電機資訊學院 2024 作 BRAIN plus HAND 實作專題競賽

Hyper-beam Coherent Plane Wave Compounding for Improving Localization Accuracy of Ultrasound Localization Microscopy

Team : EECS004 Team member : Yen-Chen Wang

I. INTRODUCTION

Diseases such as cardiovascular diseases, cancer, strokes and diabetes will make changes to capillaries in the early stages of the disease development. Thus, a way to image capillaries in vivo can speed up our research and prevention on these diseases.

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Diameters of capillaries can be down to tens of micrometers, but ultrasound can only reach resolution up to hundreds of micrometers due to physical diffraction limitation.

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To overcome limits, scientists developed an ultrasound imaging technique named Ultrasound Localization Microscopy (ULM) inspired by Photo-activated localization microscopy (PLAM).

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We typically use low bubble density to avoid overlapping of PSFs, but it also causes longer data acquisition time.

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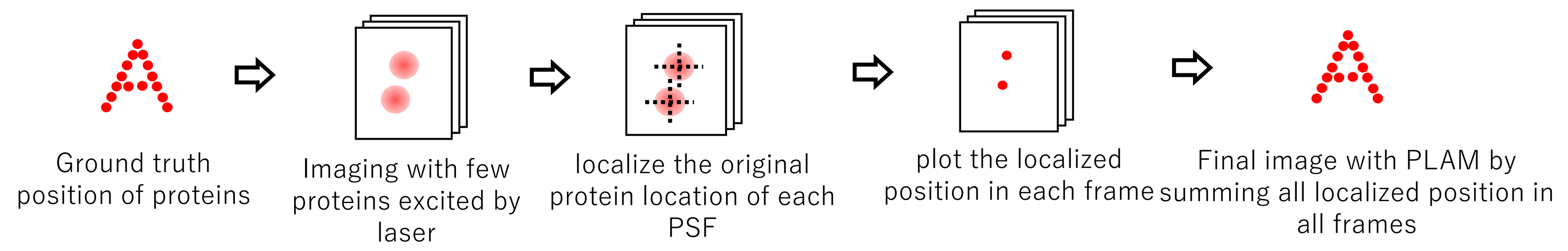
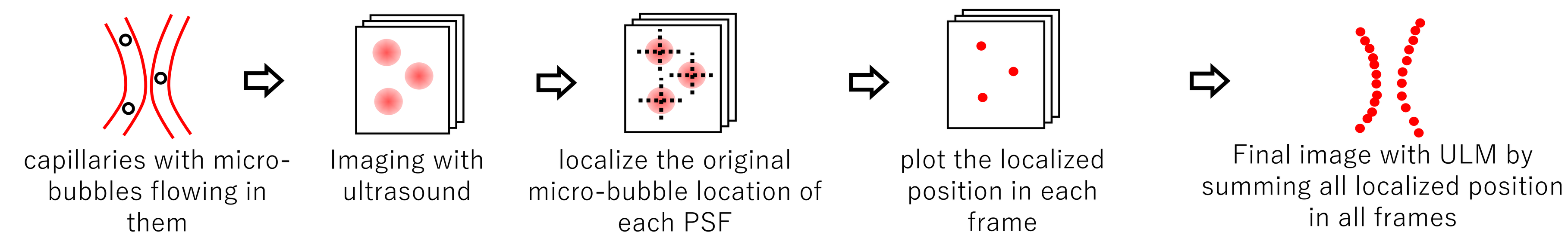
In this research, we try solving this problem by introducing a new beamforming method hyperbeam coherent planewave compounding (HB-CPWC) with narrower PSF but similar computational time with coherent planewave compounding (CPWC).



Steps of PLAM

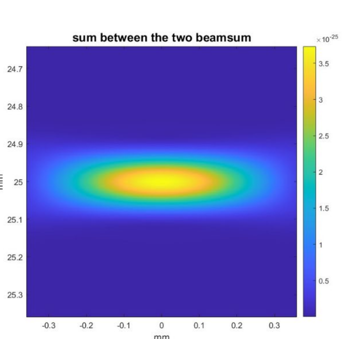


Steps of ULM

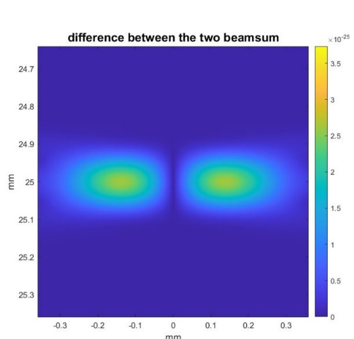
II. MATERIALS AND METHODS

Hyper-beam Coherent Plane Wave Compounding (HB-CPWC)

