Sonar imaging of structured sparse scene using template compressed sensing

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Outline

- Background
- Proposed Method
- Conclusion

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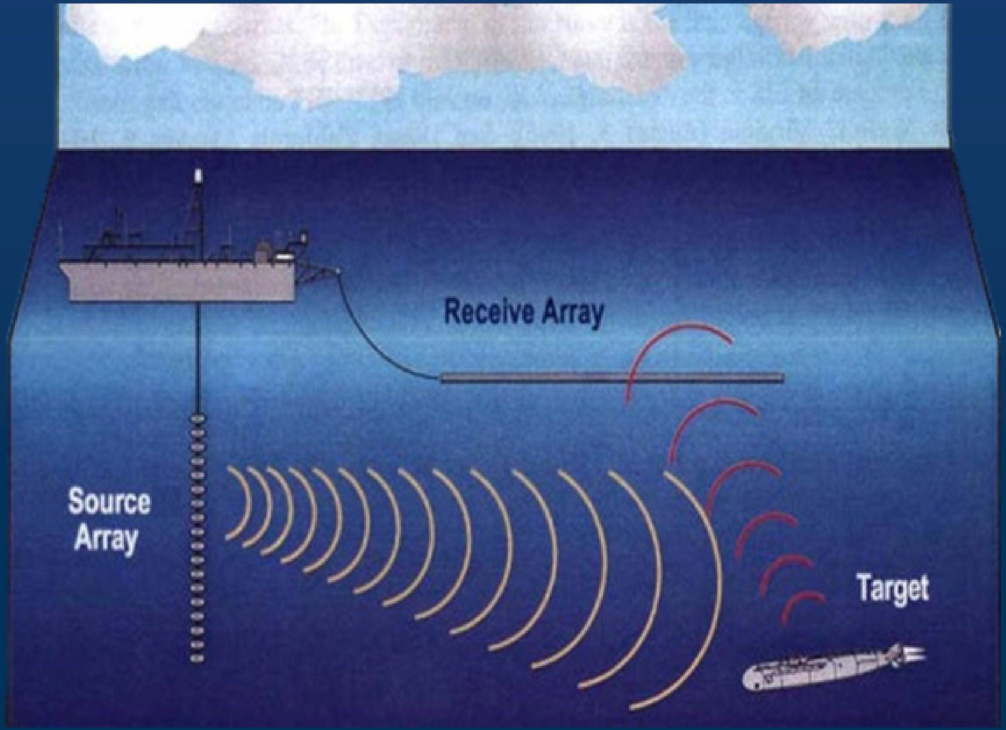
Background



Background

	Radar	Sonar
Velocity (m/s)	3×10^8	1.5×10^3
Random Motion	Small	Large
Working Distance	Far	Near
Transmitting Media	None, Steady	Changing Over Time and Distance
Noise	Receiving End	Surrounding
Bandwidth	Narrow Band	Wide Band

The efficiency of radar is 2,500,000 higher than sonar

$$\frac{2\omega r}{\lambda} < \frac{F_r}{2}$$

- To image a target of size 100m in 600m distance, and gain a resolution in along-track direction of 1m, the imaging time is 80s.

$$\rho_a = \frac{\lambda}{2\Delta\theta}$$

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Random Motion

- Because no GPS under sea, inertial navigation is used;
- For instance, the wavelength of a 200kHz sound is 75mm, motion compensation is of mm.

