Neural Network Kalman filtering for 3D object tracking from linear array ultrasound data

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INTRODUCTION

Medical imaging is frequently used in surgical procedures to visualise and track instruments. In ultrasound applications, typically only two-dimensional data are available and performing accurate positional estimation in three dimensions is difficult. In this work we consider tracking of a point object in three-dimensional space using a sequence of optical ultrasound images. To achieve this, we combine the Kalman filter and a neural network. The imaging geometry is illustrated in Figure 1.

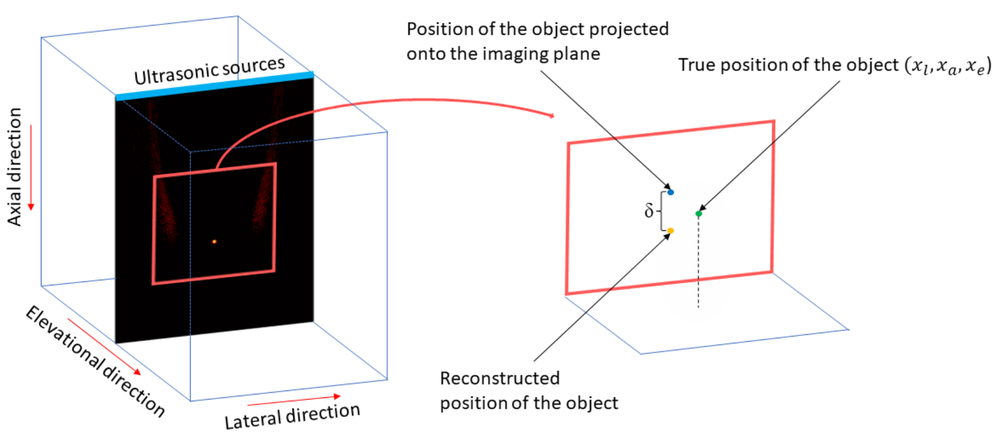

Figure 1: Imaging geometry.

METHODS

We use a realistic ultrasound simulator to train the neural network. It takes the amplitude of the measured radiofrequency (RF) data as input and outputs an estimate of the elevational coordinate (offset). The neural network learns the nonlinear relationship which is illustrated in Figure 2. Lateral and axial coordinates are estimated by processing the image. The estimates are then Kalman filtered for robust tracking (see Figure 3 for workflow).

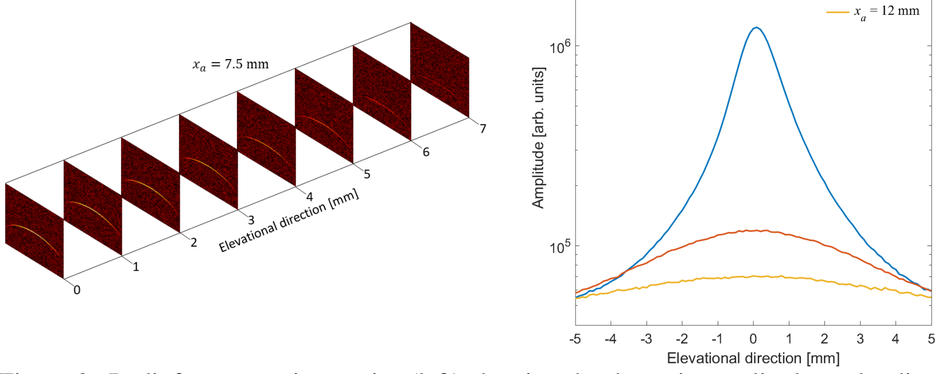

Figure 2: Radiofrequency time series (left) showing the decay in amplitude as the distance from imaging plane increases. The decay is also shown on the right for different axial depths. In general, the rate of decay decreases with increased depth.

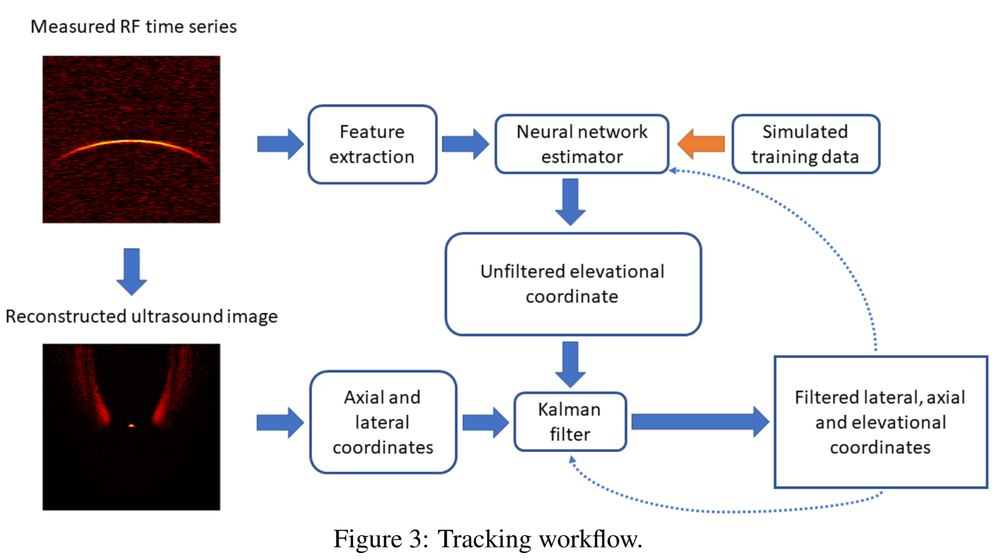

Figure 3: Tracking workflow.

