# *Development of the projection-based material decomposition algorithm for multi-energy CT*

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**Summary:** A projection-based method for material decomposition in multi-energy computed tomography is tested on the Monte Carlo simulation. A process of calculation of the material concentration integrals from the detector measurements is studied. Effect of the different experimental effects, such as detector energy response, per-pixel energy calibration, on the material decomposition is discussed.

## 1. INTRODUCTION

Significant development of pixel detectors in multi-energy computed tomography (MECT) allows to explore different approaches to a reconstruction problem. Image-based reconstruction methods are commonly used in MECT due to the simplicity of the procedure, stable results even with significant experimental artifacts. However, image-based algorithms have a variety of limitations that motivate to search for different way to perform reconstruction.

Projection-based methods were successfully used in different cases[1] to achieve a high quality of the reconstruction. The main idea of projection-based material decomposition is to distinguish contribution of different substances by their effect on the spectrum of the transmitted radiation. In this work, a Medipix detector is considered as a source of detected photons energy information. Therefore, a number of detected photons with energy higher than threshold value is known for several thresholds.

The projection-based algorithm consists of 2 stages. In the first stage, known photon counts for different energy thresholds are used to calculate contribution of different materials. For the studied object, a set of basis materials should be chosen. This choice is defined by the field of study. For example, contrast agents for medical scans or heavy metals for ore samples. An optimization problem can be solved for each pixel to determine a contribution of the material - integral of its concentration over the linear trajectory from x-ray source to this pixel. In the second stage, values of the concentration integrals are used to perform a reconstruction of concentration distribution. For this task, a variety of CT reconstruction algorithms can be used.

## 2. EXPERIMENTAL METHOD

The algorithm was initially tested on the Monte Carlo (MC) simulation data. Using Geant4 MC framework [2], an experimental CT setup was simulated. The simulation uses previously measured with Canberra LEGe detector x-ray spectrum and real attenuation curves for materials, includes main types of interaction between photons and matter of the object and energy response of the detector. Simulated object consists of 9 tubes (Fig. 1(a)). First group of three tubes (red) is filled with water, second (green) contains 95% of water and 5% of iodine (percents represent mass concentration), third group (blue) - 99 % of water and 1% of gold. Detector registers photons passing through the object and compares energy of the electron with a threshold values. The result of the simulation is a set of sinograms corresponding to different thresholds (Fig. 1(c), (d) and (e)). Simple model of the energy response is implemented: a random gaussian variable with $\sigma$ proportional to the photon energy is added to the detected value of energy.

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## 3. RESULTS

Values of the material concentration integrals are represented as a set of sinograms for every material (Fig. 1(f), (g) and (h)). The sinograms were reconstructed with the ASTRA [3] implementation of the SIRT algorithm to obtain a set of distributions for all material concentration. Reconstructed slices for all materials were combined to get a color image of the object cross section (Fig. 1(b)). Different color in the image are used to distinguish basis materials. Obtained concentrations of the materials correspond to their values in the simulation: $0.99 \pm 0.25$ for water, $(4.2 \pm 1.1) \times 10^{-2}$ for iodine, $(8.8 \pm 2.3) \times 10^{-3}$ for gold.

This material decomposition method will be tested on the experimental data obtained from a detector based on Medipix chips. Multi-contras phantom, containing iodine, gold, gadolinium etc, will be analyzed. In the course of this work, it is expected to take into account detector response function and effects of per-pixel energy calibration and pile-up due to their great influence on the projection-based material decomposition.

