UNIVERSITÄT ZU LÜBECK

DZL Deutsches Zentrum für Lungenforschung

Improved image quality in dynamic OCT imaging of airway and lung tissue by machine learning based data evaluation

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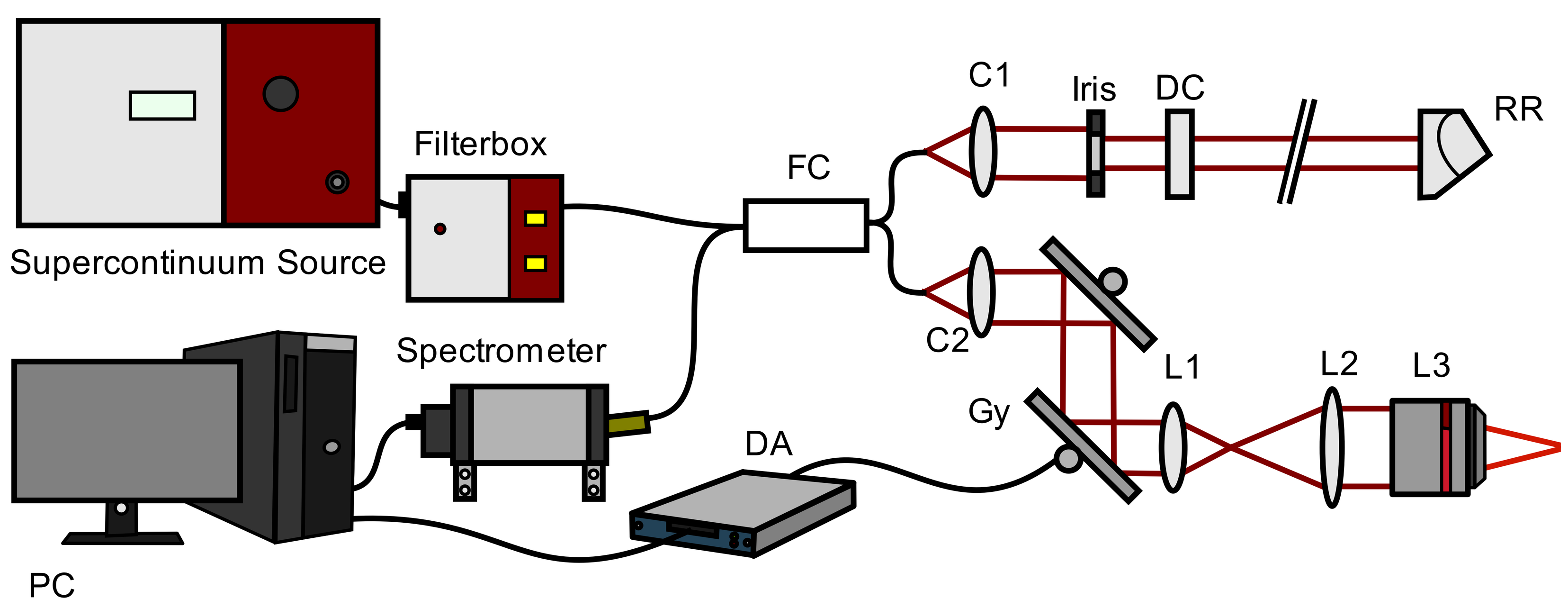
Introduction

- Endoscopic lung tissue evaluation is a first-line diagnostic tool, but provides only macroscopic images
- Dynamic optical coherence tomography (dOCT) could improve bronchoscopy by providing microscopic images with functional contrast
- However, to convert the high dimensional dynamic data into perceivable RGB images by binning, a-priori knowledge is required
- The „Neural Gas“ algorithm addresses this problem, as it automatically performs this conversion

