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THESIS OUTLINE

Title: A Study on Multi-Spectral Acoustic Imaging
(マルチスペクトル音響イメージングに関する研究)

In chapter 1, 'Introduction,' as the background of the present study, conventional acoustic imaging is reviewed. It is pointed out that few frequency information has been utilized in the previous acoustic imaging. Thus, the objective of this study is to propose a new concept of acoustic imaging and to demonstrate its effectiveness.

In chapter 2, 'Proposal of multi-spectral acoustic imaging,' as an analogy to optical multi-spectral and hyper-spectral imaging, the author has proposed a new acoustic imaging concept that utilizes rich frequency information with a wide frequency range and a fine frequency pitch, which is defined as multi-spectral acoustic imaging (MSAI). The imaging technique provides more quantitative features about the surface structure, shape and materials of objects, in comparison with the conventional acoustic imaging based on a single frequency or a limited number of frequencies. Then, acoustic responses of object surface are summarized being based on resonance phenomenon of typical structures such as a well, a hole, circular and rectangular dimples and slits.

In chapter 3, 'Measurement systems and signal processing,' to demonstrate the effectiveness of MSAI, several experiments are carried out. A frequency-swept signal with a wide frequency range from 1 to 20 kHz with a 30-Hz pitch is used to illuminate objects and the reflected signal is received by a microphone that is mechanically scanned along x and y directions. Frequency data with a fine pitch is taken at every measuring points. This means that three-dimensional multi-spectral acoustic data is obtained for one object. Acoustic images near the surface of the object are reconstructed at every frequency using the acoustic holography technique, and the features of the object are characterized by the frequency responses. A calibration method of the measured data is presented to compensate the characteristics of the illuminating sound.

In chapter 4, 'RGB representation of multi-spectral acoustic data,' a display method of the MSAI data is presented. Since a large volume of the three-dimensional data is obtained in MSAI, it is impossible to understand all the information at a glance. A new display method, RGB representation, has been proposed by relating the acoustic frequencies to the colors of red (R), green (G) and blue (B). Thus, the 635 acoustic images are fused into a single color picture. In this process, RGB windows have been introduced to filter the acoustic frequency components into R, G and B in the colored image. The different colors of the pixels denote the different acoustic frequencies in the measurements. From the distributions of the frequency characteristics, the information of the objects can be obtained. Meanwhile, this method has a limitation that all the information contained in the original MSAI data cannot be displayed in one RGB image.

In chapter 5, 'Visualizations of objects by multi-spectral acoustic imaging,' several demonstrations are carried out to show the effectiveness of the MSAI through holographic imaging and RGB representation.

First, nine vertical holes made on a rigid surface, whose diameter and depth are different each other, are investigated. The depth can be successfully identified by the MSAI, though they cannot be discriminated in optical images. The difference in the depth can be clearly visualized in the MSAI results even when the object surface is covered with a piece of thin paper.

Next, as a complex structure, a sample with five letters 'TITUO' engraved on the surface is observed using the MSAI method. The difference in the depth, also in this case, is effectively identified in the MSAI image. The complex resonance characteristics of the three-dimensional structure successfully reflect on the RGB representation.

Then, as a practical object, a controller pad is visualized using the MSAI. It indicates that the selection of the central frequencies in the RGB windows has significant effect on the obtained image.

Finally, a surface composed of two different materials is tested as a sample. The boundary between the two materials can be recognized if many frequencies are used, which is unable to be identified with a single frequency.

In chapter 6, 'Conclusions and future work,' the study is concluded, and the future work below is mentioned:

(i) For high speed measurement, a large-scale microphone array and a smart data acquisition system are required.

(ii) For more precise characterization, the evaluation of the illuminating sound source such as the uniformity of the strength in space and frequency need to be studied.

(iii) New display methods should be explored.