

Assessment of Automotive RADAR SIL Data Validity by Correlation Methods

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Abstract: As world is heading towards automation, performances required to satisfy standards and market needs are also increasing drastically. In this scenario, validation of obtained data via simulation plays a vital role to verify correctness of system during design cycles. To cater these needs, we present in this paper about the assessment of automatic RADAR Software-In-the-Loop (SIL) data validity by correlation methods. Hence we place automotive RADAR on various locations of car and detect vehicular information and thus obtained data is transmitted to Electronic Control Units (ECUs). ECU in turn takes appropriate actions on data to provoke active safety module through the SIL logins. Our aim is to prove that the real world data and the re-simulated data at the SIL output are fully correlated. Multivariable normalized Euclidean distance approach is utilized to determine whether any two targets are correlated using Microsoft's Visual Basics for Applications (VBA) Integrated Development Environment (IDE).

Keywords: Active safety, Automotive RADAR, Controller Area Network (CAN), ECUs, , Euclidean distance, Flex Ray, SIL.

Introduction

In the last few years, need for automation is increasing in every aspect of life, be it home automation, car automation etc. Hence safety becomes the highest priority in designing any automated system. In early days of automation, Advance Driver Assisted Systems (ADAS) were limited to high end luxury cars but now, the demand for quality, services, efficiency, productivity, safety is the need of the hour even in low economy cars too. Majority of the ADAS features are implemented by placing sensors like automated RADARs in rear and front end of the cars. The physical world data collected by various set of sensors is stored in ECUs [1]. These sensor data have to be processed through various ECU cores and respective feature function has to be activated. But with this approach, debugging becomes highly complex, increases the time-to-market and also incurs huge cost and man power. To overcome these issues many tools were developed which reduces the testing phase. One such robust software tool is SIL, which is cost effective and possess high degree of flexibility and as well used in designing and testing phases. SIL has the features of simulator with fidelity of hardware emulator. It helps in model validation and also links test-bed efforts with simulation [2]. In this paper we access the physical data obtained from various RADARs as real world data and feed it through SIL. The data received at the output of SIL is called re-simulated data. Our aim is to compare these simulated (also known Vehicle logs) and re-simulated data, hence determine the correlation between them. We compare the corresponding Comma Separated Values (*.CSV) of vehicle log data and re-simulated data in VBA by coding specific script using normalized Euclidean distance metric approach [3].

This paper includes: Section II contains the details about of SIL architecture, section III details the validity techniques used for comparing simulated and re-simulated data using VBS and Euclidean distance metric. Section IV explains the algorithms related to RADAR SIL data validity. Section V discusses the simulated results related to comparisons of logins. Section VI concludes the work by throwing light on future scope.

A Technological Architecture of SIL

The architecture for SIL is as depicted in Fig 1.

There are three main divisions in the architecture

- Embedded Library
- Physical Layer Protocols (CAN, Flex Ray, Ethernet)
- Calibrations

