#) | [Software](#) | [Documentation](#) | [Courses](#) | [Email list](#) | [Data](#) | [Extensions](#)

Software

Introduction

SPM is made freely available to the [neuro]imaging community, to promote collaboration and a common analysis scheme across laboratories. The software represents the implementation of the theoretical concepts of Statistical Parametric Mapping in a complete analysis package.

The SPM software is a suite of MATLAB ([The MathWorks, Inc](#)) functions and subroutines with some externally compiled C routines. SPM was written to organise and interpret our functional neuroimaging data. The distributed version is the same as that we use ourselves.



[SPM main site](#)

[SPM add-on MATLAB toolboxes](#)

PET
fMRI

MATLAB®
C

Reproducible Research *and* Teaching (through Sharing)

Scientists Do Reproducible Research with MATLAB. (Also known as open science).



Loren on the Art of MATLAB

[Recent Posts](#) [Archive](#)

15 FEB Reproducibility Musings - Hey, do that again!

12 FEB Run Code Faster With the New MATLAB Execution Engine

3 FEB Visualizing Facebook Networks with MATLAB

20 JAN Mapping Uber Pickups in New York City

6 JAN Generating an Optimal Employee Work Schedule Using Integer Linear Programming

Categories

Best Practice 56

Robustness 31

Big Data 7

Common Errors 42

Less Used Functionality 60

[more ▾](#)

Recent Comments

Chad Bernier on Mapping Uber Pickups in New York City

Loren Shure on Run Code Faster With the New MATLAB Execution Engine

Brad Stirz on Run Code Faster With the New MATLAB Execution Engine

Reproducibility Musings – Hey, do that again!

Posted by Loren Shure, February 15, 2016

[*< Run Code Faster With the...*](#)

Today I have a guest post from Lisa Kempler, MATLAB Community Strategist, MathWorks. Lisa works with MATLAB communities in domains such as geophysics, oceanography, audiology, and more, helping users developing MATLAB based tools, and creating resources for teaching and research with MATLAB. A primary goal is to have MATLAB users share their tools and best practices more widely within their communities, enhancing their use of MATLAB, and, in turn, accelerating their work. This blog talks about some efforts in research that support that sharing objective.

Contents

- [What is Reproducibility?](#)
- [Why is it important?](#)
- [Getting Consensus on Reproducible Research Needs and Approaches](#)
- [Individual Researcher Efforts and MATLAB Related Tools and Capabilities](#)
- [Your Turn](#)
- [Kevin Moerman's Affiliations](#)

What is Reproducibility?

There's been lots of buzz around the topic of Reproducible Research. Proponents as well as the researchers who would be impacted by new reproducibility expectations are raising a lot of questions, questions about

- Definition and Scope:

- Simply put, what does Reproducible Research mean?

Teaching Geoscience with MATLAB: Resources, Community (Also relevant for researchers, and educators in physics, applied math, statistics, etc.)

On the Cutting Edge – Strong Undergraduate Geoscience Teaching
managed by NAGT for the benefit of undergraduate geoscience education

Program-Wide Abilities Your Career Enhancing Teaching Courses Topics

Teaching with Data, Simulations and Models
Topical Resources

Cutting Edge > Enhance Your Teaching > Data, Simulations and Models > Tools for Teaching with Data and Simulations > MATLAB

MATLAB®
submitted by Lisa Kempler, MATLAB Community Strategist at MathWorks

General Description
You can use MATLAB for a range of geoscience-related applications, from performing basic visualization, to analyzing earthquakes, to [modeling water flow in lakes, oceans and rivers](#), [change's impact on global coral reefs](#).

MATLAB provides tools to acquire, analyze, visualize data, and develop models and simulate real-world phenomena. These capabilities enable teachers, students, and researchers in the insight while simultaneously learning and applying mathematical computing skills and techniques.

The exploration environment, language, built-in math functions, and add-on application-geoscientists to explore multiple approaches and reach a solution faster than with spread-sheets and programming languages.

[Skip to Resources for Teaching Geoscience with MATLAB](#)

[Teaching with MATLAB 2015 Workshop Program and Outcomes »](#)

Uses of the Program


Product Overview - 2:05

MATLAB can be applied to solving problems involving mathematical computation and statistics, signal and image processing, mapping, and more in the scientific and engineering fields.

Educators and researchers in geoscience develop homework sets, entire courses, and use them by their larger community, whether hydrologists, seismologists, or geophysicists, technical papers, and [coupling](#).

▶ Show more on computational tasks with MATLAB and add-ons

Case Studies

- [Students explore geosciences in the lab and classroom at University of Arizona](#)
- [Teaching Modeling and Analysis to Future Geologists at Georg-August Universität Göttingen](#) (Video talk)

On the Cutting Edge – Strong Undergraduate Geoscience Teaching
managed by NAGT for the benefit of undergraduate geoscience education

Program-Wide Abilities Your Career Enhancing Teaching Courses Topics

Teaching Geoscience with MATLAB®
Workshop: Carleton College- Northfield, MN

Cutting Edge > Enhance Your Teaching > Data, Simulations and Models > Teaching with MATLAB 2015 > Workshop Outcomes

Workshop Outcomes

The following collections of materials were submitted by faculty participants at the 2015 Teaching Geoscience with MATLAB workshop. The collections include MATLAB activities that get students using large data sets and visualizing geologic features. See the [workshop synthesis](#) to learn more about the workshop.

Teaching Activities
In association with our October 2015 workshop, participants provided activity, lab, and project descriptions of how they incorporate MATLAB. These have been organized into a browseable collection.
[Submit](#) | [View collection](#)

Essays
Also, in association with our October 2015 workshop, some participants wrote essays about their experiences with using MATLAB in geoscience teaching. These are presented in a browseable collection of essays.
[Submit](#) | [View collection](#)

Course Descriptions
Some participants and community members also provided descriptions of whole courses in which they use MATLAB.
[Submit](#) | [View collection](#)

Follow-on Products

Teaching Geoscience with MATLAB Interest Group
If you are interested in sharing ideas and discussing strategies for teaching geoscience with MATLAB, join the community! Whether you're just getting started or have been teaching with MATLAB for years, this is the place for you. [Join the Community Interest group](#)

Workshop Synthesis
Key ideas from the workshop are summarized in the [workshop synthesis](#). This document focuses on effective course structures and strategies and ideas to involve a department or program.

Content Webpages
The following pages are built around concepts that were generated in presentations, discussions, and breakout groups at the workshop, and include pedagogic guidance as well as teaching materials drawn from On the Cutting Edge and other educational projects at SERC.

- [Teaching Data, Simulations, and Models with MATLAB](#)
 - [Computational Skills](#)
 - [Visualization](#)
 - [Exploring Data and Models](#)

Find more [materials and strategies for teaching data, simulations, and models](#) from across the On the Cutting Edge project.

