Simulation-Driven Optimisation of Mobile 3D X-ray Imaging Systems:

A multi-fidelity digital-twin workflow to optimise mobile chest tomosynthesis design, balancing coverage, dose, image quality and engineering constraints

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MOTIVATION

Mobile chest tomosynthesis can bring 3D imaging to the point of care.
System design requires balancing competing factors:

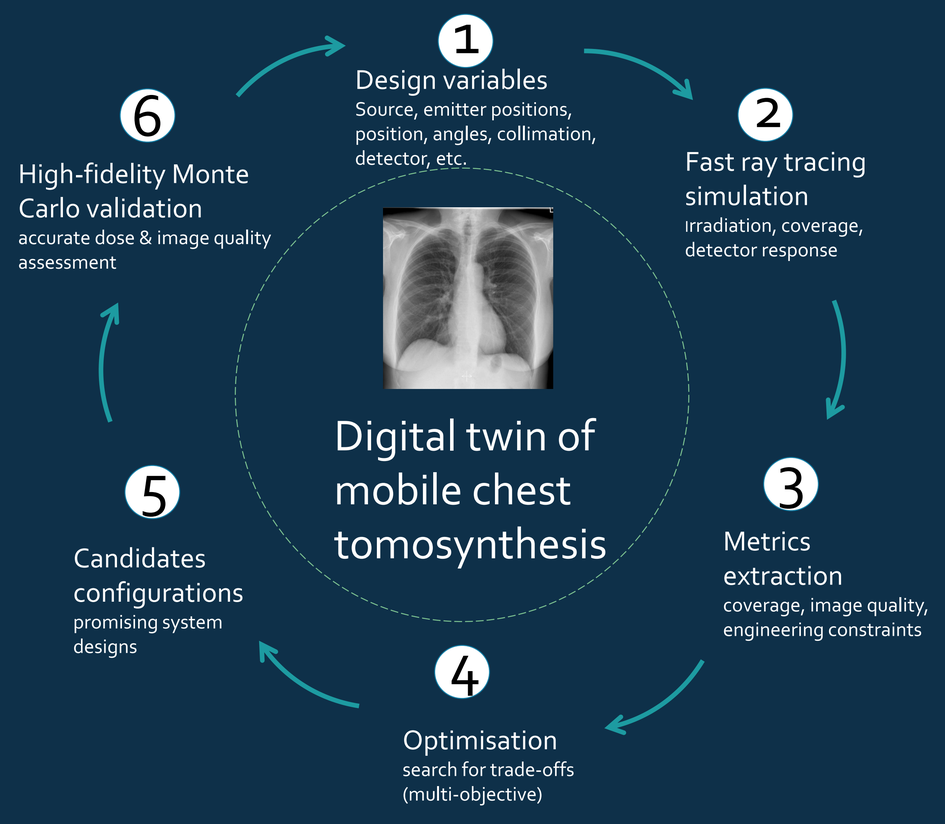
Patient coverage
maximise anatomy imaged

Radiation dose
Keep dose as low as reasonably achievable

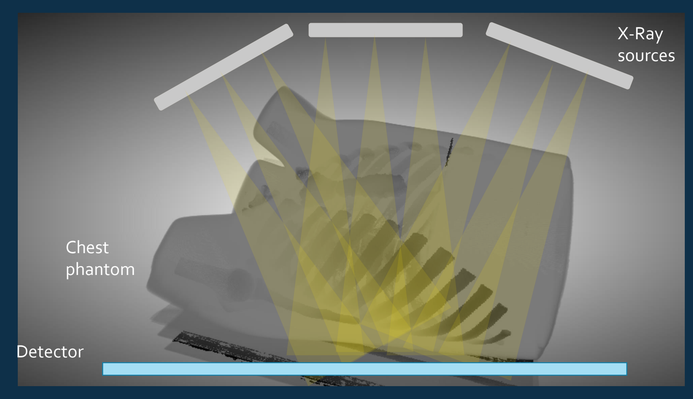
Image quality
Ensure diagnostic-grade reconstructions

