Airborne Radar Data Analysis Tool

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Abstract:

This paper describes a software tool that has been developed for analysing data collected by airborne radar. The design of tool is generic based on MATLAB. It has built in features for evaluating and analysing radar data especially during development and testing cycles of radar development. The tool integrates geographical map with features, data from GPS and AIS to present a comprehensive visual depiction of aerial and sea surface targets as detected and tracked by airborne radar. The radar scenario varies dynamically as the sensor is mounted on a flying platform. The tool aids in visualizing the scenario and evaluating the effectiveness of the mission. It aids in decision making and arriving at conclusive analysis on the performance of various algorithms that are under test.

Introduction:

Analysis of data is a process of inspecting, transforming and interpreting data with the goal of verifying results, discovering useful information, suggesting conclusions, and supporting decision making. Data Analysis helps to present results of collected data graphically for making effective interpretation of data. The techniques for analyzing the airborne radar data sets are different as compared to those for ground-based radars. Due to own platform motion, the radar position and orientation is continuously changing. To visualize the effect of same on radar detections and surveillance coverage it is intuitive to see - coverage and radar detections with respect to inertial frame of reference. Data visualization requires translation of data in different co-ordinate frames of reference. The sensor measurements are usually received in antenna coordinates. These require intermediate translations to aircraft body reference frame and aircraft centric NED frame to convert the data to ECEF reference frame and WGS 84 coordinate system for presentation. Hence for complete visualization of airborne radar data plotting is required in different frames of reference. Plotting of data on map gives a pictorial view of the various regions as it is captured by the sensor from various positions and with different orientations during flights. Geographical map also provides aid to quantify radar performance against various terrains such as forest, mountain, rail, road, urban clutter, etc.

Requirement Analysis:

For airborne radars, the number of data recording points is more during software development stage for purpose of analysis. This leads to huge data that is spread across multiple files, running into Giga bytes of data in few hours of operation. This necessitates an automated program that has capability to extract and analyze data efficiently, as well as merge them together to find the overall performance of system. Tool aids to automate and complete the analysis at faster pace.

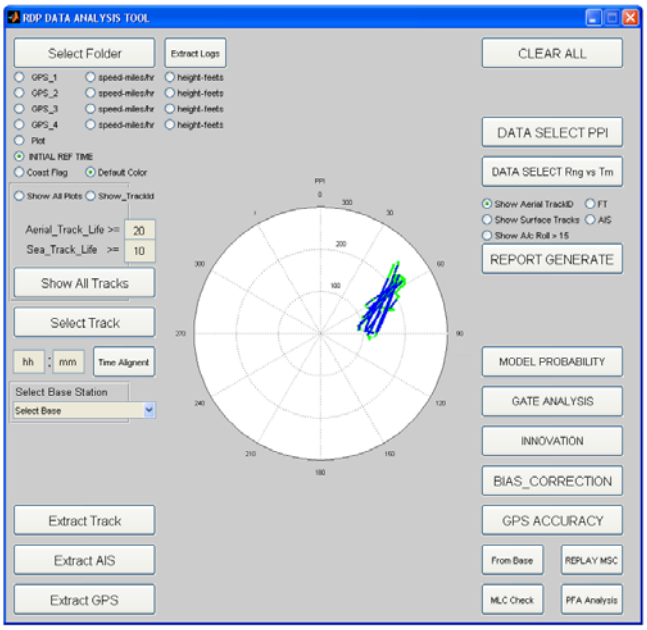

Figure 1: Radar Data analysis Tool GUI

The tool is envisaged to have the following capabilities. a) Provide the capability to select and merge the recorded files b) Provide the facility to store the merged data in the required file formats. c) Provide the facility to the user to select the log file of interest, through a Graphical User Interface (GUI). d) Provide facility to select a point of reference for the presentation of results on the map. e) Capability to select the available true reference data in the form of Global Positioning System (GPS)/ Automatic Identification System (AIS). f) It shall provide the radar picture in isolated and overplayed views with respect to time and space.