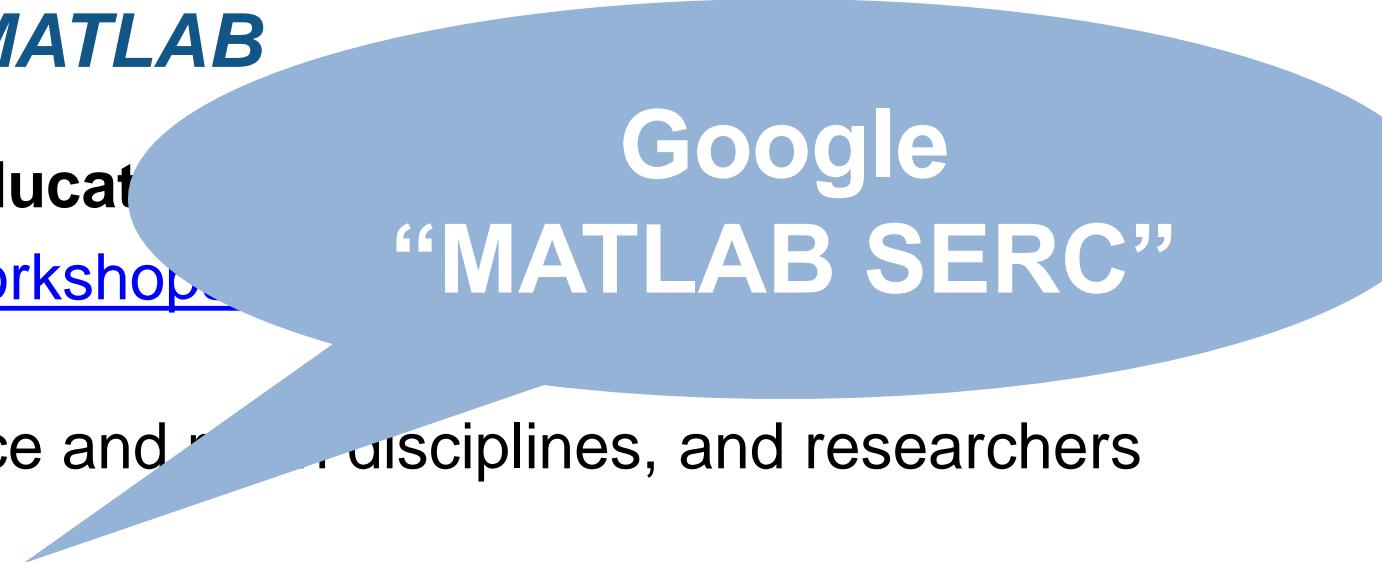
- [MATLAB for Analyzing and Visualizing Geospatial Data](#) (webinar, and [code examples](#))
- [Landsat 8 data explorer](#) (code and [video](#))
- [MATLAB product code examples](#)
- [Mapping Toolbox code examples](#)

http://serc.carleton.edu/NAGTWorkshops/data_models/toolsheets/I
https://serc.carleton.edu/NAGTWorkshops/data_models/matlab15/

SERC Site and Workshop Results: *Teaching Geoscience with MATLAB*

MATLAB page for Geoscience Education

- http://serc.carleton.edu/NAGTWorkshops/data_models/matlab15/index.html
- Useful content for multiple science and related disciplines, and researchers



Google
“MATLAB SERC”

Workshop Outcomes and Resources

- https://serc.carleton.edu/NAGTWorkshops/data_models/matlab15/outcomes.html
- Pay special attention to
 - Activities (lesson plans) and essays on teaching
 - Teaching approaches pages for philosophy re: computing, quantitative skills development

Should Computational Thinking be Ubiquitous?

Learning to Code?



Coding to Learn?

"Computational thinking is a fundamental skill for everyone, not just for computer scientists."

*Dr. Jeannette Wing, Vice President of Microsoft Research
Former Department Head of CS at Carnegie Mellon University*

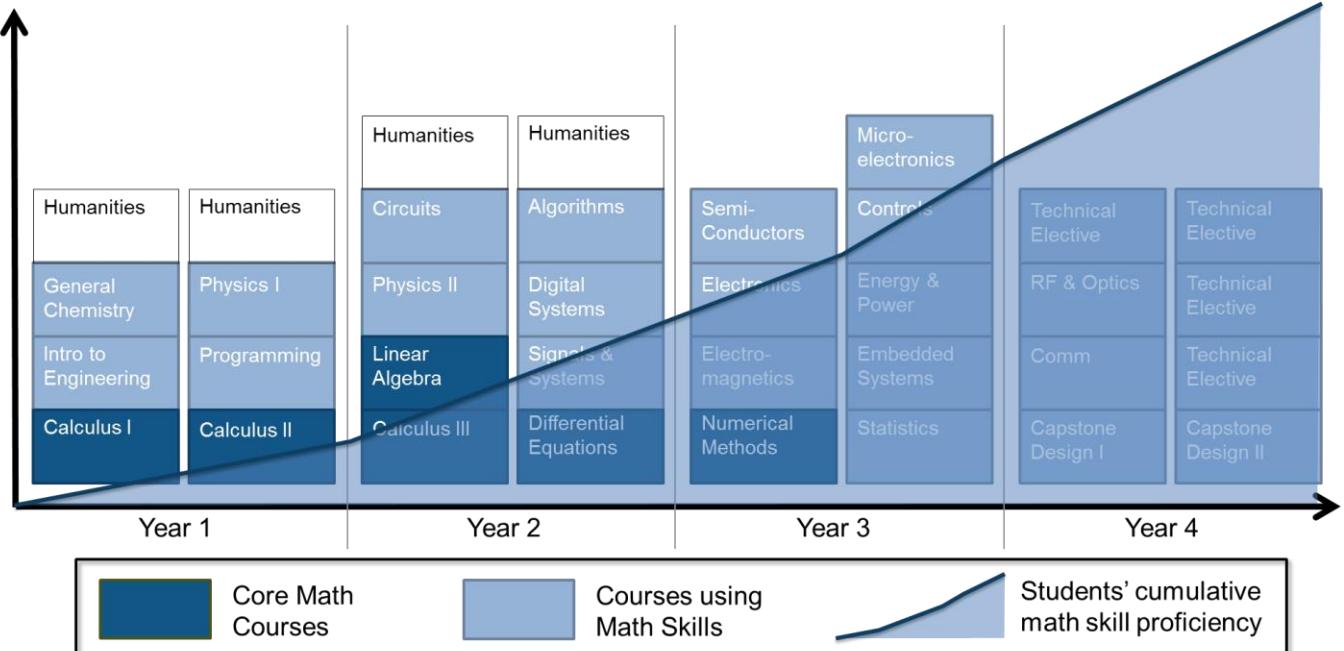
"Coding teaches me to think in a logical way"