## References


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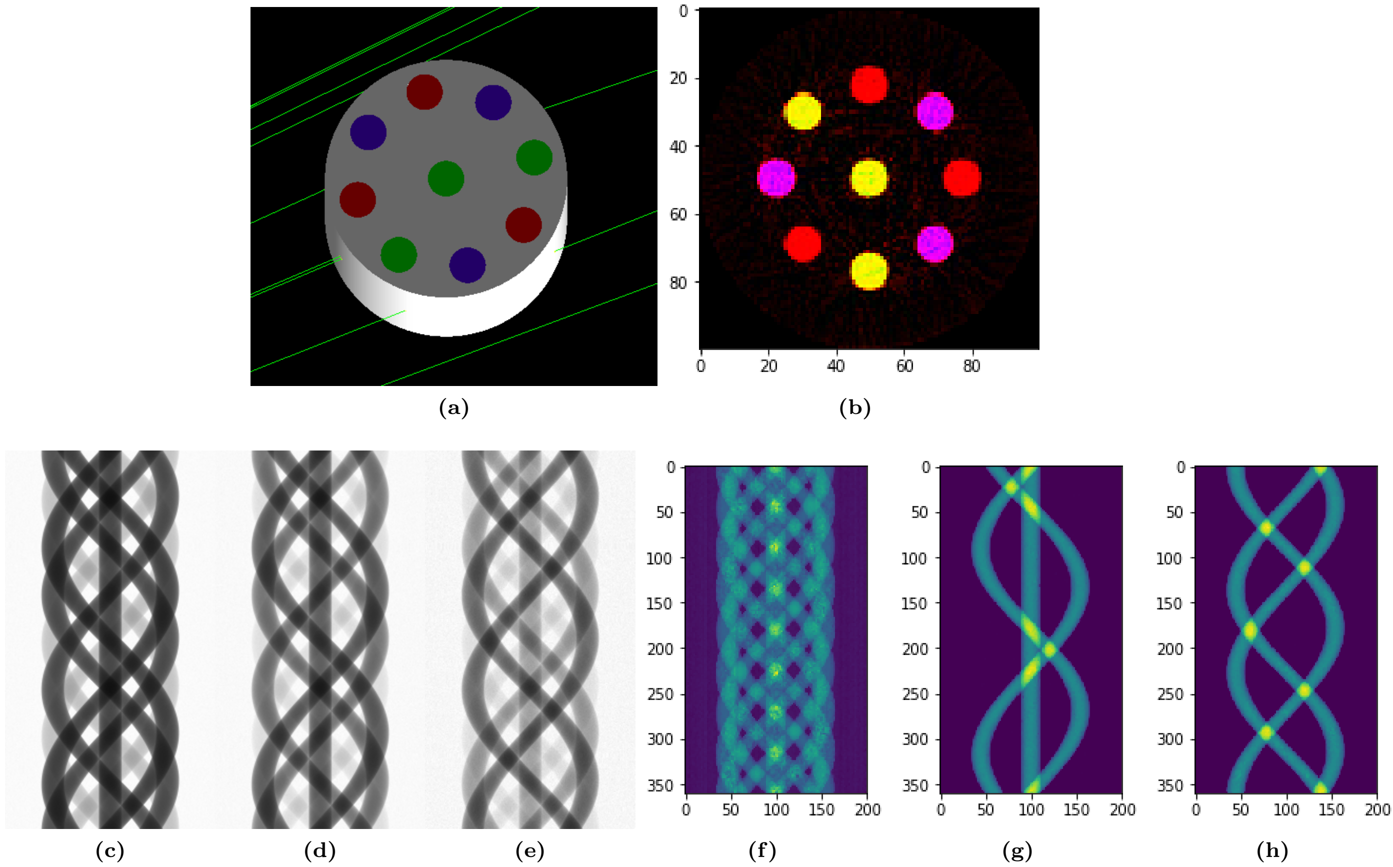


**Figure 1:** (a) Studied object in the Monte Carlo simulation. (b) Reconstructed slice: red channel shows the presense of water, green - iodine, blue - gold. (c), (d) and (e) Sinograms obtained from the detector corresponding to the threshold values of 0 keV, 40 keV and 85 keV. (f), (g) and (h) Material sinograms for water, iodine and gold.