POPULAR SCIENTIFIC ABSTRACT

[Mads Svanborg Peters]

[Development of scanning and snapshot hyperspectral imaging systems for industrial sorting machines]

This Ph.D. project, a collaboration between Newtec Engineering A/S and SDU NanoSyd at the University of Southern Denmark, with support from Innovation Fund Denmark, focuses on enhancing hyperspectral imaging (HSI) technology to improve traditional optical sorting methods. Conventional systems using monochrome or RGB cameras are limited in their ability to perform precise material analysis. HSI, which captures a broad range of spectral channels across visible and near-infrared wavelengths, offers a more detailed solution but requires further refinement for widespread use.

The primary objective of this research was to develop and optimize new hyperspectral cameras, with a particular focus on the snapshot Computed Tomography Imaging Spectrometer (CTIS). This technology enables real-time collection and analysis of spectral data, making it more practical for industrial applications.

A custom-designed CTIS prototype was developed, capable of reconstructing hyperspectral data in real-time across the 600 to 850 nm wavelength range. Significant advancements were made to the system's mechanical and optical components, including the integration of a custom near-infrared diffractive optical element, advanced 3D-printed housings, and an improved image sensor for enhanced near-infrared sensitivity. Rigorous quality control procedures were also established to ensure consistent performance.

To further improve the CTIS system, advanced computational methods were employed. Iterative algorithms, such as the Expectation Maximization (EM) algorithm, were used to enhance reconstruction accuracy and speed. Additionally, artificial intelligence techniques, including convolutional neural networks (CNNs), were developed to enable faster and more accurate imaging, paving the way for video-rate snapshot hyperspectral imaging. A CTIS simulator was also created to model system performance and generate data for training these neural networks, aiding in the technology's refinement.

The effectiveness of the CTIS system was compared with Newtec's line-scan hyperspectral systems, used as benchmarks throughout the research. A study predicting sugar content (\textdegree Brix) and acidity (pH) in grapes demonstrated that while the line-scan system had higher accuracy, the CTIS system provided promising results, particularly for sugar content estimation, indicating its potential for agricultural applications.

Beyond industrial uses, the CTIS system was applied to cultural heritage preservation. It revealed hidden features in Vilhelm Lundstrøm's paintings and enabled pigment identification. Additionally, a hyperspectral microscopy system was developed, utilizing Newtec's Vis-SWIR Oculus camera, to enable detailed spatial and spectral analysis of nanostructures, offering valuable tools for both scientific research and industrial quality control. In summary, this thesis provides a foundation for continued advancement in hyperspectral imaging, contributing to both practical applications and theoretical knowledge. The innovations achieved have the potential to impact various fields, from industrial manufacturing and agriculture to art conservation and scientific research.