Robust Correlation strategy for primary and secondary tracks with intact track identity

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Abstract:
In multi-radar target tracking the objective of track-to-track correlation process is to enhance the information content of the track report. In this paper correlator receives information from primary tracker and secondary tracker. Instead of having two tracks one can have a single track which will be able to provide primary and secondary information. The objective of this paper is to propose a methodology to correlate the primary and secondary tracks corresponding to same target. The correlator uses the track data of both the primary and secondary radars and gives the combined information. Correlated track contains range, azimuth, course, speed and track identity from the primary track, height and mode information from the secondary track. In this paper robust correlation strategy with intact track identity is achieved by using track history along with track-to-track distance. The performance of proposed scheme is explained with the simulated scenarios.

Key words: correlated track, secondary tracker, primary track, target tracking, mode information

I. INTRODUCTION

The need for correlation of tracks will arise in the case of target tracking using multiple radars. In this paper correlation techniques are developed for target tracks generated by primary and secondary radars. It is assumed that primary radar and secondary radar are co-located with each other and are rotating and transmitting signals throughout 360 deg. Tracks generated by radars will be sent to a common centre for correlation. There will be some positional bias between the reports given by both the radars and it is assumed to be negligible. The secondary radar is also referred as identification of friend or foe (IFF) radar [7] and the secondary tracks in this paper are referred as IFF tracks.

The primary radar generates the reports which consist of echoes from targets, land-clutter (buildings), sea-clutter, clouds and unwanted targets. Generation of primary tracks is bit more challenging than generating secondary tracks. The complexity comes from the primary reports which are erroneous and have more unwanted reports. The primary tracker has to generate the tracks by removing the unwanted echoes. The primary tracker contains modules like track initiation, data association and track maintenance [2, 3, 4]. The generated primary track contains parameters like range, bearing, course, speed and track identity of the target.

The majority of secondary target report may come from interference free circumstance and direct updation of plots to tracks is possible. However a portion of secondary reports may have one or the other type of errors associated with it and in such cases IFF tracker will be capable of identifying the associated errors and even be able to correct it. The first task in plot association module of secondary tracker is to match the target report with the established target track. This process is straightforward if the codes are fully matching and are unique in a given area. The generated secondary track contains the parameters like range, bearing, course, speed and mode information of the target. Mode and height information of the reports are useful in identifying a target. The correlator uses the track identities of primary and secondary tracks to correlate and provides the combined information of primary and secondary tracks. The advantages of using the secondary tracks instead of secondary plots for correlation are as follows,

1) Secondary tracks will have unique identity
2) Mode information will not be garbled in secondary tracks reports compared to plots and
3) Tracks will be maintained even when plots are not available in few scans.

The correlator setup detailed in this paper is as shown in Fig. 1. The setup consists of blocks corresponding to primary radar, primary tracker, secondary radar, secondary tracker, correlator and a display. For real time implementation of the correlator synchronizing signals such as north head marker (NHM), azimuth count pulse (ACP) are also fed to correlator apart from primary and secondary tracks.

The setup of correlator has Ethernet interface where the data will be communicated between all the blocks. Secondary radar generates the plots and output is made available to secondary tracker and then the tracker generates the tracks and output is made available in local area network (LAN). The primary radar generates the plots and the output is made available to primary tracker and the primary tracker generates the tracks and the output is made available in LAN. Correlator receives primary tracks and secondary tracks as inputs through LAN and generates correlated and non correlated tracks. The correlated tracks will be formed when the distance between the primary track and secondary track is less compared to the threshold. Threshold is a tunable parameter and the value of it is fixed based on real time observations. The correlated tracks consists of primary track parameters like range, bearing, course, speed and secondary track parameters like range, bearing, height and mode information. The non correlated tracks are the tracks in which primary track doesn't have its respective secondary track or the secondary track doesn't have its respective primary track. Non correlated tracks have either the primary track information alone or the secondary track information alone. The correlated tracks and non correlated tracks are the final outputs which are observed on the display.

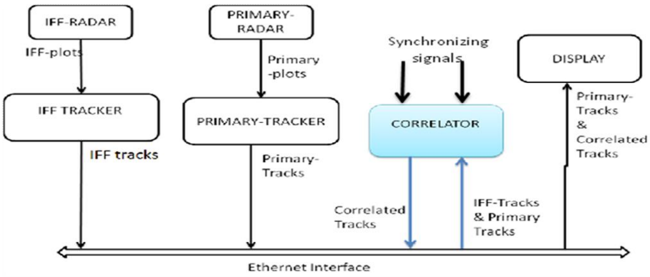

Figure 1: Correlator Setup

This paper develops a correlation scheme that will not only depend on the distance criteria but also on previous history data which is stored in a tabular format and thus maintaining the robustness. The detailed explanation of the scheme is explained in the Sec. ii.

