Rawdata-Based Higher Order Deep Beam Hardening Correction

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Research for a Life without Cancer

Introduction

With cancer being one of the leading causes for death worldwide, the effort to extend and improve cancer treatment is significant. On-board CBCTs cannot yet be leveraged for treatment planning because of inferior image quality due to artifacts such as x-ray scatter or beam hardening. Commonly, only a water precorrection is applied which leaves secondary beam hardening artifacts whenever there is tissue which is not water-equivalent (i.e. bones).

Materials and Methods

The polychromatic log attenuation reaching a detector element can be modeled as:

$$q = -\ln \int dE\, w(E) e^{-p_{\text{soft}}\psi_{\text{soft}}(E) - p_{\text{bone}}\psi_{\text{bone}}(E)}$$

Here, $w(E)$ is the spectrum normalized to unit area. The energy dependency for different materials can be found in literature [1,2]. p is the line integral through the soft tissue and bone, respectively..

To correct for beam hardening we want to estimate p_{bone} ... ed on the U-Net ... chromatic bone ... olychromatic ... tic projection if all

Der Satz ist nicht fertig.

bones are replaced by standard water. The bone contribution q_{bone} is calculated as $q_{\text{bone}} = q - q_{\text{water}}$. With the assumption

$$r = \frac{p_{\text{bone}}}{p_{\text{soft}}} \approx \frac{q_{\text{bone}}}{q_{\text{water}}},$$

a root finding method can be used to solve

$$q = -\ln \int dE\, w(E) e^{-p_{\text{soft}}\psi_{\text{soft}}(E) - r p_{\text{soft}}\psi_{\text{bone}}(E)}$$

for p_{soft}.

To simulated polychromatic projections clinical CT scans are binary segmented into bone and soft tissue. Then the line integrals are calculated for each material and a semi-empirical tube spectrum [4] is used to calculate. The bone segmentation is used to replace the bones by water and to calculate q_{water}.The network was trained on seven patients and tested on a fully simulated thorax scan of a test patient.