System Architecture: System architecture diagram for Air borne Radar Data Analysis Tool is shown in Figure 2. The architecture is split into three modular sections namely input section, processing section and graphical outputs. .The tool has data level interface to Radar data logs, GPS, AIS and operator defined data. The processing section has functional capabilities for command interpretation, extraction and formatting of data from radar, GPS and AIS, coordinate conversions in different frames of reference, time alignment, bias correction and radar data feature processing functions. The outputs of the tool are in form of various graphs and plots based on features chosen by user for analysis. The tool has built in facility for replaying the entire mission.

Development Approach: The tool has been developed in MATLAB which utilizes the GUI as shown in Figure 1, plotting capabilities, Replay facility, and file interface for GPS and AIS data. The extraction of merging of radar data is done using Microsoft visual studio. Airborne Radar Data Analysis Tool is designed for visualization of sensor measurements, beam positions as scheduled by radar during operation, tracker output along with own platform INS-GPS for pictorial representation and analysis.

Functional Capabilities:

1. Plotting information at multiple levels: The tool is capable of generating various figures for analysis at multiple levels. For example it can generate a plot of track on map as shown in figure 3. At next level the tool depicts radar measurements along with tracks on map. Going one more level in depth it can show the positions of beam as scheduled by radar Refer figure 4. Adding more information it can represent different beam types at next level of analysis.

