TECHNISCHE UNIVERSITÄT DRESDEN

Introduction to Matlab

Functions, Integration, and Signal Processing

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DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

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Today's Plan

Date	Topics	Projects
16.04.	Intro, basic operations, matrices	
23.04.	Data handling, random numbers, basic plotting	1st Project Assignment
30.04.	Advanced plotting, scripts, control flow	
07.05.	Control flow statements, signal processing,	1st Project Deadline
14.05.	Holiday (Himmelfahrt)	2nd Project Assignment
21.05.	1st Project Presentation Functions, integration, image, and sound	
28.05.	Holiday (Pfingstferien)	
04.06.	Data Analysis, statistics, 2nd Project Presentation	2nd Project Deadline

Functions

Keyword

Output Arguments

Function Name

Input Arguments

```
function [ out1, out2, … ] = fun_name( inp1, inp2, … )
% comments to be displayed go here
…
out1 = … ;
…
out2= …;
```

Function Description Comments

Output Argument Assignment

```
function [mea, varargout] = statTwo( x,varargin )
```

Variable-length Output/Input Argument List

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Functions

- In-line functions:

$$c(a,b,\theta) = \sqrt{a^2 + b^2 - 2abcos(\theta)}$$

```
c = inline('sqrt(a.^2+b.^2-2*a.*b.*cos(theta))', 'a', 'b', 'theta')
```

```
c = @(a,b,theta) sqrt(a.^2+b.^2-2*a.*b.*cos(theta));
```

- Recursive functions:

```
function f = factorial2(g)
        if g = =1
              f = 1;
              return
        end
        f = g * factorial2(g-1);
```

```
function f = factorial2(g)
        if g = =1
              f = 1;
              return
        end
        f = g * factorial2(g-1);
```

