Abstract

C-arm x-ray systems equipped with energy integrating detectors (EIDs) are the primary workhorses for endovascular and percutaneous image-guided interventions (IGIs) and are capable of both real-time planar imaging as well as cone-beam CT. Despite its clinical success, technical limitations of the EID limit the achievable image-quality from C-arms for low-contrast or ultra-high-resolution (UHR) imaging tasks. In addition, commercial C-arm systems are not capable of spectral imaging, for example, to discriminate between different materials such as iodine and calcium. These limitations are in part due to the energy integration mechanism, where the x-ray-induced signal in the detector is integrated over an entire image frame, and thus energy information for each x-ray interaction is lost; additionally, the unwanted influence of electronic noise contributes to this integrated signal and can result in increased noise in the final image. The indirect conversion scintillator sensor that most FPDs are equipped with also limits the achievable spatial resolution and has undesirable lag properties that can negatively impact image quality. In comparison to EIDs, photon counting detectors (PCDs) process each x-ray photon interaction individually, and thus can introduce spectral capabilities by measuring the charge induced by each photon interaction; this same energy thresholding mechanism enables the influence of electronic noise on the photon counts measurement to be removed. PCDs also have negligible lag effects due to the necessity for fast signal processing to count individual photons, which in practice is accomplished in medical x-ray imaging by using direct conversion semiconductor sensors. Semiconductor-based PCDs also have the potential for UHR imaging by reducing the spatial spreading of information carriers in the sensor compared to scintillators. To introduce the benefits of PCDs to the interventional suite for IGIs, this thesis work presents the development of a prototype photon counting C-arm system with a semiconductor-based PCD mounted onto a clinical C-arm gantry and the utilization of a narrow-beam geometry to reduce scatter and cone beam artifacts. Initial phantom and *in vivo* imaging studies demonstrate the potential non-spectral image-quality benefits for low-contrast CT imaging tasks, as well as added spectral imaging utility offered by the PCD. To compensate for the reduced field of view along the longitudinal direction from the use of a narrow-beam geometry, multi-sweep scan protocols were used to extend the volumetric coverage of the PCD C-arm prototype; UHR capabilities were also developed to take advantage of the properties of the semiconductor-based PCD. Additionally, proof of concept experiments were performed to validate a novel detector design that combines a smaller central PCD with the surrounding EID to facilitate the translation of PCD C-arm technology into clinical use without introducing operation or workflow issues. Lastly, a method to utilize total induced charge in a PCD to correct for photon count loss and spectral distortions caused by pulse pile-up was developed and validated.