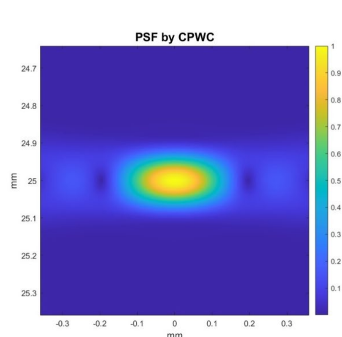
1. In HB-CPWC, we divide the ultrasound transducer array into left and right subarrays.
2. By performing delay and sum on each subarray, we can obtain two beamsums S_L and S_R
3. Calculate the sum of the two beamsums as $S_S = |S_L| + |S_R|$, as shown in Fig 1
4. Calculate the difference between the two beamsums as $S_D = |S_L - S_R|$, , as shown in Fig 2
5. By subtracting S^n_D from S^n_S and taking the nth root, we achieve a much narrower PSF as shown in Fig 4 while comparing the PSF of CPWC showned in Fig 3



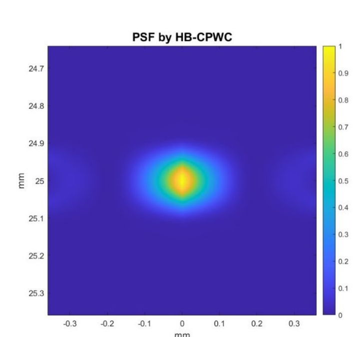
