2E1-4

Perfect recovery USCT method for estimation of scatter distribution

散乱体分布推定のための perfect recovery 超音波 CT 法

Tianhan Tang[1‡], Takashi Azuma[1], Naoki Tomii[1], Hirofumi Nakamura[1], and Ichiro Sakuma[1] ([1]Grad. School Eng., Tokyo Univ.)
唐 天漢[1†], 東 隆[1], 富井 直輝[1], 中村 弘文[1], 佐久間 一郎[1] ([1]東京大学大学院 工)

1. Introduction

Breast cancer is a very commonly diganosed cancer among women which severely threatens the people's quality of life[1,2]. Ultrasound Computed Tomography (USCT) is a good candidate for the diagnosis[3,4]. USCT has good spatial resolution, and provide not only the anatomic geometry infromatin, but also the sound speed mapping of the tissue. However, the disadvantage of USCT is that it needs time consuming data acquistion (due to the relatively slow traveling speed of sound and large number of transmissions) and heavy computation (due to the large amount of raw data) to form a useful image. Consequently, the fame refresh rate of USCT is low.

This research addresses this problem. In this paper, We focus on developing fast imaging method for the reflection mode of USCT which provides primary anatomic diagnostic information. We formulate the USCT imaging problem into a linear equation system and sovle the image formation problem by solving the inverse problem. It is demonstrated that the proposed method could drastically reduce the necessary number of transmission and thus accelerate the imaging speed of USCT.

2. Method

USCT consists of a ring array of transducer elements that each of these elements could be used both as transmitting (TX) and receiving (RX) ultrasound wave. The ultrasound wave generated by the transducer travels into the body and echoes off the tissue, with different tissues reflecting varying degrees of ultrasound. For the reflection imaging mode, the reflected ultrasound signal is sampled along time axis and recorded for further processing for image formation.

We consider the object under investigation consists of (finite) large number of point scatters. It can be shown that for a fixed TX-RX configuration, a specific single point scatter will generate a unique pattern in the received data. If multiple point scatters present in the ROI, the received data would contain the linear combination of all those unique patterns. Therefore, it is deduced that if one can differentiate each unique pattern from the received data, one could recover the distribution of the point scatters.

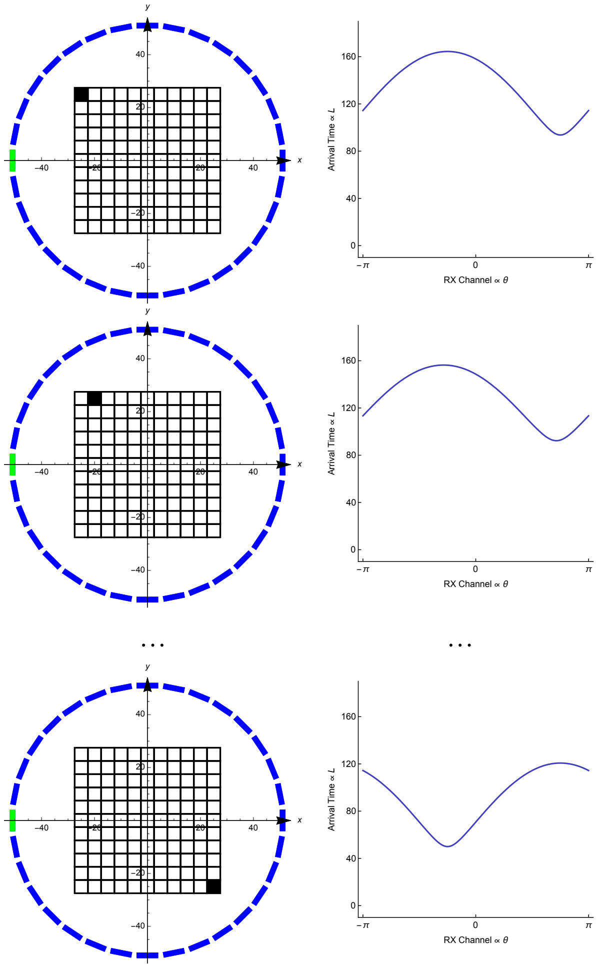


Figure 1 Process to generate reference dataset

If we grid the ROI into (finite) large number of pixels, such within each pixel, there will be only one point scatter, we can calculate the unique pattern for each possible point scatter in advance, and use it as a reference to decode the actual distribution of point scatters from the received data. The process to create the reference dataset is illustrated in **Figure 1** (green rectangle indicates the TX element).