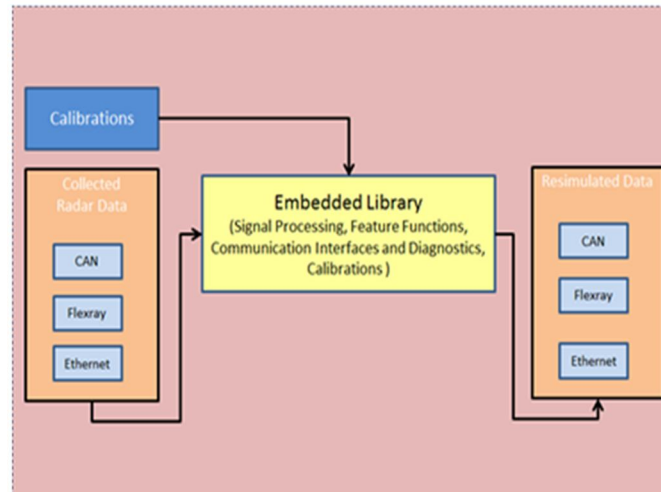


Fig 1: Standard SIL Architecture

Embedded Library

It is a multicore controller. Specifically, it has three cores in which each core is dedicated to a particular task. The cores are named as core zero, core one and core two. Core zero is the initial core which accepts the physical world data carried by CAN and/or Flex Ray and/or Ethernet. Next, core one does all the processing that needs to be done to the signal such as detections and as well generates tracks based on pre-set thresholds. Last, core two takes actions such as to provoke the respective feature function like Cross Talk Alert (CTA), Reverse Cross Talk Alert (RCTA) etc. based on the data obtained from core one.

Physical Layer Protocols

The physical world data is collected from various sensor sources within the car and has to be transmitted to the embedded library via general and/or specific protocols. Here for assessment of RADAR SIL data we use any of the three standard protocols like CAN, Flex Ray and Ethernet. Each of these protocols carries different data in different formats.

1) *CAN*: It is the standard bus specially utilized in vehicular communication. CAN bus collect the sensor information and transmits it to ECUs. Based on the obtained data various ECUs signal one another to take certain safety measures/actions. To emulate this behavior in non-real environment, we use Vector CANoe tool. Vector CANoe is one of the robust Universal development tools for CAN bus systems which help in observing, analyzing and supplementing data traffic on the bus line. CAN Access Programming Language, (CAPL) makes it possible to program the CANalyzer/CANoe for developer-Specific applications that use the CAN protocol.

2) *Flex Ray*: This is another bus standard developed for automobile manufacturers and suppliers, which are high speed, fault tolerant and reliable means of communication. Flex Ray is most preferred bus while transferring crucial data from sensors to ECUs because of its high speed and this feature makes it expensive compared to CAN.

3) *Ethernet*: This is the Local Area Network (LAN) technology used to communicate between networking devices. When the sensor data need to be transferred to another network within or outside the car, then the amount of data to be aggregated and sent is very huge. So we need Ethernet cables to do the task.

Calibration

ECU software is parameterized to such an extent that the diagnostic and control functions may be easily adapted to different system variants or vehicular models by calibrating or changing characteristic values of function algorithms, without the need to change the calculation routines every time. Hence, calibration is very crucial for vehicular performance.

RADAR SIL Data Validity Techniques

This paper aims at validating the SIL framework. The aim is to prove that the real world data and the re-simulated data at the SIL output are fully correlated. Further understanding of validity technique can be done from the figure depicted in Fig 2. When the data arrives via CAN/ Flex Ray/ Ethernet sources, it would be in DVSF format and is called as simulated data or raw data. This DVSF file is not in the readable format. Hence we need to convert it into *.CSV format. To do this conversion we code a script in SIL in prior and give input as DVSF files to convert it to *.CSV files. The high end ECUs executes the robust algorithms stored within the embedded library and also applies various calibrations to the data and generates data at

output of the SIL, which is called re-simulated data. This will be done for multiple iterations until the finest data is obtained as well as the appropriate feature functions are provoked in time.

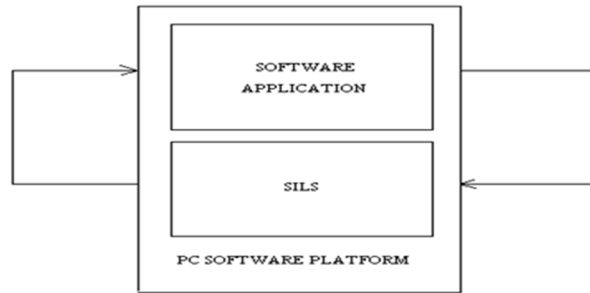


Figure 2: Simplified Block Diagram of SIL

But our aim is to verify the correctness of the re-simulated data thus obtained from SIL. To do so we use VBA tool to compare simulated and re-simulated data which are in Microsoft excel sheet format (other name is *.CSV). Microsoft’s VBA tool is used to compare any two excel sheets or any Microsoft office programs. Any excel sheet has many columns and each column is made up of many rows and our task is to compare two such excel sheets means comparing two columns of same parameter in two files. As it is the comparison of columns in excel sheets belonging to simulated and re-simulated data respectively, we need a distance measuring vector to see if difference is either equal to, greater than or less than zero. For this purpose we choose Multivariable normalized Euclidean distance approach that can be utilized to determine whether any two targets are correlated.

