

Preface

Over the last decade, terahertz (THz or T-ray) biomedical imaging has become a modality of interest due to its ability to simultaneously acquire both image and spectral information. THz imaging systems are being commercialized, with increasing interest in a biomedical setting. Advanced digital image processing algorithms are greatly needed to assist screening, diagnosis, and treatment. Pattern recognition algorithms play a critical role in the accurate and automatic process of detecting abnormalities when applied to biomedical imaging. This goal requires classification of information-bearing physical contrast patterns and identification of information in images, for example, distinguishing between different biological tissues or materials. T-ray tomographic imaging and detection technology contributes especially to our ability for discriminating opaque objects with clear boundaries and makes possible significant potential applications in both *in vivo* and *ex vivo* environments.

This monograph consists of a number of chapters, which can be grouped into three parts. The first part provides a review of the state-of-the-art regarding THz sources and detectors, THz imaging modes, and THz imaging analysis. Pattern recognition forms the second part of this monograph, which is represented via combining several basic operations: wavelet transforms and wavelet-based signal filtering, feature extraction and selection, along with classification schemes for THz applications. Signal filtering in this monograph is achieved via wavelet-based denoising. The ultrafast pulses generated by terahertz time-domain spectroscopic (THz-TDS) systems, are appropriate for decomposition in the wavelet domain as this can provide better denoising performance. Feature extraction and selection of the THz measurements rely on observed changes in pulse amplitude and phase, as well as scattering characteristics. Additionally, three signal processing algorithms are adopted for the evaluation of the complex insertion loss (CIL) function for example such as lactose, mandelic acid, and DL-mandelic acid: (a) standard evaluation by ratioing the sample with the background spectra, (b) a subspace identification algorithm, and (c) a novel wavelet packet identification procedure. These system identification algorithms enable THz measurements to be transformed to features for THz pattern recognition. Moreover, a feature extraction method

involving the use of AR and ARMA models on the wavelet transforms of measured T-ray pulse responses of ex vivo osteosarcoma cells as well as other biomedical materials is detailed. Classification schemes are carried out via simple and robust schemes, such as the linear Mahalanobis distance classifier and the nonlinear support vector machine (SVM) classifier. In particular, SVMs are used as a learning scheme to achieve the identification of two classes of RNA samples and multiple classes of powered materials.

The past decade has witnessed the tremendous development of THz instruments for detecting, storing, analyzing, and displaying images. THz-TDS is a broadband technique that generates and detects THz radiation in a synchronous and coherent manner. By contrast, the newly developed THz quantum cascade laser (QCL) is a narrowband radiation source that provides potential for realizing compact systems, producing image data with higher average power levels. The third part of this monograph discusses methods to improve the capability of both broad- and narrowband THz imaging, driven by computer-aided analytical techniques. A wavelet-based reconstruction algorithm for terahertz computed tomography (THz-CT) is represented to show how this algorithm can be used to rapidly reconstruct the region of interest (ROI) with a reduction in the measurements of terahertz responses, compared with a standard filtered back-projection technique. These reconstruction algorithms are applied to the analysis of acquired experimental data and to locally recover the two-dimensional (2D) and three-dimensional (3D) structures of several optically opaque objects. Moreover, a segmentation technique based on two-dimensional wavelet transforms is investigated for the identification of different materials from the reconstructed CT image.

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