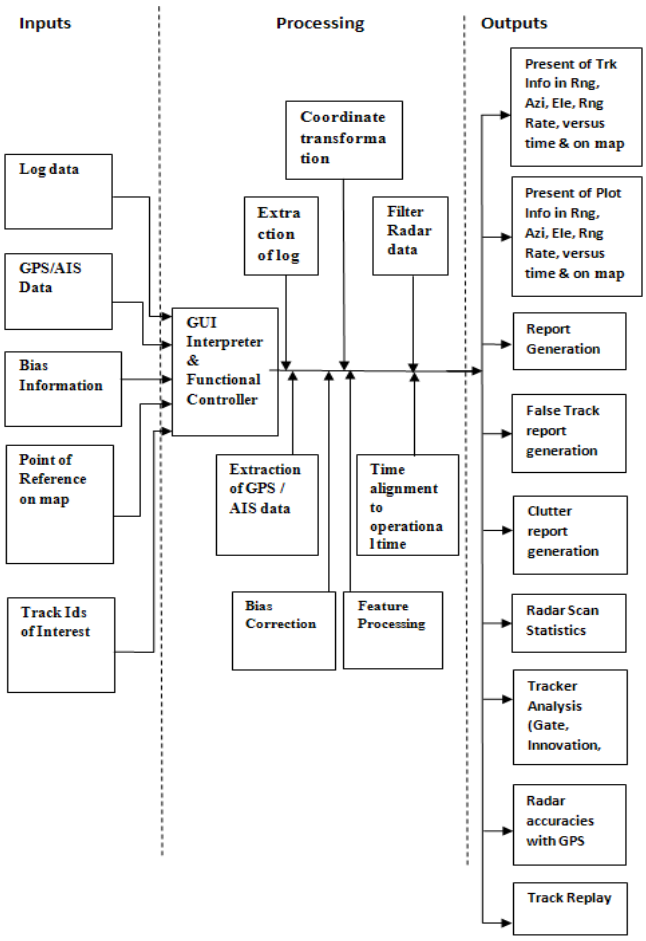

Figure 2: Architecture Diagram

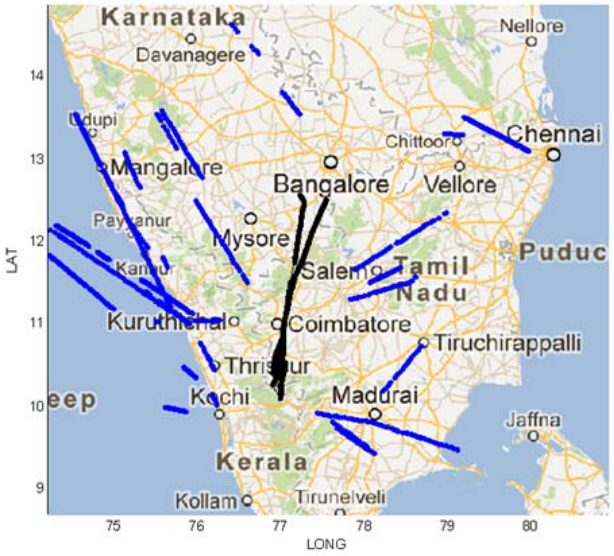

Figure 3: Radar Tracks

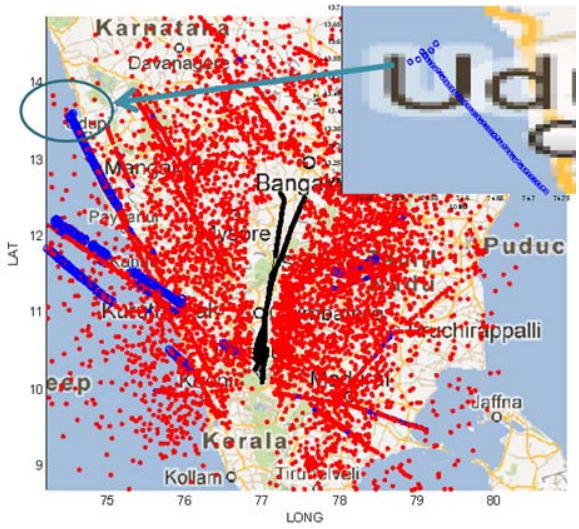

Figure 4: Tracks, Plots and Beams

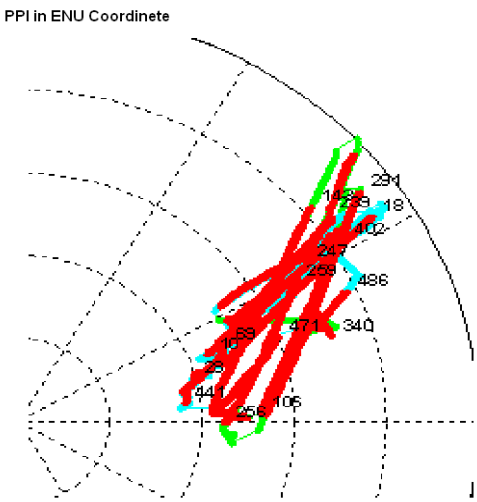

Figure 5: Target true data and Measurement

2. Analysis with GPS: For verification of the radar performance, controlled targets are flown and detections from target is recorded. The GPS or DGPS mounted on aircrafts records the true position of target for comparison with radar detections. GPS/DGPS data received from target contains parameters like time, latitude, longitude, speed, heading, altitude, etc. Tool has features to extract multiple GPS and DGPS data and to stores it into text file. This text file is used along with the radar navigation data. The GPS data is interpolated with respect to radar time and is converted into range, azimuth & elevation of the target as seen by the radar while flying. This GPS data is overlaid along with radar measurements for performance evaluation.. Tool provides the facility to identify and extract through GUI visually, the radar tracks and radar detections which is correlating with GPS data on map, range, azimuth and height graphs. GPS data is used for radar performance analysis which includes verification of beam positions for target under track, radar detections for the targets under observation, computation of track accuracies and report generation. Figure 5 shows GPS data overlaid with radar detections and track for comparison.

3. BIAS analysis and corrections: To compute the target's true position with respect to radar, it is necessary to identify the bias between GPS data and radar data. Tool converts the radar data in WGS 84 and overlays it with GPS data after correction of bias in system. In Figure 6, blue line shows radar track and green line shows GPS data. There is difference in GPS data and radar data which is removed by user. After correction, GPS data is in aligned with radar data.