The following rules can be used.

- Normalized Euclidean distance of multiple selected parameters must be within 2 (sigma).
- Selected parameters are range, range rate, angle and lateral offset.
- Sigma values of these parameters used for computing the normalized Euclidean distance should be as follows:
 - 1) Sigma range = 1m,
 - 2) Sigma range rate = 0.25 m/s,
 - 3) Sigma angle = one degree and
 - 4) Sigma lateral offset = one.

If the sigma values obtained are as prescribed above then both logs are correlated else not correlated if otherwise. For better understanding of validity techniques, a detail know how of VBA tool and Euclidean distance is required which is covered as sub sections.

Microsoft’s VBA IDE Tool

This is a very robust software tool used to perform any event driven operation on two excel sheets. There are three main windows in VBA tool namely Editor window, Command window and Result window.

Editor Window: The window is shown in figure 3.

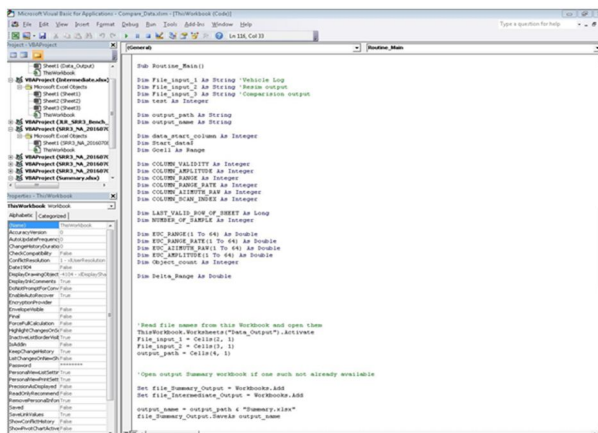


Figure 3: VBAs’ Editor Window

$$d = \sqrt{\sum_{i=1}^p (V_{1i} - V_{2i})^2} \quad (1)$$

Where d is the Euclidean distance, V_{1i} and V_{2i} are the values in column 1 of first and second *.CSV files respectively and p is total number of rows in each column.

VBA Pseudo Code for Assessment of RADAR SIL Data

Algorithm for assessment of RADAR SIL is as depicted in Fig 6.

VBA Pseudo Code

1. Read file names (Vehicle_Log and Re-simulated_Log) from the Workbook to compare and open them in read mode.
2. Open output Summary Work book to show the Euclidian_distance result and Scan_Index values and open them write mode.
3. Calculate Total Number of Rows for Log files.
4. Compute the Euclidian_distance for objects from 1 to few.
5. If the Scan_Index of the Vehicle_Log and Re-simulated_Log are same then only compute the Euclidian_distance.
6. If Veh_Scan < ReSim_Scan Then Scan in Vehicle log is not present in Resimulated output.
7. If Veh_Scan > ReSim_Scan Then maintaining I (the row corresponds to Vehicle_Log) at same index, decrementing 1 and increment J (the row corresponds to Re-simulated_Log).

Figure 6: Algorithm for Assessment of RADAR SIL Data

Simulation Results and Discussion

Simulation results obtained from VBA are as depicted in Fig 9 through Fig 10. To get the desired results the input that is fed to VBA are the *.CSV files of simulated and re-simulated data which is shown in Fig 7 and Fig 8 respectively.

