Tutorial Creation
DA623: Computing with Signals
Weightage: 20%

Deliverables:
A github link to your (stand-alone) repository created for this task. It should contain:

a. A jupyter notebook presenting the topic in a tutorial fashion, integrating python and markdown code cells
b. Any data or Python scripts required to run the above notebook

Submission Timeline:
11:59 am, 27-Apr-2024 | Saturday
Updating the repository beyond the above timeline will lead to disqualification

Recommended Guidelines:

a. Clarity is very important. Make sure your friend understands without you explaining.
b. Try to state as bullets whenever possible
c. A figure should have meaningful label, gridlines, aspect ratio, legends
d. Stating your interpretation is important
e. Equations look better when written using latex

Topics:

1. Understanding nature as a repository of different kinds of signals

2. Concept of orthogonality, and its usefulness in modeling real-world signals

3. Matrix decompositions, types, and demonstration of their practical usefulness

4. Polynomials, different polynomial bases (namely, Vandermonde, Legendre Chebyshev), and demonstration of the same

5. Usefulness of Chebyshev polynomials, with application to some real world signals

6. Concept of correlation demystified using synthetic 2-D data, real-world data, and its link with diagonality of covariance matrix in fitting a 2-D Gaussian distribution

7. Linear regression on synthetic 2-D data, concept of overfitting and underfitting, impact of outliers on MSE

8. Ridge and Lasso regression explained and performance contrasted on synthetic 2-D data

9. Demonstration of application of regression to a real-world problem, quantify the performance and the interpretation

10. Fourier Series, demonstration of its properties by creating different types of synthetic signals

11. Fourier Series, demonstration of its application to some signals which are not a function of time

12. Fourier Series, demonstration of its application on ~10 sec signals drawn from different solo western music instruments

13. Tutorial on Fourier Series, demonstration of its application to some signals which are not a function of time

14. Sampling and Reconstruction: Comparing Shannon reconstruction, issues of undersampling and oversampling

15. Compare and contrast Shannon reconstruction with polynomial-based reconstruction (for various degrees)

16. Recovery from non-uniform samples: Comparison with uniform sampling, methods, and applications

17. DFT transform, its computation and illustration of its properties using synthetic signals and real-world signals

18. Comparison between PCA, Gram-Schmidt, and DFT by applying and approximating a collection of random gaussian vectors (128 dimensional each).

19. 2-D DFT transform, its computation and illustration of its properties using synthetic and real-world images

20. Comparison between PCA, Gram-Schmidt, and DFT by applying and approximating images (example, refer to Eigen faces).

21. 1-D convolution demystified: Illustration on synthetic and practical signals

22. 2-D convolution demystified: Illustration on synthetic and practical signals
23. Change detection in 1-D time-series data: Demonstrate with applications
24. Edge detection on 2-D images: Compare different approaches
25. Demonstration of application PCA on Color Images
26. Change detection in 1-D time-series data: Demonstrate with applications
27. 1-D convolution demystified: Illustration on synthetic and practical signals
28. 2-D convolution demystified: Illustrate application to filtering and blurring
29. 1-D inverse problem solving using convolution: Demonstrate with one application
30. 2-D inverse problem solving using convolution: Demonstrate with one application
31. Discrete Cosine Transform (DCT) and its Applications
32. Short-Time Fourier Transform (STFT) and Spectrogram Analysis
33. Time-frequency Representations
34. Power Spectral Density Estimation Techniques (for 1-D signals)
35. Sparse Representation and Dictionary Learning: Application to Image
36. Dictionary Learning and its Applications to Speech/Image Denoising
37. Principal Component Analysis (PCA) for Dimensionality Reduction: Demonstrate the eigenvectors estimated for synthetic 2-D data distributed in different ways
38. Demonstrate Principal Component Analysis (PCA) as a regression approach
39. Visualize the spectrum (and spectrogram, separately) of computed from 2 secs utterances corresponding to a few phonemes of a spoken language of your choice
40. Visualize the time-domain signal, DFT magnitude spectrum (and spectrogram, separately) computed from 2 secs utterances corresponding to a few phonemes (>6) of a spoken language of your choice.
41. Visualize the spectrum (and spectrogram, separately) computed from 2-5 secs utterances corresponding to a few animal and bird calls (>6).
42. Visualize the spectrum (and spectrogram, separately) computed from 2-5 secs utterances corresponding to a few animal and bird calls (>6).
43. Compute spectrograms of synthetic chirp signals
44. Implement an illustration of gradient descent in 2-D data for a polynomial regression problem
45. Train and demonstrate the decision boundaries for logistic regression, for binary classification
46. Implement an illustration of gradient descent in 2-D data for a regression problem. Show as an animation (MP4 file).
47. Implement k-means clustering on an image dataset
48. Implement k-means clustering on an sound dataset
49. Linear Discriminant Analysis (LDA) for Dimensionality Reduction
50. Logistic Regression for Binary Classification

51. Neural Networks and their Applications
52. Demonstrate how the summary statistics of NNs weights evolve as the NN gets trained over epochs for a problem of your choice
53. Convolutional Neural Networks for 1-D signals for a problem of your choice
54. Convolutional Neural Networks for 2-D signals for a problem of your choice
55. Visualize the filters learnt by 1-D CNNs for a problem of your choice
56. Visualize the filters learnt by 2-D CNNs for a problem of your choice
57. Implement a NN which computes the DFT of a fixed length input data (1-D)
58. Typing behavior analysis: Illustrate and analyze the data at : http://cvlab.cse.msu.edu/typing-behavior-dataset.html
59. Demonstrate the frequency spectrum of different artifacts in EEG signals
60. Demonstrate the frequency spectrum of different artifacts in EEG signals
61. Compare and contrast PCA and auto-encoder, Use MNIST dataset for demonstration
62. Demonstrate the distribution of different image features in a pool of natural images associated with different categories
63. Demonstrate the impact of quantization for images, through clustering
64. Demonstrate the perceptual (and spectral) impact due to amplitude quantization in audio
65. Analyze word2vec embedding by demonstrating clustering on a subtitle file of a movie of your choice
66. Demonstrate exploratory data science on subtitle file(s) of a movie of your choice

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