A NOVEL MOTION COMPENSATION APPROACH FOR SAS

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OUTLINE

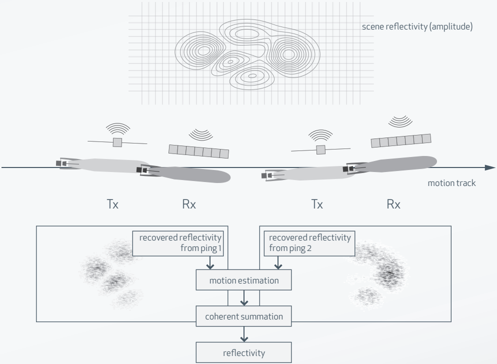
> The acoustic model

> Synthetic Aperture Sonar (SAS) and Phase Center Approximation (PCA)

> The motion estimation problem and the Displaced Phase Center Antenna (DPCA) solution

> An algebraic approach

A QUICK LOOK AT SAS



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ISSUES IN SAS

- The motion speed is limited by the desired cross range resolution and maximum range
- The coherent summation of pings requires an accurate knowledge of ping positions
- Vehicles have to be equipped with an Inertial Navigation System (INS)
- Further corrections are implemented by digital signal processing

GOALS

Is it possible to extract motion information from raw data and give up to micronavigation?

Is it possible to measure the amount of coherency among pings contributing to the synthetic aperture?

ACOUSTIC MODEL

> Narrowband input

> Exploding source model

$$\alpha^2 \propto \delta(z_t, z) + \delta(z_r, z) \propto \tau(z_t, z_r, z)$$

> Output signal

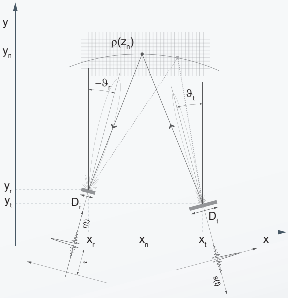
$$r(t) = \int_z \rho(z)\, \alpha(z_t, z_r, z, \vartheta_t, \vartheta_r)\, s(t - \tau(z_t, z_r, z))\, \mathrm{d}z$$

> Green's function

$$G(z_n) = \alpha(z_t, z_r, z_n, \vartheta_t, \vartheta_r) e^{-j2\pi f_0 \tau(z_t, z_r, z_n)}$$

> SISO model

$$\phi(t_m) = A(t_m, z_n)\, G(z_n) \rho(z_n)$$



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SAS AS A MIMO SYSTEM

> By collecting the outputs of monostatic SISO systems on a straight path, the reflectivity can be recovered with constant range resolution

$$\rho(z_n) \approx \sum_{l \in \mathbb{Z}} G_l^*(z_n) A_l^\dagger(z_n, t_m) \phi_l(t_m)$$

BACKPROJECTION

> Design example

$$D = 5\,\mathrm{cm} \qquad R = 150\,\mathrm{m}$$

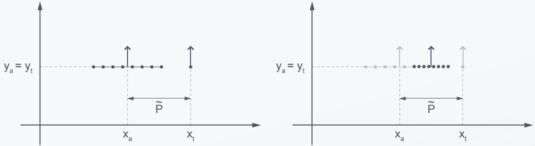
$$v \leq {}^{D}/_{4 \max(\tau(z_{l,t}, z_{l,r}, z_n))}$$

$$v = 6.25\,\mathrm{cm/sec}$$

PHASE CENTER APPROXIMATION

> To increase the AUV speed, SAS is obtained as a collection of bistatic systems approximating the designed monostatic systems

> The differential rotation between Tx and Rx is not represented



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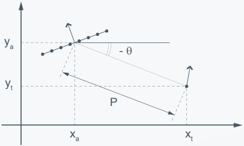

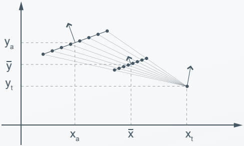

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DISPLACED PHACE CENTER ANTENNA

- Displaced Phase Center Antenna is the state of art technique for estimating the perturbations between two pings
- Some of the PCA equivalent monostatic positions are shared between successive pings
- The INS has to guarantee that the along track speed is constant, i.e. no longitudinal perturbation (surge)
- Rotation (yaw) and lateral perturbation (sway) are estimated by performing correlations between corresponding locations

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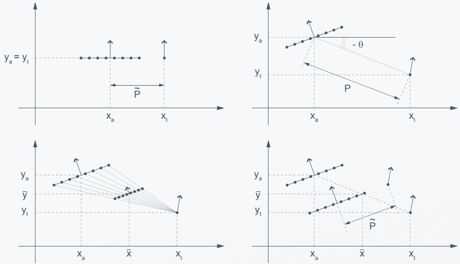
EFFECTIVE PHASE CENTER APPROXIMATION

> A new approximation capable of representing the differential rottion between Tx and Rx



MOTION ESTIMATION

METHOD

> Estimate Tx to Rx rotation by means of a heuristic procedure

> Estimate the ping to ping displacement with no priors by projecting on the algebraic intersection between the corresponding subspaces

OUTCOMES

> Surge, sway and yaw are estimated at the same time

> An accurate INS is not necessary

> The trajectory can be non straight

PING TO PING DISPLACEMENT

- Consider the orthogonal projector at each ping
- Consider the projection on the intersection of the subspaces corresponding to two pings
- Compute the intersection with respect to the two pings as a function of the hypothetical displacement

$$Q^{(p)} = (\tilde{T}^{(p)})^{-1}\tilde{T}^{(p)}$$

$$\psi = \lim_{i\to\infty}(Q^{(q)}Q^{(p)})^i\rho$$

$$\psi^{(p)}_{\tilde{\mu},\tilde{\nu},\tilde{\xi}} = \lim_{i\to\infty}(Q^{(p)}S_{\tilde{\mu},\tilde{\nu},\tilde{\xi}}[Q^{(p)}])^i\breve{\rho}^{(p)}$$

$$\psi^{(q)}_{\tilde{\mu},\tilde{\nu},\tilde{\xi}} = \lim_{i\to\infty}(S_{\tilde{\mu},\tilde{\nu},\tilde{\xi}}[Q^{(p)}]Q^{(p)})^i\breve{\rho}^{(q)}$$

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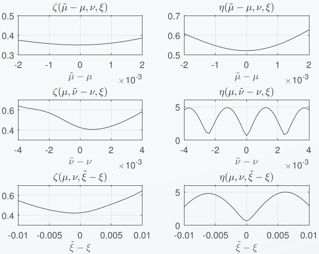
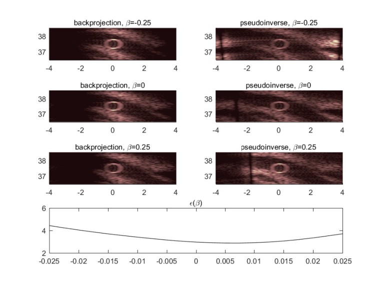
PING TO PING DISPLACEMENT

> Employ an error function based on amplitude for rough estimation and and error function based on phase for fine estimation



TX TO RX ROTATION

> Consider the scene reconstruction performed by backprojection and pseudoinverse with respect to an estimated differential rotation error



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CONCLUSION

- An accurate motion estimation procedure has been identified
- The computational cost is remarkable but less prior information is required
- Further experiments on real data are need to validate the procedure

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THANKS FOR YOUR ATTENTION