▲ Fig. 1 beampattern of S_S



▲ Fig. 2 beampattern of SD

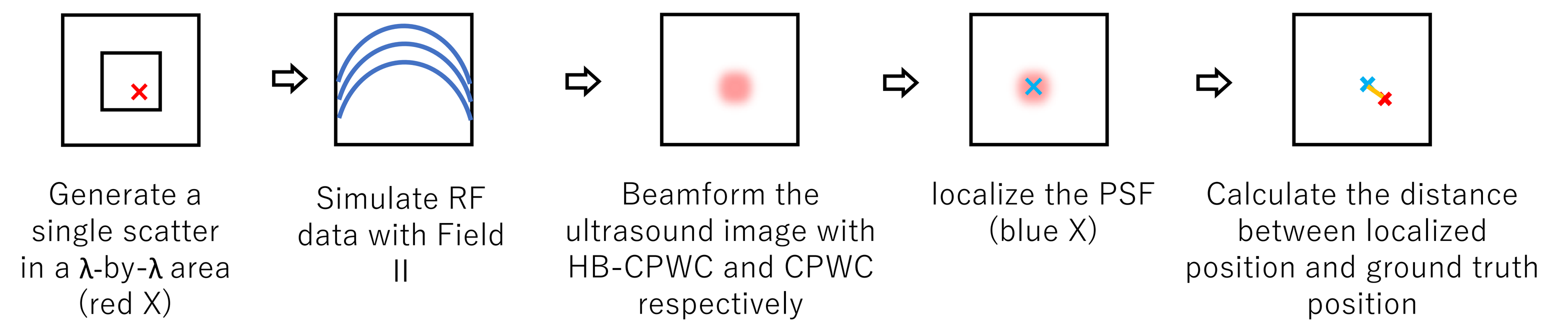


▲ Fig. 3 PSF of CPWC

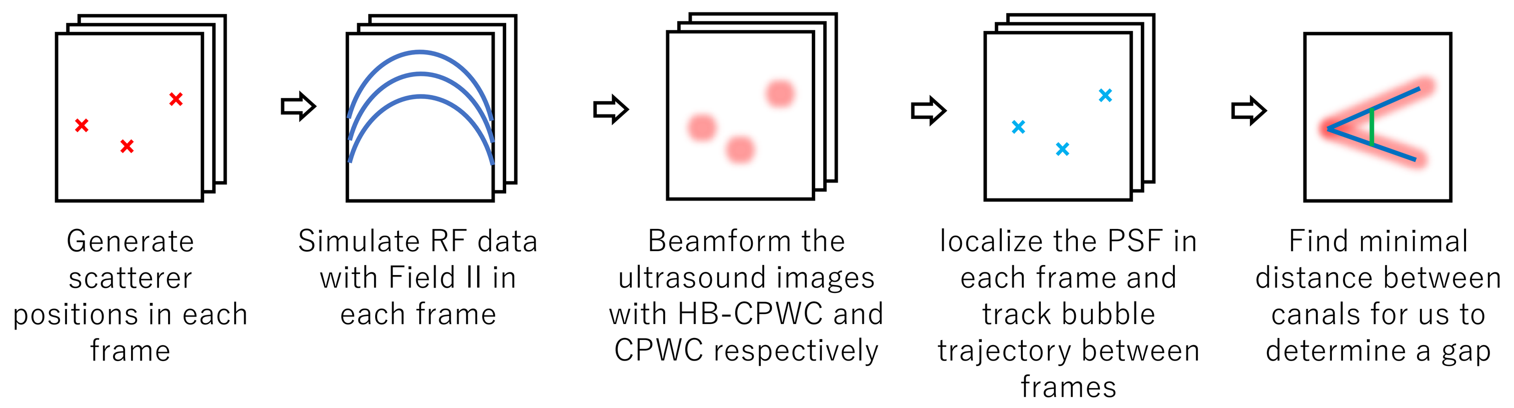


▲ Fig. 4 PSF of HB-CPWC

A. In Silico PSF

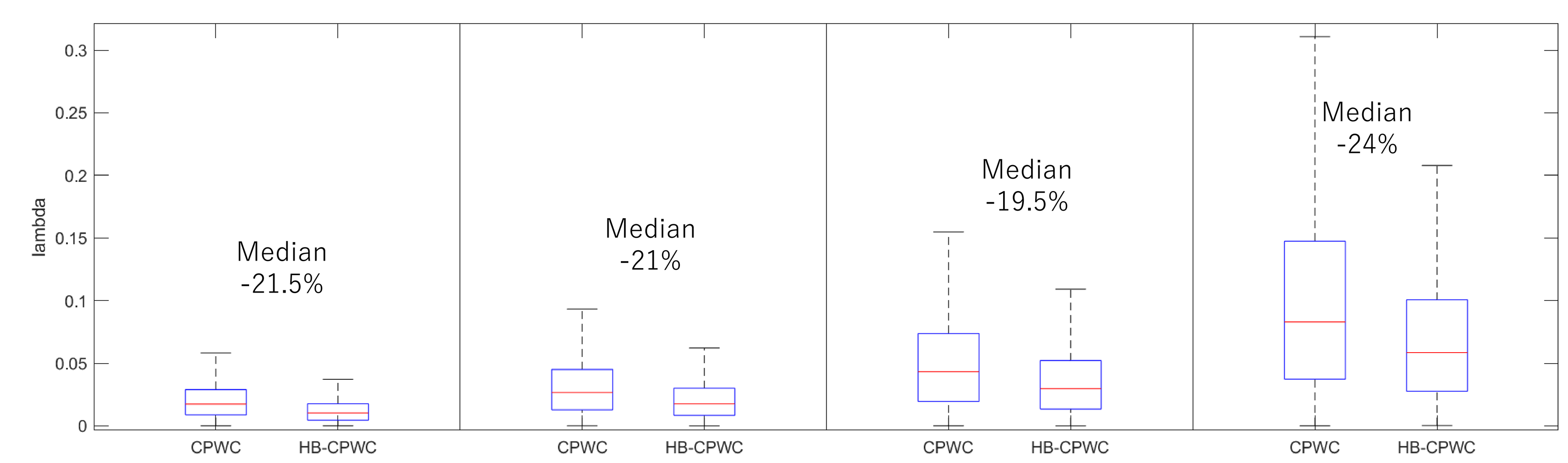


B. In Silico flow



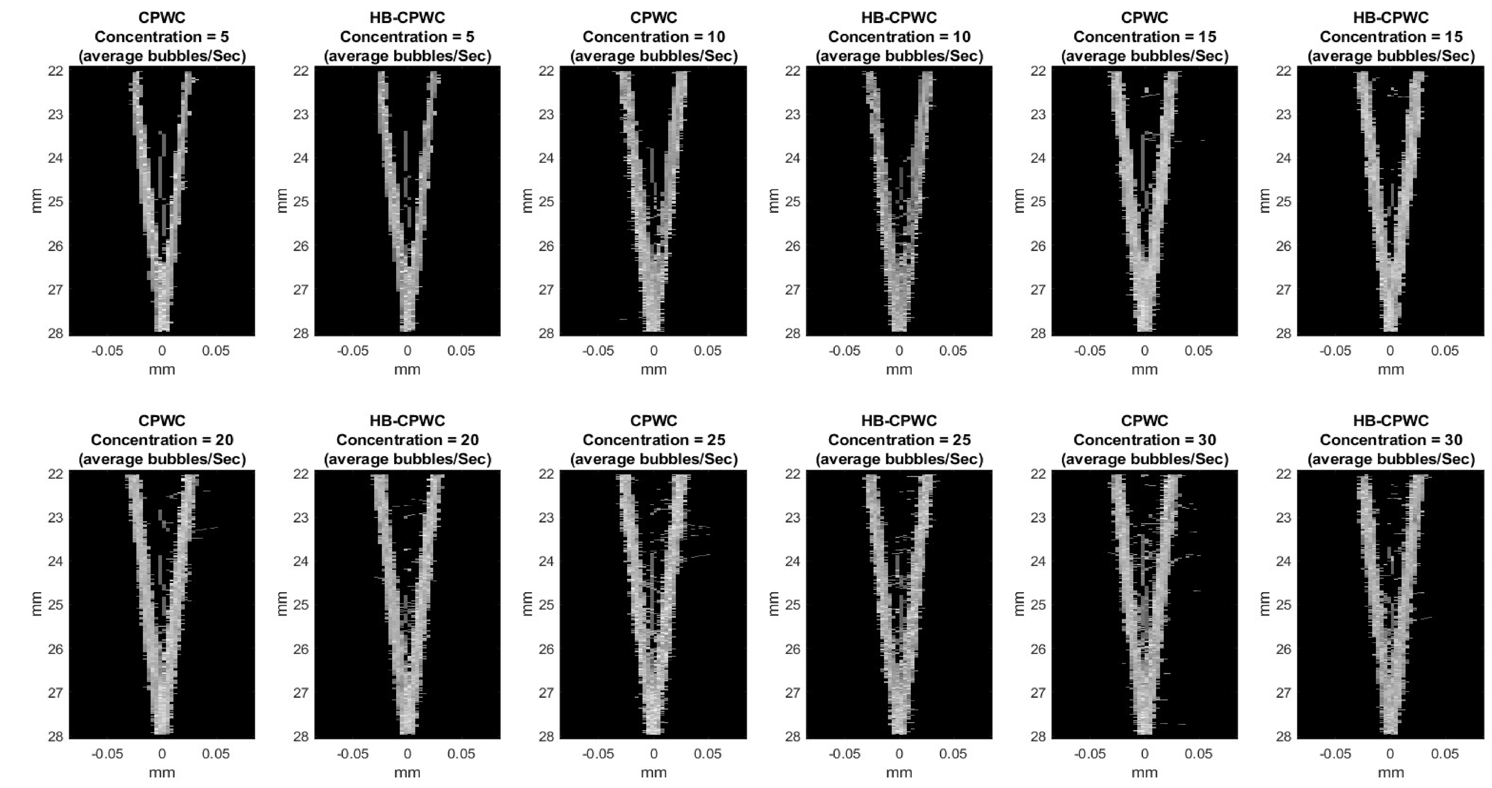
III. RESULTS

In Silico PSF Simulation : Testing Localization Error

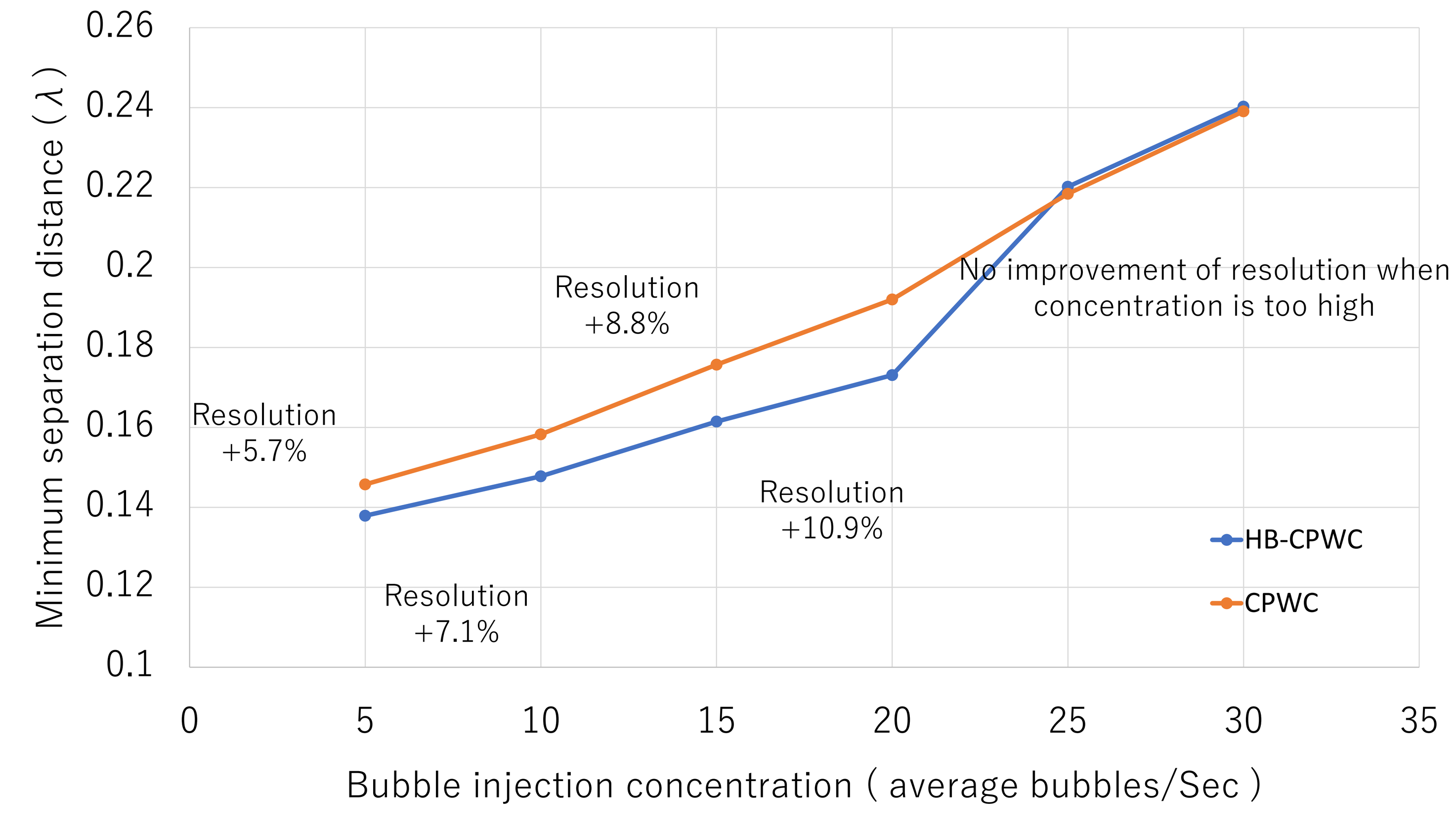


▲ Fig. 5 Root mean square error of HB-CPWC and CPWC under various SNR conditions. The RMSE values obtained with HB-CPWC were consistently lower than those obtained with CPWC across all tested signal-to-noise ratio (SNR) conditions

In Silico Flow Simulation : Testing Microvessel Resolvability



▲ Fig. 6 Simulation results of V-shaped blood vessel with HB-CPWC and CPWC respectively under different bubble concentrations



▲ Fig. 7 Minimum separation distance with HB-CPWC and CPWC respectively under different bubble concentrations. The minimum distances achieved for identifying the two vessels with HB-CPWC consistently outperformed those achieved with CPWC across moderate bubble concentrations.

IV. CONCLUSIONS

1. Here we propose a novel hyper-beam coherent plane wave compounding technique (HB-CPWC) which can produce narrower PSF while maintaining a computational complexity similar to that of the traditional coherent planewave compounding (CPWC) beamforming algorithm.
2. The results obtained from In Silico PSF simulations indicate that HB-CPWC can enhance microvessel localization accuracy and improve resolution compared to CPWC.
3. The improved microvessel distinguishability obtained from In Silico Flow simulations suggests that HB-CPWC can better differentiate closely positioned microvessels.