Imaging Setup

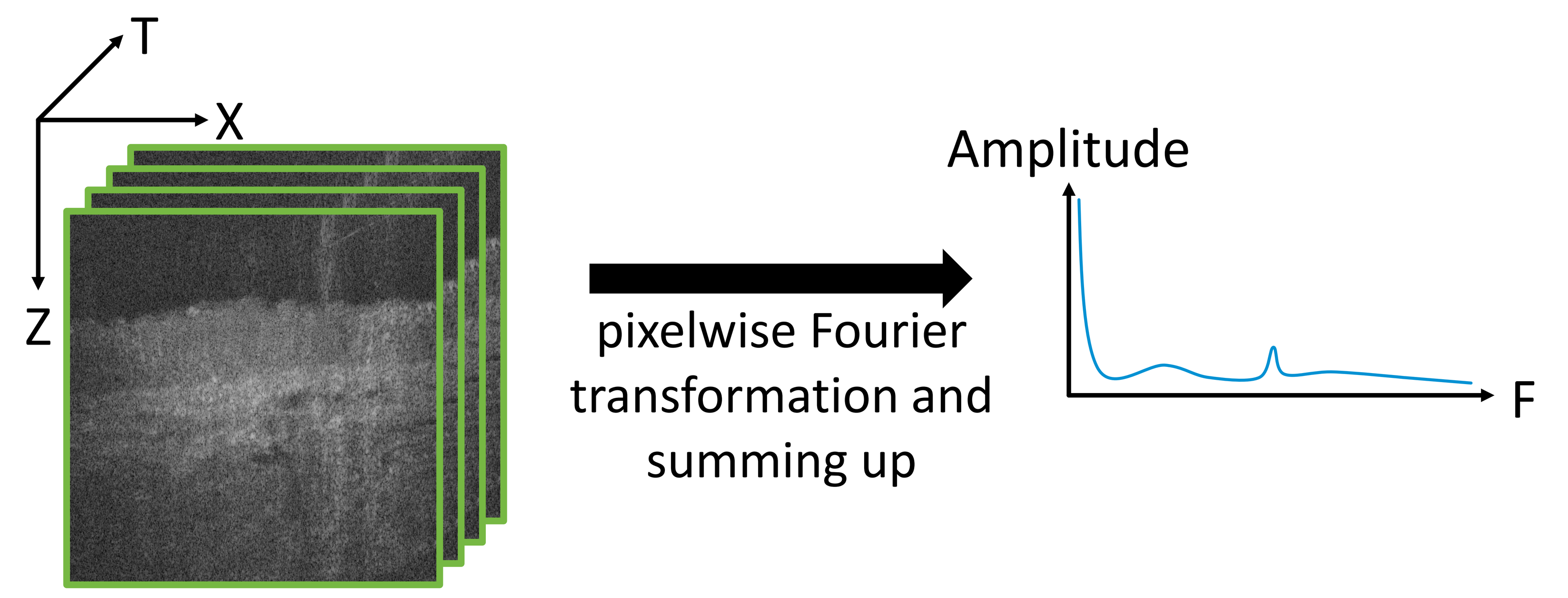


Our custom build OCT setup with microscopical resolution. FC: Fiber-coupler, C: Collimator, DC: Dispersion Correction, RR: Reference Reflector, G: Gyroscopic mirror, L: Lens, DA: Digital-Analog-converter

- Freshly excised human and mice lung tissue was imaged
- Per sample 150 B-Scans were acquired using a B-Scan rate of about 100 Hz