Figure 7: *.CSV File for Simulated Data

The screenshot shows a Microsoft Excel spreadsheet with a data table. The columns are labeled BNT, BNJ, BNW, BNV, BNX, BNY, BNZ, BOA, BOB, BOC, BOE. The rows contain numerical values, likely representing radar data points. The spreadsheet interface includes the ribbon with tabs like Home, Insert, Page Layout, Formulas, Data, Review, View, Developer, and Team.

Figure 8: *.CSV File for Re-Simulated Data

The columns in the Fig 7 and Fig 8 are named as Range, range Rate, Angle and Lateral Offset respectively. The same parameters are calculated for few objects.

The values in four columns of Fig 9 and Fig 10 are obtained after applying the multivariate normalized Euclidean distance in VBA tool. As mentioned in the last section, the standard values expected to be reached by range, range rate, angle and lateral offset are as seen in results. Range is approximately one and range rate is also reaching almost one for most of the values which is acceptable. But other two parameters like angle and offset are slightly deviated from expected values for certain readings. These readings are depicted in red color to show the difference. The deviations in angle and offset can be fine-tuned to fall in the designed range by carrying out another iteration in SIL with required changes in the script.

The screenshot shows a Microsoft Excel spreadsheet with a data table. The columns are labeled Range, Range Ra, Azimuth, Amplitude. The table contains numerical values for radar parameters. Some cells in the Azimuth and Amplitude columns are highlighted in red, indicating deviations from expected values. The spreadsheet interface includes the ribbon with tabs like Home, Insert, Page Layout, Formulas, Data, Review, View, Developer, and Team.

Figure 9: Values obtained after applying Euclidean Distance

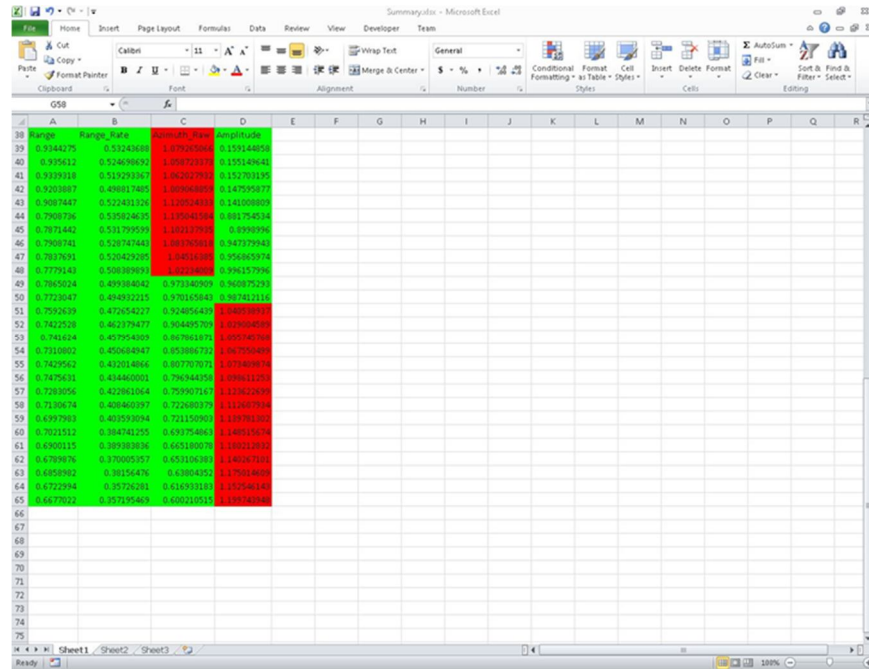


Figure 10: Values obtained after applying Euclidean Distance

Conclusion and Future Scope

The assessment of RADAR SIL data using VBA tool is done successfully using Multivariate Normalized Euclidean Distance. We obtained high level of correlation between simulated and re-simulated data in terms of range, range rate, angle and lateral offset. As a part of future scope we intend to obtain perfect correlation between data and flash it onto the hardware and test it in real world scenario.

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