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# *MATERIAL CHARACTERISATION BY USING DUAL-ENERGY CT*

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**Summary:** Dual-energy Computed Tomography (DECT) can be particularly useful when multiple materials inside a sample need to be distinguished. A DECT method based on Rutherford's DECT theory [1] is presented. This method needs the knowledge of the polychromatic properties of the source and detector of a CT system to characterise the material inside each voxel of a reconstructed 3D volume in terms of composition and density.

## 1. INTRODUCTION

In a reconstructed 3D volume obtained by performing an X-ray CT scan, each voxel contains a reconstructed linear attenuation coefficient visualised by a grey value. This attenuation coefficient $\mu$ is the product of the material and energy dependent local mass attenuation coefficient $\mu/\rho(E)$ and the local density $\rho$ of the material. For this reason, two materials of different composition and different density can have a very similar grey value in a reconstructed volume. As such, when multiple materials are present it may occur that no specific scan settings can be found in which all materials can be distinguished. In such a case dual-energy CT (DECT) can be a solution. Here a DECT method is proposed in which a priority knowledge of the polychromatic properties of the scanning system is used to perform a material identification and density determination inside each voxel of the reconstructed volume.

## 2. EXPERIMENTAL METHOD

It can be shown that the reconstructed attenuation coefficient inside a voxel of the reconstructed volume can be expressed in first order as

$$\mu = \rho \frac{\sum_i S_i D_i \ \mu/\rho(E_i)_z}{\sum_i S_i D_i}.$$

In this equation $S_i$ and $D_i$ represent the photons emitted by the source and the mean energy detected by the detector per incident photon in photon energy bin i, respectively. These functions can be determined by Monte Carlo simulations as described in [2]. The composition of the material, indexed by z, is characterised by the mass attenuation coefficient $\mu/\rho(E_i)_z$, which is also energy-dependent. Together with the density $\rho$, these are the two unknown parameters in the above equation. By combining two CT scans taken with different energy spectra, a solution for the composition and density in each voxel can be obtained by minimising the following equation for each voxel in the 3D volume by varying the composition ( represented by $\mu/\rho(E_i)_z$ ) of the material:

$$\frac{\mu_1}{\mu_2} - \frac{\sum_i S_{1,i} D_{1,i} \ \mu/\rho(E_i)_z}{\sum_i S_{1,i} D_{1,i}} \Bigg/ \frac{\sum_i S_{2,i} D_{2,i} \ \mu/\rho(E_i)_z}{\sum_i S_{2,i} D_{2,i}}$$

Further, once the composition is known, the first equation can be used to determine the density inside the corresponding voxel. Contrary to conventional DECT methods which assume a photoelectric part proportional to $Z^4/E^3$ and a Compton part proportional to $\rho Z$, this method reproduces the polychromatic aspects of the real scanner setup to estimate the reconstructed attenuation coefficients.

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## 3. RESULTS

The proposed method is tested on simulated and real data. One example of each is shown in Figure 1. Both were simulated or scanned with the HECTOR setup [3], which is a CT scanner developed by the Ghent University Centre for X-ray Tomography (UGCT). A virtual phantom of which a slice is shown in Figure 1a was used in the simulation tool Arion [2]. This tool generates radiographs which correspond very closely with real radiographs because it takes the energy dependent behaviour of all components and the sample attenuation into account. The reconstructed slices of these simulated scans are shown in Figure 1b and c. The simulations were performed at a tube voltage of 50 and 160 kV, respectively, both with a beam filtration of 1mm Al. From the reconstructed slices a composition and density could be extracted. A slice which represents the composition in the corresponding voxels is shown in Figure 1d. The composition found with the method differs in 1.44 % of the voxels with the ground truth (note that the composition of water and ice is the same).
Furthermore the reconstructed slices of a real scan are shown in Figure 1e and f. A mouse leg was scanned inside a plastic container at HECTOR at a tube voltage of 50 kV and with a beam filtration of 1 and 3 mm Al, respectively. The corresponding composition map is shown in figure 1g. Adipose tissue is represented in grey, muscle tissue in red, cortical bone in yellow, polyethylene in green and air in light blue.
Next to the composition in each voxel, the densities of each voxel can be calculated but these are not shown in the figure. The current disadvantages of the method are that a correct beam hardening correction is necessary to obtain a correct result and that no partial volume effects are taken into account. Although the method is still in development, the first experiments show promising results.

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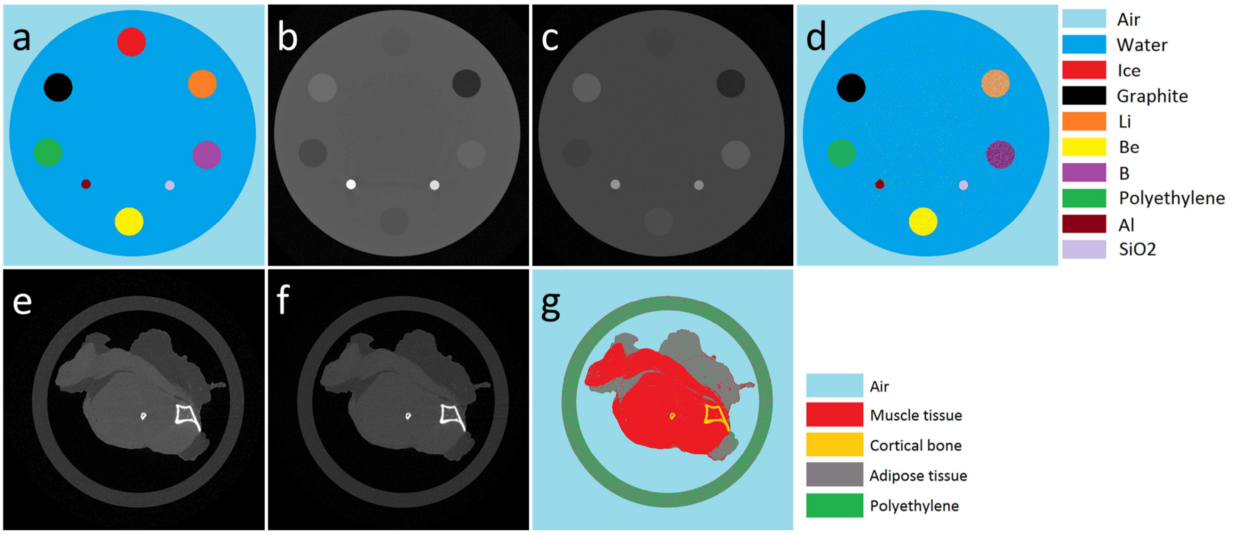


**Figure 1:** (b) and (c) show the reconstructed slices of a simulated CT scan for which a virtual phantom (a) was used. The composition map for the corresponding slice is shown in (d). (e) and (f) show the reconstructed slices of two scans of a mouse leg in a plastic cylinder. In the composition map (g) adipose tissue is represented in grey, muscle tissue in red, cortical bone in yellow, polyethylene in green and air in light blue.