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# Quantitative Comparison of Continuous and Step Scan Motions in a micro-Computed Tomography System

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## 1. Introduction

Micro-computed tomography(μ-CT) can be used in various spheres such as biological, medical and industrial fields. In the case of in-line non-destructive inspection in an electronic integrated circuit manufacturing process that requires thorough inspection of the product, μ-CT can be used to detect defects in the total products. Conventional μ-CT systems usually perform full scans using step motion to achieve high resolution as shown in Fig. 1(a). However, it takes a lot of time to full scanning.

In order to solve these problems, it is possible to use the method of scanning the object with continuous motion as shown in Fig. 1(b). This method has the advantage of taking less time to scan, but it has a disadvantage in the quality of acquired image that is deteriorated [1]. Therefore, in order to select a suitable scanning method for the requested task, the quantitative characteristics evaluation of the two methods of scanning is required in the μ-CT system.

The purpose of this study is to investigate the signal and noise characteristics of continuous scanning μ-CT system experimentally. In addition, we compare these with the characteristics of step motion scanning.

## 2. Materials and Methods

We acquired images experimentally in order to quantitatively represent signal and noise characteristics of system and evaluate them using Fourier analysis based on factors such as modulation transfer function (MTF), noise power spectrum (NPS) and noise equivalent quanta (NEQ) [2].

### *2.1 Experimental CT system*

A tungsten anode x-ray source (Series 5000 Apogee, Oxford Instruments, USA) was used in this study. The maximum current and voltage of the source are 1 mA and 50 kVp, respectively. The nominal focal spot size of X-ray source is 0.035 mm. The complementary metal-oxide semiconductor (CMOS) detector (Shad-o-Box 1548 HS, Teledyne Rad-icon Imaging Corp., USA) with 0.099 mm sized pixels arranged in a 1032 × 1548 format was used as an imaging detector.

Fig. 2 shows phantoms used for characteristic analysis experiments. For the MTF measurements, a tungsten wire phantom (QRM-Micro-CT-Wire, QRM GmbH, Germany) was used. For the NPS measurements, a cylindrical phantom which is filled with water (QRM-Micro-CT-Water, QRM GmbH, Germany) was used. The specific dimension is shown in Fig. 2.

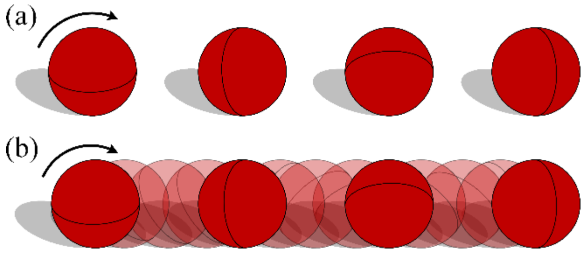


Fig. 1. Concept of step motion (a), and continuous motion (b).

We applied 1.5 for the magnification factor and 45 kVp x-ray spectrum with additional 2.5-mm-thick aluminum filtration for the experiment [3]. Each projection view for full scan was acquired in 1 degree increments. The image acquisition time of a single projection was 250 ms.

### *2.2 Modulation Transfer Function*

The spatial resolution performance was evaluated by measuring the MTF, which was an indication of signal transfer performance of the system. For measuring MTF, the wire phantom of Fig. 2(a) was scanned and reconstructed. A slit projection-like image was acquired by Radon transform of each slice of the reconstructed volume. A wire spread function was extracted from the slit projection-like image. The MTF could be obtained by fast Fourier transforming the wire spread function.

### *2.3 Noise Power Spectrum*

The NPS describes the noise transfer performance into spatial frequency domain. For the measurements of the NPS, we scanned and reconstructed the water cylindrical phantom as shown in Fig. 2(a). 12 volumes of interest (VOIs) were extracted from the reconstructed water phantom. The NPS was measured from squared fast Fourier transform of VOIs average [4].

### *2.4 Noise Equivalent Quanta*

The NEQ can be calculated based on the measured MTF and NPS [5]:

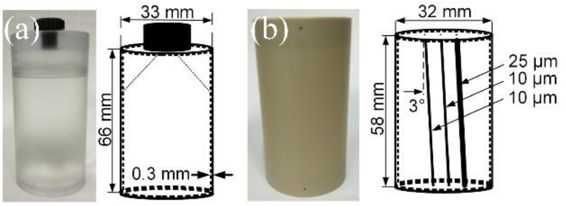


Fig. 2. Phantoms used in this study. The water phantom (a), the wire phantom (b).

$$\mathrm{NEQ}(f_x, f_y, f_z) = \pi f \frac{\mathrm{MTF}^2(f_x, f_y, f_z)}{\mathrm{NPS}(f_x, f_y, f_z)} \quad (1)$$

where $\pi f$ accounts for radial sampling density. $f_x$, $f_y$, and $f_z$ are the spatial frequency variables corresponding to the spatial variables. The NEQ means the number of quanta falling on an ideal μ-CT system.

## 3. Preliminary results

The slice images of mouse acquired by step and continuous motion scanning are shown in Fig. 3. Due to continuous rotation movement of mouse, the tomographic image acquired by continuous motion scanning was blurrier than that by step motion scanning.

## 4. Further study

In order to evaluate the signal and noise characteristics of continuous scanning, the experiment using wire and water phantom will be conducted. Moreover, we will quantitatively compare these characteristics between continuous and step motion scanning. For the comparison, total exposure of both motion conditions should be the same.

## ACKNOWLEDGMENTS

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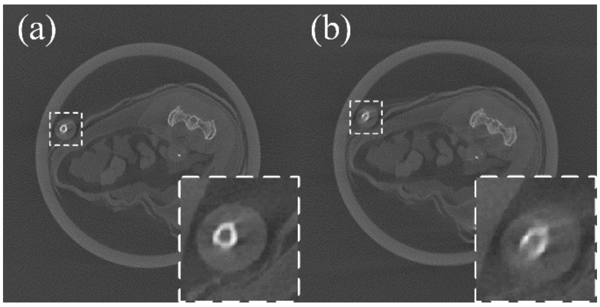


Fig. 3. Reconstructed mouse images from step motion scanning (a), and continuous motion scanning (b).