Indian Institute of Technology Kharagpur
Department of Mechanical Engineering

Data-driven methods in thermal and fluid sciences-ME41201

Mid-sem examination

Timing: 2:00 to 4:00 PM | September 19th, 2023 | Max mark: 200

Instructions

1. A working (automated) python code with proper syntax should be constructed.
2. Figures (or plots) should have appropriate labels. Axes scales should be justified with reasonable limits.
3. Examination is for 200 marks with any four questions out of five.

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1. An automated code consisting of three modules (or cells) to be constructed. The cumulonimbus cloud (see Q1cloud.jpeg) forms due to rising thermal plumes from hot spots on earth when they condenses in the sky above 2 km from the sea level. The provided picture is in total of 10 km in width and 4 km in height. Compute (a) singular values as a function of first r singular values, (b) reconstruct images using SVD technique for 70% and 90% of cumulative sum of singular values, (c) find two-dimensional projected area of the white vapor content in square kilometers. **(50 M)**

2. Solve the mystery photograph (Q2Fourier.png) and the tag line involved, if the picture is based on FFT? **(50 M)**

3. Padma Vibhushan Ilayaraja is one of the greatest film composers of modern India who has composed music for more than 1000 films with 7000 or more songs. He was born in a scheduled caste in a remote village in Tamilnadu (bordering Kerala), and despite having many troubles, dedicated his life to learning music with love and passion. His music composition consisted of playing Indian classical ragas on Western instruments, and he composed many masterpieces. One of such finest pieces is the '3-note' supplied with this examination (Ilayaraja3in1.mp3). Usually, to make a masterpiece, one needs the support of as many notes as possible (like Sapta swaras), but our maestro made a beautiful '3-note'. Being a science and technology lover, can you find the frequencies and their range involved by plotting a power spectral density and spectrogram via the wavelet transforms of your choice? Can you remove one of the notes (and nearby range) and reconstruct a 2-note clip? How does it sound? **(50 M)**

4. For $n = 1000$ and $K = 5$, create a K-sparse vector s of Fourier coefficients in a Fourier basis Ψ. For each p from 1 to 100, create a Gaussian random sampling matrix C to create a measurement vector $y = C\Psi s$. Use compressed sensing based on this measurement to estimate $\hat{s}$. For each p, repeat this with at least 10 realizations of the random measurement matrix C. Plot the average relative error of $||\hat{s} - s||_2/||s||$ versus p. Explain the trends. Also plot the average l_1 and l_0 error versus p. **(50 M)**

5. A high resolution signal consists of 4096 points out of which 256 measurements are randomly chosen (see Q5xvsy.txt). Using compressed sensing matching pursuit method estimate the dominant signal frequencies, phase-lag, and amplitudes of individual signals which are superimposed. **(50 M)**