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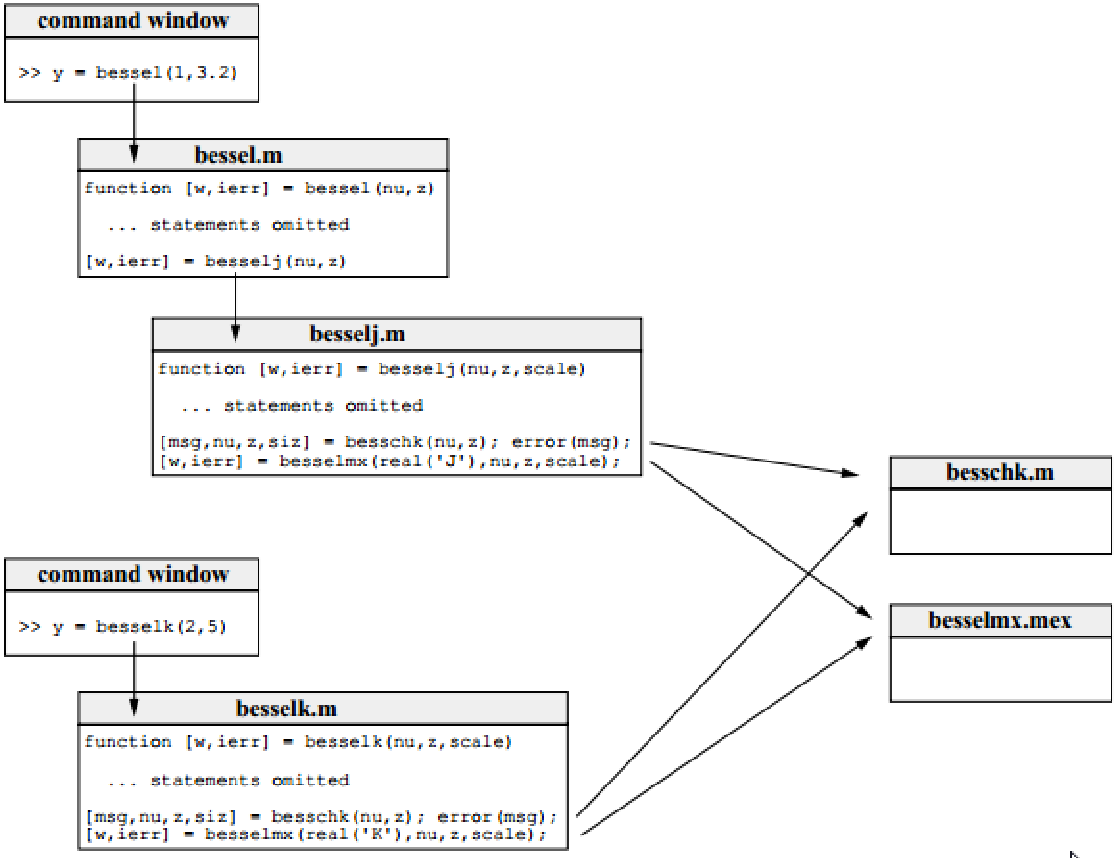
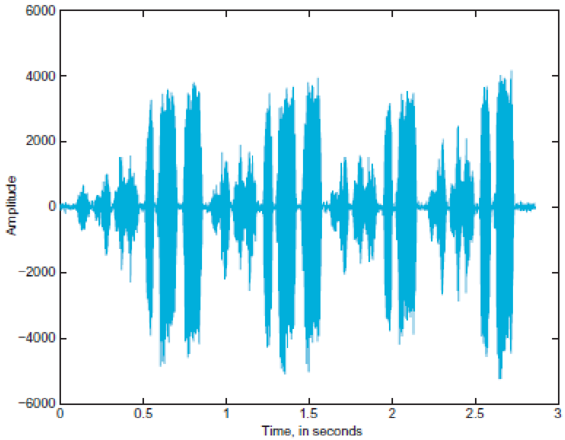
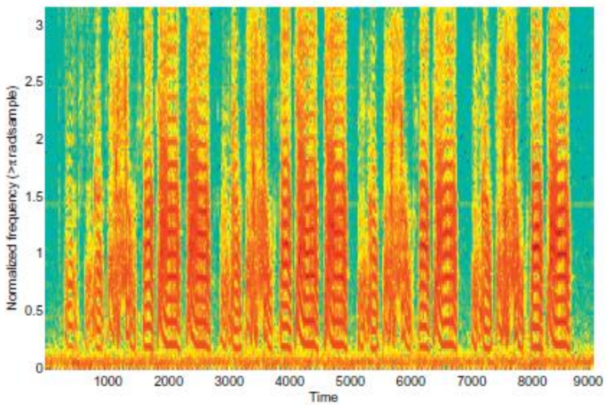
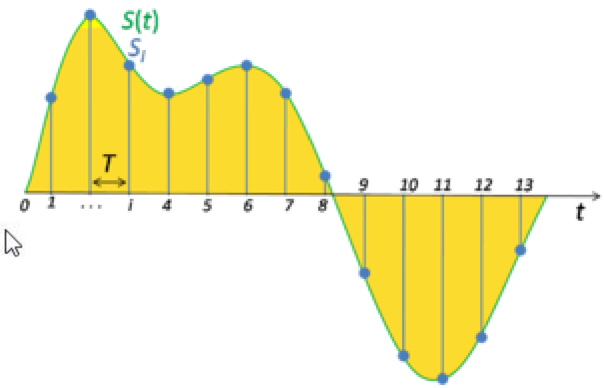
Integration and Modular Programming



