The GigaCT: Advancing Photon-Counting CT for Next-Generation Spectral Imaging

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Introduction

Computed tomography (CT) has revolutionized medical imaging, yet conventional CT systems utilizing energy-integrating detectors (EIDs) face inherent limitations in spectral information and material differentiation. The emergence of photon-counting detectors (PCDs) promises to overcome these challenges, enabling energy-selective and thus material-selective imaging that can enhance diagnostic capabilities across clinical and research applications. In addition, the much higher spatial resolution of PCDs leads to higher accuracy in many areas of medical diagnosis. However, current photon-counting CT systems are constrained by data throughput bottlenecks and spectral resolution, which not only limit their performance but also their utility in many clinical imaging scenarios.

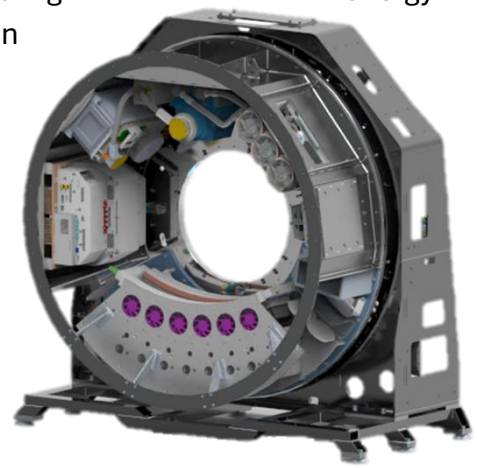

Fig. 1: GigaCT system rendering

The GigaCT: System Overview

The GigaCT represents a novel prototype photon-counting CT system designed to address the data transfer and spectral resolution limitations of existing technologies. Featuring a state-of-the-art architecture, the system achieves a data transfer rate of 320 Gbit/s, supporting high-resolution imaging with a pixel size of 150 µm and six energy bins per pixel. The gantry, installed at the Technical University of Munich (TUM) in Germany, integrates advanced X-ray generation components, including the Varex MCS-

7500 rotating anode tube (100 kW max power, 140 kV peak voltage, and magnetic focusing), and a detector arc composed of 48 Varex Pyxis modules providing a total active area of 936 x 77 mm^2 and a total of over 3 million pixels.

Technical Innovations

Key innovations in GigaCT include a parallel data acquisition system utilizing a Varex developed high speed acquisition system and a Schleifring proprietary ultra-fast parallel data transfer system using eight GigaCAP HD transmitters and nine receivers, proprietary data routing, and FPGA-based control units as well as an innovative liquid cooling system for the detector. The system's slipring technology supports high-speed, uni-directional image data transfer, and bi-directional configuration & control. The TUM server infrastructure achieves writing speeds of up to 484 Gbit/s. Detector modules employ CdTe material with 1.6 mm thickness, charge sharing correction, and ASG support, allowing to operate at frame rates of up to 10,000 fps (2x2 binned) – while supporting up to six energy bins per pixel.