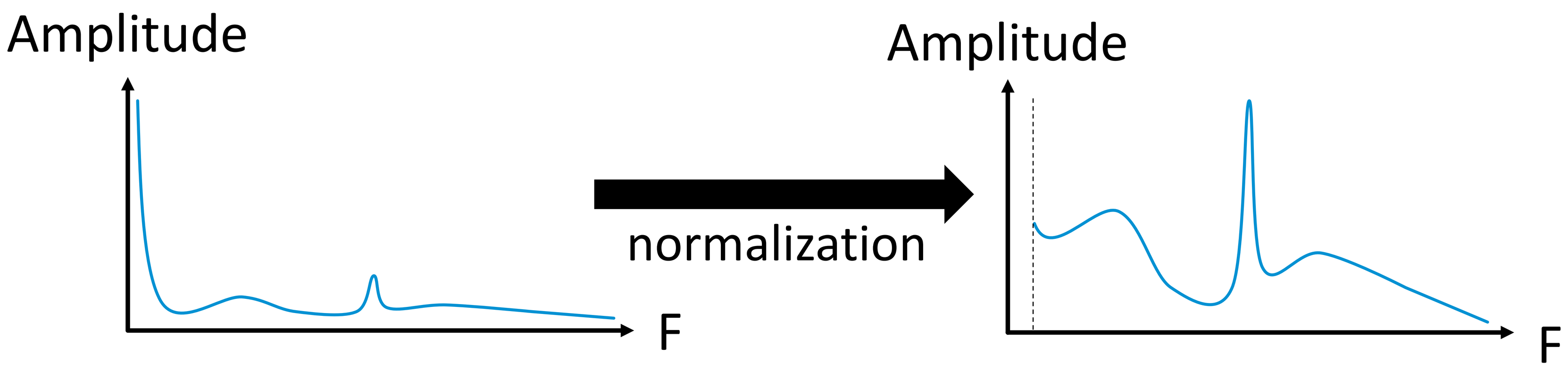
Processing

- Pixelwise Fourier transformation over the time yields the frequencies of the signal fluctuations in each pixel
- Calculating the average spectrum by summing all pixel spectra



Pixelwise Fourier Transformation over the 150 B-Scans yields a frequency spectrum of the signal changes for each pixel. However, this data still needs to be compressed into RGB images. Summing the spectra enables Neural Gas to perform the clustering.

- Define blue channel as spectral DC part
- Normalize remaining amplitudes to the interval [1, 1000]

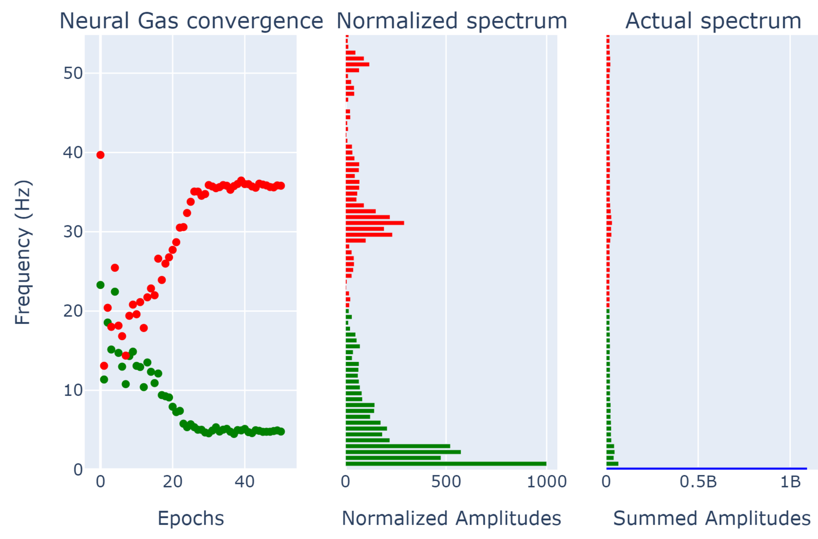


Left: Sum of all pixel spectra. Right: Sum of all pixel spectra without the zero-frequency bin. Further, the remaining amplitudes have been normalized to the interval [0, 1000]

