Spectral analysis

Spectral analysis is a technique used to examine the frequency components of a signal, whether it is in the form of sound, light, electromagnetic waves, or other types of signals. By decomposing a signal into its constituent frequencies, spectral analysis helps to understand its behavior in different domains. There are several key applications and methods within spectral analysis:

Applications of Spectral Analysis: Signal Processing: Used in audio, image, and speech processing to break down signals into frequencies for analysis, filtering, or compression. Physics and Engineering: Helps analyze waveforms, vibrations, and oscillations to better understand phenomena like sound waves, light spectra, and other oscillatory systems. Medical Imaging: Applied in technologies such as MRI and EEG to analyze signals from the human body. Astronomy: Used to determine the composition, velocity, and properties of distant stars and galaxies by analyzing the light spectrum. Chemistry: Helps identify substances based on their molecular spectra in techniques like mass spectrometry and infrared spectroscopy. Key Methods in Spectral Analysis: Fourier Transform (FT): Converts a time-domain signal into its frequency components. This is the most common method of spectral analysis.

Fast Fourier Transform (FFT) is a computationally efficient version of FT, widely used in digital signal processing. Power Spectral Density (PSD): Measures the power present in a signal as a function of frequency, commonly used in vibration analysis and EEG data.

Wavelet Transform: A more flexible method that allows for time-frequency analysis, useful for analyzing non-stationary signals.

Short-Time Fourier Transform (STFT): Combines time and frequency analysis by using a sliding window to perform Fourier Transforms over segments of a signal.

Steps in Spectral Analysis: Preprocessing: This involves filtering, removing noise, and preparing the signal. Transform: Applying a Fourier Transform or other methods to convert the signal from the time domain to the frequency domain. Interpretation: Analyzing the resulting spectrum to extract meaningful information about the signal's frequency content.

Hyperspectral imaging sensors have rapidly advanced, aiding in tumor diagnostics for in vivo brain tumors. Linescan cameras effectively distinguish between pathological and healthy tissue, whereas snapshot cameras offer a potential alternative to reduce acquisition time.

Aim: Our research compares linescan and snapshot hyperspectral cameras for in vivo brain tissues and chromophore identification.

Approach: We compared a linescan pushbroom camera and a snapshot camera using images from 10 patients with various pathologies. Objective comparisons were made using unnormalized and normalized data for healthy and pathological tissues. We utilized the interquartile range (IQR) for the spectral angle mapping (SAM), the goodness-of-fit coefficient (GFC), and the root mean square error (RMSE) within the 659.95 to 951.42 nm range. In addition, we assessed the ability of both cameras to capture tissue chromophores by analyzing absorbance from reflectance information.

Results: The SAM metric indicates reduced dispersion and high similarity between cameras for pathological samples, with a 9.68% IQR for normalized data compared with 2.38% for unnormalized data. This pattern is consistent across GFC and RMSE metrics, regardless of tissue type. Moreover, both cameras could identify absorption peaks of certain chromophores. For instance, using the absorbance measurements of the linescan camera, we obtained SAM values below 0.235 for four peaks, regardless of the tissue and type of data under inspection. These peaks are one for cytochrome b in its oxidized form at $\lambda = 422$ nm , two for HbO_2 at $\lambda = 542$ nm and $\lambda = 576$ nm , and one for water at $\lambda = 976$ nm .

Conclusion: The spectral signatures of the cameras show more similarity with unnormalized data, likely due to snapshot sensor noise, resulting in noisier signatures post-normalization. Comparisons in this study suggest that snapshot cameras might be viable alternatives to linescan cameras for real-time brain tissue identification [1).].

1)

Martín-Pérez A, Martinez de Ternero A, Lagares A, Juarez E, Sanz C. Spectral analysis comparison of pushbroom and snapshot hyperspectral cameras for in vivo brain tissues and chromophore identification. J Biomed Opt. 2024 Sep;29(9):093510. doi: 10.1117/1.JBO.29.9.093510. Epub 2024 Sep 24. PMID: 39318966; PMCID: PMC11420787.