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Research on the Path Plan for Searching Acoustic Beacon of Black Box based on AUV

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1. Research Background

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Applications:

Military application: detect the underwater weapons.

Civilian application, find and locate the black box.

Existing research:

Nonsynchronous localization method: the DOA based method and the TDOA based method.

Path plan: usually use the comb path, and the comb interval is decided mainly on experience.

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2. The proposed path plan method

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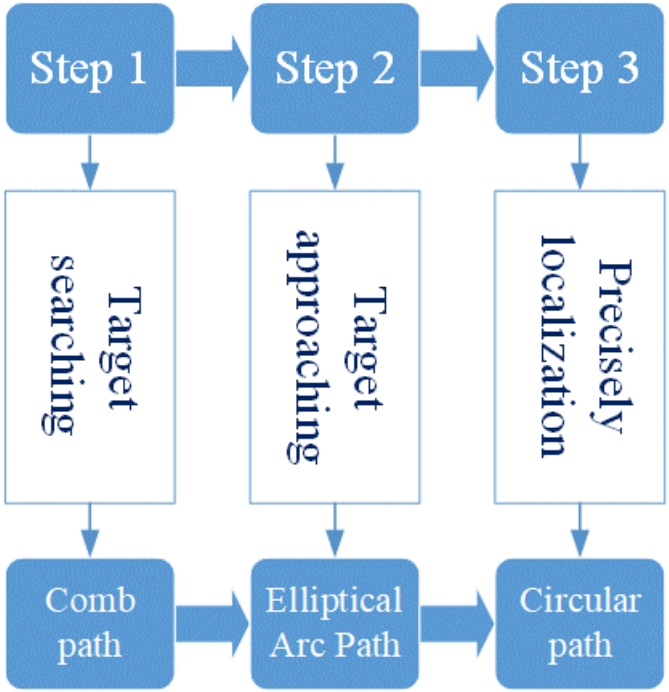
The planned path is composed of three steps.



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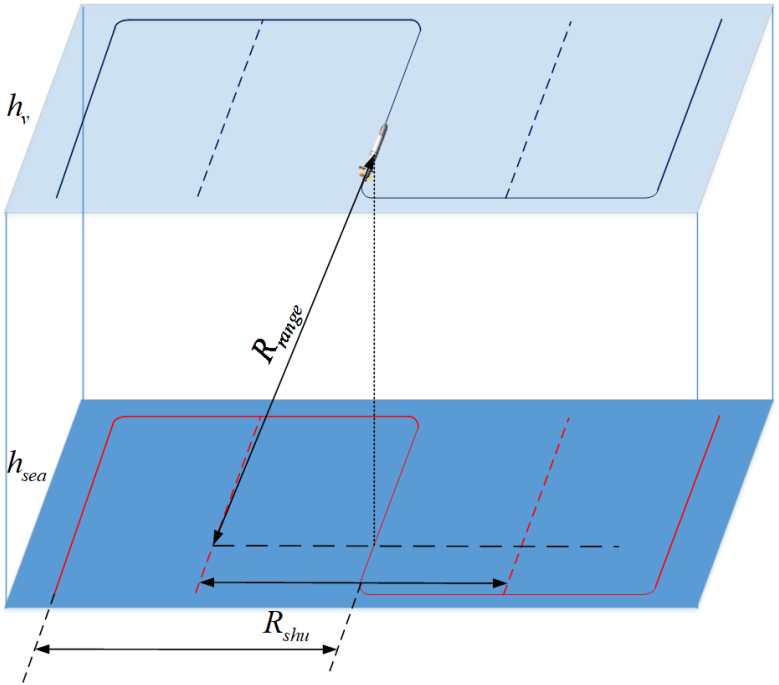
Step 1: Target searching using the comb path



Designed comb interval:

$$R_{\text{shu}} = 2\sqrt{(R_{range} - R_{al})^2 - (h_{\text{v}} - h_{\text{sea}} - h_{al})^2}$$