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Media is time-variant and place-variant

- Multipath and refraction happens.
- It is not a problem since the random motion is not well compensated.[M. P. Hayes and P. T. Gough, 2009]

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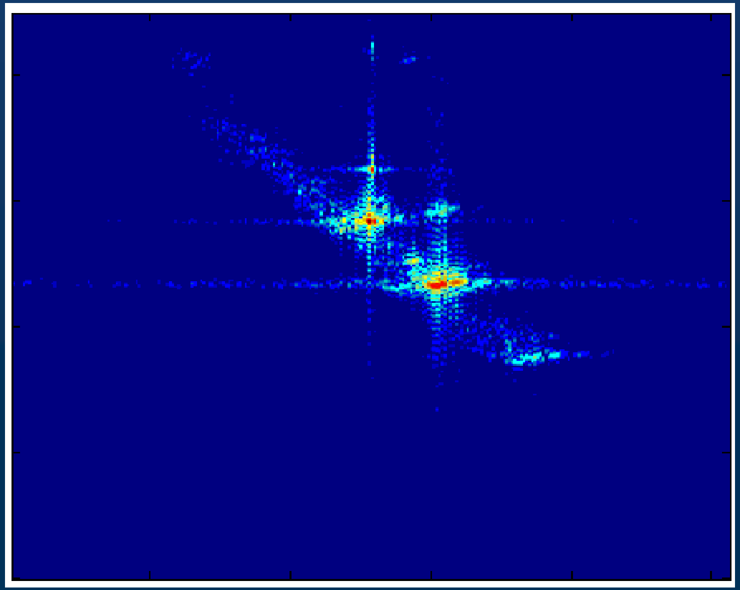
The noise is abundant

•Noise comes from the surrounding. Divided in to ambient noise和self noise. The former includes earthquake, traffic, tide, thermal noise, etc.; the latter includes mechanical, propeller noise, etc.

Background

- Scenario of monitoring submarines for a given area under sea.



SPARSE!

STRUCTURED SPARSE!

Background

- Propose a system to deal with two problem:
  - The efficiency of imaging —velocity of sound;
  - The resolution of imaging —random motion.