Trinity School high school student

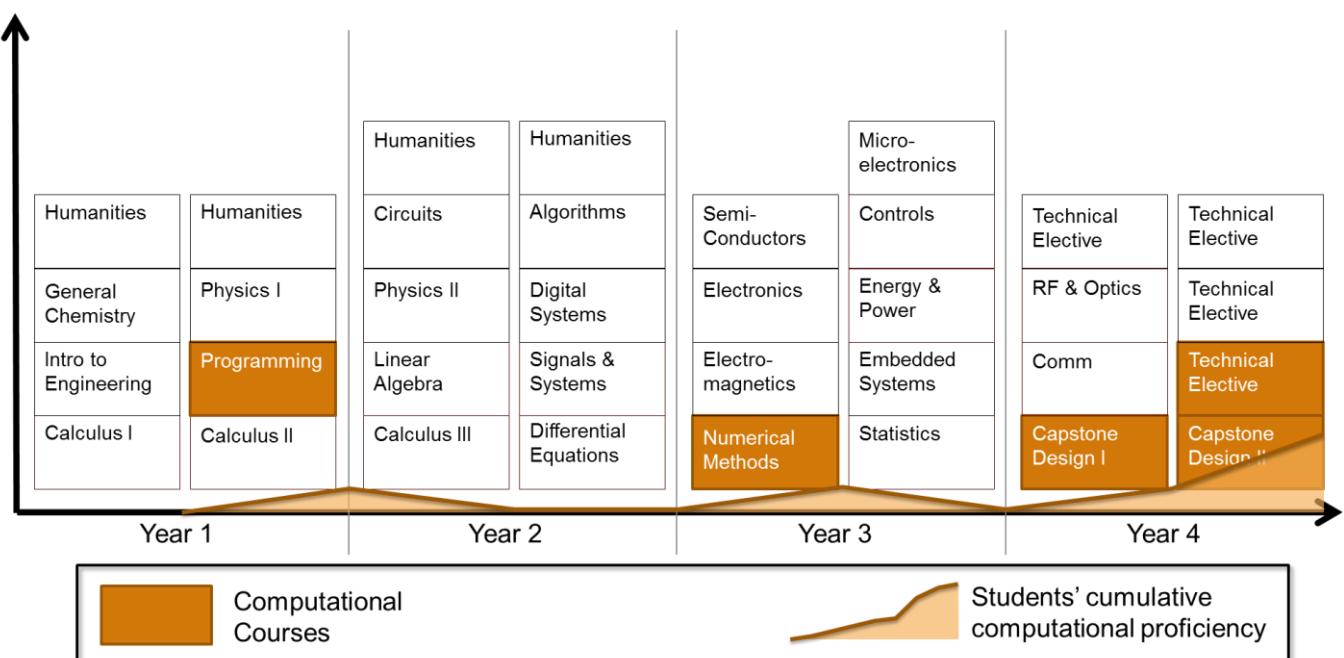
Accepted at MIT



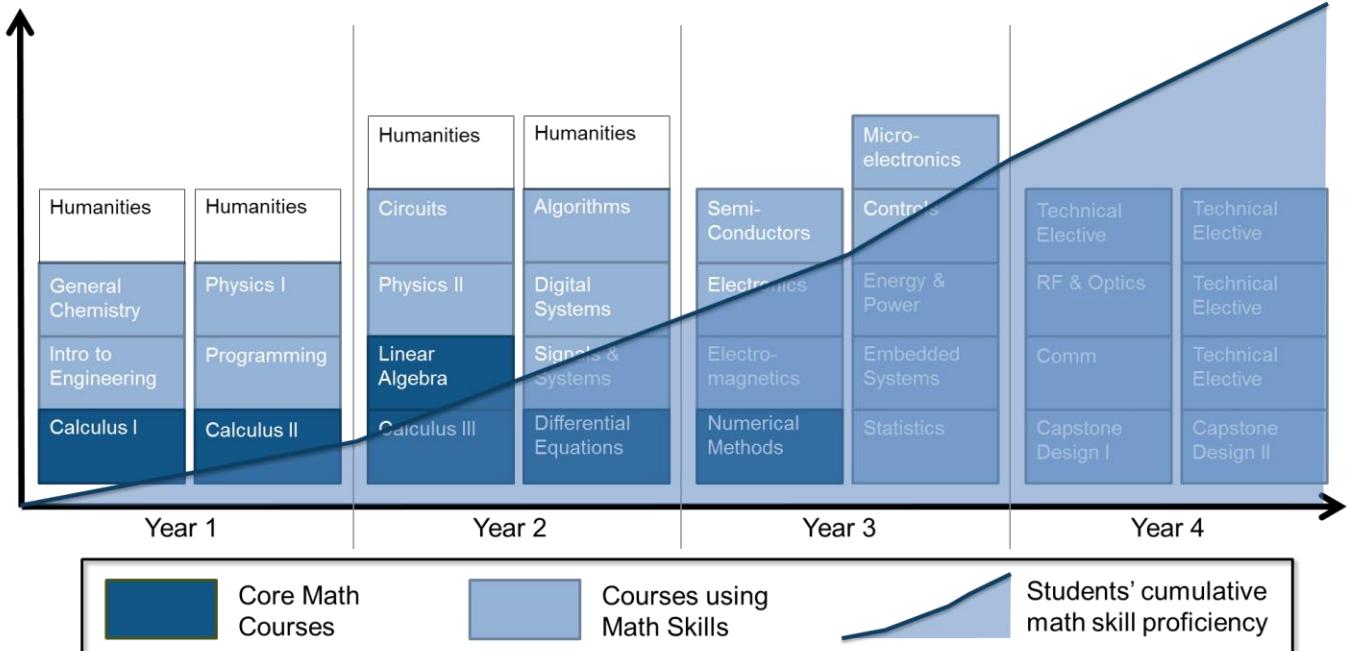
How Math is introduced in the curriculum



