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Defocus correction in Scanning Acoustic Microscopy

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1. Introduction

Microscopic images are widely used to facilitate basic biomedical or in materials research to investigate, measure, or to image an object. Ultrasonic imaging is important and a well-established method for use in nondestructive testing (NDT), bio-medical imaging, and in structural health monitoring(1-6). It provides abundant and quantitative information about the objects under inspection. Obtaining an in-focus microscopic images poses one of the biggest challenges in the field of scanning acoustic microscopy. A lack of proper focus and/or blurry images represent one of the most common problem in high frequency ultrasonic imaging. The lateral resolution of constructed images is therefore reduced by the diffraction behavior of the ultrasound signals. The degraded lateral resolution in the out-of-focus region needed to be corrected for a better visualization of the images. In such condition, the image quality is proportional to the ultrasound propagation distance from below or above the focal plane. Several methods have been adopted to eliminate the focusing problem. Yichen *et. al.*, have presented a machine learning based convolutional neural network approach that simultaneously performs autofocusing. Later on, phase recovery has been performed in order to extend the depth of field and the reconstruction speed in holographic imaging. Gabrielle *et. al.*, have demonstrated in two-photon scanning microscope with an extended and adjustable depth of field, which improves the temporal resolution for sampling thick samples (7) The concept of the extended depth of field with a wide field of view in the scanning acoustic microscope (SAM) is absence from the literature.

In order to overcome such issues, the synthetic aperture focusing technique (SAFT) was introduced in the 1970's (8). The SAFT is widely used to provide significant improvement in the lateral resolution of ultrasonic images. The idea of the ultrasonic SAFT reconstruction was adopted from optical holography and from the synthetic aperture techniques in radar technology (8).

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2. Experimental Setup

A similar experimental setup for acoustic imaging has been employed by our group (5, 9). A custom-made ultrasonic scanning platform was build-up around a Leica DMi8 inverted microscope, integrated with an ASI MS-2000 XYZ high precision scanning stage. The scanning stage and other components of the microscope was controlled using LABVIEW. The ultrasonic functionality was implemented using PXIe FPGA modules and FlexRIO hardware from National Instruments inserted in a PXIe chassis (PXIe-1082). This hardware includes an arbitrary waveform generator (AT-1212) and a following 3W RF-amplifier (E&I 403LA) for pulse excitation, and a 12-bit high-speed (1.6Gs/s) digitizer used for pulse recording (NI-5772).

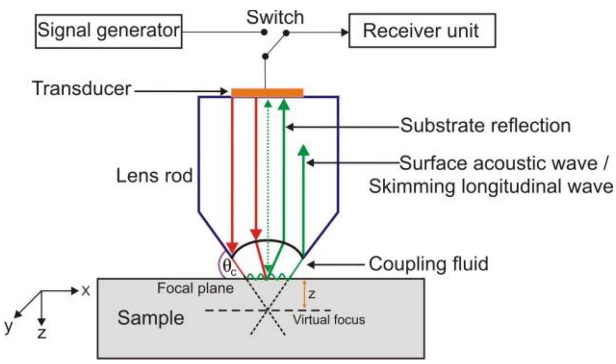

Fig. 1: Schematic diagram of the experimental setup for SAFT imaging

An Olympus 40 MHz transducer with a 6.35 mm aperture diameter and 12 mm focal distance. **Fig. 1** demonstrated the schematic representation of the acoustic transducer. The scans were performed on a one cent Euro coin. Scanning of the coin was performed in the different focal depth. For ground truth, a reference scan of the coin was performed and marked as in focus image. Later on, scans were performed on different focal depth like; 4 mm above the focal plane (denoted as +4mm) and 4 mm below the focal plane (denoted as -4 mm).

3. Results and discussion

After completing the scan of the sample, SAFT algorithm was employed in the post-processing for all the scanned images. The 2D version of the synthetic aperture focusing SAFT is a computational technique that basically consists in performing the focusing of an acoustic field recorded along the x-axis toward a point located at depth z. Scanning area of the object is 20×20 mm^2 and step size of each pixel was 50 µm in each direction.

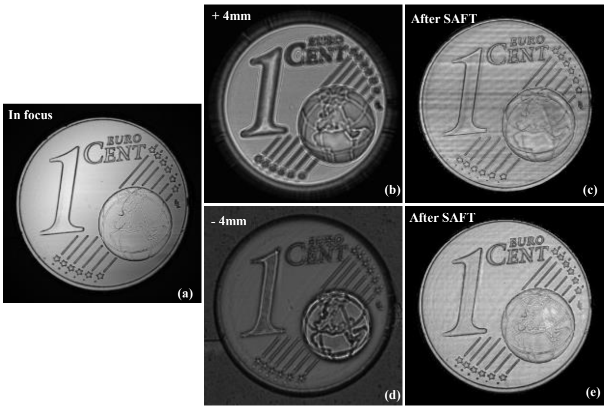

Fig 2: Figure (a) represents the +4 mm above the focal plane, (b) after SAFT have been implemented, (c) reference image marked as in focus. Figure (d) -4 mm below the focus and (e) after the correction with SAFT.

Here, we assume the reflected acoustic waves coming from the scanned object are spherically symmetric then the acoustic wave coming from directly underneath the sensor hits it first and the waves from the surrounding area will come split seconds later. This time delay Δt can be calculated and is used to compensate the signals to achieve a focused estimate of the scanned image. Fig. 2 (a) represents the +4 mm above the focal plane of the 50 MHz acoustic transducer, (b) is the after SAFT have been implemented, (c) ground truth or the reference image marked as 'in focus'. Fig. 2, (d) -4 mm below the focus, and (e) after the correcting with SAFT.

Now, we shift each surrounding signal using the Δt matrix and sum them up for a classic delay and sum based SAFT algorithm but as the time complexity for shifting algorithms is better in the frequency domain, we have used that approach to shift the signals.

The signal to noise ratio (SNR) and peak signal to noise ratio (PSNR) have also been calculated for all the scanned and SAFT corrected images. Table 1 represents the SNR and PNSR value of the images presented in the **Fig. 2**, respectively.

Figure	PSNR	SNR
+4 mm (b)	10.38	5.92
After SAFT (c)	13.59	9.13
- 4 mm (d)	7.99	3.53
After SAFT (e)	13.52	9.06

Table 1: PSNR and SNR determined value of Fig. 2

4. Conclusion

In this paper, we have demonstrated that with SAFT it is possible to extend the depth of the focusing of a transducer by reconstructing the image from defocused reflected echoes. Typically, a 50 MHz ultrasonic transducer have a depth of focus around 2 mm. After implemented the SAFT in the post processing, we have extended the depth of focus around 8 mm (±4 mm out of focus).

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