RESULTS

We were able to accurately track the object from simulated data. The accuracy deteriorates when moving to experimental data but is still sufficiently high. Tracking performance is visualised in Figures 4 and 5.

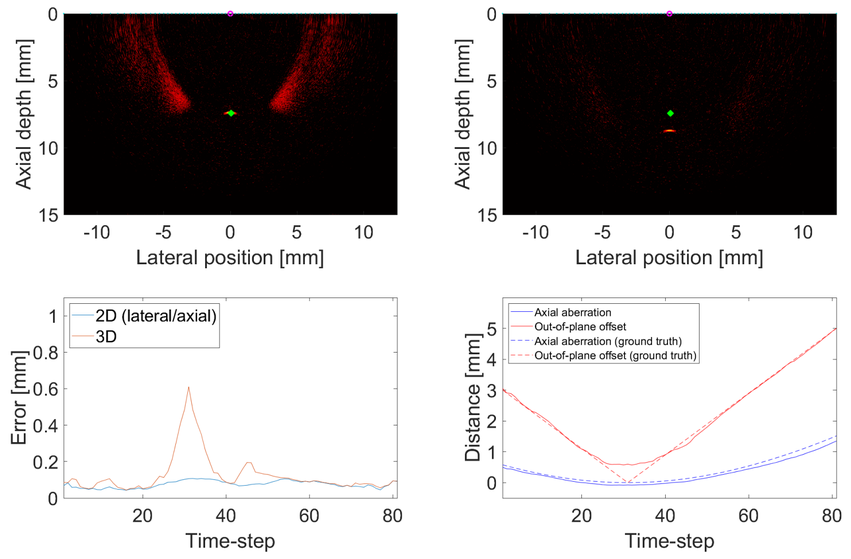

Figure 4: Tracking for simulated data. (Top left) tracked location (green dot) at time step 40 (out-of-plane distance ∼1 mm), (top right) tracked location at the last time step (out-of-plane distance 5 mm), (bottom left) 2D and 3D error (Euclidean distance) from the ground truth and (bottom right) out-of-plane offset (elevational distance) and axial image aberration over time.

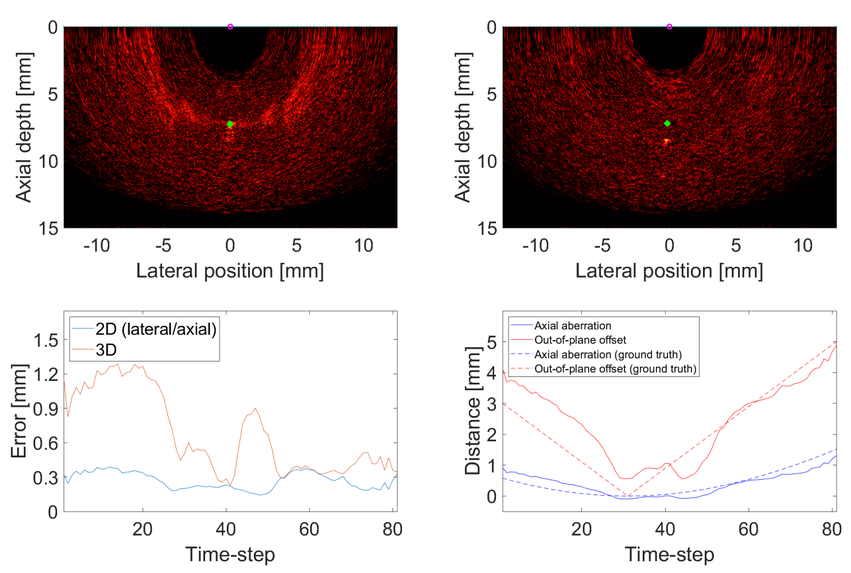

Figure 5: Tracking for experimental data. (Top left) tracked location (green dot) at time step 40 (out-of-plane distance ∼1 mm), (top right) tracked location at the last time step (out-of-plane distance 5 mm), (bottom left) 2D and 3D error (Euclidean distance) from the ground truth and (bottom right) out-of-plane offset (elevational distance) and axial image aberration over time.

CONCLUSION

- We track a pointlike object in 3D using 2D ultrasound images.
- The tracking algorithm combines neural network and Kalman filter.
- The neural network is trained using data from a realistic ultrasound simulator.
- Full paper can be found in arXiv (Arjas et al., 2021).

References

Arjas, A., Alles, E. J., Maneas, E., Arridge, S., Desjardins, A., Sillanpää, M. J., and Hauptmann, A. (2021). Neural Network Kalman filtering for 3D object tracking from linear array ultrasound data. *arXiv e-prints*, page arXiv:2111.09631.