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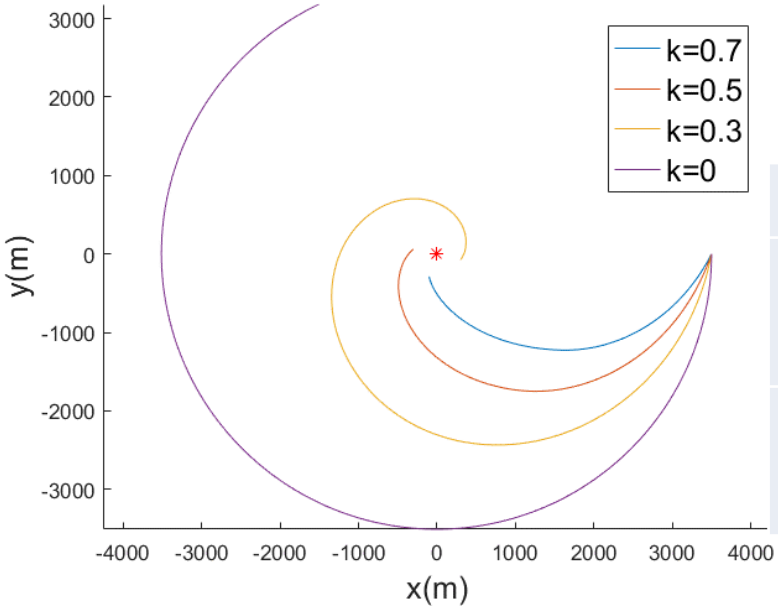
Step 2: Target approaching using the elliptical arc path



Designed approaching direction:

$$\boldsymbol{v} = k\boldsymbol{v}_l + (1-k)\boldsymbol{v}_v$$

k	0.7	0.5	0.3	0
Approaching distance	4460 m	5990 m	10120 m	-
Localization precision	37.3 m	15.8 m	7.4 m	-

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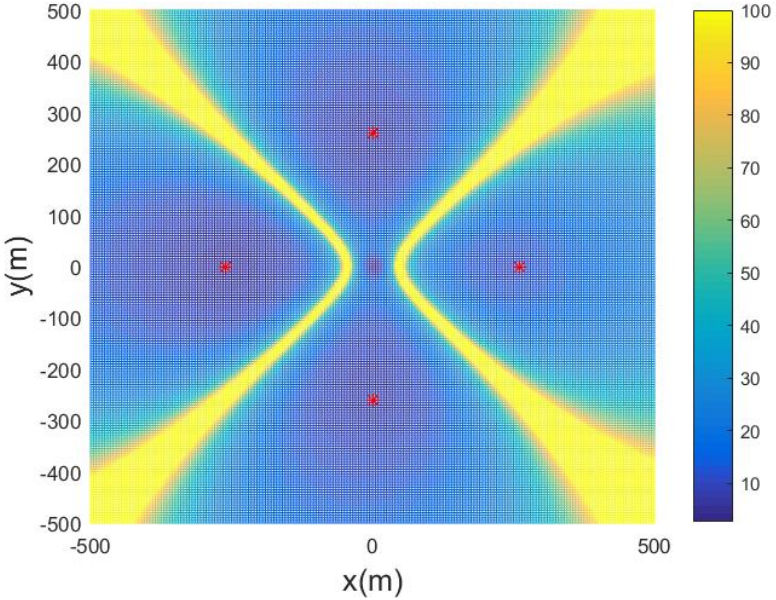
Step 3: Precisely localization using the circular path

Localization precision distribution for TDOA based method



$$\mathbf{H}_{TDOA} = \mathbf{M}_x^{-1} \cdot (\mathbf{M}_t \cdot \mathbf{D}_t \cdot \mathbf{M}_t^T + \mathbf{M}_0 \cdot \mathbf{D}_0 \cdot \mathbf{M}_0^T + \mathbf{M}_1 \cdot \mathbf{D}_1 \cdot \mathbf{M}_1^T + \mathbf{M}_2 \cdot \mathbf{D}_2 \cdot \mathbf{M}_2^T + \mathbf{M}_c \cdot \mathbf{D}_c \cdot \mathbf{M}_c^T) \cdot \mathbf{M}_x^{-1\mathrm{T}}$$