This paper compares the performance of the proposed approach with the scheme which depends on distance alone. As the number of tracks increases the processing time for correlation will increase and depending on distance alone and instant decision in correlation will provide incorrect results. Hence there should be a mechanism to find minimum distance globally by taking all the tracks into consideration and to correlate the tracks depending on the previous history of correlation. There are many techniques to find out the global minimum distance in literature. In this paper the optimal assignment problem is solved efficiently and in minimal processing time using munkres algorithm [1]. Efficient implementation using Munkres algorithm helps to save the processing time. Time comparison of Munkres algorithm and the basic level assignment algorithm has been carried out and the results are provided in Sec. iii.

II. CORRELATION FUNCTIONALITY

Correlation algorithm is implemented in this paper using the following 3 steps:
1) Storing the data ,2) Processing the data and
3) Correlation process.

1 Storing the data:

The data from both primary and secondary trackers at any instant are stored in a two dimensional (2D) array. 2D array contains fixed columns and variable rows. Columns refer to number of sectors. Rows refer to the number of tracks present in a scan. The complete 360 deg is divided into 64 sectors and each sector width is 5.625deg. The tracking algorithms use the sector processing methods to implement the tracking process efficiently as they will work on few tracks at any instant. So the correlation scheme uses sector processing for fast implementation and to maintain synchronization with the trackers. The primary tracks received from primary tracker and secondary tracks received from secondary tracker in the respective sectors are fed to correlator as inputs along with the synchronizing signals like sector numbers and north head marker (NHM). The time interval between the two NHM packets is referred as scan interval and is denoted as T. NHM and sector numbers are used in correlator to maintain synchronization with the trackers.

2 Processing the data:

Radar will give plots with respect to the antenna direction. If Radar is pointing and generating plots in n^{th} sector, secondary tracker will generate tracks at $\boldsymbol{\Delta_1}$ sector with a delay. The fixed delay $(n-\boldsymbol{\Delta_1})^{th}$ sector is maintained in secondary tracker to ensure the delays of generating plots by the interrogating process. This delay is shown in Fig. 2 which is a constant and will be maintained throughout the tracking. Correlation process will also maintain fixed delay with respect to the tracker as $(\boldsymbol{\Delta_1} - \boldsymbol{\Delta_2})$. The fixed delay in correlation is maintained to ensure the availability of both primary and secondary tracks for the correlation process.

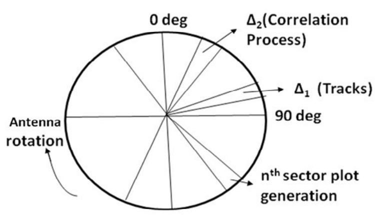

Figure 2: Representing the delay between the tracker and correlation process

3 Correlation algorithm:

The correlation algorithm uses the velocity and positional parameters of the primary and secondary tracks for the association. The tracks which satisfy the threshold will be correlated and are represented as correlated tracks. The formed correlated track data is saved in a table format as shown in Fig. 6 which consists of parameters like primary track-identity, secondary track-identity, scan count and mode information of the secondary tracks. Scan count indicates the scan at which the track has been correlated and is used in updating and clearing the table contents. The fusion count will help in initiating the correlated track. The tracks having fusion count more than 2 are initiated as correlated tracks. The contents which are not updated in the table for at least 5 scans are cleared from the table so as to minimize the memory usage and processing time. For every correlated track the table is updated and new parameters are stored.

For every one sector data of primary tracks three sector data of secondary tracks are compared. If n^{th} sector primary tracks are considered for correlation then $(n-1)^{th}$, n^{th} and $(n+1)^{th}$ sectors of secondary tracks are considered . There will be m1 primary tracks and m2 secondary tracks for correlation at any instant. The m1 primary tracks have to be assigned to the m2 secondary tracks by considering globally. There should be a mechanism to solve the assignment problem efficiently and with less processing delay.

The Munkres algorithm will be able to solve the optimal assignment problem which will give the minimal distance considering all these tracks [6]. It works on the assignment matrix method for assigning targets to the tracks. The assignment matrix is formed with rows as primary tracks and columns as secondary tracks. The (i,j) element in the matrix gives the distance between the primary track and secondary track. The objective of the assignment matrix is to assign p primary tracks to p secondary tracks and p is the minimum of m1 and m2. The algorithm provides minimum cost which is the sum of p distances considering the required cases. The Munkres algorithm is computationally less complex and takes less processing time compared to the basic level assignment solution. The basic level assignment solution is a straight forward mechanism, it considers all possible assignments and compute the total distance of each possibility and finds the minimal path among the computations.

