EXPANDING THE DYNAMIC RANGE OF FLAT-PANEL DETECTORS USED IN SMALL-ANIMAL CONE-BEAM CT: AN AUTOMATED DUAL-EXPOSURE TECHNIQUE

Poster no: 019

Sisniega A[1], Vaquero J.J[1], Vidal-Migallón I [1], Abella M [1], Desco M[1]
1Unidad de Medicina y Cirugía Experimental. Hospital General Universitario Gregorio Marañón. Madrid. Spain

Introduction: Cone-Beam micro-CT (CBCT) is usually employed in small animal imaging as a stand-alone technique, or to provide complementary anatomical information for other molecular imaging modalities such as PET or SPECT. However, the Flat-Panel (FP) semiconductor detectors commonly used in CBCT suffer from a limited dynamic range, compromising image quality when a sample has both low and high density materials (like a brain inside a skull, or metallic probes inside the body). Dual-exposure, single-energy techniques (acquiring several images using X-ray exposures with differing energy but the same spectral characteristics) can extend the dynamic range of these detectors. There are some previous works addressing this issue, using dual-exposure [1] or hardware modifications [2]. We introduce here an automatic dual-exposure technique based on a weighting scheme that takes into account both detector and sample properties.

Methods: The sample is scanned twice. The first scan uses the maximum X-ray flux that does not saturate the detector in soft-attenuating areas; the X-ray source anode current for the second scan is calculated from the average histogram of the angular projections obtained in the first scan. Assuming a linear detector response [3, 4], the algorithm calculates the new current value to shift the 75% value of the total histogram to the high-gain region of the detector response curve. Both scans are subsequently combined using the multi-exposure technique described in [5], adapted to X-ray FP detectors. The value for pixel j and acquisition i (i=1, 2) is modelled as Yij=Ai/(eμx)j + Nij, where Ai is the ratio between the first and the ith acquisition currents (exposures), and Nij is an additive noise term. We assume that each acquisition follows an independent Gaussian variable. The new pixel value is the result of a Maximum-Likelihood calculation based on the joint probability density function (JPDF). This JPDF is calculated weighting the raw pixel values as a function of their position on the detector response curve. We have tested the algorithm on data obtained from imaging phantoms and small animals using the Argus PET-CT system (Suinsa Medical Systems).

Results: Multi-exposure images have an extended dynamic range (16 vs. 12 bits), decreasing quantification noise. Thus, imaging a homogeneous PTFE rod the noise level measured as the standard deviation in a multi-exposure projection image is four times lower than in the single-exposure projection image. For the case of an aluminium rod, the noise improvement increases by a factor of five. For reconstructed images, the SNR inside a PTFE rod is three times greater for a multi-exposure scan than for a single-exposure one. Similar increases in performance are also achieved with animal images, where some structures masked by noise in the single exposure acquisition become visible in the combined one.

Conclusions: The proposed method achieves good performance both in phantom and animal scans. Dual-exposure images have a lower noise level and a larger effective dynamic range, achieving a better Contrast to Noise Ratio (CNR) and low contrast resolution. The proposed method could be further extended to a multi-exposure approach. Downsides of these techniques include increased radiation doses and longer acquisition times.

Acknowledgement: This work is supported in part by Ministerio de Ciencia e Innovación (TEC2008-06715 and TEC2007-64731), EU-FP7 project FMTXCT-201792 and CD-TEAM project (CENIT program).

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