Evaluation of GPS and RADAR data for Analysis of Target Tracking System

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Summary:
The GPS data is obtained by the target and host aircrafts. The data obtained from the GPS is in the NEMA format. Each target aircraft will pass the parameters such as longitude, latitude, altitude, speed and range to the Host. The HOST aircraft stores the information and uses the same to display on the map. To improve the accuracy and to obtain the multiple flying targets position relative/absolute to the HOST aircraft during sortie, a perfect and efficient multiple tracking systems like RADAR is available. The RADAR data is fine tuned to better the performance in tracking the multiple TARGETs accurately. To do so the navigation parameters of both HOST and TARGET aircrafts received through GPS receivers and RADAR is recorded in separate files on-line, in an industrial computer onboard HOST aircraft during sorties and use the same data in offline for analyzing. MIL-STD 1553B bus is used to get data from multiple target system in Asynchronous mode. All the information obtained by the RADAR is stored in a file. Each and every line of the file is read by the system and after parsing the entire file for 4-R-1-1 and 4-R-2-30 messages all the valid data is written to another file. This file contains all the valid RADAR data. Now this file is parsed line by line to get the time tag information and GPS Host and Target file is opened and checked for the corresponding time tag and a comparison is made if they match then the other information such as speed, azimuth, range etc., are extracted and displayed on the GUI with aircraft positions. If there is no corresponding GPS data for the time tag extracted by the RADAR, then interpolation of the GPS data for the corresponding RADAR time tag data is carried out and simultaneously the user will be shown navigation specific messages and data on the Graph.

Key words: GTTS, GPS, NEMA, MIL-STD 1553B

1. Introduction

1.1 GPS System: GPS technology is based on a constellation of 24 satellites revolving in 6 orbits. These satellites transmit very precisely time synchronized signals using which, GPS receivers are able to compute their position. GPS is being added to the primary computer systems of large aircraft, increasing their navigation abilities [1]. Small investigations have been made in the control of aerial vehicles. The major advantages of GPS based equipments are reliability, accuracy, round the clock operation, availability in any part of the earth and above all, very low cost of ownership and size.

Because of these advantages today GPS technology is being used for a wide range of applications such as high speed digital communication, time synchronization of computer networks, personal, air and marine navigation, tracking of mobile assets, land and hydrographic survey, geodesy, ionospheres and seismic studies etc. The other major applications are collision avoidance [2], landing [3, 4, 5, 6] of aircraft in poor visibility

From the GPS based air born system the user is responsible for controlling the aircraft's location, namely altitude, latitude and longitude. By implementing a GPS-based navigation system we can eliminate the need for human interaction, and instead rely on the GPS for measurements of altitude, latitude and longitude.

The accuracy of GPS data is subject to several sources – the ionosphere, troposphere, multipath, selective availability, receiver noise, satellite ephemeris, clock bias and clock scale factor errors of the user equipment and satellite vehicles. Details regarding these errors can be found in [6]. An excellent source of information, regarding the error source, selective availability, which is the dominating error source for commercial GPS equipment as well as current methods to mitigate all previously, mentioned errors can be found in [7].

1.2 Radar System: Radar remote detection system is used to locate and identify objects. The transmitter sends out a high energy signal which bounces off objects in their path back to the radar whenever it strikes a reflecting object. The radar determines range to an object by the round trip time-of-flight (at the speed of light) of a transmitted pulse. The uncertainty in range is the distance that the transmitted pulse travels in a time equal to one-half the width of the pulse. Thus, time and range are identical to the radar. MIL-STD 1553B bus is used to read the data into the system. The primary purpose of the data bus is to move data between black boxes. How these boxes are connected and the methodology with which the communication is accomplished is central to the operation of the data bus. A data bus is used as a medium to provide the exchange of data and information between various systems.

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2. Literature Survey

2.1 GPS technology is based on a constellation of 24 satellites revolving in 6 orbits. These satellites transmit very precisely time synchronized signals using which GPS receivers are able to compute their position to a very high degree of accuracy. In addition to position, GPS receivers are capable of providing high stable and accurate time information. [8]

The major advantages of GPS based equipments are reliability, accuracy, round the clock operation, availability in any part of the earth and above all, very low cost of ownership.