Signal Processing



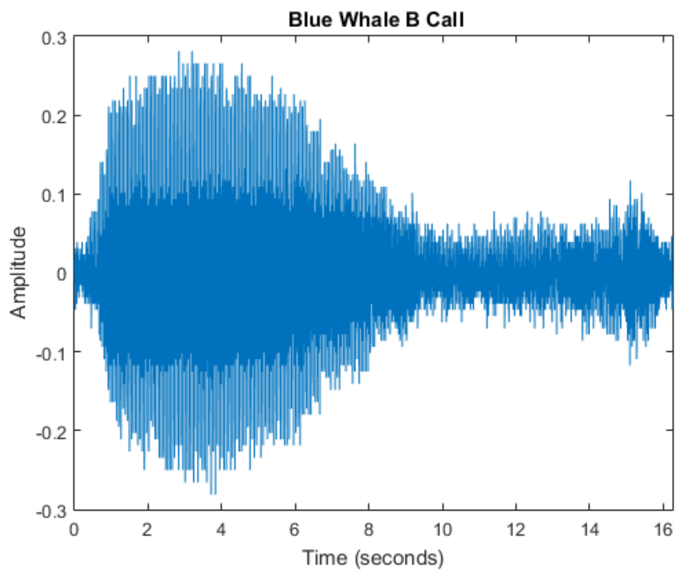




- Basic cocepts:
  - Discrete-time vs. continuous-time signals
  - Sampling rate (sampling frequency)
  - Signal energy
  - Time domain vs. frequency
  - Fourier transform
  - Filters: High-pass, low-pass, band-pass
  - Cut-off frequency