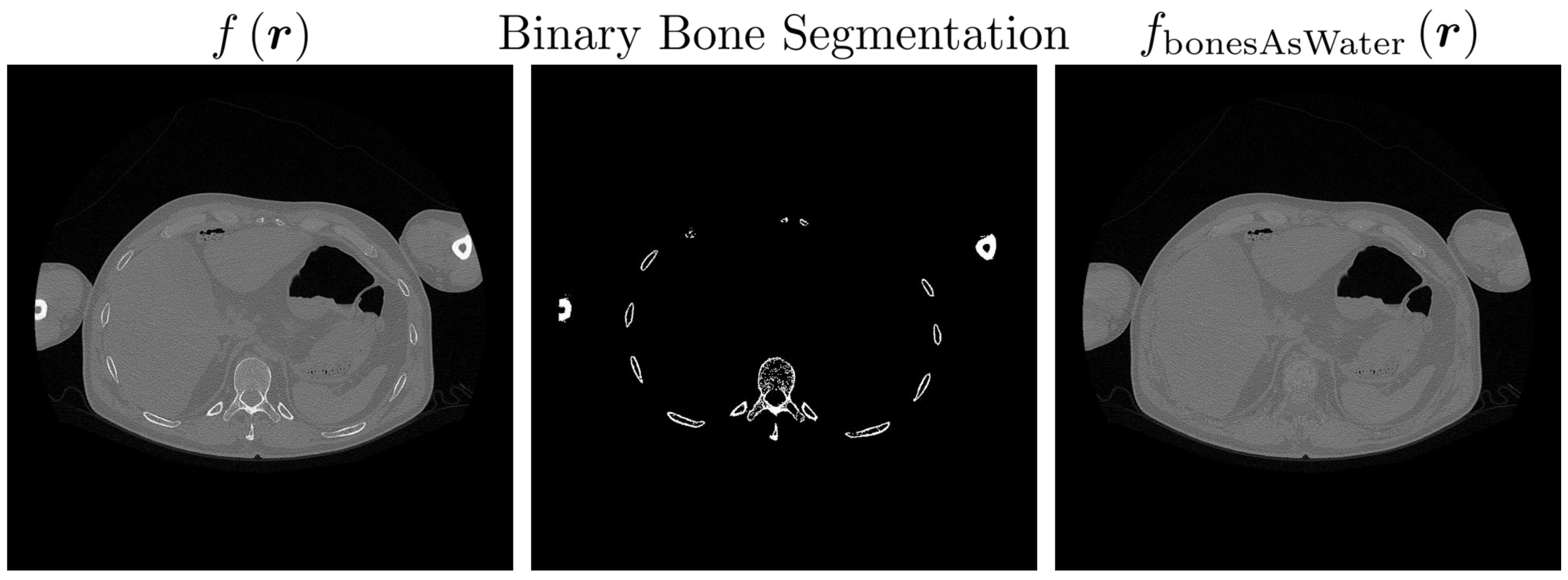

Figure 1: Example slice of a clinical CT used for data generation (left) with the corresponding bone segmentation and the bones replaced by standard water. ***C* = 0 HU, *W* = 700 HU**

