AI ultrasonic microscope for long-term, high-resolution observation of living cells

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Abstract

An AI-assisted ultrasound microscope has been developed, enabling-high resolution, long-term observing living cells. While optical microscopes are usually used for cell observation, light exposure damages cells, making prolonged observation of living cells difficult. Although ultrasound is far less invasive to biological tissue, its long wavelength has made high-resolution imaging difficult. Under this backdrop, we have developed a unique AI specialized for ultrasound imaging and succeeded in generating high-resolution images with optical microscope-level resolution from low-resolution ultrasound images. The key to achieving high resolution was deliberately incorporating low-resolution images created from longer-wavelength ultrasound into the learning process. This counterintuitive approach has enabled the generation of high-resolution images that were previously difficult to achieve.

Background & Results

Ultrasound is known to be non-invasive to living organisms. However, its wavelength is considerably longer than that of light, making it unsuitable for imaging small objects like cells. In this study, we acquired ultrasound and optical microscope images of the same cells to construct a large-scale dataset and trained a newly developed AI model. As a result, we successfully generated high-resolution images equivalent to those by optical microscopy from low-resolution ultrasound data. To achieve this, we implemented the following unique approach. We superimposed ultrasonic waves of various wavelengths and input them into an acoustic lens to irradiate the cells. Figure 1 illustrates this concept using a piano analogy. Instead of striking a single key to produce one note, we strike all keys simultaneously, gathering the resulting chords to irradiate the cells. Then, from the various tonal ultrasonic waves returning from the cells, we extracted only three specific tones. We used these tones to create three separate images. We then superimposed these images to form an RGB color image and trained the AI on this composite. At this stage, we deliberately assigned the blurred image from the longer wavelength to a single color to form the RGB image. We discovered that incorporating this blurred image from the longer wavelength ultrasound dramatically increased the resolution of the generated image (Figure 2). This result defies conventional notion that one should input images in the highest resolution possible to achieve the highest possible resolution. Using this technique, we successfully monitored structural changes in living cells over extended periods exceeding 24 hours.

Significance of the research and Future perspective

This result deepens understanding of life sciences and can be utilized for evaluating various drug effects and diagnostics. Furthermore, contrary to conventional wisdom, it demonstrates the potential to achieve high resolution by deliberately incorporating lower resolution images, providing a crucial guideline for AI-driven high-resolution enhancement of all types of microscope images.

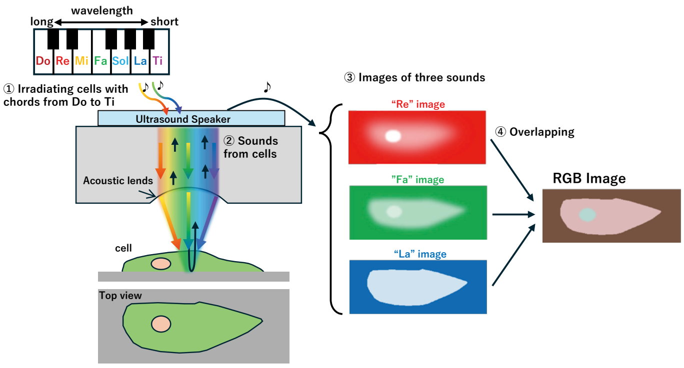

Figure 1: Ultrasonic waves composed of various tones are superimposed, focused by an acoustic lens, and directed at cells. From the sound returning from the target cell, only three wavelengths are extracted and imaged. This is analogous to striking all the keys of a piano simultaneously to create a chord, sending this to cells, and then detecting only three specific sounds (e.g., “Re” “Fa” and “La”) returning from the cells to create an RGB image.

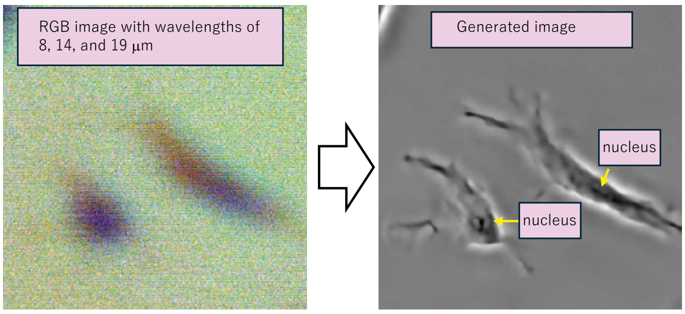

Figure 2: Image (right) generated from an RGB image (left) composed of three ultrasonic images at wavelengths of 8, 14, and 19 μm.

Patent	
Treatise	Fujiwara, Natsumi; Uno, Midori; Ogi, Hitotsugu et al. Deep-learning generation of high-resolution images of live cells in culture using tri-frequency acoustic images. Phys. Rev. X. 2025, 15, 021015. doi: 10.1103/PhysRevX.15.021015
URL	http://www-qm.prec.eng.osaka-u.ac.jp
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