12379-154

Visualisation of medical needles using photoacoustic imaging with candle soot composites coatings and deep learning

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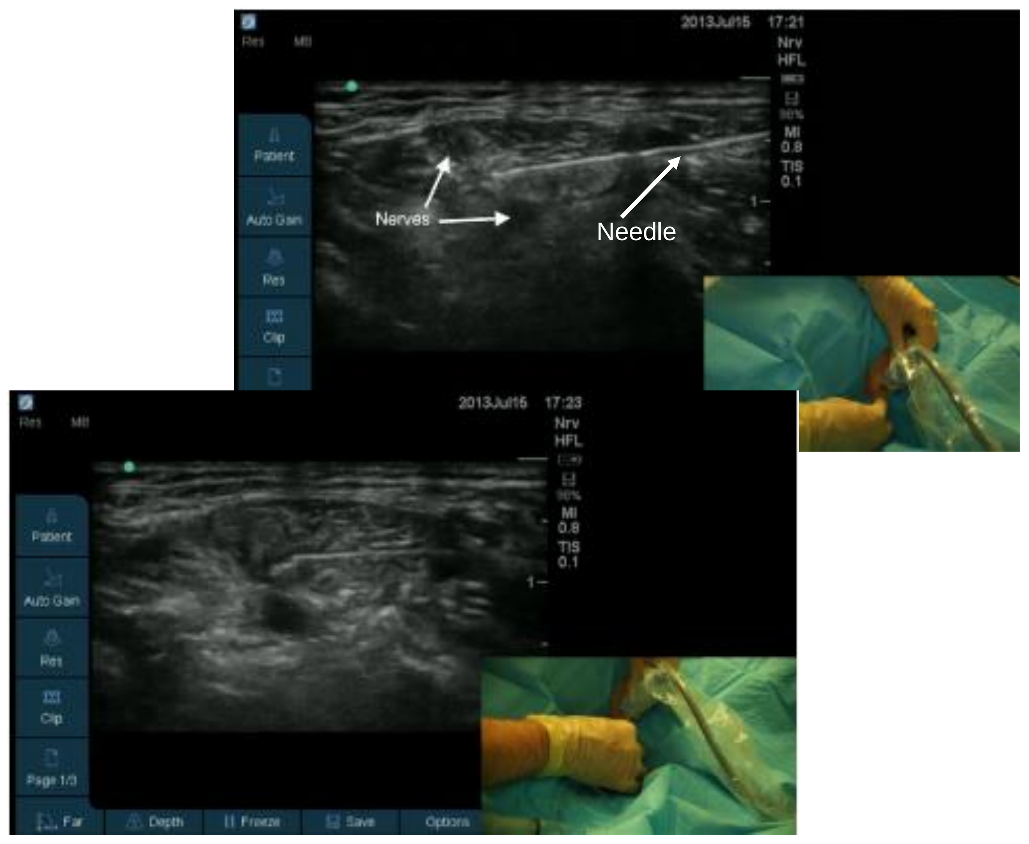
Clinical problem