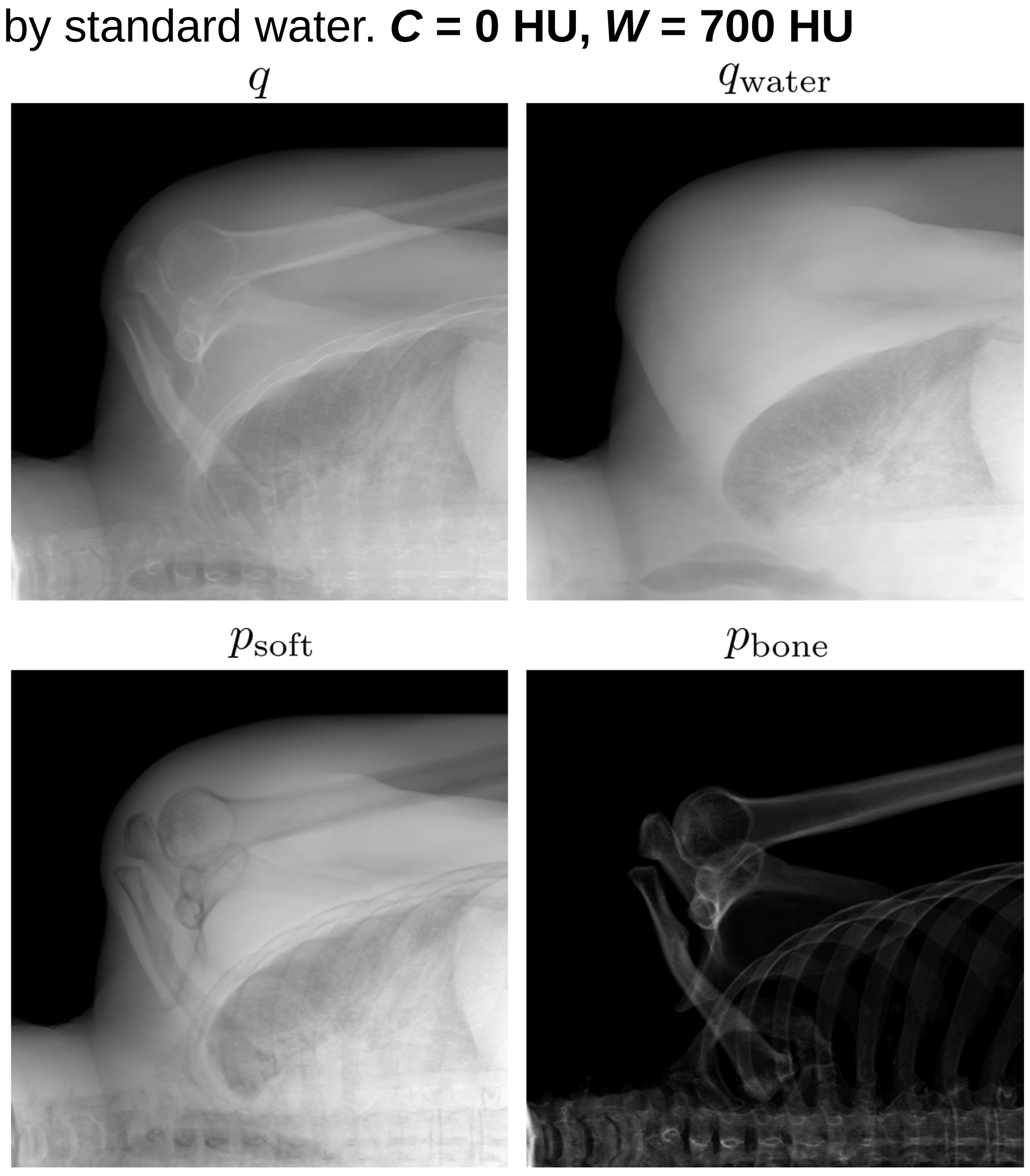

Figure 2: Example line integrals (bottom) corresponding polychromatic projection (top left) and bone free polychromatic projection of . ***C* = 2.25, *W* = 4.5**

Results

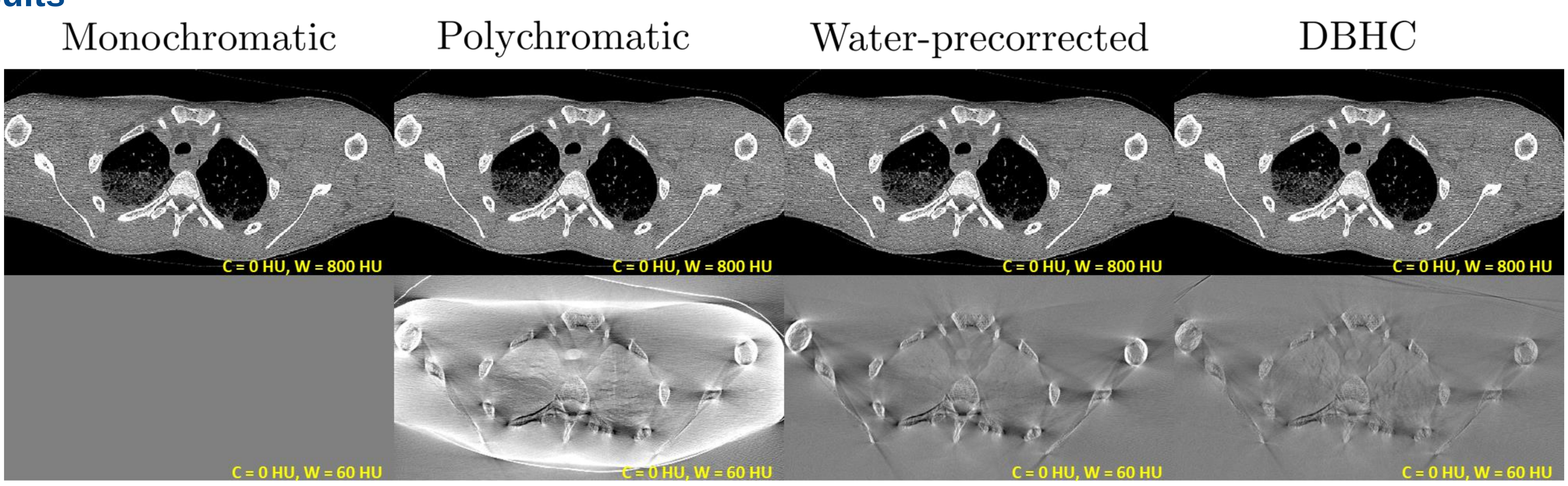

Figure 3: Example slice of the fully simulated test scan. The mean absolute error between the ground truth and the uncorrected (polychromatic) reconstruction, the water-precorrected and our deep beam hardening correction (DBHC) are 3.4 HU, 2.3 HU and 1.7 HU, respectively.

Conclusion

Our proposed, rawdata-based beam hardening correction reduces the error in reconstructed bone, if compared to the classical water precorrection.

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