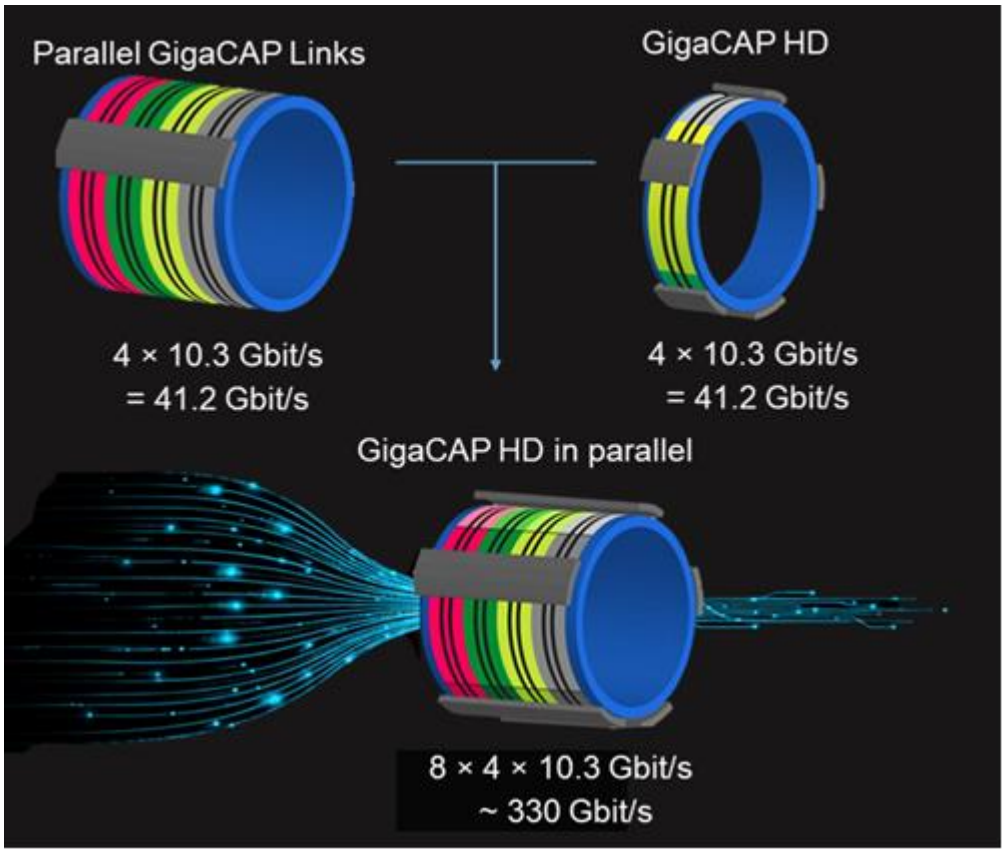

Fig2: Slip ring data transfer architecture of GigaCT provided by Schleifring GmbH

Performance and Early Results

Initial tabletop imaging tests have demonstrated promising results, with corrected projections processed using Varex proprietary CST software to address challenges such as pixel and material inhomogeneities as well as geometric corrections. Comparative

studies between a prototype PCD tabletop system and conventional EID-CT scans have highlighted superior spatial resolution and indicated material decomposition and spectral response, particularly in distinguishing different tissue types. The collaboration with TUM will lead to further enhancements calibration, correction, reconstruction, and material segmentation algorithms, as well as first pre-clinical demonstration experiments on human specimens.

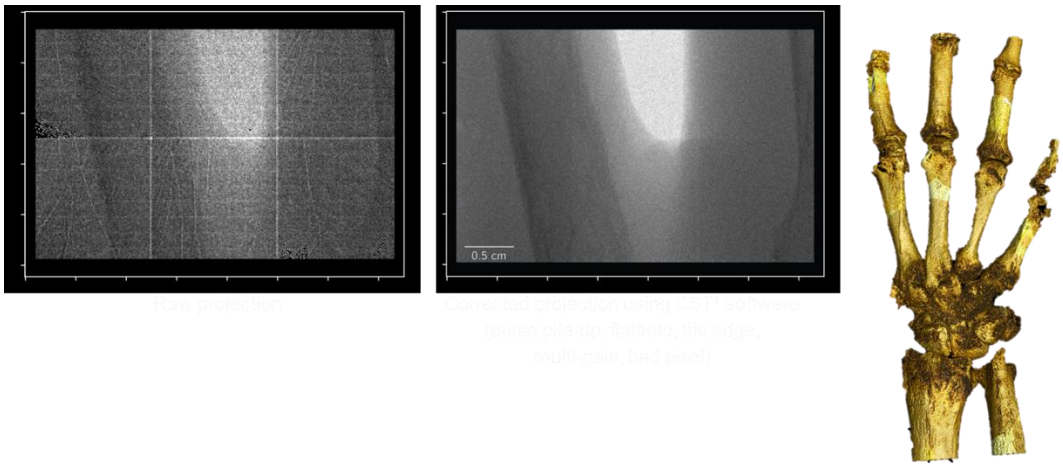

Fig.3: Raw data from a Pyxis detector module (left), corrected data using Varex CST software and 3d rendered high resolution image of a hand phantom (please note: data acquired previously on a tabletop setup).

Clinical and Research Applications

The GigaCT is positioned as a research platform, enabling exploration of photon-counting CT applications in cardiovascular imaging, oncology, musculoskeletal medicine, and material analysis. Its high spatial resolution and spectral capabilities support e.g. delicate bone structure visualization, improved soft tissue contrast, and dynamic perfusion studies. The system is designed to push the limits of what is possible in Photon Counting CT (PCCT) today, both in clinical and non-clinical applications

Outlook

Looking ahead, further system optimization will focus on dedicated acquisition materials separation and reconstruction protocols, detector parameter optimization, and user interface development. The ongoing assembly and testing of the full detector arc will facilitate broader research into multi-contrast agent differentiation, virtual mono-energetic imaging, and reduced-dosage scans. The GigaCT's data architecture and advanced imaging capabilities mark a significant step towards next-generation spectral CT, with the potential to transform both medical diagnostics and material science.

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