Design, Analyze, and Implement Radar Sensors' Alignment Algorithm with MATLAB

Liang Ma
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Delphi Electronically Scanning Radar

Three main properties of radar targets:
- Range
- Range rate
- Azimuth

Main features:
- Adaptive Cruise Control
- Collision Mitigation
- Rear and Side Detection System
Alignment Algorithm

- Radar sensor misalignment angle is the angle difference between real radar boresight and designed radar boresight.
- Lateral offset = range * sin(azimuth)
Least Square solver for Dynamic Alignment

Combine all the equations/detections:

\[ A(\text{azimuth}) \times x = B(r') \]
\[ x = A \backslash B \]
Simulation results (No noise added, injected misalignment angle: 0.3 degree)

Input host speed, radar targets’ real time azimuth, range and range rate, then simulate the LS solver alignment algorithm with MATLAB.

The simulation results shows that there is no error on the calculated misalignment angle. This algorithm is effective.
Cont. (Add azimuth noise : 0.3°*randn + 0.1°)

Raw Misalignment Angle Updates. Median: 0.39781 degree
Cont. (Add range-rate noise : $0.1^\ast \text{randn}$)

The greater the angle spreading, the less the noise, why?
A Matrix Condition Number ( $\text{cond}(A)$ )

Condition number is a relative error magnification factor.

Ref. : Cleve Moler, 'Numerical Computing' e-book

Cond($A$) keeps decreasing with the increasing angle spreading of detections' azimuth.
Real Vehicle Logs Processing Results (600+ logs, 80+ GB, 3 days' testing)

![Smoothed Misalignment Angle](image-url)
Cont.

Raw misalignment angles

Histogram of raw angle updates
Implement with Matlab Coder
Verify Generated Code

% [YC_output, YC_Cals, YC_Params] = yawRateComp(YC_input, YC_output, YC_Cals, YC_Params);
% MATLAB Specs found here
    [YC_output, YC_Cals, YC_Params] = yawRateComp_mex(YC_input, YC_output, YC_Cals, YC_Params);  % Verify generated code here and accelerate
Coder Code Performance

Conclusions:

✓ Reliable. Coder code has been used in production code for half a year and no bug is found;

✓ Efficient. This improved alignment algorithm with coder code can run as fast as previous old algorithm with hand code.

✓ Easy to integrate.
Summary

- Radar Sensors’ Alignment Algorithm design, simulation, data analysis, and implementation are done together within Matlab only;
- One algorithm engineer can completely responsible with one algorithm block. Save time to coordinate with software engineer.
- In the future, Matlab plus Coder will be popular in algorithm development area.