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EDITORIAL

Photon Counting: Detectors and Applications

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Over the last few years, photon counting detectors (PCDs) have made the transition from research lab to clinical prototypes and are on the verge of FDA clearance for commercial computed tomography (CT) scanners. By logging each individual photon into one or more energy bins, such detectors offer significant potential advantages over traditional energy-integrating detectors (EIDs). EIDs simply sum the energy deposited by all the photons interacting during a given sensing interval, making it impossible to distinguish the energy of the individual photons. Worse, the signal is energy-weighted, which overemphasizes the higher-energy photons that typically carry the least tissue contrast information. Finally, this integrated, non-optimally weighted signal is then read out through electronics that contribute additional electronic noise.

By contrast, PCDs attempt to sense the individual pulse created by each interacting photon, comparing it to one or more thresholds to distinguish real events from noise and, in spectral PCDs, to assign photons to one or more energy bins. Such spectral bins allow objects to be decomposed quantitatively into multiple tissue and contrast agent materials, allowing for new kinds of studies such as virtual non—contrast exams, where iodinated contrast agents can be removed computationally from images, obviating the need for a second pre-contrast scan. PCDs have also shown promise for phase X-ray retrieval methods and fast spectroscopic methods.

Despite their promise, PCDs face challenges. At high count rates, the pulses pile up faster than the electronics can process, leading either to dead time or erroneous energy estimates. A common way to reduce the count rate per pixel is to make the pixels smaller, which has led to ultra-high resolution CT, a mode that many clinicians find just as promising as the spectral exams. PCDs also suffer charge sharing between pixels that compromises spectral resolution. These distortions (in particular charge sharing) can be partially corrected with changes in the detector hardware. However, the distortions are coupled with other spectral distortions due to beam hardening, fluorescence from the sensor material, and spectral changes in object scatter. Thus, the benefits of PCDs can be flux dependent and significantly lower than what is theoretically predicted unless accurate correction methods are implemented.

The papers in this JMI special issue span a range of topics of interest in PCD research. Some address fundamental questions about detector operations, such as choosing the number of energy bins in the paper by Taguchi or assessing detectors under pileup conditions in the paper by Leibold et al. Other papers, such as those by Fan et al. and Liu et al., evaluate the use of PCDs in new commercial scanners. A set of papers contributes to algorithmic work in denoising (Chang et al.) or improved spectral correction, optimization, and quantification (Wang et al. and Luna and Das).

Looking forward, papers by DeBrosse et al. and Jadick et al. consider the potential for non-spectral PCDs in comparison with or combination with emerging imaging modalities such as x-ray fluorescence CT and dual energy kilovoltage-megavoltage CT. Finally, Larsson et al. consider the use of PCDs in an important clinical application: estimating proton stopping powers in the context of proton radiotherapy. It seems inevitable that PCDs will soon find widespread use in clinical and industrial imaging and these papers provide a timely snapshot of this exciting transition.