Outline

- Background
  - Sonar imaging is different with radar in velocity and random motion;
  - Sonar image is sparse and structured sparse in some applications.
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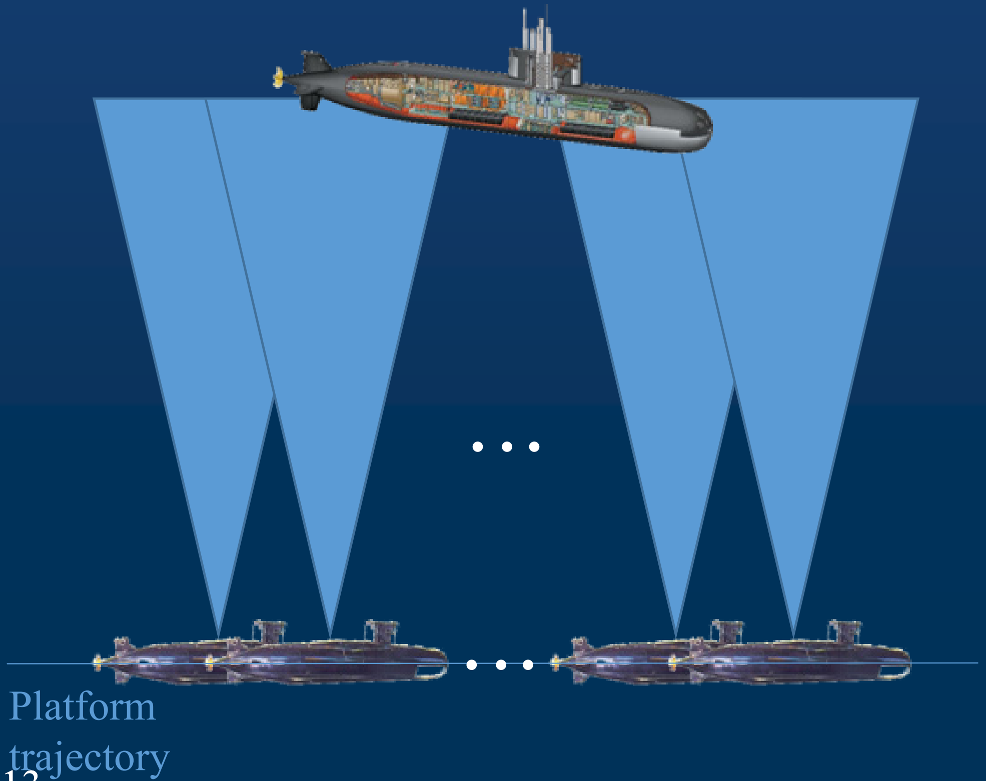
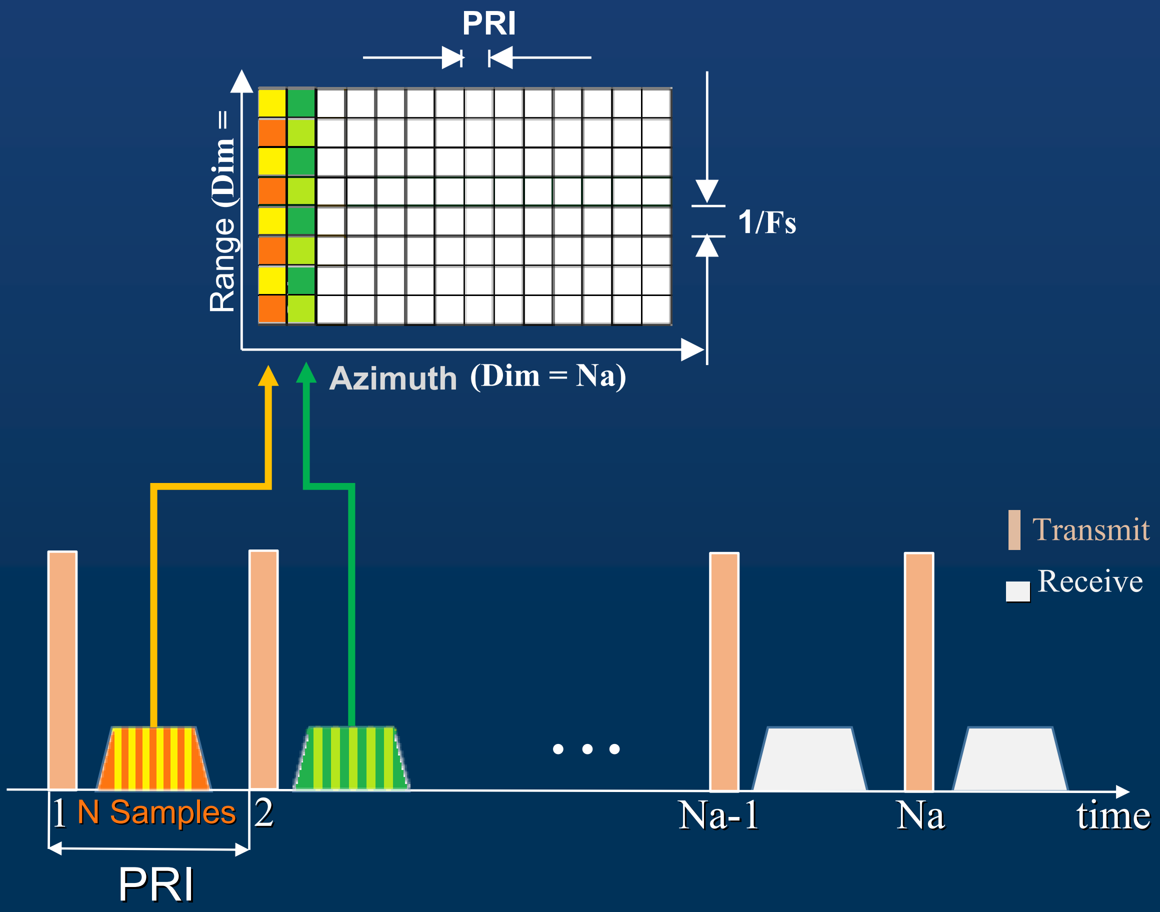
Proposed Method