Engineering constraints
Geometry, mobility, space, detector size, collimation

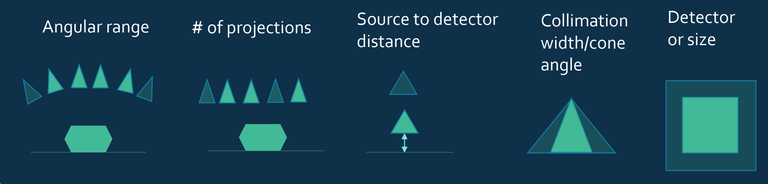
DIGITAL-TWIN OPTIMISATION WORKFLOW



SYSTEM GEOMETRY

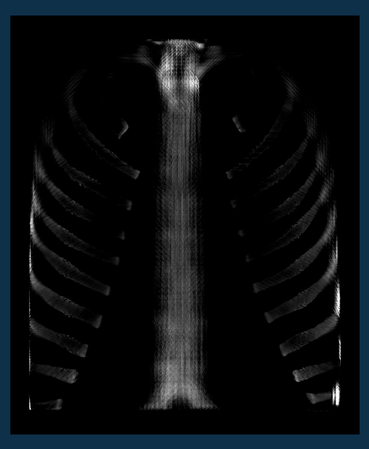


Design variables



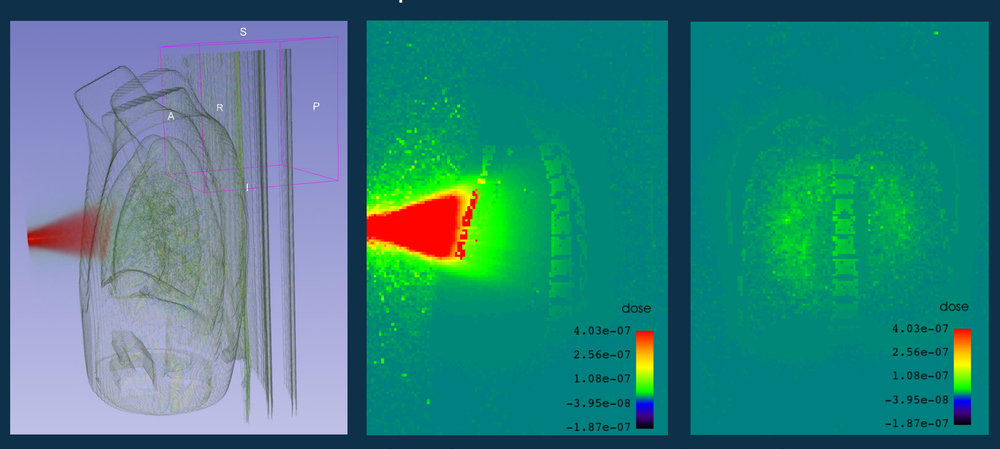
SIMULATION OUTPUT EXAMPLES

A: Simulated image



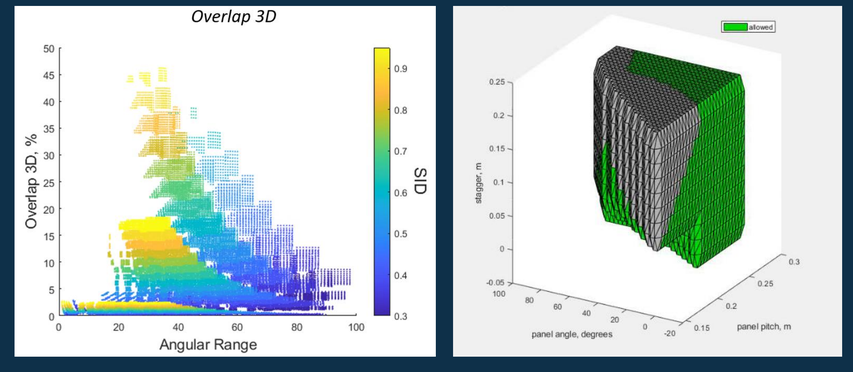
Reconstrued slice of the simulated images of bone structure using ray tracing image

B: Deposited dose



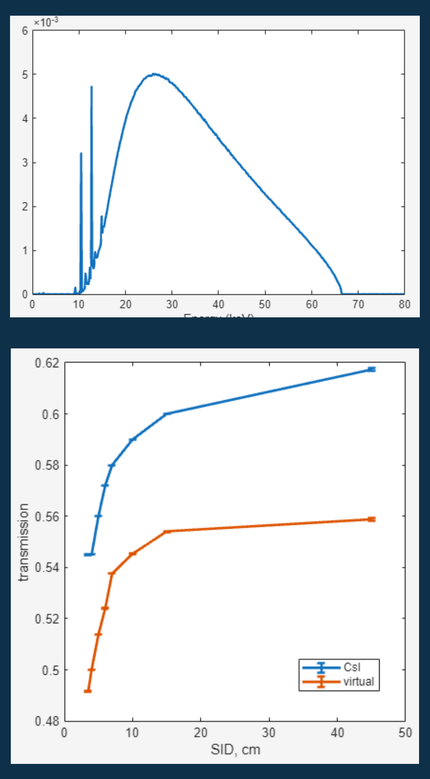
Dose maps calculated using Monet Carlo simulations

OPTIMISATION TRADE-OFFS



Optimisation explores thousands of configurations to identify designs with the best balance of dose and quality

DETECTOR AND SOURCE



Both detector and source has impact on the final image

CURRENT PROGRESS

Geometry definition & parametrisation
chest phantom, source/detector models simulated with Monte Carlo

Fast ray-tracing framework
Irradiation and coverage metrics, angular sampling studies

Initial optimisation studies
Candidate ranking using image quality and dose metrics

Preparation for high-fidelity Monte Carlo
Workflow integration and validation plan

EXPECTED IMPACT

Faster virtual prototyping
reduce time and cost of hardware iterations

More systematic design-space exploration
Identify promising system configurations efficiently

Informed trade-offs
Balance between image quality, dose, coverage and practical considerations

Better patient care
Support the development of advanced, sustainable mobile imaging systems

More broadly, the approach demonstrates how simulation-driven design can support efficient development of advanced medical-imaging systems.

Innovations for a Sustainable Tomorrow