Because of these advantages today GPS technology is being used for a wide range of applications such as high speed digital communication, time synchronization of computer networks, personal, air and marine navigation, tracking of mobile assets, land and hydrographic survey, geodesy, ionospheres and seismic studies etc.[9]

There are different means of getting data for the air craft. Dr. Runnalls compares long and short batches (transects) of terrain contour navigation using a radar altimeter and an extended Kalman filter or an equivalent function algorithm. It is not only to find the altitude but also to find the likely position.[10]

TERPRON and PENTRATE were developed by British Aerospace. It uses terrain profile navigation system. The vehicle navigation is based on the data obtained by radar altimeter and a digital map to determine the precise position.

The two military systems SITAN and TERCOM use digital-map navigation technique. SITAN uses terrain slopes, derived from the digital map and processed using a modified Kalman filer. The TERCOM relies upon internal correlation techniques. Neither system focuses on enhancing vertical accuracy enhancing aircraft flight safety.[11]

In the patent #4144571 – "Vehicle Guidance Systems", a non-linear Kalman filer approach is used. The altitude is measured using a barometric altimeter and radar altimeter in combination with contour maps.

3. System overview

The two or more aircrafts flying require the position of the other aircrafts during navigation. One of the aircraft under consideration is called the HOST/HACK aircraft and the other aircrafts are called the TARGET aircraft. During sortie, it is required either relative/ absolute position of the aircrafts. To facilitate this situation one is to be provided with a perfect and efficient multiple tracking systems and display system on board. To do so navigation parameters of both HOST and TARGET aircrafts are received through GPS receivers. GPS data arrives every one second.

To improve the accuracy and to obtain the multiple flying objects position relative/absolute to the HOST aircraft during sortie, a perfect and efficient multiple tracking systems like RADAR and display system on board is also provided. The RADAR data analysis team and test engineers require to fine tune the RADAR system's hardware's and software's to better the performance in tracking the multiple Target's accurately. To do so the navigation parameters of both HOST and TARGET aircrafts received through GPS receivers and RADAR is recorded in separate files on-line, in an industrial computer onboard HOST aircraft during sorties and use the same data in offline for analyzing RADAR data.[15] The navigation parameters of both HOST and TARGET aircrafts received through GPS receivers and RADAR is stored in separate files. These data is received on-line, is stored in an industrial computer onboard HOST aircraft during sorties. The same data is used offline for analyzing RADAR data.
The task is divided into two parts, in the first part the positions of HOST and TARGET aircrafts are recorded and displayed on HOST aircraft's PC. In the second part the recorded data are parsed and used for displaying position of each aircraft on a graphical window and analyze the data.

4. System Design

4.1 Reading value from the port

The GPS receiver receives the HACK aircraft position information and the data link receives the target aircraft position information. The Hack aircraft has data recorder, which is connected to receiver and also connected to the PC through RS-232 COM1 and COM2 ports. [16] From the recorder the target aircraft's information is stored in the text file.

4.2 Sample Data

#000, Ju30, 092650, 1256.8415N, 7739.8101E, 893, G3, 25, ON, 030T, 1, 3, 11, 14, 15

4.3 Radian Conversion

The data of the target aircraft and the hack aircraft, which is received from the GPS Receiver, is in the form of geographical co-ordinates. To convert it to the radians the formula used is –

$$d = a\cos\begin{bmatrix}\sin(LatH \;\; x\sin(LatT\;) + \cot(LatH\;) \\ x\cos(LatT\;)\,x\cos(LonH \;-LonT\;))\end{bmatrix}$$

where d = distance between two aircraft’s in radian

Bearing is defined as the angle measured horizontally from the north to the current direction of travel. North can be true north or magnetic north. The bearing formula is

$$c = a\cos\left[\frac{\sin(LatT)-\sin(LatH)x\cos(d)}{\cos(LatH)x\sin(d)}\right]$$

where c course or bearing

4.4 **Degree Conversion**

The range and Elevation values are in radians and these data are converted back to degrees (ddmm.mmmm). In the real environment, the display should be in degrees for the easy understanding of information. This is done by using the following formula,

Degrees = radians x 5.2957795

To convert back to the form ddmm.mmmm , save dd, multiply .dddd by 60, and add the exponent to the result, yielding mm.mmmm. Then concatenate the saved dd, resulting in ddmm.mmmm