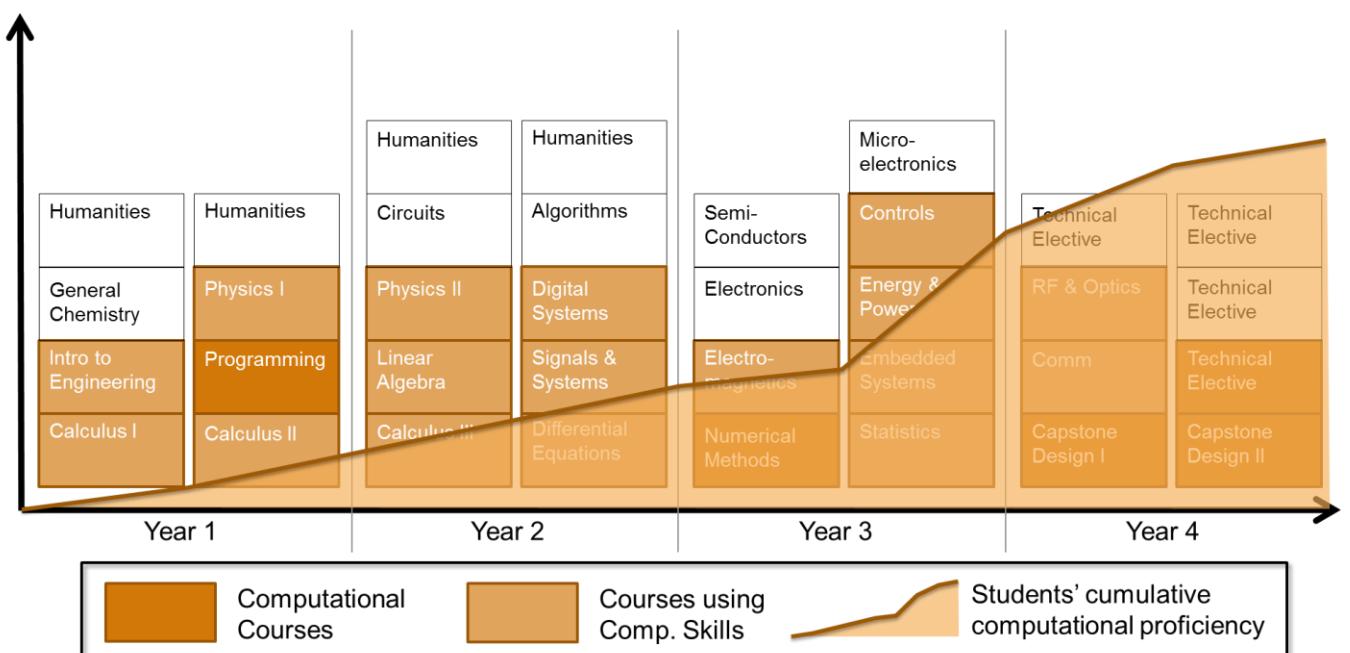
How is Computational Thinking introduced?



How Math is introduced in the curriculum



Should Computational Thinking be built up like we introduce Math?



MATLAB Tools from MathWorks for Research and Teaching

Products and Services

Products by: [Category](#) | [Alphabetical](#) | [Product Map](#)

MATLAB® Product Family

[MATLAB](#)[Parallel Computing](#)[Parallel Computing Toolbox](#)[MATLAB Distributed Computing Server](#)[Math, Statistics, and Optimization](#)[Symbolic Math Toolbox](#)[Partial Differential Equation Toolbox](#)[Statistics and Machine Learning Toolbox](#)[Curve Fitting Toolbox](#)[Optimization Toolbox](#)[Global Optimization Toolbox](#)[Neural Network Toolbox](#)[Model-Based Calibration Toolbox](#)[Control Systems](#)[Control System Toolbox](#)[System Identification Toolbox](#)[Fuzzy Logic Toolbox](#)[Robust Control Toolbox](#)[Model Predictive Control Toolbox](#)[Aerospace Toolbox](#)

Simulink® Product Family

[Simulink](#)[Event-Based Modeling](#)[Stateflow](#)[SimEvents](#)[Physical Modeling](#)[Simscape](#)[SimMechanics](#)[SimDriveline](#)[SimHydraulics](#)[SimRF](#)[SimElectronics](#)[SimPowerSystems](#)[Control Systems](#)[Simulink Control Design](#)[Simulink Design Optimization](#)[Aerospace Blockset](#)[Robotics System Toolbox](#)[Signal Processing and Communications](#)[DSP System Toolbox](#)

Polyspace® Product Family

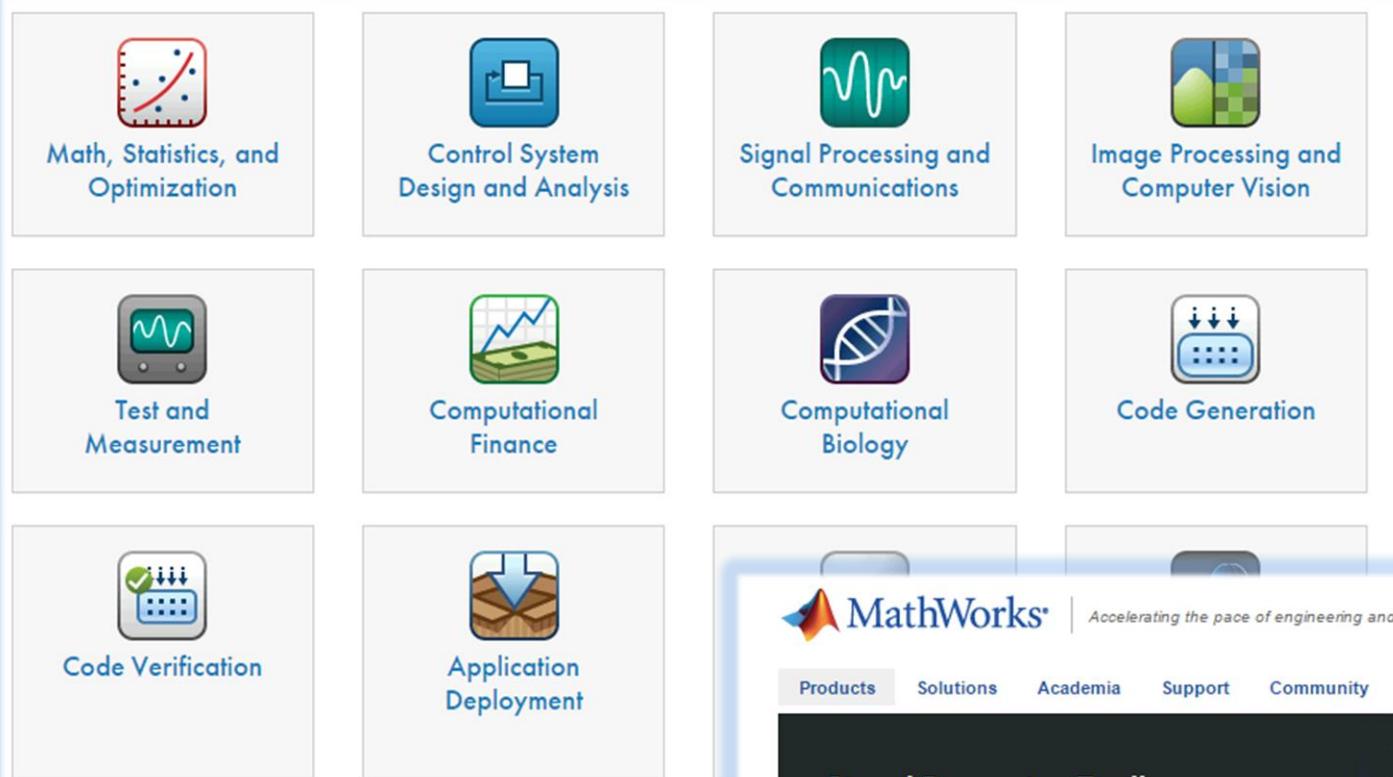
[Polyspace Bug Finder](#)[Polyspace Code Prover](#)[DO Qualification Kit \(for DO-178\)](#)[IEC Certification Kit \(for ISO 26262 and IEC 61508\)](#)