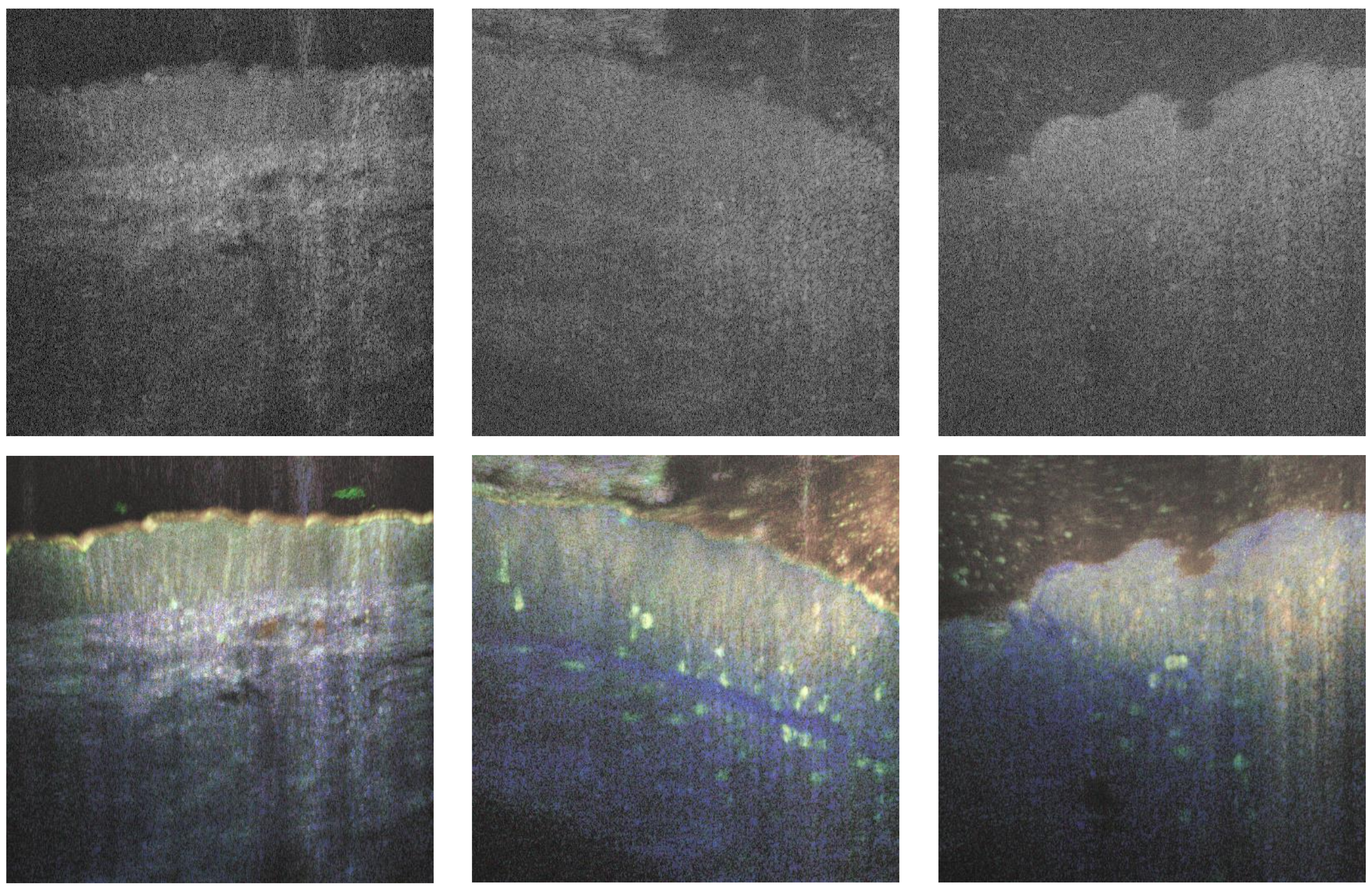
- A point cloud is created where per frequency a number of points according to the normalized amplitude are placed
- The Neural Gas algorithm is applied to the point cloud
- Two clusters are used to represent the green and red channel respectively

Results

- The algorithm converges well on the normalized spectra
- Resulting images are indistinguishable from manually binned ones
- Neural Gas clustering enables fast data evaluation