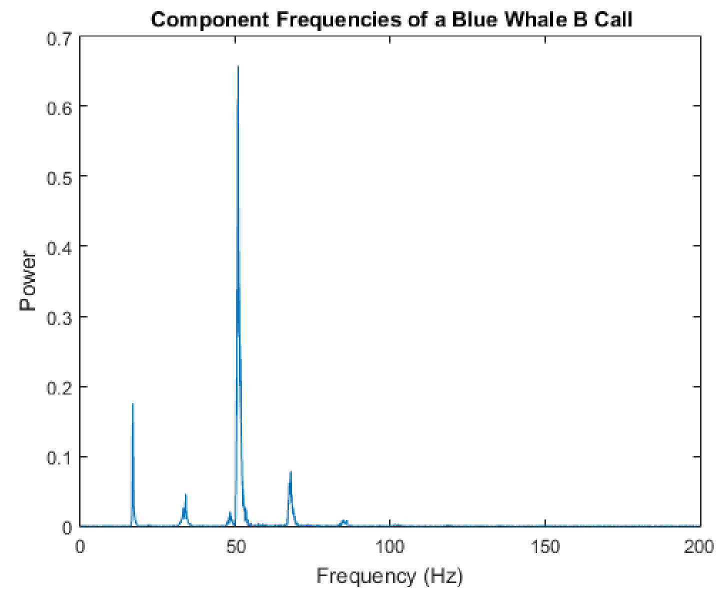
Fast Fourier Transform

`Y = fft(X,n)`



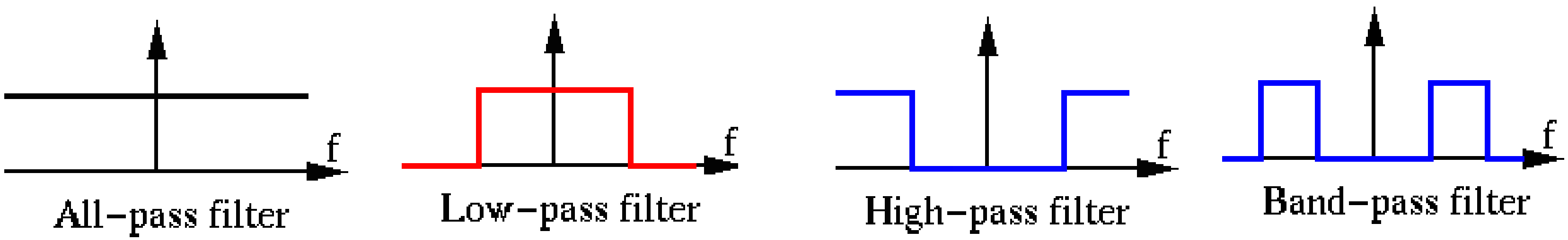
FFT →

← iFFT



`y = ifft(X,n)`

Filters



Butter-worth filter:

```
[b,a] = butter(n,Wn,ftype)
```

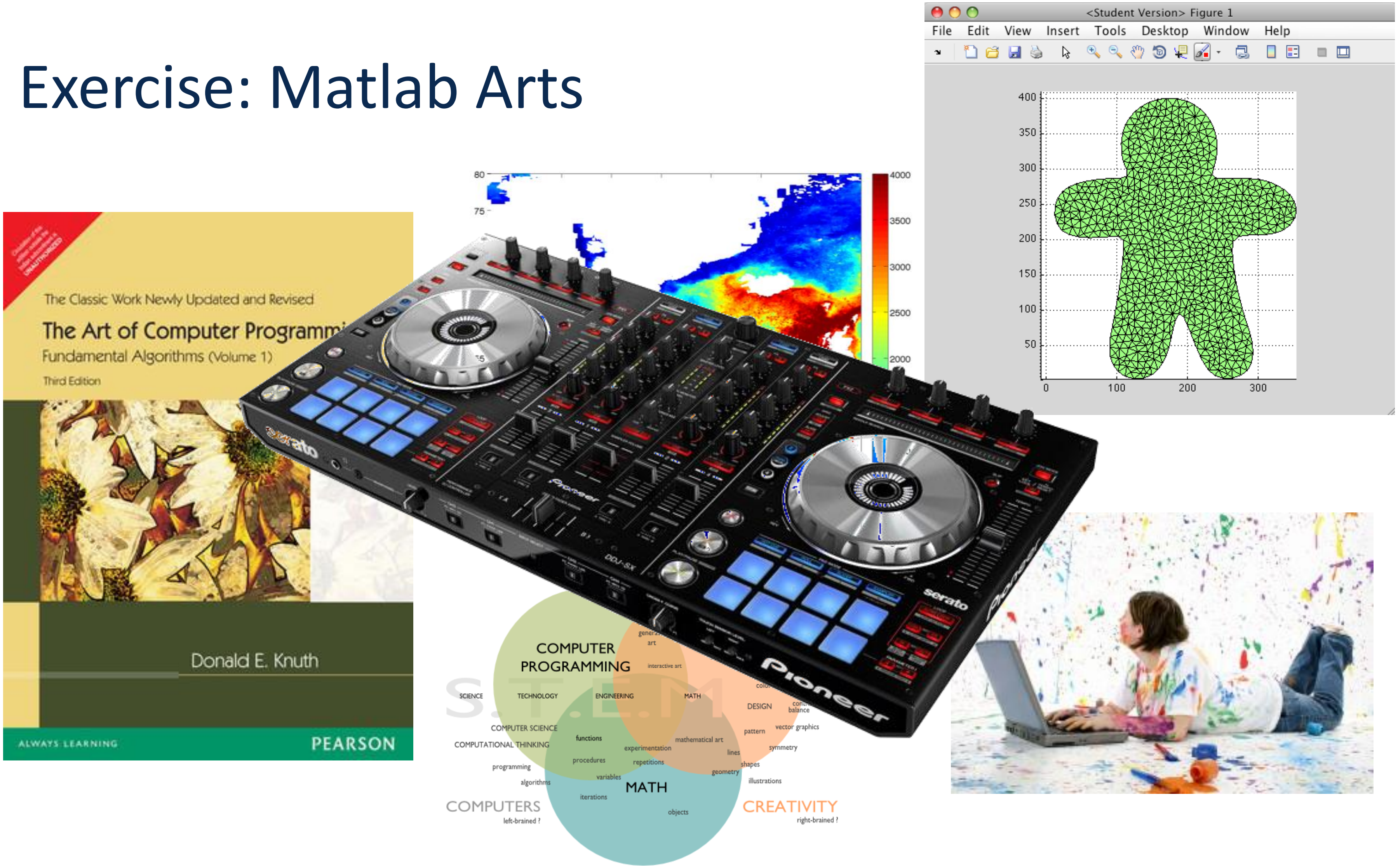
- [b,a]: Transfer function coefficients
- n: Filter order
- Wn: Cut-off frequency
- ftype: Filter type e.g. 'bandpass'

