Ultrasonic Phased Array Imaging for Industrial Process Analysis

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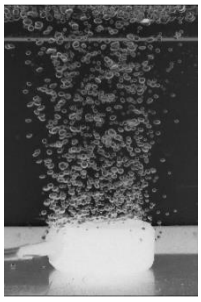
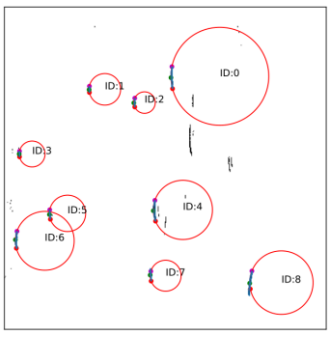
Background, Motivation and Objective In this paper, the application of ultrasonic phased arrays for imaging of dynamic industrial processes is investigated. Ultrasound provides a significant advantage over optical-based methods for imaging of industrial processes because it can image into optically opaque materials. Recent developments in multiple-channel phased array controllers coupled with graphics processing units has facilitated the deployment of ultrasonic phased array imaging towards dynamic systems. For example, measurement of bubble size distribution (BSD) presents a specific application of ultrasonic phased array imaging in industrial process analysis. The motivation for this work is to demonstrate the applicability of linear phased arrays to visualise a typical industrial process.

Materials and Methodologies The target application presented is the imaging of bubbles rising to the surface of a fluid, shown in Figure 1A. A 32 element array is positioned within a water load at 20 ^{0}C and is deployed using full matrix capture (FMC) followed by total focussing method (TFM) imaging. The range of bubble diameters tested is between 1-5 mm, generating strong specular reflections when insonified using the 5 MHz array. An image processing algorithm is presented to extract the BSD from these images. This algorithm has been developed using stationary circular reflectors of known diameter. It was further tested under controlled dynamic conditions up to 500 mm/s by coupling the phased array to a programmable robotic arm and scanning the array across reflectors of known diameter.

Results and Conclusions For the stationary reflectors the algorithm predicted the diameter within 25% for reflector diameters greater than 3 wavelengths. When tested under dynamic conditions, the algorithm was stable for speeds below 200 mm/s with an accuracy within 65%. Finally, the algorithm was applied to images relating to the experiment in Figure 1A. The typical output of a single image frame is shown in Figure 1B and these were collated across 100 image sequential frames in the histogram in Figure 1C. Overall this demonstrates successful application of ultrasonic phased arrays to imaging of a typical industrial process stream to extract quantitative information about the process. A key challenge to its practical application is the balance between data throughput and image quality; as more information is incorporated within the image, the data acquisition rate and data throughput are compromised. Hence, the choice of array aperture will be discussed in terms of useable image quality and FMC data throughput.

A. 

B. 

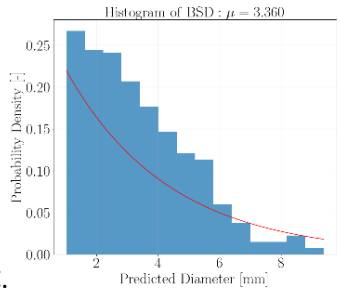
C. 

Figure 1: A. Bubble column target application. B. Output from image processing of TFM image of bubble column. C. Resulting histogram of BSD relating to 100 TFM images.