The 2-D array of pixels could be unrolled into a 1-D vector (denote it as x), as well as the 2-D matrix of the unique pattern for each point scatter (denote it as s). The received data from a measurement of a specific TX-RX configuration could also be unrolled into a (very long) 1-D vector (denote it as y). The process of USCT imaging could be abstracted into a measurement operator G (in matrix form). Consequent, the imaging problem is formulated into a linear equation system as

$$Gx = y$$

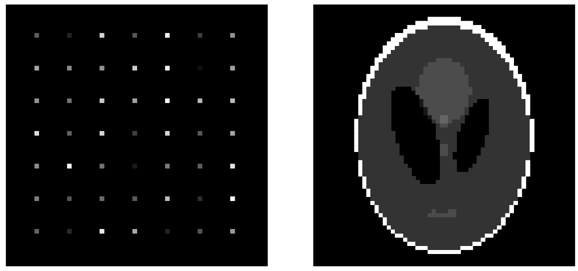
where the ith column of G is composed by the ith corresponding point scatter's unique pattern (i.e. s).

For a specific imaging process, one collects the received data y, and construct the appropriate measurement matrix G, and then create the image by solving x which could be solved by an off-the-shelf algorithm. This research utilized *Mathematica* to solve this problem.

Simulation has been performed on two data sets. The first one consist of 7 x7 point scatters with different echogenicity distributed on regular grid. The second one is a 64-by-64 pixel Shepp-Logan phantom. The simulation condition is summarized in **Table 1**.

Table 1 Simulation Conditions

Parameters	Specification
Number of USCT element	*16*
Radius of USCT ring	*50 mm*
Assumed sound speed	*1500 m/s*
Sampling frequency	*5 MHz*
Number of samples per channel	*1024*
Excitation	*Unit impulse*
ROI	*64 x 64 mm*^{2}
Pixel size	*1 x 1 mm*^{2}



Ground truth

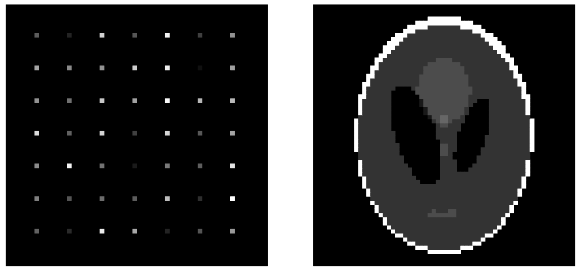


Image created using proposed method

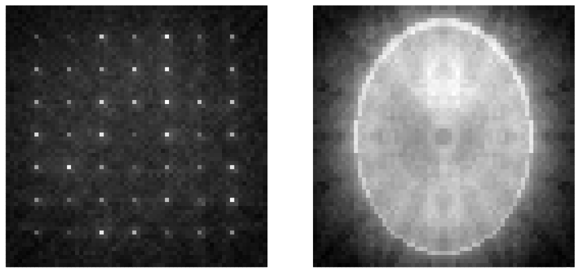


Image created using synthetic aperture method

Figure 2 Simulation results

3. Results

The results of the two simulations is shown in **Figure 2**. The proposed method recover the object within the ROI exactly with a single TX. The full synthetic aperture method utilizes all 16 times TX, but still results in severe artifacts. The proposed method exhibits both superior time resolution (16x) and spatial resolution over the conventional synthetic aperture method.

4. Discussion

Although the simulations indictate that the proposed method is capable of both high speed (with only a single TX) and high resolution (perfect recover) imaging, there are several assumptions of ideal condtions. First of all, the proposed method is based on linear acoustics. It currently could not handle nonlinear systems such as that includes nonuniform sound speed. It is a major focus in our future study. Second, the effect of random noise in measuremnt data y is not investigated and would be considered to assest the robustness of the proposed method. Third, finite-band width excitation and attenuation along with other physical characteristic of ultrasound wave needs to be take into account.

5. Summary

This research proposed a new USCT imaging method utilizing linear matrix inversion that is capable of high speed and high resolution imaging.

Acknowledgment

The author would like to thank the China Scholarship Council for financial support.

References

1. 日本乳癌学会, 全国乳がん患者登録調査報告, 2011 年次症例
2. American Cancer Society. Atlanta Am. Cancer Soc. 1–64 (2015)
3. Duric, N. et al. Med. Phys. 34, 773–785 (2007)
4. Li, C. et al. Ultrasound Med. Biol. 35, 1615–1628 (2009)