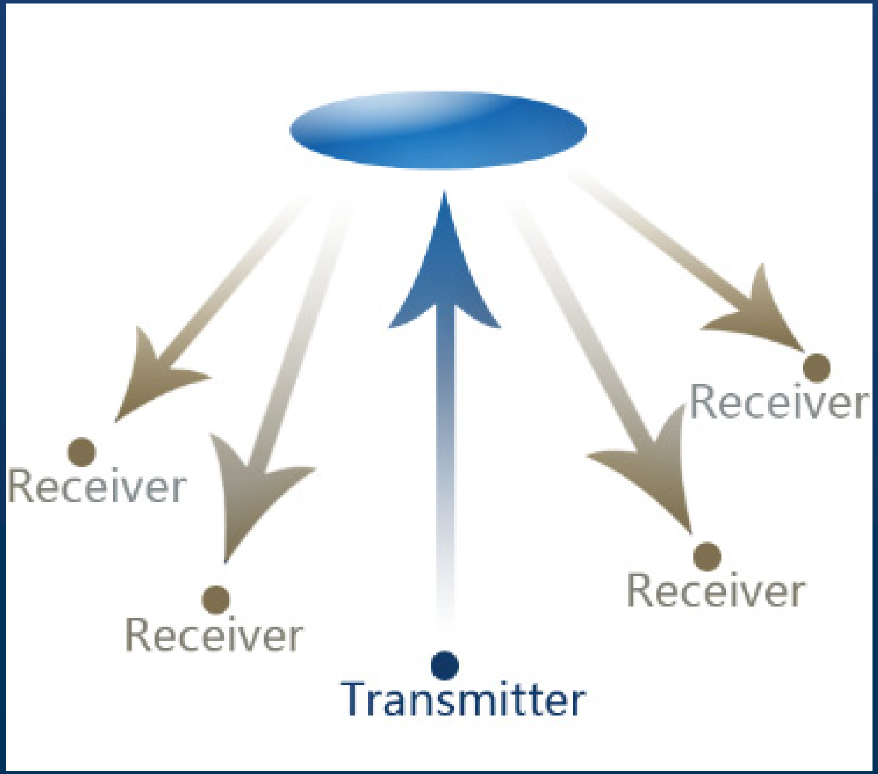
- Traditional model





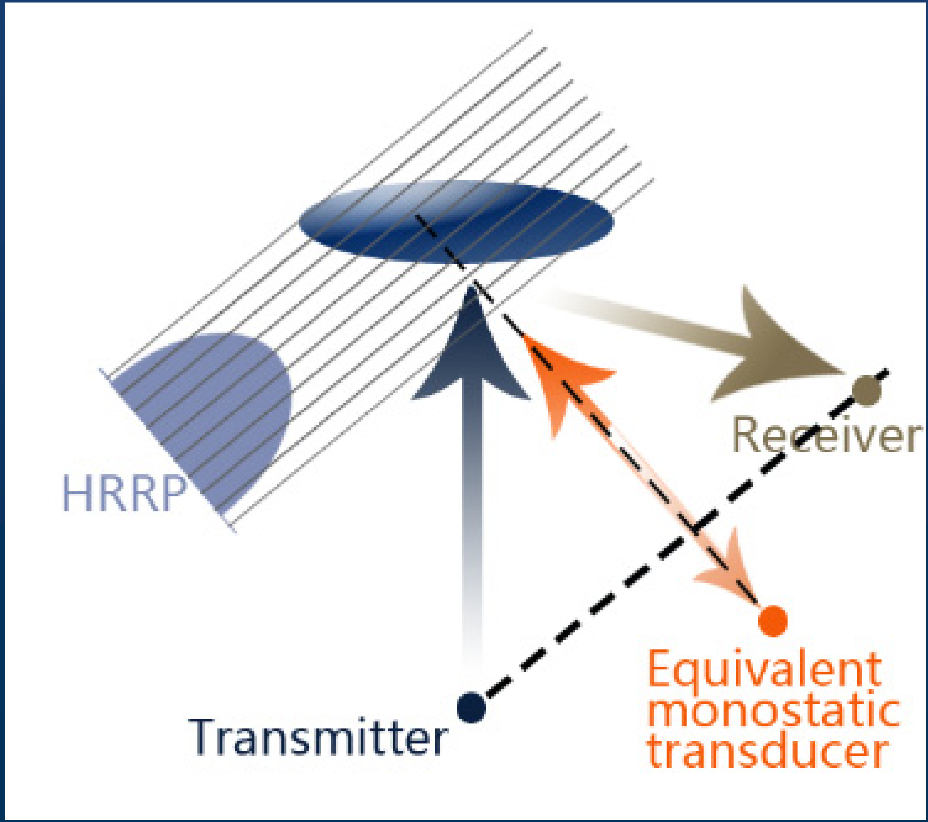
Proposed Method

Tomography model



Single Input, Multiple Output

Proposed Method



$$\underset{n\times 1}{y_1} = \underset{n\times n^2}{A_1}\ \underset{n^2\times 1}{x}$$

Proposed Method

m transducers:

$$\begin{cases} \boldsymbol{y}_1 = \boldsymbol{A}_1 \boldsymbol{x} \\ \boldsymbol{y}_2 = \boldsymbol{A}_2 \boldsymbol{x} \\ \quad \vdots \\ \boldsymbol{y}_m = \boldsymbol{A}_m \boldsymbol{x} \end{cases} \quad \boldsymbol{Y} = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_m \end{bmatrix} \quad \boldsymbol{A} = \begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{bmatrix}$$

$$\boldsymbol{Y} = \boldsymbol{A}\,\boldsymbol{x}$$

Proposed Method

$$Y = A x$$

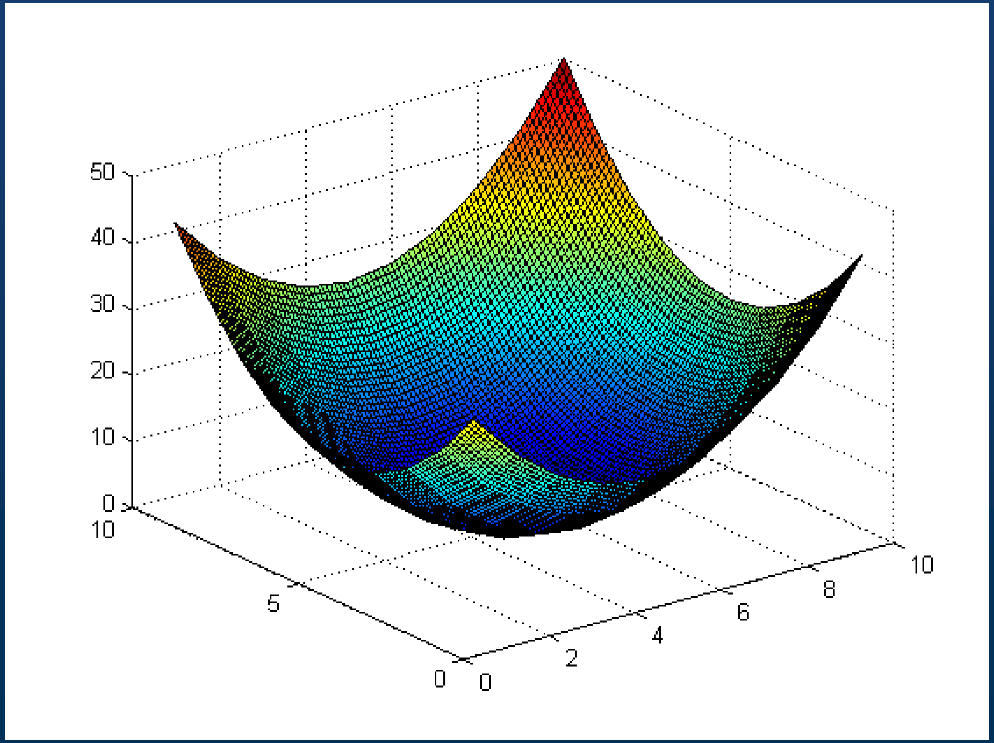
- x is structured sparse.
- Idea: **to exploit single echo prior.**