Additional Products and Services

[Services](#)[Software Maintenance](#)[Training](#)[Consulting](#)[Third-Party Products & Services](#)[Access](#)[MATLAB for Student Use](#)[MATLAB for Home Use](#)[MATLAB for Primary and Secondary School Use](#)[Apps](#)[MATLAB Mobile](#)[MATLAB Answers](#)[MATLAB Examples](#)

[MATLAB and Simulink Products](#)

MATLAB Toolboxes



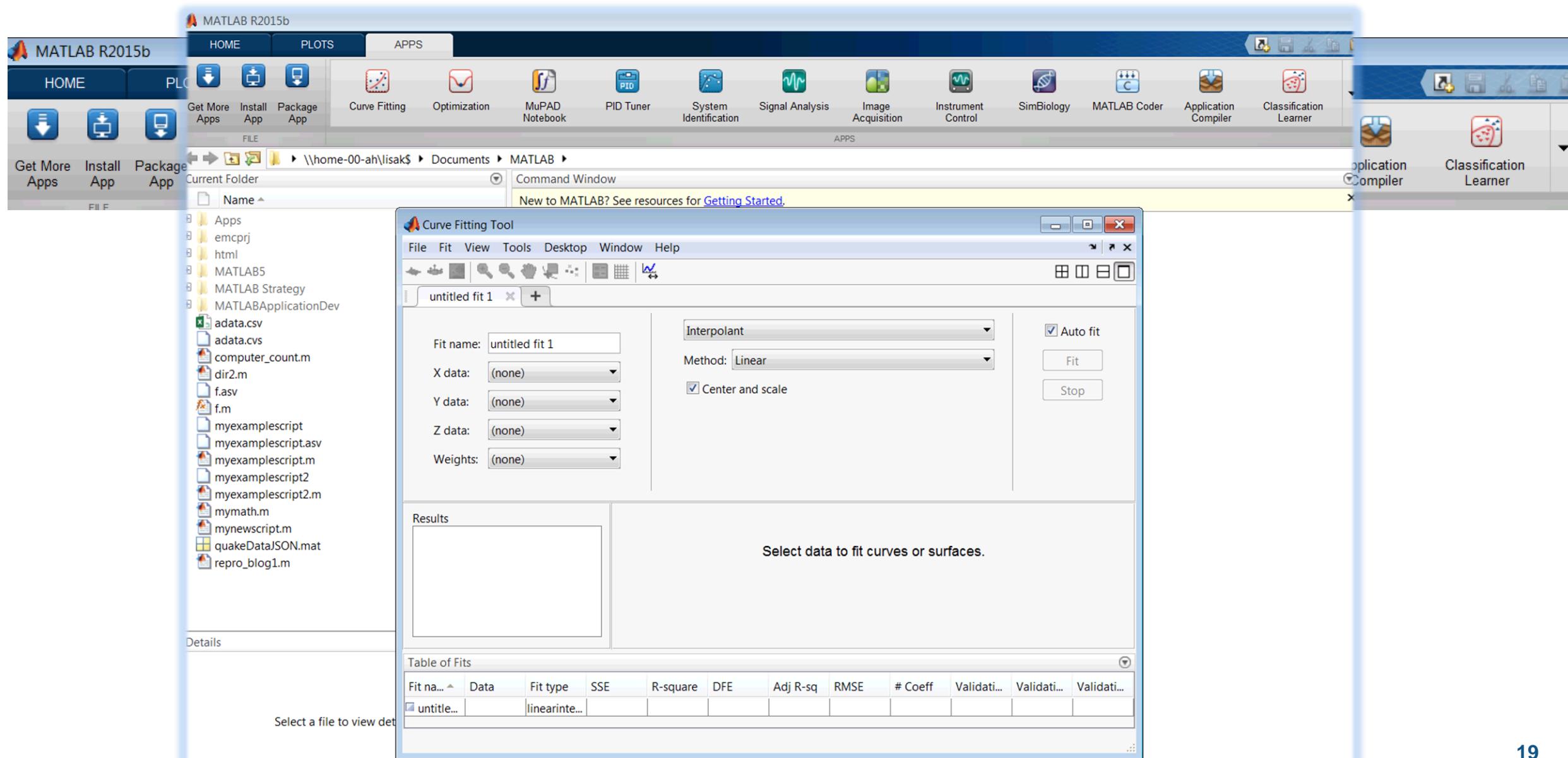
See code examples

Watch videos

Add your own documentation

The screenshot shows the MathWorks website with a blue header bar. The header includes the MathWorks logo, the tagline "Accelerating the pace of engineering and science", and links for "United States", "Contact Us", "How To Buy", "Search MathWorks", "Lisa Kempler", "My Account", and "Log Out". Below the header, a navigation bar has tabs for "Products" (which is highlighted in orange), "Solutions", "Academia", "Support", "Community", "Events", and "Company". A large banner for the "Signal Processing Toolbox" is displayed, featuring the text "Signal Processing Toolbox" and "Perform signal processing and analysis" above a plot of a signal spectrum. Below the banner is a horizontal menu with links: "Overview" (highlighted in orange), "Features", "Code Examples", "Videos", "Webinars", "Related Products", "What's New", and "Product Trial".

MATLAB Apps Tab and Curve Fitting App



MATLAB in the Cloud and on Your Phone: MATLAB Online and MATLAB Mobile

 MathWorks® Products Solutions Academia Support Community Events Company Contact Us How To Buy Lisa ▾

MATLAB Online
Tech Preview

Overview | Features | Limitations | System Requirements

Access MATLAB from your web browser

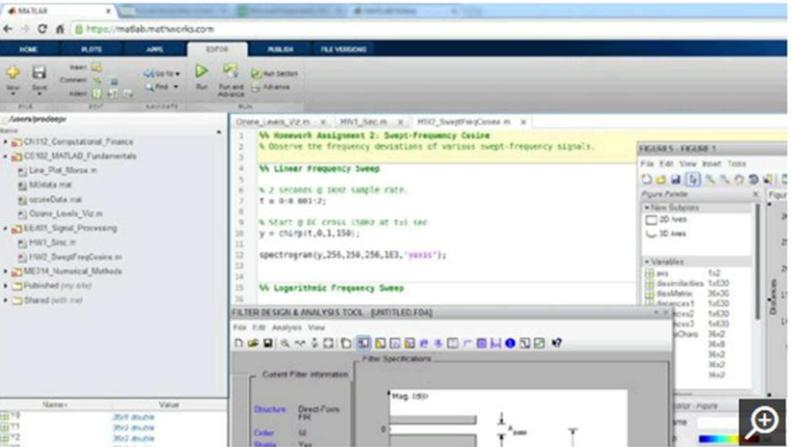
MATLAB Online™ provides access to MATLAB® from your web browser. Just log in to use MATLAB.

With MATLAB Online, your files are stored on MATLAB Drive™ and are available wherever you go. MATLAB Drive Connector synchronizes your files between your computers and MATLAB Online, providing offline access and eliminating the need to manually upload or download files. You can also run your files from the convenience of your smartphone or tablet by connecting to MathWorks Cloud through the MATLAB Mobile™ app.

