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Acoustic localization with multi-layer isogradient sound speed profile using TDOA and FDOA

Key words: Underwater acoustic sensor network; Acoustic localization; Sound speed profile; TDOA; FDOA

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Motivation

- In the underwater medium, the speed of sound varies with the water depth, temperature, and salinity.
- The inhomogeneity of water leads to bending of sound rays, which makes the existing localization algorithms based on straight-line propagation imprecise.
- To realize high-precision node positioning in underwater acoustic sensor networks (UASNs), a multi-layer isogradient sound speed profile (SSP) model is developed using the linear segmentation approximation approach.

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Main idea

- Sound rays bend with the inhomogeneity of water.
- Convert the sound ray tracking problem into a polynomial root searching problem.
- Based on the derived gradient of the signal’s Doppler shift at the sensor node, the localization algorithm can effectively handle the sound ray bending phenomenon.

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Method

- Describe sound ray tracking with the multi-layer isogradient SSP model.
- Derive the gradient of the frequency shift of the arrival signals between the target and sensor nodes, and then we obtain the FDOA-based node localization algorithm.
- The joint estimation algorithm based on TDOA and FDOA can estimate the target accurately.

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Major results

- The straight-line propagation model error is at least 20 dB larger than that of the multi-layer model.

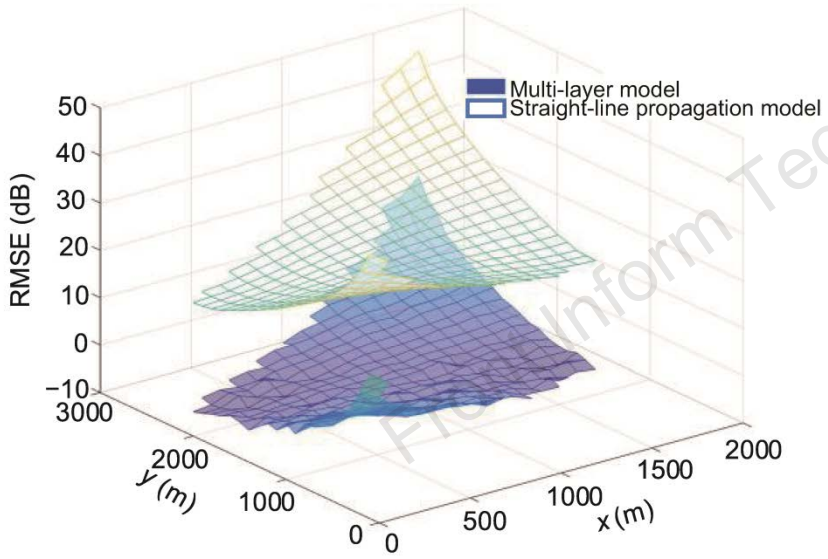

Fig. 5 Positioning error surfaces of the two models

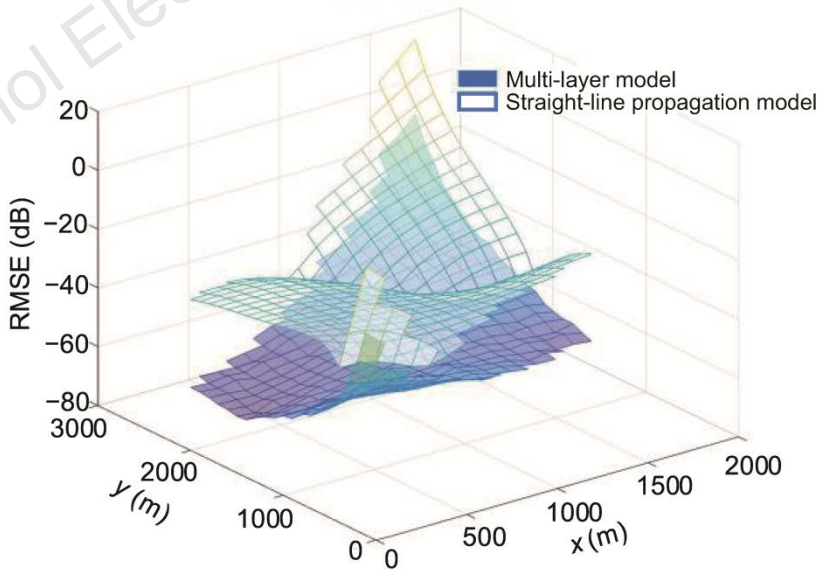

Fig. 6 Velocity error surfaces of the two models

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Major results (Cont'd)

- The position accuracy tends to be influenced by the measurement accuracy instead of the modeling accuracy.