- Case: the submarine is in the middle of the scene.

Proposed Method

$$\min \quad \left\| \mathrm{vec}\left(\boldsymbol{W} \odot \boldsymbol{X} \right) \right\|_1$$

$$s.t. \quad \boldsymbol{Y} = \boldsymbol{A}\boldsymbol{x}$$



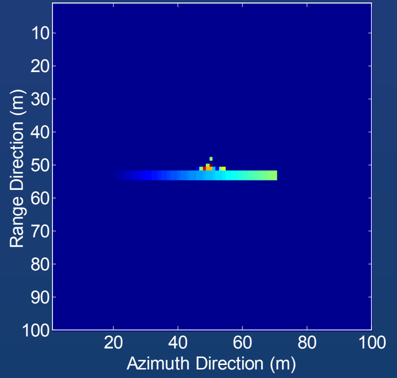
W matrix

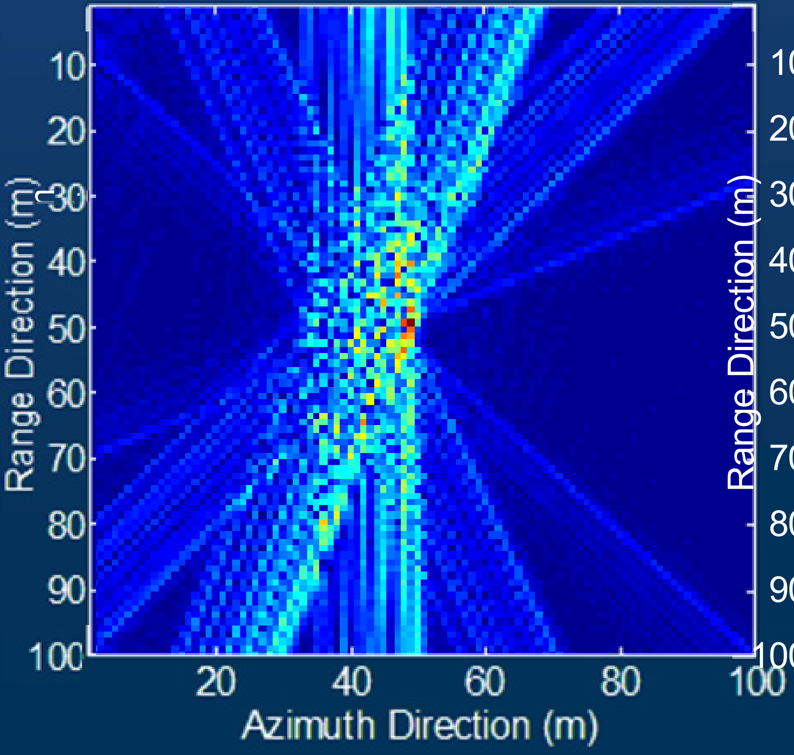
Proposed Method

- Method: Sonar sound
- Aim: To cope with the random motion & slow speed of sound
- Advantage: Imaging time is largely shorten;
- Disadvantage: Increase the number of sensors;
- Application: Monitoring of the sea.

