



Hardware Integration and Characterization for Dual-Energy X-ray Fluoroscopy in ExacTrac Dynamic

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Purpose

This work aims to develop and characterize a dual-energy (DE) fluoroscopy imaging setup for integration into the ExacTrac Dynamic system, enabling real-time markerless tracking of liver, lymph node, and pancreatic tumours within the “Intelligent Tumor Tracking for Radiotherapy” (INSIGHT) project.

Materials and Methods

- Two DE strategies were assessed: dual-layer detection and fast kV switching.
- ExacTrac Dynamic was upgraded with a new X-ray generator, source, and flat-panel detector to enable the selected DE fluoroscopy approach.
- A new control architecture was established using EtherCAT terminals for communication between the source, detector, and generator, supported by a UI for Image acquisition management.
- The control system was used to realize a technical DE fluoroscopy acquisition sequence, programmed in TwinCAT 3.
- Detector performance was characterized across binning modes using MTF, NNPS, and DQE to identify suitable acquisition settings.

Results

The upgraded ExacTrac Dynamic system was successfully integrated, enabling dual-energy fluoroscopy with synchronized control of the source, generator, and flat-panel detector. Among the evaluated acquisition approaches, fast kV switching was selected for its straightforward integration into the existing setup. Detector characterization showed that the Azure 3131Z-100 provided higher spatial resolution and competitive DQE compared with the clinically used PaxScan 3030DX. The 1×1 mode achieved up to approximately twice the spatial resolution, while 2×2 binning, providing a comparable effective pixel size to the clinical detector, maintained an improved DQE.

Conclusion

This work demonstrates the feasibility of integrating dual-energy X-ray fluoroscopy imaging into the updated ExacTrac Dynamic platform. The developed framework provides the basis for future optimization of DE fluoroscopy and its potential application in improving soft-tissue visualization for image-guided radiotherapy of moving targets in the thoracic and abdominal region.

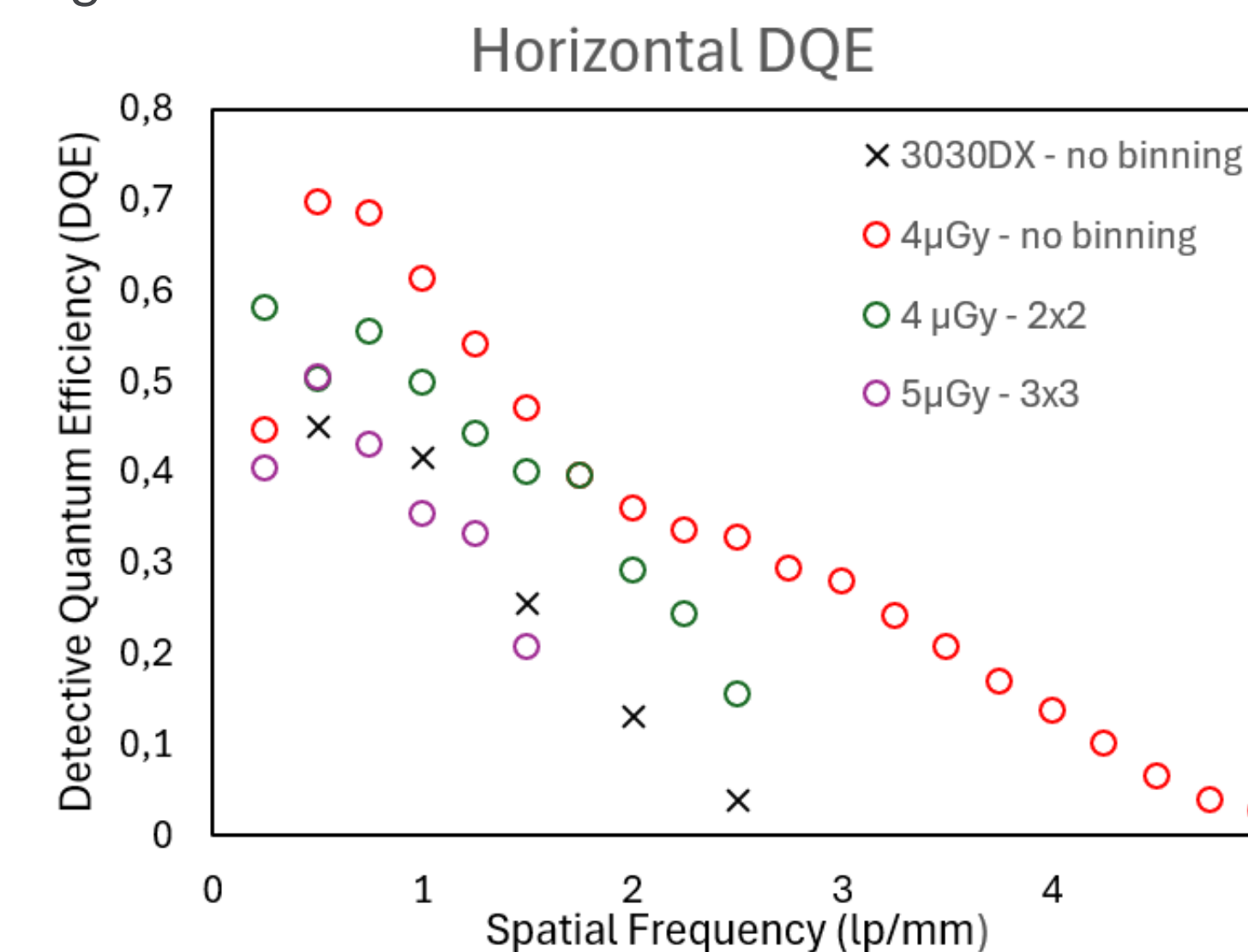


Figure 1 DQE comparison between the clinical ExacTrac Dynamic detector (PaxScan 3030DX) and the prototype Azure-3131Z-100 detector for different acquisition modes.



Figure 2 Soft-tissue basis image of the Lungman phantom obtained by DE decomposition using a 60/125 kV acquisition pair with 2 mm Sn filtration at HE

Outlook

Ongoing work focuses on optimizing DE acquisition parameters, including additional Sn filtration for improved spectral separation and the development of a robust material decomposition algorithm. Experimental validation of the fluoroscopy sequence is pending the availability of a functional phantom, which is currently under development.