Flow chart of Correlator

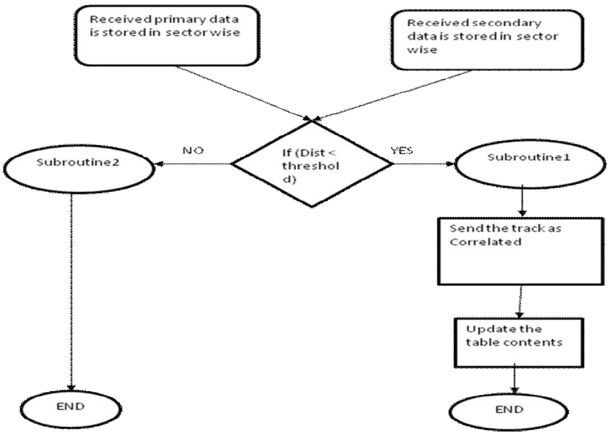

Figure 3: Flow chart of Correlator

The sequence of steps in correlation algorithm is shown in Fig. 3 as a flow chart.

The data received from primary and secondary tracker are stored in a separate 2D array in sector wise. Distance between the primary track and secondary track is compared with the threshold. If the distance is lower than the threshold then the tracks are forwarded for subroutine1 and if the distance is greater than the threshold then they are forwarded to subroutine2 for further steps.

The subroutine blocks are shown in Fig. 4 and Fig. 5. The subroutine1 is used for checking the tracks which have satisfied the threshold criteria. The tracks which meet the threshold are checked with the table which the previous scans history is stored. If the tracks are already available in the table, then the table is updated with the following parameters of primary track like range, azimuth, course, speed and track identity will be updated in the table and the parameters of secondary track like height, mode information, range and azimuth are updated with the new values. Scan count (n_{sc}) and fusion count (n_{fc}) are incremented in the table as shown in Fig. 6. If tracks are not available in the table then the new correlated track will be added to the previous correlated track list. The tabular column contents are shown in Fig. 6.

The tracks which haven't satisfy the threshold criteria are checked in table for previous list of correlated tracks. If it is available then the tracks are updated in the table and formed as correlated tracks. If the tracks are not satisfying the criteria and are not in the table are treated as non correlated tracks and will have the information of either primary or secondary track alone. The distance is found out by considering positional and velocity parameters of the tracks.

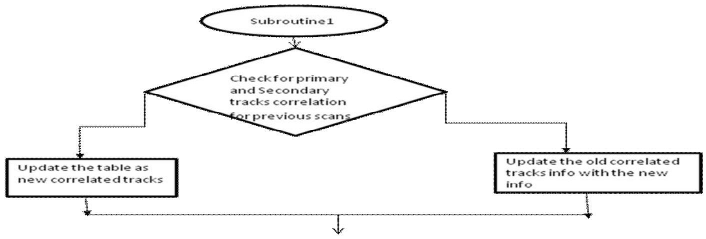

Figure 4: Subroutine1 for Correlator

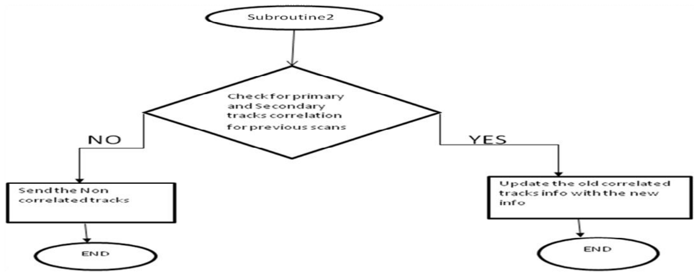

Figure 5: Subroutine2 for Correlator

Primary Track information	Parameters 1,2,3…	Secondary Track infromation	Parameters 1,2,3..	Scan_count (n_{sc})	Fusion_count (n_{fc})
P1		S1		10	5

Figure 6: Tabular format referred as fusion table used for storing correlated tracks. P1 indicates primary track and S1 indicates secondary track, parameters like range, azimuth, track identity are stored.

III. SIMULATION RESULTS

The advantages of the proposed approach of using Munkres algorithm and the robust correlation technique using the track table are verified using the simulated scenarios.

1 Scenario description:

Consider a scenario where three targets T1, T2 and T3 are at 1km, 2km and 100m from the radar. Target 2 is moving in a straight line path with velocity 100m/sec in X-direction. Target1 and target2 are moving with 100m/sec in both X and Y directions. The Fig. 7 shows the true trajectory path of the targets. The targets move closer to each other from 8 to 22 scans and then after 22 scan they move apart. During 10 and 20 scans the distance between target1 and target2 is 20m, target3 and target1 is 20m and target2 and target3 is 40m. T is assumed as 1 sec. The track output generated by the trackers from the plots will have an error of standard deviation 8m in X and Y directions.

