Measurement of bone quality using multispectral X-ray imaging with Medipix3 detectors

Layman's summary

Osteoporosis is a common disease characterized by a decrease in bone density that indicates weakness of bones and an increased risk of fractures, negatively impacting a person's quality of life. Doctors often use Bone Mineral Density (BMD) measurements to diagnose this disease. However, current methods to evaluate bone quality have limitations as they do not consider all factors influencing risk of fracture. This thesis explores the potential of Medipix3 detectors, which can capture X-ray images with high precision at multiple energy levels. The goal is to improve our understanding of bone composition and density in order to provide an earlier and more accurate diagnosis of osteoporosis.

The pipeline described in this research started by calibrating the Medipix3 detectors' energy thresholds to accurately measure the effective X-ray energy reported by the detector. This calibration involved using a known plastic (PEEK) to create a reference for energy levels. Then, plastic samples were imaged to test the accuracy of the calibration and evaluate any shape distortions in the images.

Next, the thesis focused on material decomposition, a process for identifying different substances within an object. For this, three materials were glued together (Graphite, Teflon, and PVC) and imaged to assess how well the Medipix3 detectors can distinguish these materials based on their X-ray properties. The composition of the object was calculated by solving a system of equations based on the physics of material behaviour.

Finally, the thesis shows an example of bone imaging. A pig bone sample was imaged to see if the selected energy ranges were suitable for studying bone composition.

Findings indicate that Medipix3 detectors have great potential to better understand bone density and composition. The calibration method improves the shape reconstruction of PEEK plastic sample, and the material decomposition pipeline shows to perfectly distinguish materials in a simulation dataset. However, the material separation calculations give inconsistent results for the three material sample, which indicates that some assumptions and approximations might introduce errors that have a great impact when solving the equations. Effects such as Compton scattering should be more specifically studied.

In summary, while this setup is still in experimental phase and requires further study before being applied in clinical practice, great progress was made, showing the potentials of Medipix3 detectors and outlining the further steps needed for improvement. This research demonstrates how technology used in particle physics can have exciting applications in medicine, paving the way for earlier and more accurate osteoporosis diagnoses in the future.