MATLAB Online facilitates collaboration by enabling you to share files with friends or publish them as formatted HTML or PDF documents.

MATLAB Online is available for use with MATLAB Student and MATLAB and Simulink® Student Suite R2014a or later. The following toolboxes are available at this time:

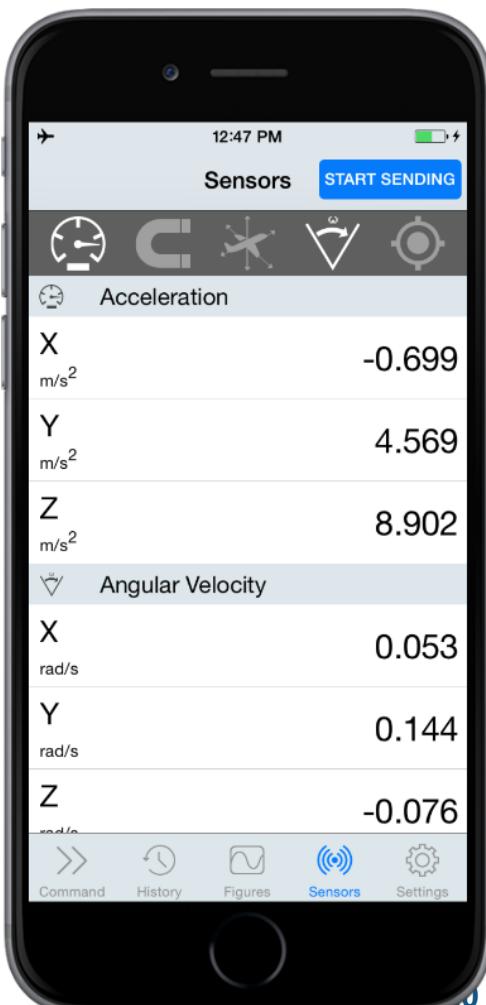
- Computer Vision System Toolbox
- Control System Toolbox
- Curve Fitting Toolbox
- Econometrics Toolbox
- Financial Toolbox
- Financial Instruments Toolbox
- Fuzzy Logic Toolbox
- Global Optimization Toolbox
- Model Predictive Control Toolbox
- Neural Network Toolbox
- Optimization Toolbox
- Partial Differential Equation Toolbox
- Phased Array System Toolbox
- Robust Control Toolbox
- Signal Processing Toolbox
- Statistics and Machine Learning


MATLAB Online

[Start using MATLAB Online](#)

[Synchronize files with MATLAB Drive](#)

MATLAB Mobile for iOS or Android



Support for Educators

- Courseware
- Autograding
- On-Ramp Tutorials & Videos
- Code examples
- All-Campus License
- MATLAB Online

The screenshot shows the MathWorks Academia page. At the top, there's a navigation bar with links to Educator Home, Classroom Resources, Hardware Support, License Options, and Research. Below the navigation is a large blue banner with the text "Download MATLAB Courseware" and a subtext "Teach system dynamics with Arduino, MATLAB, and Simulink." A "Learn more" button is visible. To the right of the banner is a diagram of a circuit board connected to a computer and a water tank. Below the banner, the word "Educators" is displayed in orange. A text block encourages adding MATLAB and Simulink to the classroom, mentioning 5000 universities and career preparation. Three cards below the text provide links to MATLAB Courseware, Webinars for Instructors, and Hardware for Project-Based Learning. At the bottom, three more cards offer Trial Software, MATLAB Campus License, and Primary and Secondary Schools resources.

Academia

Educator Home | Classroom Resources | Hardware Support | License Options | Research

Download MATLAB Courseware
Teach system dynamics with Arduino, MATLAB, and Simulink.

[Learn more](#)

Educators

Add MATLAB and Simulink to the classroom, as 5000 universities already have, and you inspire critical thinking and innovation. You also prepare students for prominent careers in industry, where the tools are the de facto standard for R&D. Get started and get inspired.

MATLAB Courseware
[Download courseware](#)

Webinars for Instructors
[Explore curriculum ideas](#)

Hardware for Project-Based Learning
[Connect hardware to MATLAB and Simulink](#)

Trial Software
Try MATLAB, Simulink, and Other Products
[Get trial software](#)

MATLAB Campus License
[Get MATLAB for everyone](#)

Primary and Secondary Schools
[Teach with MATLAB and Simulink](#)

Autograde MATLAB Code
[Create and grade assignments](#)

Create MATLAB Examples
Find links to videos, code, models, and other resources
[Learn how](#)

MATLAB and Simulink Student Challenges
[Learn more](#)

Next Steps

LOOP

- Tell each other what you're doing
- Make your tools and methods available for reuse

How will ARO share best practices and resources in 2016?

Continue the discussion post session and post ARO!

