Methods of processing and image compression in an X-ray micro tomographic scanner

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Abstract:

The article is to study operating procedures of an X-ray micro tomographic scanner and the module of 3D-image recovery and analysis of the test sample in particular. Initial data compression and filtering algorithms, based on shadow projections are presented. The main attention of the paper is paid to saving resources of the computer system during the X-ray tomography. This is achieved by pre-processing of the initial shadow projections. Preprocessing includes getting rid of the background noise in the image, which reduces the amount of shadow projections and improves the efficiency of the group compression of shadow projections. The calculations supporting the effectiveness of these methods described, as well as examples of the original and processed images are presented.

Keywords: X-ray tomography, data compression, background noise removing, defect search.

Introduction

X-Ray micro tomography is a layer-by-layer method of study of the internal structure of an object with the aid of multiple radiographic X-rays in different directions, followed by 3D-reconstruction recovery and processing of images. Scanning visualizes the entire internal 3D structure of the object, keeping it safe for other types of research. High-resolution of the model received is another advantage of the X-ray micro tomographic scanning method.

3D-reconstruction requires a large number of high resolution images of the sample, which needs a computer system with advanced performance and capacity of memory resources for storing and processing the data [1].

The input data represents monochrome bitmaps with 16 bit color depth. This means that one pixel is encoded in two bytes of information, which is interpreted as brightness of the pixel.
**Background noise removing from the images**

Removing background noise is an important function of the image processing, which allows to replace homogeneous background areas with single color in order to improve final image compressibility. Finding areas of the image corresponding to the background, allows to get rid of the data containing no useful information.

Each image of a shadow projection areas where there is no shadow of the object studied, if the projection of its section is inscribed geometrically in the projection area of the detector matrix. In the ideal case, when radiation of as X-ray tube is totally homogeneous and the detector has no residual luminescence of the screen, on which the radiation falls, the shadow image area will have one brightness value. Obviously, this value is the maximum brightness of image points, as all other areas correspond to the shadow of the object, the radiation at these points will be absorbed by the object (assuming that the object under study has a higher density of X-rays than the environment).

In practice, the image of the shadow projections are very noisy. The main noise sources - inhomogeneous X-ray tube radiation and the residual luminescence of the detector screen. As a consequence, the image of shadow projections, both in the background and in the shadow areas of the object have a wide range in the brightness level. The basic idea of a method determining the area of the image corresponding to the background noise, is to break the image into sections and then analyze its sites.

Operating mode of the tomographic scanner includes such specifications as:

1) The density of pixels and the resolution of the detector;
2) Radiation power X-ray tube;
3) Filters (generally aluminum or copper ones) and the materials applied.

The specifications calculated are:

1) The minimum brightness of the pixel;
2) The maximum brightness of the pixel;
3) The average brightness of the pixel;
4) The mean square deviation of the pixel brightness.

Among all the areas of the image, belonging to the background, two areas - the area with highest average brightness and lowest dispersion (**background area**) and the one with lowest average brightness points and lowest dispersion (**object area**) – are selected.
To improve the speed and quality of background noise removal it is convenient to define a boundary value of pixel brightness the way it will be possible to interpret any point of greater brightness as background and replace it with the highest possible brightness value (65535 for 16-bit color).

If you select the minimum brightness as the boundary brightness for the points of the background area, a small part of the background noise belonging to border areas of the object will remain on the image, as the area close to the boundary is noisier than in the background. If you select maximum brightness as boundary brightness of the object, then some part of the image pixels belonging to the object on the border with the background will be interpreted as background and replaced with the maximum brightness. Due to the statistical averaging, both ways for removing pixels may lead to the same results (in terms of accuracy required for reconstruction) and improve the quality of reconstruction.

Figure 1 – Shadow projection images

Figure 2 – Shadow projection images after the removal of background noise.

Figure 1 shows the typical images of shadow projections received using an X-ray microtomographic scanner, Figure 2 - modified images with background noise removed. [2,3].
Data compression

In conditions of increased requirements for performance and system uptime, as well as because of the great specificity of images (high resolution with a large number of points) methods of lossless data compression with high speed are in demand.

There are various methods of data compression without sacrificing. The fastest and easiest to implement is RLE- compression: coding of the series of repeated values, which can be done in one pass.

If the original image is represented by a sequence of double-byte characters (16 bits), the values of which range from 0 to 65535, then after the construction of the difference each point must be encoded by 17 bits, as the values must range from -65535 to 65535.

Obviously, all of the N points there will be the following distribution: for \(N_i\) number of points to encode the value of \(i\)-bit number, where \(i\) changes in the range from 1 to 17 and

\[ N = \sum_{i=1}^{17} N_i. \]

The way to reduce the size of memory occupied by the image is the following: determine the \(j\) number of bits which code the number of points \(N_j\) at which the total memory occupied by the amount of the memory points and remaining points coded with 16 (maximum) - bit numbers, is minimal.

Original image occupies \(P_o = 2 \times W \times H\) bytes of information, where \(W\) and \(H\) - number of dots (pixels) horizontally and vertically. Transformed image, in which each pixel is encoded with \(i\) number of bits, will occupy the following number of bytes:

\[P_i = W \times H \times \frac{i}{8}\]

Points, the storage of which require more than \(i\) bits, are entered into delete set, which takes

\[E = 2 \times (N-N_i)\) bytes. The total volume of the transformed data:
\[ S_l = W \times H \times \frac{1}{2} + 2(N - N_0) \]

Thus, the required number of bits \( j \), which is required to encode the image is

\[ S_j = \min (S_0, S_1, ..., S_{17}) \]

Described methods form the image preprocessing module of the X-Ray microtomographic scanner software, developed with the support of the Ministry of Education and Science in the framework of the Federal special purpose program of the Russian Federation (State contract № 16.523.11.3009).

Image preprocessing module connects with other modules through the integrated management environment and provides the undistorted compression and decompression of the images received on the X-ray microtomographic scanner.

References