4.5 Data conversion to screen co-ordinates

The calculated values are plotted on the display screen using the window to viewport conversion. The actual data are in the world co-ordinates. It should be converted into screen co-ordinates, and range, bearing values are plotted on the screen for the targets with respect to the hack aircraft. The formula for window to viewport transformation is ,

$$X_s = \frac{V_{xr} - V_{xl} \quad (X_w - W_{xl}) + V_{xl}}{W_{xr} - W_{xl}}$$

$$Y_s = \frac{V_{yt} - V_{yb}}{W_{yt} - W_{yb}} \quad (Y_w - W_{yb}) + V_{yb}$$

where,

Xs –x coordinate value of screen

Y_{s-y} coordinate value screen

X_{w-}x coordinate value of window

Y_{w-}y coordinate value of the window

V_{xr-} Viewports x coordinate right

V_{xl-} Viewports x coordinate left

V_{yt-}Viewports y coordinate top

V_{yb}-Viewports y coordinate bottom

W_{xr-}Windows x coordinate right

W_{xl-}Windows x coordinate left

W_{yt-}Windows y coordinate top

W_{yb-}Windows y coordinate bottom

4.5.1 Data Structure

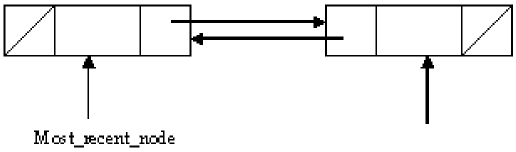

Figure 4.1 Data structure

The data structure is a Doubly Linked List. We will create one such DLL for each target aircrafts and the host aircraft. Each DLL has only two nodes: one node will contain the most_recent_data and the other node will contain the previous_data.

When the data from each source is received, it will be put in the most_recent_node of the corresponding aircraft’s DLL. Then the time field of this data will be checked for synchronization. If the data is synchronized then the pointers will be swapped and the data of most_recent_node (previous_node before swapping) will be saved in the corresponding file.

If the data is not synchronized, then the pointers will not be swapped. In all cases, only the previous_node data is used for mapping the aircraft’s icon on the map. The most_ recent _node data field is just to check the synchronization.

The Radar data read from the bus has the following format

Time: Chronologic= 1 Milisec Message Time: 0.360000 Milisec RADAR Bus-1 CMD 1cc9 03-T-06-09 RT – BC STATUS 1800 DATA 0001 0444 1000 0080 0ac6 0000 0722 e561 0000

The RADAR file is parsed line by line for valid messages like 4-R-1-1 followed by 4-R-2-30. Once found these data are extracted and stored in a file. The required parameters are extracted from this file.

5 System Implementation

To implement the system without errors we need to consider the different error that may creep in GPS system. Some of the errors that are identified are Ephemeris data [12] - Errors in the transmitted location of the satellite, Satellite Clock – Errors in the transmitted clock, including SA, Ionosphere–Errors in the corrections of pseudo range caused by ionospheric effects, Troposphere – Errors in the corrections of pseudo range caused by tropospheric effects, Multipath – Errors caused by reflected signals entering the receiver antenna and Receiver –Errors in the receiver's measurement of range caused by thermal noise, software accuracy, and inter-channel biases. Flight test error statistics are provided considering the absolute difference from both vertical and horizontal errors source associated with radar altimeter.

The errors that are being calculated are plotted:

1. Latitude V/s time error

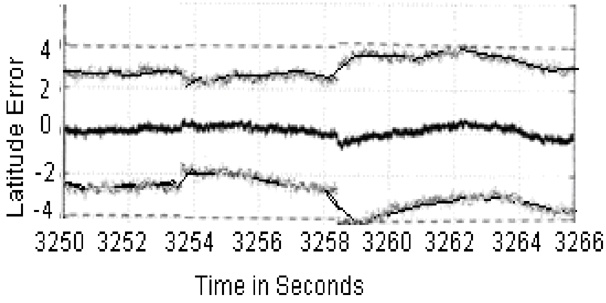

Fig-4.1 Latitude Error

2. Longitude V/s Time

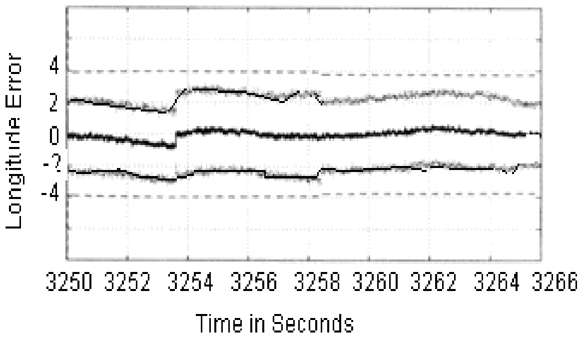

Fig-4.2 Longitude Error

3. Altitude Error

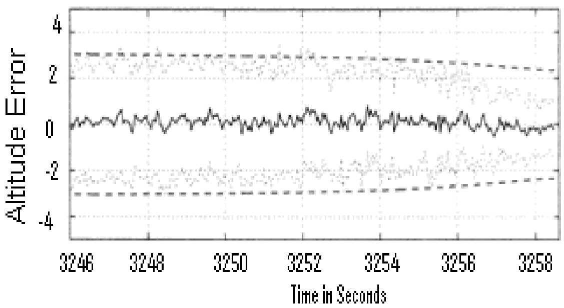

Fig-4.3 Altitude Error in meters

4. GPS User Clock Error

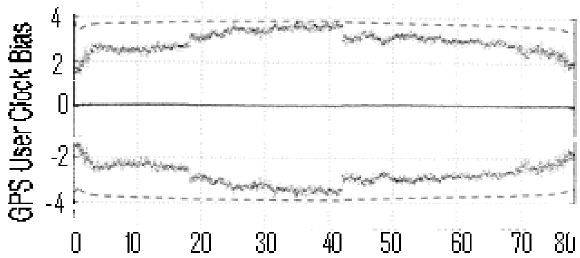

Fig-4.4 Clock Error

Considering all the error that may creep in, it is inevitable to compare the data obtained by the GPS with the RADAR data and interpolate the missing data and correct the data before plotting.

5.1 Test Result

The data collected is captured and analyzed. The time considered is from 2.30p.m to 2.32 on 22-4-2008. The Target1 aircraft was flying at an altitude of approximately 3245 meters to 3265 meters at that instant of time. The HOST aircraft has collected Target1 aircraft position data from the Target1 aircraft. Target1 aircraft has sent its position that is received from the GPS system. The Host Aircraft also captures the information of the Target1 aircraft whenever it comes in the range of its RADAR. This data is also available in the HOST aircraft. The graph 5.1 shows Altitude v/s Time plot for Target1 aircraft. Similarly the Longitude v/s Time and Latitude v/s Time for the Target1 aircraft is plotted in fig 5.2 and fig. 5.3 respectively.

5.2 Analysis:

The three graphs plotted are analyzed. In all the three graphs it should be noted that the plotting of the RADAR data is asynchronous. Hence there is no data available in consistent manner. The Radar data is available for the MIL-STD 1553B bus. The data is available only when the Target aircraft is in the vicinity.

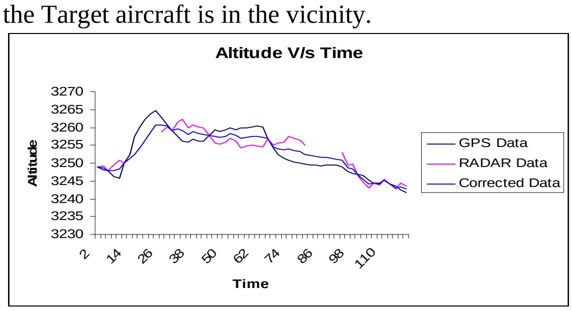

Fig 5.1 Altitude v/s Time for Target-1

Since there is a variation in the Altitude data from the GPS as well as the RADAR data it is advisable to consider the average when ever both the data is available. The graph shows the corrected line taking the corrected data.

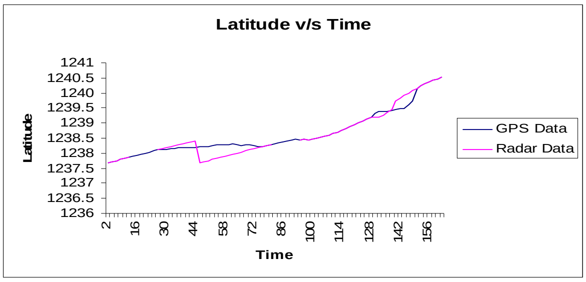

Fig 5.2 Longitude v/x Time for Target – 1

The Latitude V/S time shows the data almost all the time synchronizing except that the RADAR data has deviated from the 44th to 40th second. It may be ignored. This difference may be due to some problem with the RADAR system while calibrating.