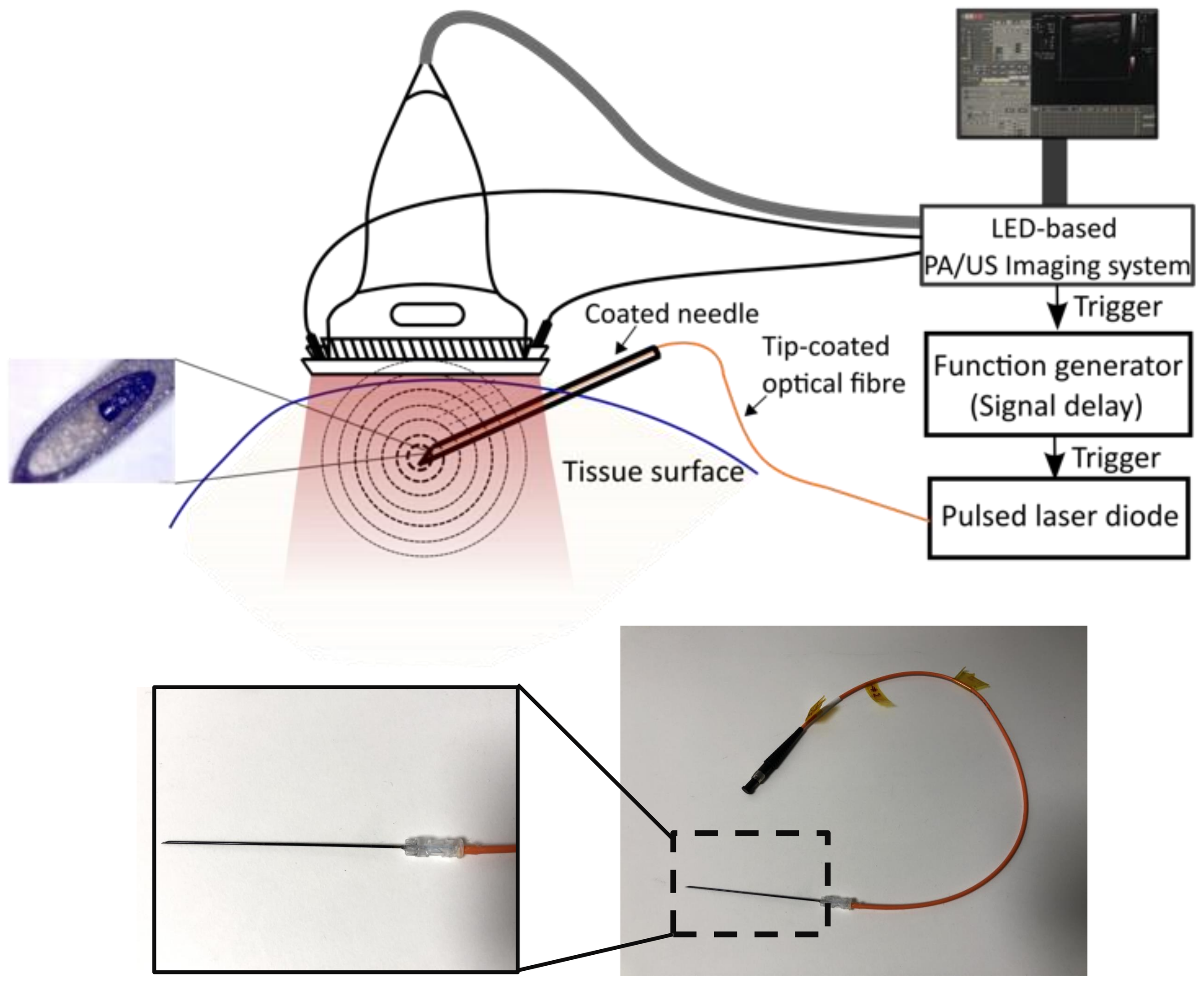
- Ultrasound (US) imaging is widely used for guiding minimally invasive procedures, but the visibility of the invasive medical devices such as metallic needles can be poor, thereby elevating the risk of complications [1].



- Photoacoustic (PA) imaging is promising for visualising invasive devices and peripheral targets. Low-cost PA excitation sources such as light-emitting diodes (LEDs) accelerate the clinical translation of PA imaging, but the image quality is sub-optimal due to the low pulse energy, leading to limited imaging depth for in vivo applications [2,3].