Panel Discussion

APPENDIX

› Data Access

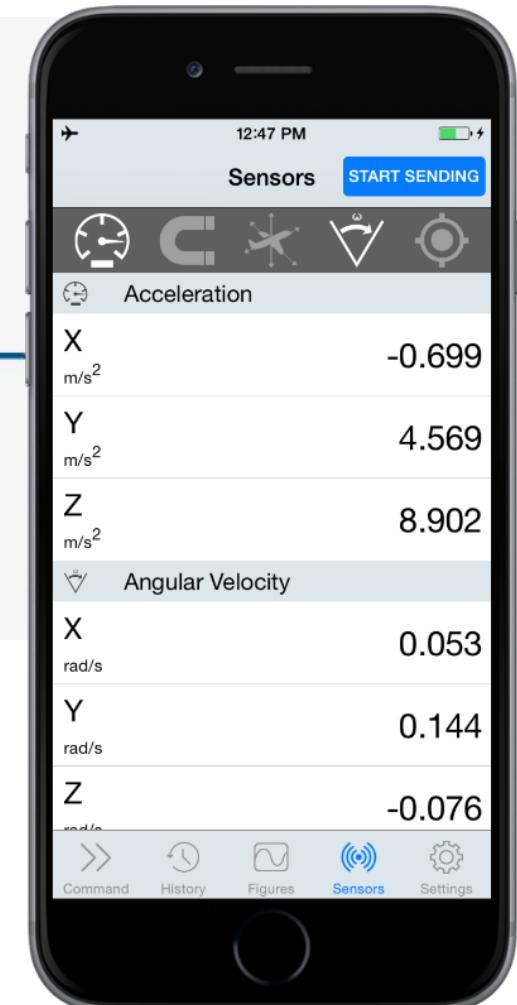
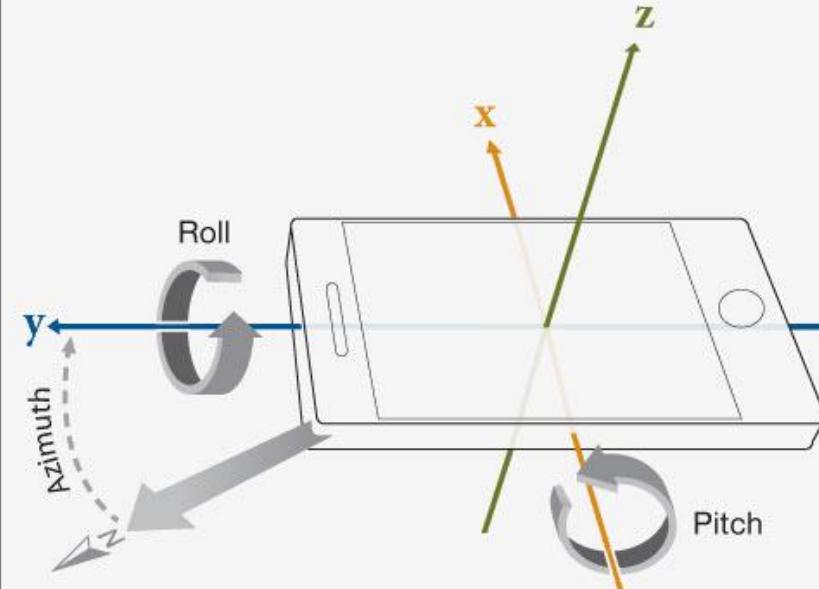
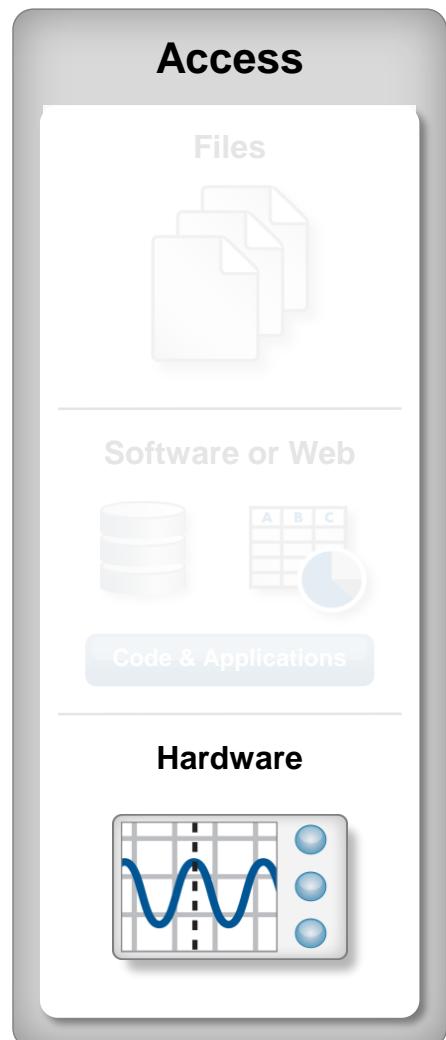
Analysis, Modeling,
and Visualization