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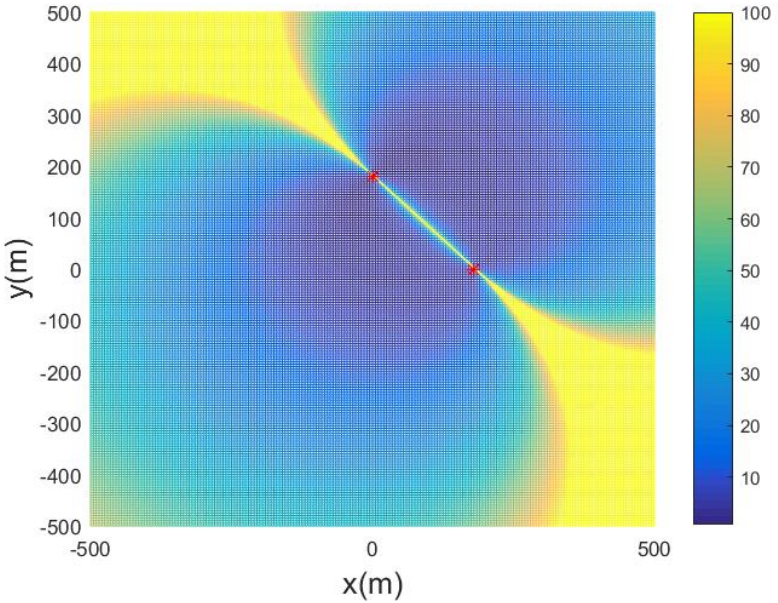
Step 3: Precisely localization using the circular path

Localization precision distribution for DOA based method



$$\mathbf{H}_{DOA} = \mathbf{M}_a \cdot \mathbf{D}_a \cdot \mathbf{M}_a^T + \mathbf{M}_b \cdot \mathbf{D}_b \cdot \mathbf{M}_b^T + \mathbf{M}_L \cdot \mathbf{D}_L \cdot \mathbf{M}_L^T$$

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Step 3: Precisely localization using the circular path

Result fusion:

$$\boldsymbol{x}_f = \frac{\sigma_{TDOA}^2}{\sigma_{TDOA}^2 + \sigma_{DOA}^2}\boldsymbol{x}_{TDOA} + \frac{\sigma_{DOA}^2}{\sigma_{TDOA}^2 + \sigma_{DOA}^2}\boldsymbol{x}_{DOA}$$

Designed optimal radius:

$$r_{op} = \arg\min_{r_{op}=r} \frac{2\,\mathrm{tr}[\mathbf{H}_{TDOA}(r)]\,\mathrm{tr}[\mathbf{H}_{DOA}(r)]}{\mathrm{tr}[\mathbf{H}_{TDOA}(r)] + \mathrm{tr}[\mathbf{H}_{DOA}(r)]}$$

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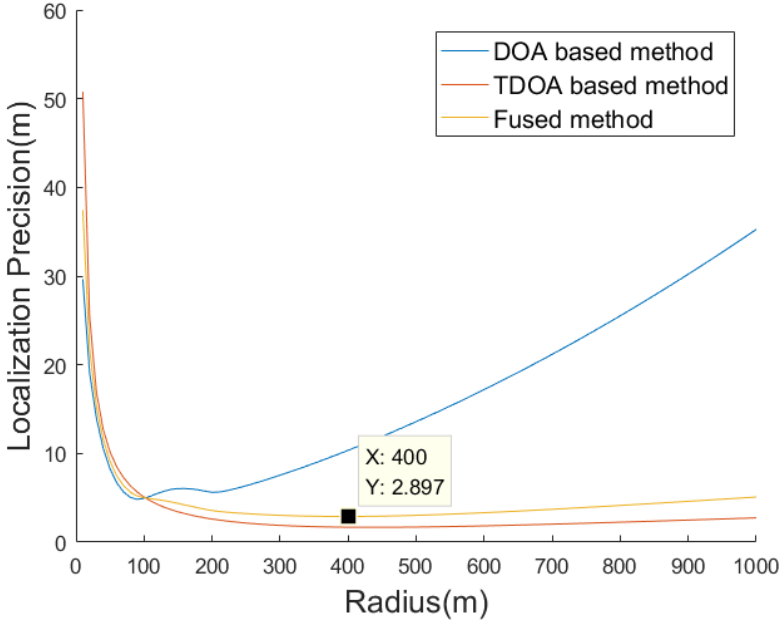
Step 3: Precisely localization using the circular path