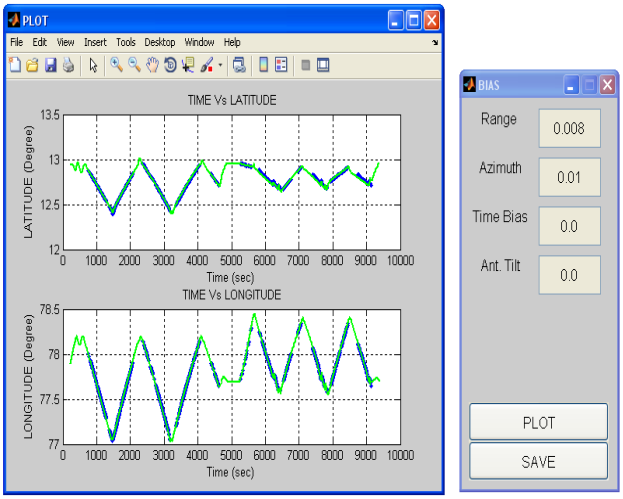

Figure 6: Bias Correction

4. Analysis with AIS: Automatic Identification System (AIS) is used to identify the sea surface targets and their positions. The AIS data is used as reference for performance checks with the radar tracks during air to sea mode of operation. AIS data records true GPS positions which are broadcasted by the individual ships. Thus multiple ships positions are recorded along with their unique Maritime Mobile Service Identity (MMSI) code. The tool extracts multiple AIS data, merges them together and stores it as AIS.txt. This file is used along with the radar navigation data, to compute range, azimuth & elevation of the sea surface target as seen by the radar. Tool provides the facility to select desired AIS data of ship using MMSI code, extract it from GUI, and compare it with the radar track of interest. Tool computes the accuracies and generates the report.

5. Tracker analysis: Tool has capability to do in depth analysis for multi target tracker. The following are the features available for analysing the tracker performance:

a) **Tracker accuracy analysis**: Tool generates the figures for tracker's performance along with GPS/AIS data showing graphs for range, azimuth, elevation, speed, heading, range rate, computed Radar Cross Section (RCS) and generates reports. It also generates histogram for accuracies of range, azimuth, elevation, height, speed, and heading for tracker with respect to true target data GPS/AIS.

b) **Gating:** In multi-target tracking system prior to data association between radar detections and tracks, gating process is executed for selection of candidate plot-track pairs for carrying out association. The tool generates figures for the gates of desired target tracks in all dimensions along with available GPS/AIS data.

c) **Data association analysis:** Tool has feature to depict the correctness of plot-track associations visually. It can visually depict the correlation between multiple detections and tracks which is useful in performance checks of association algorithms.

d) **Innovation:** Tool plots the associated plot-track's innovation in range, and azimuth during updating of filter.

e) **Probability analysis:** If multiple models are used for tracking the tool provides features for analysis of model selected during tracking and their probabilities are shown on graphs during the target tracking.

f) **Plot of revisit rate:** In phased array radar several targets can be under track and revisit control mechanisms form an important part of design. The tool has feature to plot revisit rates for target under track.

g) **Probability of Detection (PD) computation:** Detection of target by radar is collected along with the number of scans, when target is with in the radar coverage. The ratio between detections and the detection attempts by the radar at different ranges gives the computed PD at that range bracket.

h) **Track Replay:** Tool has feature to replay the track data along with platform data on map and in range versus time and azimuth versus time in different coordinates for viewing of the tracker performance of radar

6. False Track and Clutter Analysis: Clutters analysis involves detection belonging to specific regions on geographical map as rail, road, forest, cities, mountains, forests, etc. A false track gets initiated over such measurements, and it loads the radar resources. Tool provides the facility to user to select such plots and tracks from geographical map and it separates and groups clutters and false tracks based on its location on map as well as its occurrence at different range and Doppler values. Figure 7 shows road clutter identification on map. This gives the facility to user to analyze data together which is collected over different flights. This information helps to offline evaluate the criteria for reducing the false track initiation and to enhance radar performance.

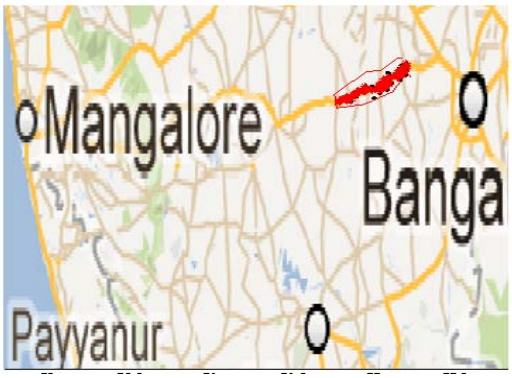

Figure 7: Road clutter identification

7. Other Features: For airborne phased array radar the analysis and correctness of radar navigation parameters like North velocity, East velocity and Down velocity is also of prime importance and can be easily carried out with the tool. Evaluation of several other statistics such as number of plots, tracks, usage of radar resources, scan time can be carried out with tool.

Conclusion:

The tool developed is generic in nature and can be adapted for analysis of data collected by airborne surveillance radar. The tool is especially useful in development and testing phase of airborne radar as it aids in analysis.

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