Ultrasonic Cuisine: Proposal of Ultrasonic Non-contact Stirring Methods

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Figure 1. Left:The acoustic radiation force generated at the focal point of the ultrasonic phased array can stir the liquid. Right:We believe that our study will extend kinds of usage scenes of ultrasonic phased arrays and make them familiar to our lives.

ABSTRACT
In this paper we propose a method of non-contact stirring. Ultrasonic waves have been studied for various applications. However, devices using ultrasound have been devised only to specialize in one role up to now. In recent years, we aim at generalization of aerial ultrasonic equipment used for various applications such as tactile presentation and super directional speaker, and propose applications closely our real life.

Author Keywords
Ultrasonic; Ultrasound; stirring

ACM Classification Keywords
J.4. SOCIAL AND BEHAVIORAL SCIENCES (e.g. HCI): Miscellaneous

INTRODUCTION
Ultrasonic waves have been studied for various applications such as washing, cutting, degassing, atomization of moisture, and component extraction. Since speakers and tools using ultrasonic waves have appeared, they are gradually becoming familiar to us. In this study, we generate ultrasonic waves in the air using ultrasonic arrays and consider the non-contact stirring method of liquid. Harada et al. [1] clarify that it is possible to swell dry matter without missing umami by utilizing ultrasonic waves, and demonstrate that ultrasonic irradiation is useful for food processing. Katou et al. [3] proposed the method to stir liquids in a vessel without contact by using a radiation pressure of ultrasound waves. In addition to these studies, ultrasound cooking utensils include UP200Ht - Handheld Ultrasonic Homogenizer (hielcher ultrasonics gmbh), and so on. These are the devices that make it possible to emulsify and ripen liquid by ultrasonic vibration. In UP200Ht - Handheld Ultrasonic Homogenizer, the transducer and metal are brought into tight contact, and the liquid is ultrasonically vibrated by placing them in it directly. In this products, the medium is used between the transducer and liquid so that the air is not caught.

Uragami et al. [5] conducted experiments to irradiate ultrasonic waves from the outside of the container against water in the internal vessel of 4 x 5 x 30 mm small vessel. Ochiai et al. [4] also conducted the research on tactile presentation in the air with powerful aerial ultrasound waves. In our lives, it is very rare for us to put the liquid in such a container with small volumes and stir it, or require tactile presentation by ultrasound waves. Therefore, in this study, we try to stir a cup of liquid in order to consider how to utilize ultrasonic waves effectively at home using ultrasonic arrays.

METHOD
Hoshi et al. [2] fabricate the prototype consisting of 285 airborne ultrasound transducers and produce a stress field in a 3D space by controlling ultrasonic waves with the device. It enables a tactile display that provides unrestricted haptic feedback in air without any mechanical contact. The ultrasonic phased array creates a spherical synthetic wave by arranging ultrasonic speakers in an array and oscillating ultrasonic waves while shifting the phase from each array. This allows the focal point of the ultrasonic wave to be freely controlled. The generated force at the array's focal point is up to 16 mN.

In order to agitate the surface of the liquid without contact by utilizing the acoustic radiation force generated by sound reflection, we gradually injected the liquid while irradiating its surface with the focal point of the ultrasonic phased array. The acoustic radiation force is generated by pressure differences between mediums by the reflection of sound

UIST 2017, October 22–25, 2017, Quebec City, QC, Canada.

ACM ISBN 978-1-4503-4981-9/17/10$15.00
https://doi.org/10.1145/3131785.3131801

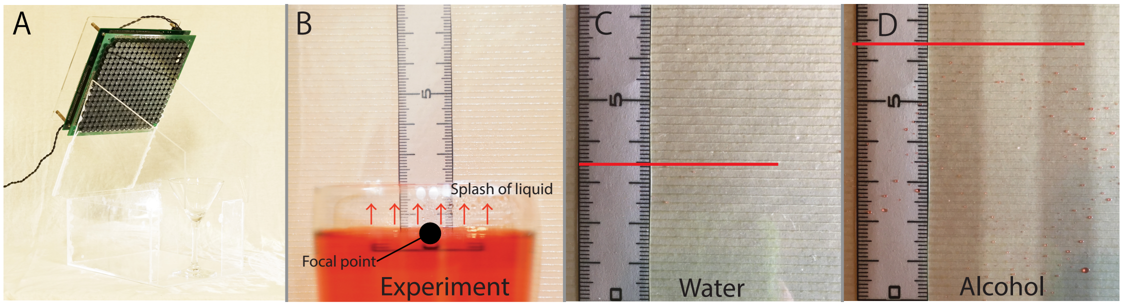

Figure 2. A: Experimental environment. B: Experimental scene comparing splashed height of each liquid by ultrasonic waves. C: In the case of red colored water. D: In the case of red colored alcohol.

Figure 3. By amplifying the scent when you drink or eat some foods, you can enrich your own experience about eating and drinking.

waves. Since acoustic waves have a property of totally reflecting at boundary surfaces between mediums with acoustic impedance largely different from each other, so they reflect at the boundary surface between the air and water (the ratio of these acoustic impedance is 0.0004:1.5) and acoustic radiation pressure is generated. This creates waves on the surface of the liquid and allows for agitation of the liquid. It is also possible to scatter the flavor of the dish or impregnate the meat with a sauce by raising the power of the array to ripple the liquid surface and scatter droplets.

In the experiment, we placed an array on a table using an acrylic plate and irradiated with ultrasonic waves obliquely to the liquid surface, so we made a spiral flow and stirred the liquid by shifting the focus from the center. Figure 2 shows a photograph comparing the splashed height in the case of water and alcohol. The difference between specific weights of the liquids makes a difference in the splashed height.

FUTURE WORK

Spread flavor with mouth

Foods and drinks such as a truffle and wine can enrich the taste by there flavors. As we could observe the phenomenon that the flavor was diffused to the surroundings by applying ultrasonic waves, we will establish this ground and propose application that we can enjoy everyday meal more by ultrasonic device. Figure 3 is an image of flavor diffusion.

Infiltrate seasonings into ingredients

By irradiating with ultrasonic waves, the effects of ”cavitation pressure”, ”deaeration action”, ”promotion of capillary phenomenon by material vibration” work to promote seasoning infiltration into foods. It usually takes time to infiltrate seasonings into foods, but degradation of foods progresses with time. In this study, it can be minimized by inflicting seasonings into foods at high speed by the action of ultrasonic waves.

CONCLUSION

In this study, we proposed new applications about an ultrasonic device which had only been recognized as a superdirectional speaker, as cooking tools to help everyday cooking and amusements to amplify the pleasure of meals. Regarding the stirring of the liquid, its ingredients are scattered when strong ultrasonic waves are applied to it which has a light specific weight like alcohol. To the contrary, if ultrasonic waves are weak, the liquid cannot be sufficiently stirred. In addition, it is necessary to stimulate the boundary surface of the liquid separated vertically due to the difference in specific weight for stirring, but there is a problem to stir only the surface. When alcohol was stirred, it was scattered, so it was easy to reproduce the taste like that after shaking the liquid.By considering the specific gravity of the liquid, it is possible to stir thoroughly by injecting liquid while irradiating ultrasonic waves.

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