

\[ L \sin(\theta - \alpha) = c + \varepsilon \]

which can be expanded as
\[ L \cos(\theta - \alpha) \sin(\theta \cos(\theta)) = c + \varepsilon \]

Multiple Radon transform results, i.e.
\[ \cos(\theta - \alpha) \sin(\theta \cos(\theta)) = c + \varepsilon \]

and its matrix form can be written as
\[ \mathbf{A} \mathbf{x} = \mathbf{c} + \varepsilon \]

By using the least square method, the range walk angle can be estimated by
\[ \mathbf{A}^\top \mathbf{A} \mathbf{x} = \mathbf{A}^\top \mathbf{c} + \mathbf{x} \]

and then the velocity of moving target can be obtained as
\[ \mathbf{c} = \mathbf{A} \mathbf{x} = \mathbf{A} \mathbf{c} + \mathbf{x} \]

To improve the robustness further, we modified the geometry model as
\[ \mathbf{A} = \mathbf{K} = \mathbf{L} \]

Geometry information is used to weight the error
\[ \mathbf{A} \mathbf{x} = \mathbf{G} \mathbf{d} \]

and the range walk angle can be estimated by
\[ \mathbf{A}^\top \mathbf{A} \mathbf{x} = \mathbf{A}^\top \mathbf{c} + \mathbf{x} \]

The multiple transforms method

Estimation performance comparison

The basic methods

Radial velocity can be estimated by range walk angle
\[ v = c + \tan(\theta - \alpha) \]

And then the range velocity estimation turns to angle estimation. Conventionally, the range walk angle is searched by the Radon transform with low efficiency, as shown in Fig. 1(a).

By analyzing the projection nature of Radon transform, we can obtain the geometry relationship between the Radon transform results and the range walk angle
\[ L \sin(\theta - \alpha) = c + \varepsilon \]

Since the limited range velocity brings limited range walk angle, and the absolute operation can be removed. And two Radon transform results can be written by
\[ L \sin(\theta - \alpha) = c + \varepsilon \]

and the range walk angle can be estimated by using the formulas above as
\[ L \cos(\theta - \alpha) \sin(\theta \cos(\theta)) = c + \varepsilon \]

and then the velocity of moving target can be obtained as
\[ \mathbf{c} = \mathbf{A} \mathbf{x} = \mathbf{A} \mathbf{c} + \mathbf{x} \]

The weighted method

To improve the robustness further, we modified the geometry model as
\[ \mathbf{A} = \mathbf{K} = \mathbf{L} \]

Geometry information is used to weight the error
\[ \mathbf{A} \mathbf{x} = \mathbf{G} \mathbf{d} \]

and the range walk angle can be estimated by
\[ \mathbf{A}^\top \mathbf{A} \mathbf{x} = \mathbf{A}^\top \mathbf{c} + \mathbf{x} \]

The multiple transforms method

Estimation performance comparison

Parameters Estimation Efficiency and Accuracy Improvement

Radial transform of range

(a) Searching based method

(b) Radon transform based method

Radar transform results

(c) Radon transform results

(d) Geometry relationship

(e) Averaging result

(f) Searching result

(g) Generalized result

(h) Noise suppression result

(i) Noise suppression result

(j) Motion estimation results

(k) Motion estimation results

(l) Radon transform result

Fig. 1 Concept of efficiency Radon transform based estimation method

Fig. 2 Estimation performance comparison versus SNR

Chatter and Noise background

(a) Range transform angle of A

(b) Radon transform angle of A

(c) Ideal Radon transform result of A

(d) Ideal Radon transform result of A

(e) Range transform angle of B

(f) Radon transform angle of B

(g) Ideal Radon transform result of B

(h) Ideal Radon transform result of B

(i) Range transform angle of C

(j) Radon transform angle of C

(k) Range transformation results of C

(l) Radon transform results of C

Fig. 3 Radon transform used for clutter suppression.

Fig. 4 Radon transform used for noise energy cancelling.

Fig. 5 Concept of robust Radon transform based estimation method

Fig. 6 Estimation robustness comparison versus SNR

SNR vs. RTR

(a) Searching based method

(b) Radon transform based method

(c) Multiple Radon results

(d) Multiple normalized results

(e) Range transform results

(f) Range transform results

(g) Range transform results

(h) Range transform results

(i) Range transform results

(j) Range transform results

(k) Range transform results

(l) Range transform results

Fig. 7 Estimation accuracy comparison versus computing time.

Fig. 8 SAR and moving targets detection results.

Fig. 9 Moving target imaging and localization results.

Fig. 10 Concept of efficient compressed sensing method.

Fig. 11 Real data processing.

Fig. 12 Imaging results comparison.

Other Applications

Doppler Rate Efficient Estimation

Geometry information can also be used such as efficient Doppler rate estimation. By analyzing the nature of WVD, the edge of the searching based results can be parameterized as
\[ \phi = \sin(\theta - \alpha) + \varepsilon \]

The Doppler rate can be estimated by
\[ \phi = \sin(\theta - \alpha) + \varepsilon \]

Efficient Sparse Imaging

This can be further used for sparse imaging. The compressed sensing model can be written by the discrete fractional Fourier transform as
\[ \phi = \phi(\theta - \alpha) + \varepsilon \]

And the geometry information of the two transform results
\[ \phi = \phi(\theta - \alpha) + \varepsilon \]

are used for moving targets efficient sparse imaging by
\[ \phi = \phi(\theta - \alpha) + \varepsilon \]

Real Data Processing Results

Related Publications

