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Acoustic Shadow Moiré – A Solution for 3D Biomedical Imaging

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Abstract

This article introduces a new 3D imaging technique for biomedical applications. The new technique uses shadow moiré principles to produce 3D acoustic imaging. Optical shadow moiré principles have been used in many industrial applications, but the acoustic counterpart has not been seriously investigated. The feasibility of using acoustic shadow Moiré in 3D imaging have been investigated by the author's research group. This review argues that using acoustic shadow Moiré mechanism can provide surface and volumetric 3D biomedical imaging technology with the safety and resolution needed for medical radiology.

Keywords: Shadow Moiré; Acoustic shadow moiré; 3D imaging; Acoustic imaging; Medical diagnosis

Introduction

The moiré effect is a result of the interference between two repetitive structures or images; e.g. grids, gratings, and their shadows. The interference between the superimposed patterns creates an image of alternating dark and bright areas. The shape of this image is sensitive to the topology of the surface on which the waves are reflected.

An example of moiré effect is shown in Figure 1 [1]. In part (a) of the figure, the lower arrow represents the illumination ray. The upper arrow represents the viewing camera or eye. The illuminating wave goes through the physical grating creating an image of the grating on the sphere. The reflected image of the grating from the sphere surface goes again through the physical grating to the observer's eye. The observer sees the image shown in part (b). As can be seen from the figure, the image that the observer sees is a sphere, formed as a result of patterns interference. The intensity and the shapes of the pattern determine the vertical dimension, which is the curvature of the sphere. If the imaged object was a plate, the pattern would show the topology of its surface. In other words, moiré pattern gives a 3D image of the surface.

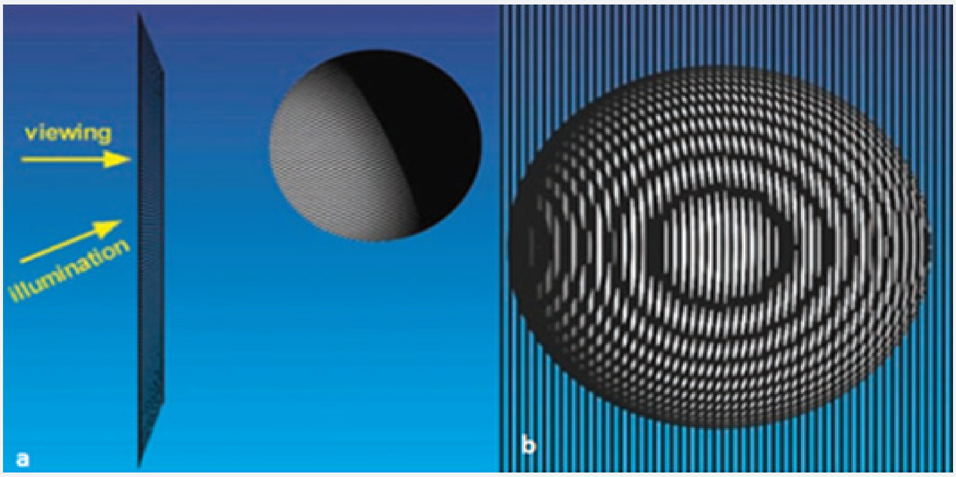

Figure 1: Shadow moiré method. (a) A physical grating and a physical sphere, where a light beam is illuminated and applied to the grating, casting an image of the grating on the sphere. (b) The moiré fringes as seen by the observer after the image interferes with the grating [1].

The resolution of the image is determined by the grating pitch and the beam wavelength. A smaller pitch can be used with a shorter wavelength to provide higher resolutions or sharper images. However, to create the real image of the object and show the contour of the surface topology, signal processing algorithms are used. For optical shadow moiré imaging, many advanced algorithms have been developed and are commercially available.

Optical shadow moiré has been used in many applications. It has been used in contour mapping of the human body to detect any asymmetries caused by certain illness, such as scoliosis deformation in the body. This technique can also be used in strain measurements and in studies of metal deformation. The size of the strain, the deformation, or the buckling can be seen in the shadow moiré photographs. Shadow moiré can also be used in manufacturing. For example, it can be used to establish the contours of sheet metal stampings. It can also be used for quality-control, by comparing the contour of a manufactured object with that of a master object. Shadow moiré has recently been adopted by the electronics industry to measure the war page or the co planarity of microelectronic devices and integrated circuits.

Acoustic Shadow Moiré

Can shadow moiré fringes be formed, if acoustic waves are applied? This question motivated the author to investigate the feasibility and practicality of using acoustic shadow moiré imaging. This issue was investigated experimentally and using numerical analysis. Ultrasound wave with a MHz frequency was applied to an aluminum grating and reflected from a flat surface to interfere with the grating again before being detected by an ultrasound camera [2]. The image from the camera showed that interference patterns were formed, providing the proof that moiré fringes can be created using ultrasound waves. Acoustic moiré fringes were also investigated using finite element numerical analysis [3]. COMSOLTM, a multi physics numerical analysis program, was used in this study [4]. The results from the experimental and numerical studies were found to be in full agreement, proving the existence of acoustic shadow moiré effect.

Discussion and Conclusion

In diagnostic radiology, ultrasound is preferred because it has two advantages: (a) it does not pause lasting harm to the living cells, and (b) it can penetrate tissues with a penetrating power related to its frequency. Waves with lower frequencies penetrate deeper that those with high frequencies. Therefore, for deep abdomen imaging, 2.5MHz is used; for gynaecological imaging, 3.5MHz is used; for vascular imaging, 5.0MHz is used; for breast and thyroid imaging, 7.5MHZ is used; for superficial veins and masses imaging, 10.0MHz is used; and for musculoskeletal imaging, 15MHz is used. In conventional ultrasound imaging, a beam is applied to the tissue and the scattered beam is collected to form an image. The diagnosis is made based on the inspection and interpretation of the different intensities of the reflected beams. Ultrasound imaging is good for initial qualitative check, but for a more conclusive diagnosis, high resolution techniques, such as X-ray or MRI, are normally used.

Acoustic shadow moiré imaging is expected to result 3D imaging with sub millimeter resolutions. This is because the resolution (size of minimum feature) is proportional to the wave length. For a 2.5 MHz wave, a resolution of sub millimeter can be obtained. The resolution will increase for higher frequencies. This technique can also be holographic and multi-shaded volumetric imaging. The author expects that by using different frequencies, not only the surface of the object can be imaged, but the volume from inside can also be visible. This would be possible by using beams with different frequencies to image at different penetrations. This technique can also be used to produce videos to capture real time change in the body.

Ultrasound shadow moiré imaging still needs a great deal of development. In this regards, practical imaging systems need to be developed and tested. Sophisticated digital signal processing algorithms, especially for real time imaging, must be developed before the full potential of this technique can be realized.

Conclusion

In conclusion, the research conducted by the author and his group has proven, experimentally and theoretically, that shadow moiré effect can be created using acoustic waves. With the advantage of ultrasound in biomedical imaging, shadow moiré can provide safe 3D imaging with high resolution. The images can be holographic as well as volumetric, where the surface as well as the interior can be imaged. This simple imaging technique is expected to move biomedical imaging to new frontiers, where using different frequencies and different grating pitches can provide more degrees of freedom.

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