LED based PA/US needle imaging system

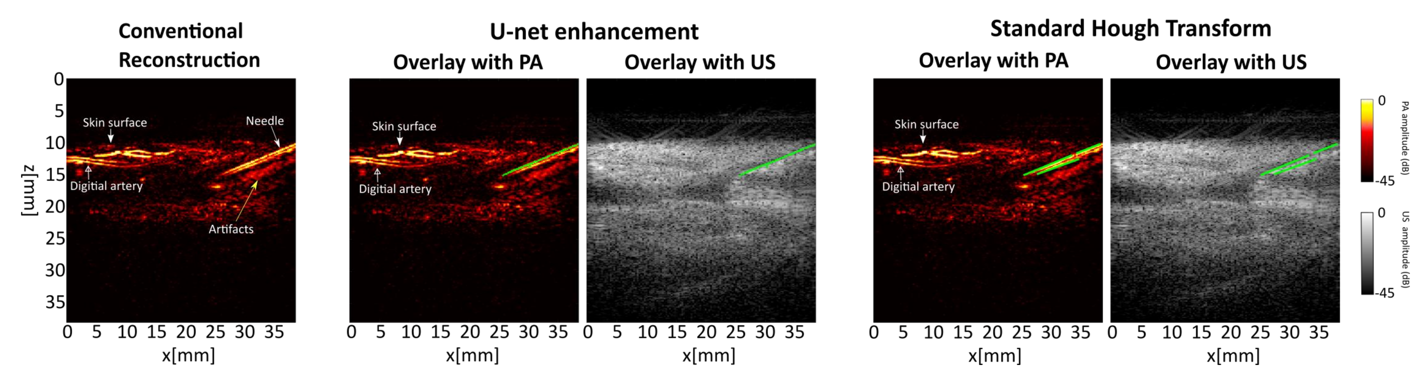
- The system was based on a commercially available LED-based PA/US imaging system (AcousticX, CYBERDYNE INC, Tsukaba, Japan).



- Candle soot nanoparticle-polydimethylsiloxane (CSNP-PDMS) composites with high optical absorption and large thermal expansion coefficients were applied onto the needle exterior and the end-face of an optical fibre

Results

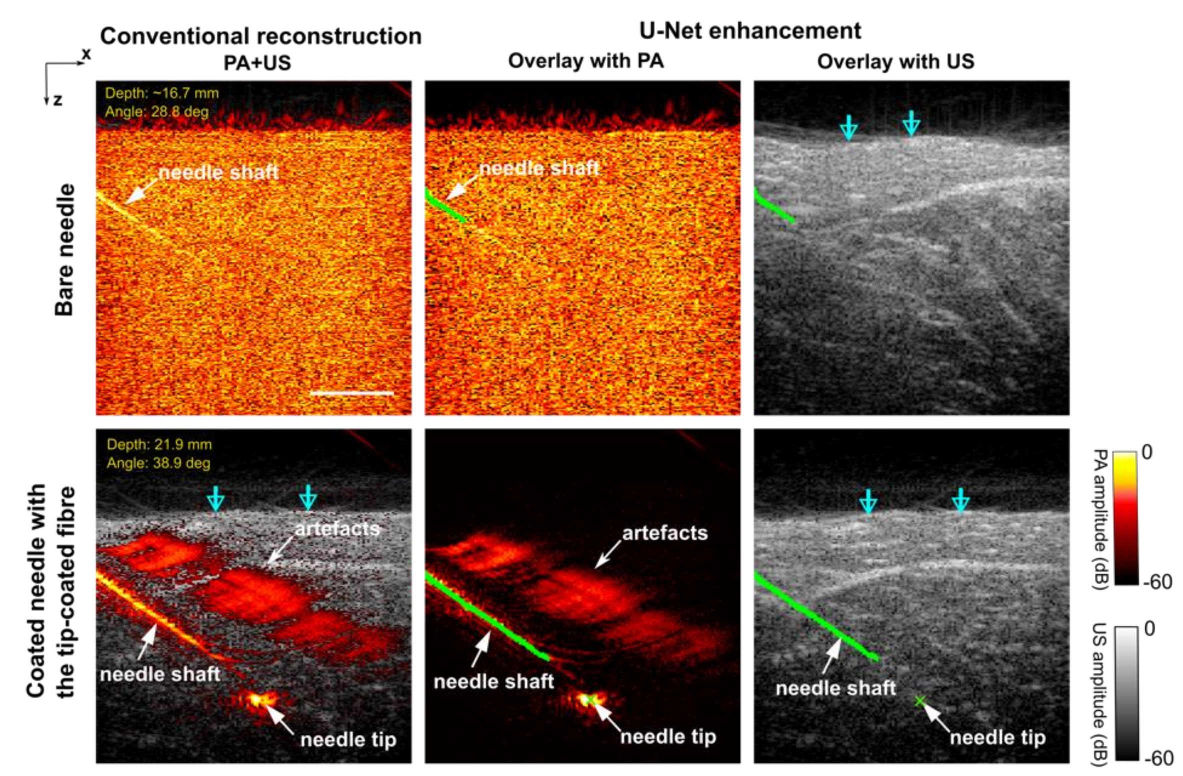
- The enhanced PA visualization of needle images (needle uncoated) with in vivo human fingers was achieved.