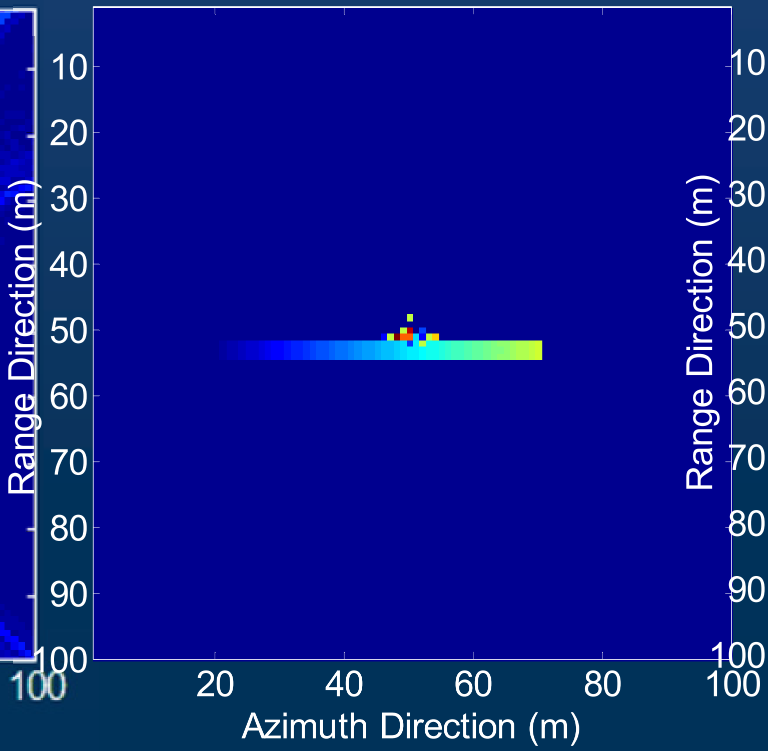
Proposed Method

100*100Scene:

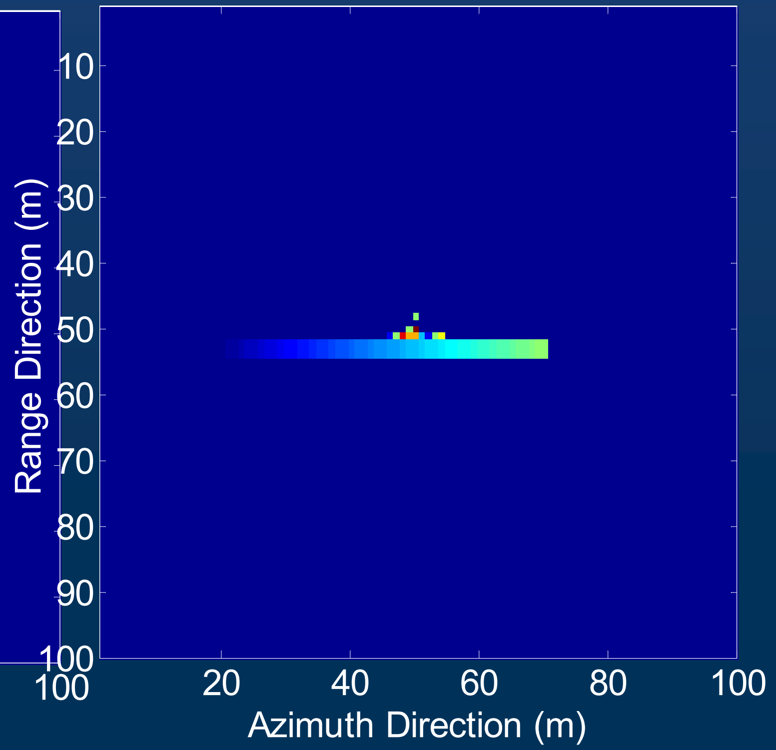




Tomography method



CS method



template CS method

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Conclusion

- CS is very suitable for sonar imaging.
- We proposed a method to cope with the low velocity of sound and random motion.
- We took advantage of each echo, and exploited the structured sparse of the scene, and obtained better results.

References

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Thank You!

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Q&A