Optimal radius:
400 m

Best localization precision:
2.90 m

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3. Simulation

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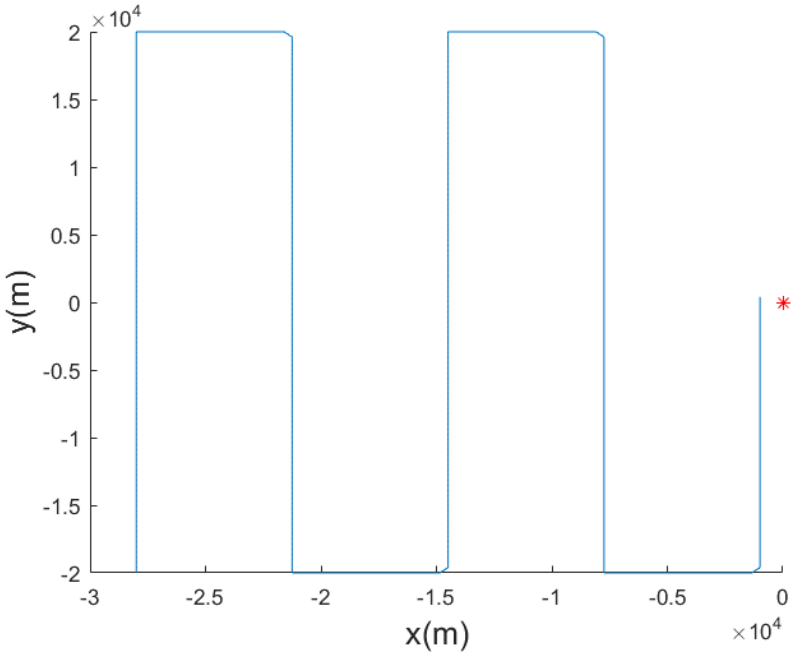
Step 1



Designed comb interval: 6753 m

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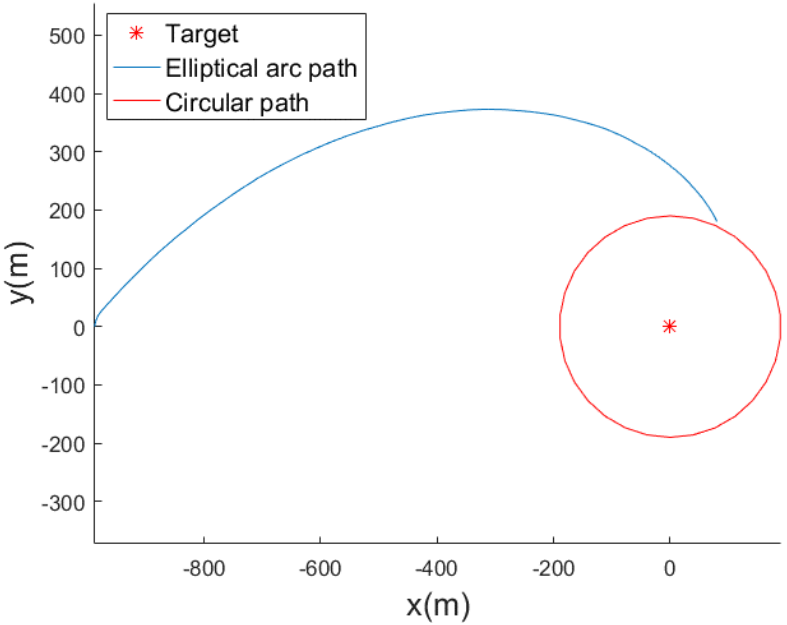
Step 2 and Step 3



Designed optimal radius:
210 m

Localization error:
3.23 m

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4. Conclusion

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The planned path is composed of three steps.

Step 1: Target searching using the comb path.
- Comb interval design

Step 2: Target approaching using the elliptical arc path.
- Approaching direction

Step 3: Precisely localization using the circular path.
- localization precision analysis
- Result fusion
- Optimal radius design

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Thanks !