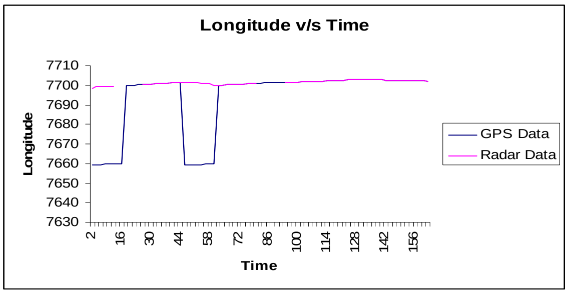

Fig 5.3 Longitude v/s Time for Target 1

The Longitude v/s time graph shows a huge difference in GPS data initially. This may be due to the some obstacles while receiving the data. During all the other time the GPS and RADAR data co-inside with each other, it is considered relatively accurate.

5.5 Interpolated Result Analysis:

HOST may miss out the data sent by the TARGET due to the orientation of the antenna. Under such circumstances the GPS data sent by the TARGET would be missing. This comparison is made by the system and the missing data is interpolated into a new file called Interpol_target file. This file contains the time, latitude, longitude, altitude, speed, bearing, range, and elevation. The latitude and longitude has a constant value of 1238 meters and 7700 meters respectively. The altitude varies considerably in a time period of 415 seconds which is shown in fig 5.4

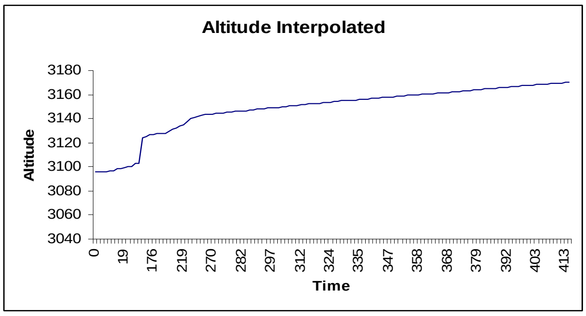

Fig 5.4 Interpolated Altitude for TARGET1

5.6 GTTS file

The data that is obtained from the target aircraft is collected in a file with all the parameters. The graphs are drawn to have a comparison with respect to the Host and the target aircraft which indicates that they were in a safe zone. It is shown in fig 5.5

Graph 5.6 shows the comparison of two target aircraft. The altitude with respect to the time clearly gives the indication that the two flights are at a save distance from each other even if their longitude and altitude are the same.

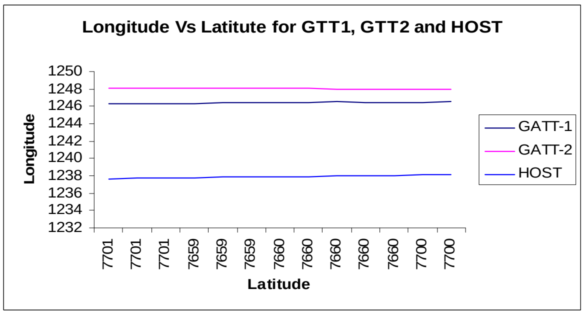

Fig 5.5 Comparison of Latitude and Longitude

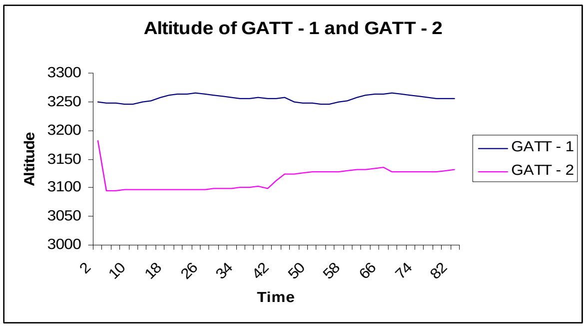

Fig 5.6 Comparison of Two target Altitudes

6. Conclusion

This system will help the flight test engineers and pilots to find out the position of the target aircraft and display

the range and bearing of the target air craft dynamically. This system is very helpful in real time. The main advantage of this system is that it could trace 10 target aircrafts position at a time. This system displays the target aircraft information and the hack aircraft information simultaneously in real time.
The study also indicates that the GPS data obtained could be used with the required correction. The missing data could be interpolated from the RADAR data and analyzed.

The main advantage of having both the RADAR and GPS data is that dynamically we can conclude the correct data because of the consistency of RADAR data. RADAR data is more accurate here because the RADAR is fixed on the HOST aircraft and gets the information of the TARGET dynamically.

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