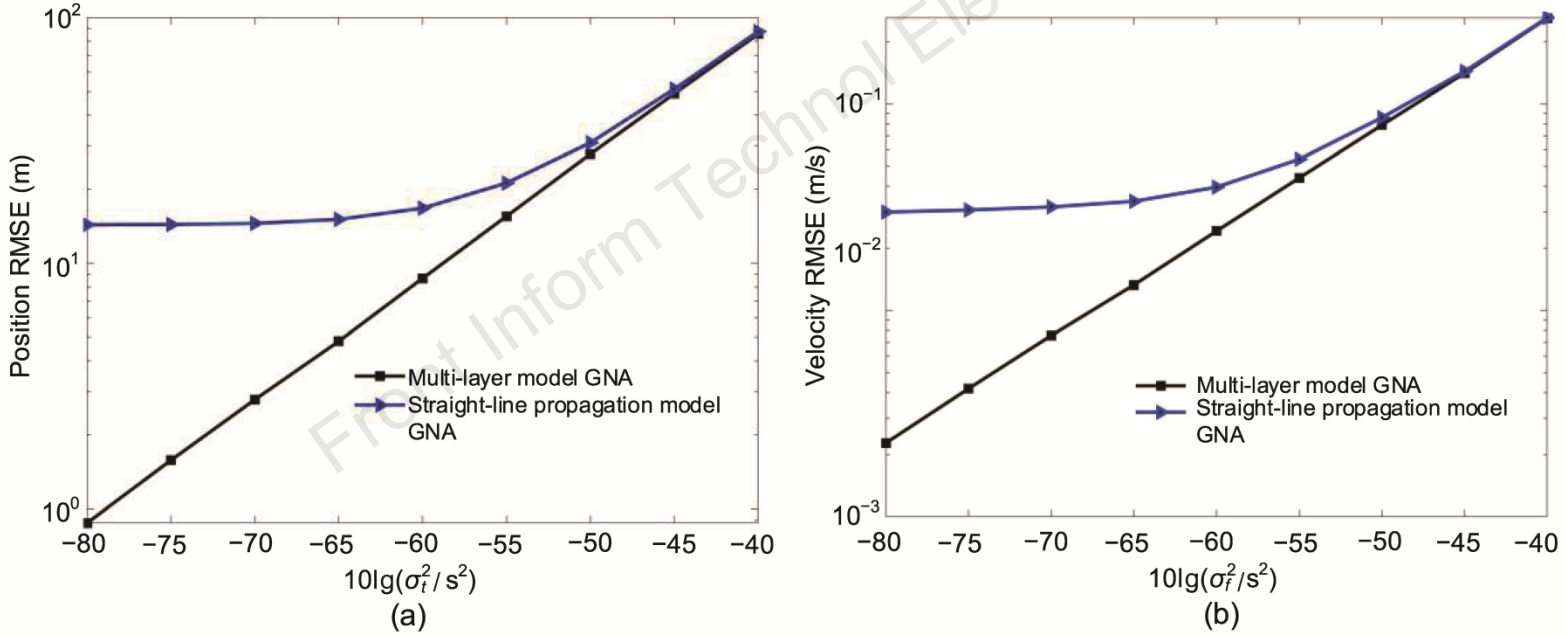

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Fig. 9 Positioning (a) and velocity (b) errors of the joint estimation algorithm (RMSE: root-mean-square error; GNA: Gauss–Newton algorithm)

Conclusions

- Aiming to mitigate the effect of the curvature of the sound ray, we establish an analytical expression of the SSP.
- We propose the gradient calculation method for the Doppler shift between the target and the sensor nodes to improve target localization.
- Simulation results show that the algorithm based on the multi-layer model gives more reliable and accurate estimates of the position and velocity of the moving target.

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