Zero-phase digital filtering:`

```
y = filtfilt(b,a,x)
```

- y: Filtered Signal
- b,a: Transfer function coefficients
- x: Input Signal

Exercise: Matlab Arts



Exercise: Matlab Arts

- Create a simple software audio mixer:
  - load the audio tracks (using audioread function)
  - Plot each of 3 tracks along with each other using subplot
  - Extract a segment of first 10 seconds of each track (sampling rate=44100 samples/sec)
  - Make a composite signal simply by adding signals of three tracks
  - Increase the volume of bass track by multiplying the amplitude by 3, and decrease the volume of guitar track by multiplying the amplitude by 0.4
  - Play both mixed signals
  - Plot the spectrogram of all 4 audio signals (using specgram function)
  - [Optional] increase the volume of the bass track gradually during the track

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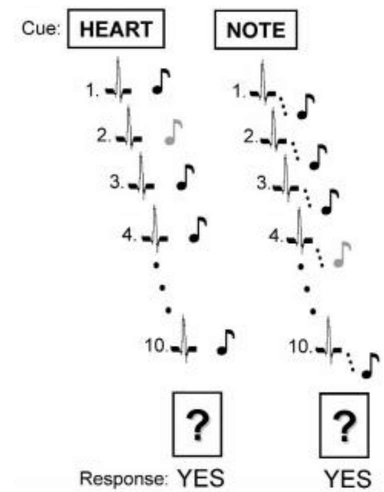
Exercise: Listen to Your Heart

nature neuroscience

Neural systems supporting interoceptive awareness

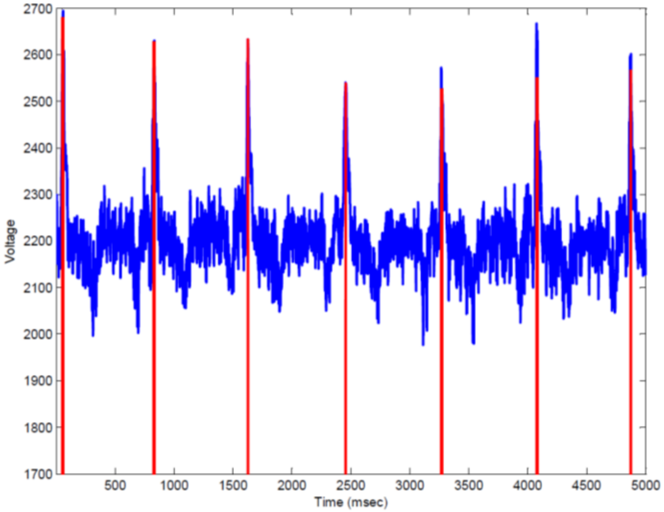
Hugo D Critchley[1–3], Stefan Wiens[4], Pia Rotshtein[1], Arne Öhman[4] & Raymond J Dolan[1]

Influential theories of human emotion argue that subjective feeling states involve representation of bodily responses elicited by emotional events. Within this framework, individual differences in intensity of emotional experience reflect variation in sensitivity to internal bodily responses. We measured regional brain activity by functional magnetic resonance imaging (fMRI) during an interoceptive task wherein subjects judged the timing of their own heartbeats. We observed enhanced activity in insula, somatomotor and cingulate cortices. In right anterior insular/opercular cortex, neural activity predicted subjects' accuracy in the heartbeat detection task. Furthermore, local gray matter volume in the same region correlated with both interoceptive accuracy and subjective ratings of visceral awareness. Indices of negative emotional experience correlated with interoceptive accuracy across subjects. These findings indicate that right anterior insula supports a representation of visceral responses accessible to awareness, providing a substrate for subjective feeling states.



