Measurement-based Detector Characteristics for Digital Twins in aRTist

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Various software products for the simulation of industrial X-ray radiography have been developed in recent years (e.g., aRTist 2, CIVA CT, Scorpius XLab, SimCT, Wilcore) and their application potential has been shown in numerous works. However, full systematic approaches to characterise a specific CT system for these simulation software products to obtain a truthful digital twin are still missing. In this contribution, we want to present approaches to obtain realistic grey values in X-ray projections in aRTist 2 simulations based on measured projections. In aRTist 2, the displayed grey value of a pixel is based on the energy density incident on that pixel. The energy density is calculated based on the X-ray tube spectrum, the attenuation between source and detector as well as an energy-dependent sensitivity curve of the detector. The first approach presented in this contribution uses the sensitivity curve as a free modelling parameter. We measured the signal response at different thicknesses of Al EN-AW6082 at different tube voltages (i.e., different tube spectra). We then regarded the grey values displayed by these projections as a data regression respectively an optimisation problem and obtained the sensitivity curve that is best able to reproduce the measured behaviour in aRTist 2. The resulting sensitivity curve does not necessarily hold physical meaning but is able to simulate the real system behaviour in the simulation software. The second approach presented in this contribution is to estimate the sensitivity curve based on assumptions about the characteristics of the scintillation detector (e.g., scintillator material, scintillator thickness and signal processing characteristics). For this approach, a linear response function (linear relationship between the deposited energy per pixel and the resulting grey value) is assumed. If the detector characteristics, which affect the simulated deposited energy, are properly modelled, the slope and offset of the response function to match the measured grey values should be the same for different tube spectra. As the offset is constant and given by the grey values measured at no incident radiation, the slope is the remaining parameter to evaluate the success of the detector modelling. We therefore adapted the detector characteristics by changing the detector setup until the slope was nearly the same for all measured tube spectra. We are aware that the resulting parameters of the scintillator material and thickness might not the real one, but with those modelling parameters we are able to simulate realistic grey values in aRTist 2. Both of those approaches could potentially be a step forward to a full systematic approach for a digital twin of a real CT system in aRTist 2.