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Evolution of Data Acquisition and Processing in Medical Imaging with Radiation

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With the discovery of X-rays and radioactivity more than a century ago, the need for data acquisition and processing soon became one of the foundations of medical imaging. Contrary to the early devices where simple integration of the radiation signal over time was the way to build contrast in images, modern imaging systems rely on the detection and real-time characterization of every quanta of radiation to extract relevant information for forming images reflecting underlying physical parameters. The most common parameters of interest in imaging modalities using ionizing radiation, such as positron emission tomography (PET) and X-ray computed tomography (CT), are position of interaction, energy and time. Traditionally, such information was extracted through pulse shaping and processing with analog components prior to digitization and data acquisition. Nowadays, most systems rely on early digitization of the signals by sampling with free-running analog-to-digital converters and by replacing analog processing with real-time digital algorithms implemented in high-density FPGA and DSP. While such fully digital data acquisition architecture improves flexibility, scalability and upgradability, future requirements make this approach impractical due to performance limitations, power management constraints, and prohibitive cost. For instance, the number of channels had to be raised from the few hundred of early devices to several tens of thousands to reach sub-mm spatial resolution in PET. Similarly, the coincidence time resolution had to be improved from tens of ns to the few hundred ps regime for achieving time-of-flight measurement. The introduction of single-photon counting spectral CT requires individual events no only to be counted, but the energy to be simultaneously recorded. New technological advances must be sought to cope with these stringent requirements. The challenges to reach these next frontiers in medical imaging will be reviewed with special emphasis on the significance for real-time data acquisition and processing.

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