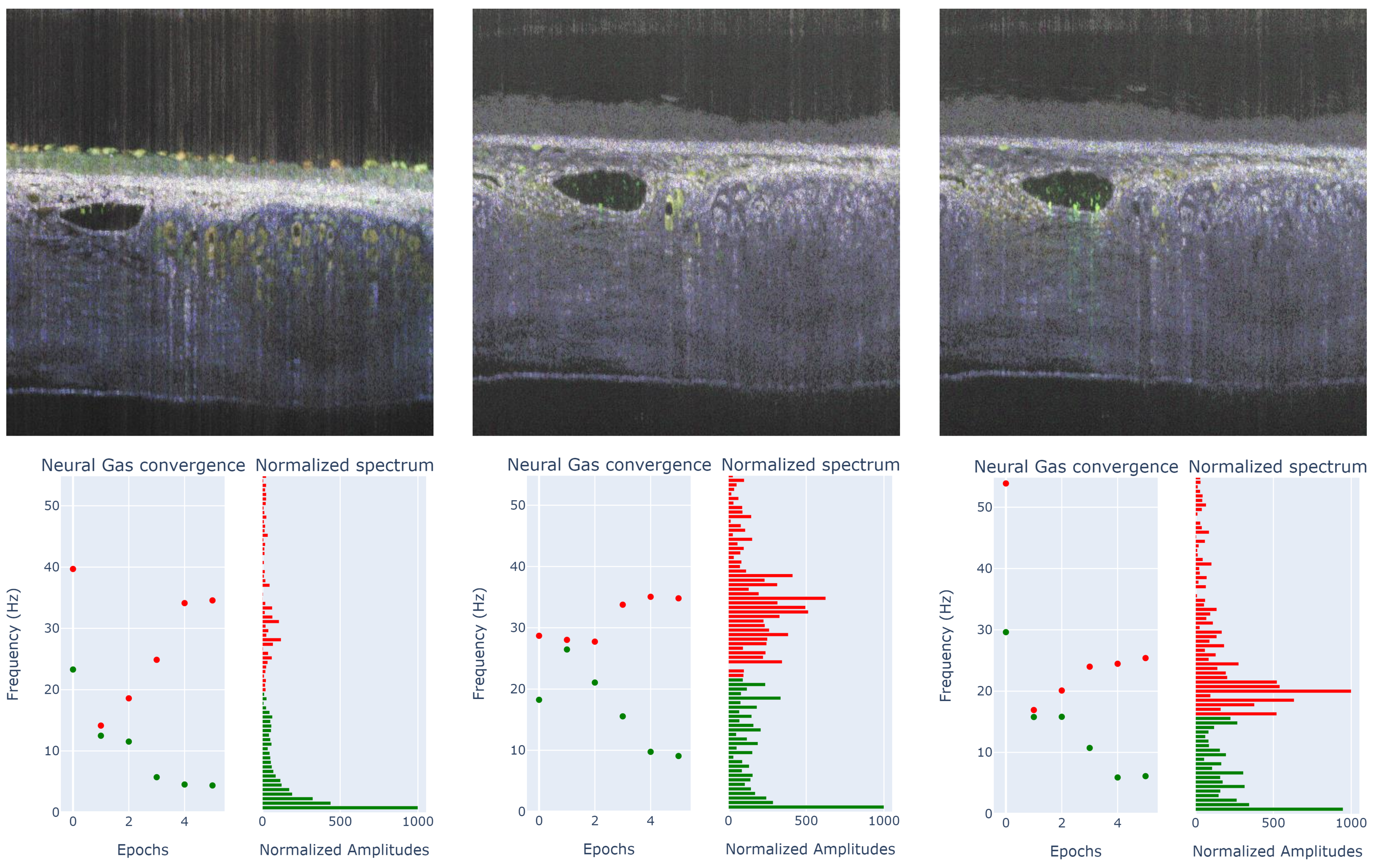


Exemplary binning by Neural Gas. Left: Neural Gas convergences to spectral key points. Middle: Normalized spectrum coloured by final binning. Right: Actual spectrum coloured by bins.



Per column the first B-Scan of a time series and the respective dOCT using Neural Gas clustering. All samples are human tissue. Left: Normal bronchus tissue. Middle: Bronchus with inflammatory cells and thickened basement membrane. Right: Malignant transformation of the bronchial epithelium.

- Neural Gas automatically adapts the contrast for each measurement
- Convergent behavior occurs even for few epochs



Top: dOCT of a mice trachea imaged at different times before and after adding 2% PFA for fixation. Bottom: Respective summed pixel-spectra with Neural Gas clustering. Left: Sample before application of PFA. A high frequency centre of gravity is located at around 30 Hz. Middle: Beginning cell death due to fixation. The low frequencies decrease compared to the high ones. Right: Sample with progressed cell death. The cellular movements become slower and the centre of gravity has shifted to around 20 Hz. Neural Gas can account for this and produces the best contrast automatically. Convergence occurs even for just 5 epochs.

Summary

“Neural Gas” clustering generates optimal contrast between spectral key points by iteratively clustering the spectrum. The algorithm shows a rapid converging behaviour even after a few epochs. Since the algorithm requires no a priori knowledge, an autonomous analysis is possible, enabling a large throughput or even real time diagnosis.

Acknowledgement

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