Performance and
Big Data

Sharing Code and
Tools

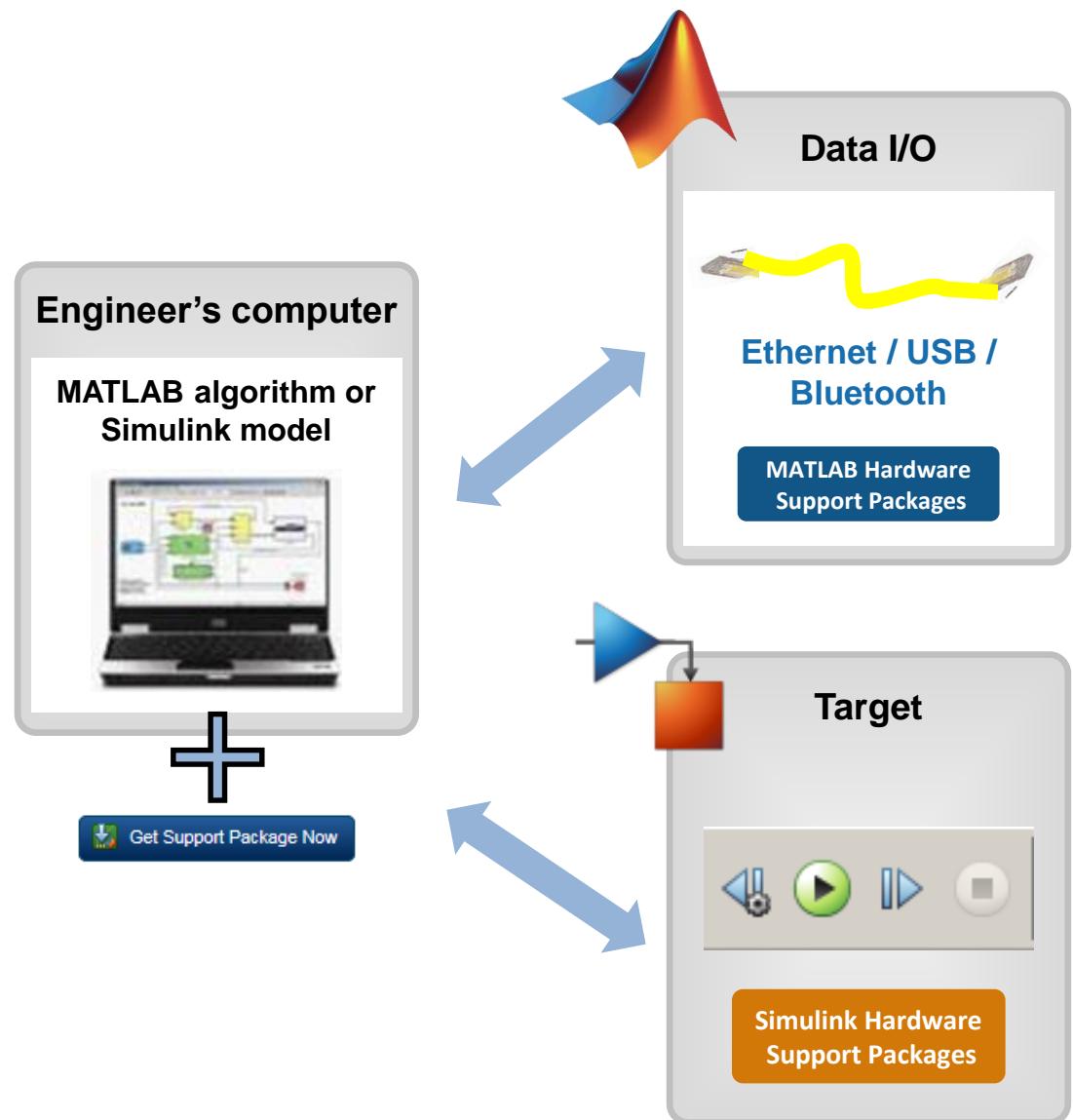
Teaching Resources

Access Sensors on Mobile Devices



**MATLAB Mobile
for iOS or Android**

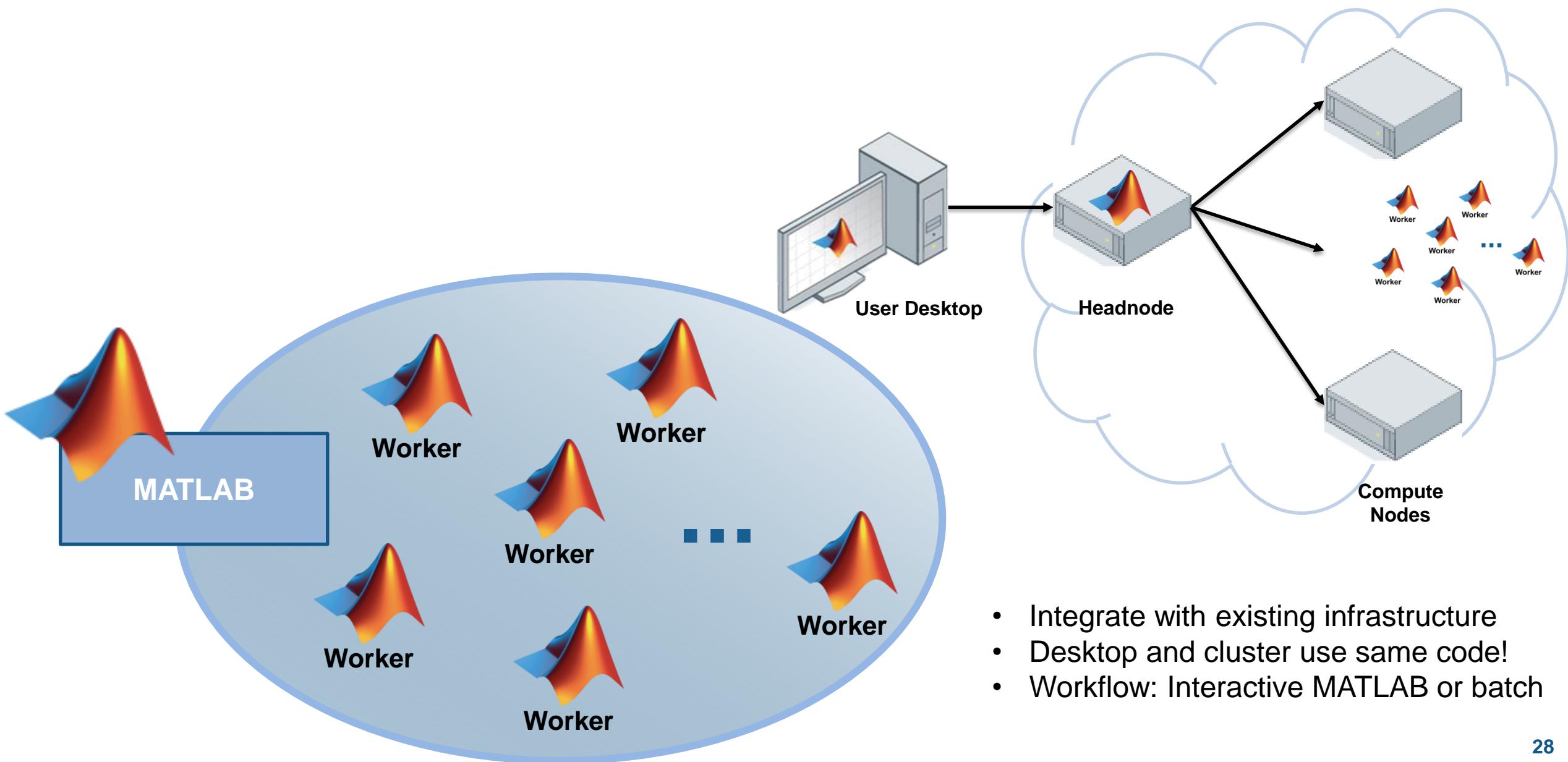
Connecting to Low Cost Hardware



Screenshot of the MathWorks Hardware Support page for Microsoft Kinect for Windows:

- Header:** Shows "Low Cost Hardware" (R2014b), "Android Sensors", "Lego 'EV3", and "Arduino".
- MathWorks Logo:** Accelerating the pace of engineering and science.
- Navigation:** Products, Solutions, Academia, Support, Community, Events, Company.
- Section: Hardware Support**
 - Overview, Search Hardware Support, Request Hardware Support.
- Section: Microsoft Kinect for Windows Support from Image Acquisition Toolbox**
 - Acquire data from Microsoft Kinect For Windows into MATLAB and Simulink. Kinect is a natural interaction device with an RGB camera and 3D depth sensor.
 - ▶ Microsoft Kinect for Windows Support from Image Acquisition Toolbox
 - ▶ Microsoft Kinect Support from Simulink
- Text:** Using Image Acquisition Toolbox™, you can acquire data from Microsoft® Kinect for Windows into MATLAB® and Simulink®. Microsoft Kinect for Windows is a natural interaction device with an RGB camera and 3D depth sensor.
- Image:** Microsoft Kinect for Windows device.
- Right Sidebar:** Ready to install, Before installing, Get Started, Expand all, Getting Started, Examples, Using the Image Acquisition Toolbox, Solution.

Beyond Serial MATLAB → Integrating with Clusters and Cloud



MATLAB for Parallel Computing: SNIC/XSEDE



The screenshot shows the XSEDE website's "Education and Outreach Blog" section. The header includes the XSEDE logo, a search bar, and a sign-in link. The main content area displays a blog post titled "HPC Research and Education News for the Week of May 19, 2014 Sponsored by XSEDE". The post is dated 5/20/14 11:44 AM and is categorized under "HPC in the News". The text discusses MathWorks' selection by SNIC to provide HPC capabilities to researchers. Below the main post, there is a link to "NCSA Visualizations Featured at Adler Planetarium".

XSEDE
Extreme Science and Engineering
Discovery Environment

Search XSEDE... SIGN IN

HOME ABOUT USER SERVICES RESOURCES EDUCATION & OUTREACH TECHNOLOGY DATABASE GATEWAYS

Education and Outreach Blog

HPC Research and Education News for the Week of May 19, 2014 Sponsored by XSEDE [« Back](#)

5/20/14 11:44 AM [HPC in the News](#)

MATLAB Selected to Provide HPC Capabilities to Researchers

MathWorks today announced that the Swedish National Infrastructure for Computing (SNIC) has selected MATLAB and MATLAB Distributed Computing Server as vehicles to enable researchers at all Swedish universities to utilize resources at the national data centers for high-performance computing (HPC) and to more effectively collaborate with colleagues across the country. SNIC is a national research infrastructure created to provide a balanced and cost-efficient set of resources and user support for large-scale computation and data storage. With data centers located at six key research universities, SNIC meets the needs of researchers from all scientific disciplines through an open-application procedure to ensure that the best research is supported. To read further, please visit <http://www.hpcwire.com/off-the-wire/matlab-selected-provide-hpc-capabilities-researchers/>.

NCSA Visualizations Featured at Adler Planetarium

30 XSEDE HPC
Mentors at 17
Organizations –

Program initiated
in 2015