- Schirmer-Mokwa , K., Fard, P.R., Zamorano, A.M., Finkel, S., Birbaumer, N., and Kleber, B.A. (2015), **Enhanced interoceptive awareness in professional musicians**, *Submitted*.

Exercise: Listen to Your Heart



- Real-time heartbeat monitoring:
  - Receiving ECG data (reads it from a file)
  - Filtering received data
  - Detecting the peak in heart waveform
  - Presentation of the data to the user:
    - Visualization of ECG data with detected heartbeats
    - Playing the sound

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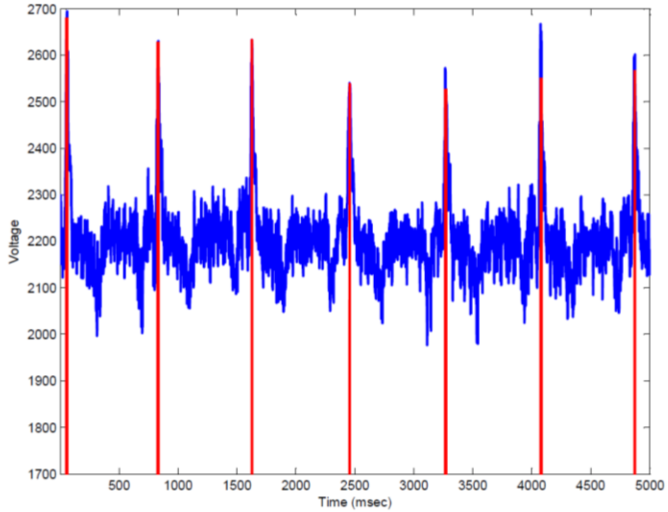
Exercise: Listen to Your Heart

- Read the filtered ECG data from a text file (filtere_ecg.txt)
- Write a function that detects the R-peak in ECG data:
  - Input arguments: signal, sampling rate (1000)
  - Output arguments: a vector containing values representing the peaks
  - Filter the data using a second-order butterworth band-pass filter with cut-off frequencies of 0.5 and 40*
  - Calculate the signal energy (signal.^2) *
  - Set the threshold used in detection algorithm
  - Perform the loop for the values of the signal energy that are over the threshold
  - Make sure that there won’t be a peak in a certain amount of time
- Visualize the data along with the peaks using the functions you wrote

* Plot and compare it with the original data

Exercise: Listen to Your Heart



- Use the implemented function to create the real-time setup:
  - Run this function each 100 ms on a segment of data to detect the peaks of respective time-window
  - Visualize each segment of the data, with the peak
  - Play a beap if there is peak in this segment of data

References

- **MATLAB for Psychologists (2012),** Borgo, M., Soranzo, A., Grassi, M., Springer-Verlag, 2012, ISBN. 978-1-4614-2196-2.
    - Chapter 4-5., pp. 67-128.
- **MATLAB for Neuroscientists, 2nd Ed: An Introduction to Scientific Computing (2014),** *Wallisch, P., Lusignan, M.E., Benayoun, M.D., Baker, T.I., Dickey, A.S. and Hatsopoulos, N.G.,* Academic Press, ISBN. 978-0123838360.
    - Chapter 4. pp. 103-140.

- **Websites:**
    - http://pundit.pratt.duke.edu/wiki/MATLAB:Inline_Function
    - http://www.mathworks.com/help/matlab/matlab_prog/anonymous-functions.html
    - http://web.cecs.pdx.edu/~gerry/nmm/course/slides/ch04Slides.pdf
    - http://www.mathworks.com/help/matlab/math/fast-fourier-transform-fft.html
    - http://fourier.eng.hmc.edu/e161/lectures/gradient/node1.html
    - http://www.mathworks.com/help/signal/ref/butter.html
    - http://www.mathworks.com/help/signal/ref/filtfilt.html