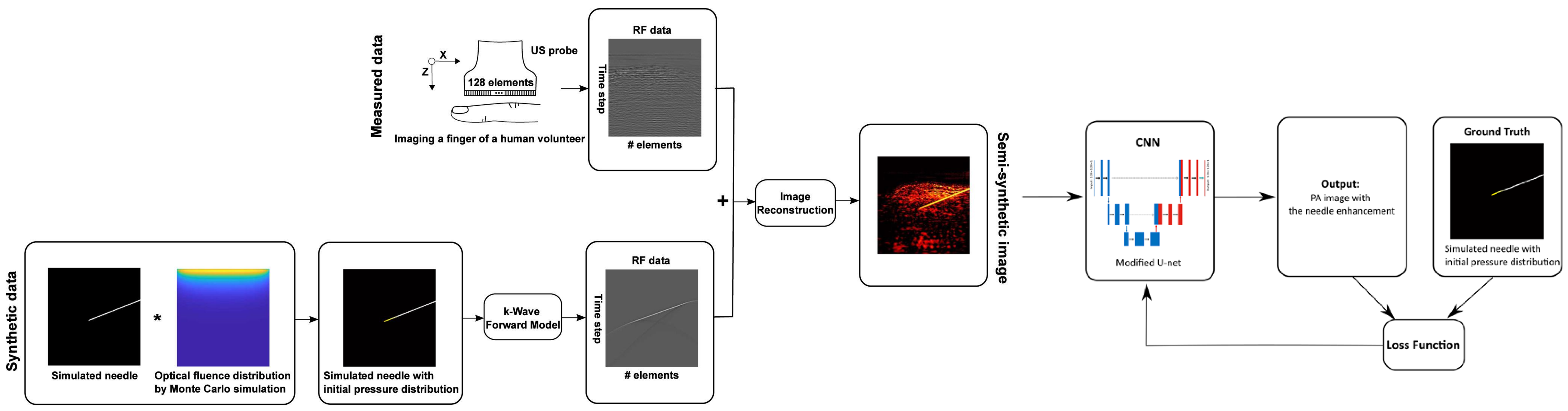
Metrics	CR[a]	U-Net Enhancement	U-Net Enhancement with Post-processing	SHT[b]
SNR	8.8 ± 1.5	51.0 ± 11.8	-	-
MHD	87.7 ± 24.4	19.4 ± 5.0	0.6 ± 0.1	55.7 ± 38.5

[a] Conventional Reconstruction [b] Standard Hough Transform

- With the robust PA enhancement via elastomeric coatings, the deep learning model resulted in 6.5- and 1.2-times improvement in SNR and MHD, respectively, indicating its high efficiency and accuracy of needle identification.



Deep learning-based needle enhancement



- A deep learning-based framework using semi-synthetic dataset was proposed for enhancing photoacoustic visualisation of clinical needles [5].

Conclusions

- Elastomeric coatings can be applied on the needle surface to improve its visibility; but the PA visualisation of the needle was degraded by the synchronous strengthened artefacts.
- The deep learning model based on semi-synthetic dataset further improved the needle visualisation in PA imaging with high robustness and sensitivity.
- The proposed method could be helpful in US-guided minimally invasive procedures by accurate visualisation of clinical needles

Acknowledgements

- The authors would like to acknowledge the funding support from Wellcome Trust [203148/Z/16/Z, WT101957], EPSRC (NS/A000027/1, NS/A000049/1) and King's – China Scholarship Council PhD Scholarship program (K-CSC).

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