AN EFFICIENT TARGET LOCALIZATION ESTIMATOR FROM BISTATIC RANGE AND TDOA MEASUREMENTS IN MULTISTATIC RADAR

ICASSP 2018

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Abstract

Problem Description
- Target localization problem in multistatic passive radar

Method
- Algebraic closed-form method
- Based on two-stage WLS estimator
- Using the hybrid BR and TDOA measurements

Advantage
- Provide a better target localization accuracy than using BR alone
- Be able to reach CRLB accuracy

Data Model
- 3D space
- M transmitters, \( t_i = [x_i, y_i, z_i]^T \)
- N receivers, \( s_j = [x_j, y_j, z_j]^T \)
- A single target, \( u = [x, y, z]^T \)

Method Derivation

First Stage
- BR positioning equation
  \[ 2r_j^2 \Delta u_j = u_j^2 + r_j^2 + d_j^2 + d_j^2 \]
- TDOA positioning equation
  \[ 2r_j^2 \Delta \tau_j = r_j^2 + s_j^2 + s_j^2 - 2(s_j - s_j)u + 2\tau_j^2 \]
- Matrix form equation
  \[ B_j \Delta \varphi = h_j - G \varphi \]
- WLS solution
  \[ \varphi = (G_j^T \Omega_j^{-1} G_j)^{-1} G_j^T \Omega_j^{-1} \]

Second Stage
- First stage solution
  \[ \varphi = \hat{\varphi} + \Delta \varphi \]
- Dependency relationship
  \[ \Delta \varphi = \hat{\varphi} + \Delta \varphi \]
- Matrix form equation
  \[ B_j \Delta \varphi = h_j - G \Delta \varphi \]
- WLS solution
  \[ \Delta \hat{\varphi} = (G_j^T \Omega_j^{-1} G_j)^{-1} G_j^T \Omega_j^{-1} \]

TDOA Measurement
- TDOA: time difference of arrival
  \[ \Delta TDOA_j = r_j - r_j + \Delta \tau_j \]

Simulation Results

Simulation 1
- Be illustrated in Fig.3 and Table.1
- Performance of proposed method is best, due to introduction of TDOA
- Accuracy improvement is affected by the number of transmitters

Simulation 2
- Be reported in Fig.4
- The hybrid method outperforms the BR-based method, even though TDOA-based method fails to work

Simulations
- 5 transmitters, 5 receivers, 1 target
- \( Q_0 = \delta_j I_N, Q_m = \delta_j I_{N-1} \), \( Q_m = \text{diag}(Q, Q_0) \)
- 5000 ensemble runs

CRLB for BR + TDOA: \( \delta_j = 4 \)

Table.1. Average accuracy improvement, \( N = 5 \)

<table>
<thead>
<tr>
<th>Improvement</th>
<th>M=2</th>
<th>M=3</th>
<th>M=4</th>
<th>M=5</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE (dB)</td>
<td>3.80</td>
<td>1.37</td>
<td>0.96</td>
<td>0.56</td>
</tr>
<tr>
<td>CRLB (dB)</td>
<td>1.41</td>
<td>0.87</td>
<td>0.81</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Conclusion

- (1) This paper proposed a target localization algorithm using hybrid BR and TDOA measurements
- (2) It can provide a better location accuracy than BR-based method
- (3) It's able to attain CRLB bound, under small Gaussian measurement noise.