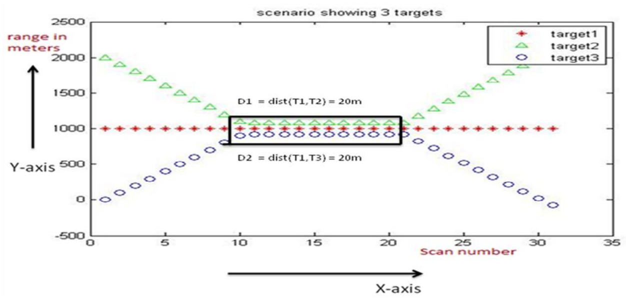

Figure 7: Scenario of 3 targets in X-Y plane

2 Comparison of results:

The primary track of target1 will overlap with the secondary track of target2 making distance between them very less. The primary tracks and secondary tracks

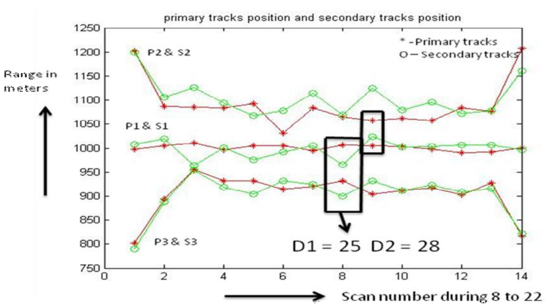

Figure 8: Trace of primary and secondary tracks during 8 to 22 scans. P1, S1 corresponds to primary and secondary track of target1. P2, S2 corresponds to primary and secondary track of target2. P3, S3 corresponds to primary and secondary track of target3. D1 is the distance between the primary track of target1 and secondary track of target2 and D2 is distance between the primary track of target1 and secondary track of target1.

trajectory of three targets during 8 to 22 scans are been shown in Fig. 8. If distance alone is considered for correlation then wrong correlations will happen during the 8 to 22 scans and the result in tabulated in Tab. 1. In Fig. 8 the thick rectangular box shows the ambiguity area where the distance between the primary track and secondary track of target1 is more compared to the distance between the primary track of target1 and secondary track of target2 during 8 and 9 scans. The distance between the primary track of target1 and secondary track of target2 is 25m and is greater than the distance between primary track of target1 and secondary track of target1 which is 28m.

	Target1	Target2	Target3
Proposed method	0	0	0
Distance alone as a criteria	4	4	4

Table 1: Comparison of results between distance alone as a parameter for correlation and proposed method

So if distance alone is considered as a parameter in correlation without considering the previous history of correlation then primary track of target1 will be wrongly correlated with target 2 secondary track as it is near compared to secondary track of target1. The number of miss correlations during a period of 10 to 20 scans is depicted in Tab. 1 using distance alone and with the proposed history based approach. In Tab. 1 there are no miss correlations if previous history is used in correlation and few miss correlations will occur if distance alone is used as criteria in correlation.

3 Scenario description:

The scenario considered for depicting the advantage of Munkres algorithm is as follows. There are three cases considered where 3 targets, 5 targets and 10 targets are present in an instant. The Munkres algorithm is used when 2 or more targets are nearby and the gates of the tracks are overlapping with each other as shown in Fig. 9. The distance between the targets is considered to be 20m for all the cases.

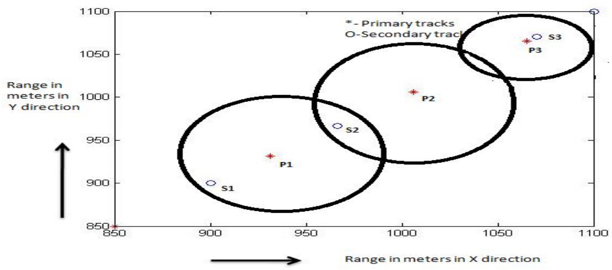

Figure 9: Primary and secondary track positions during 20th scan number. The gates are calculated from the error covariance of primary tracks generated by the primary tracker. The S2 secondary track of target2 falls in the overlap region of both primary track of target1 and target2 (P1 and P2).

4 Advantage of Munkres algorithm:

The Munkres algorithm solves the optimal assignment problem by reducing the time delay in processing. The Fig. 9 shows the tracks which are nearby and the gates of the tracks are over lapping with each other. In Fig. 9 the secondary track of target2 is falling in the overlapping region of both primary tracks of target1 (P1) and target2 (P2). Distance should be found out globally considering all the tracks at such instants. Individual distance calculation will lead to miss correlations. The targets which are far away from each other need not require optimal assignment solutions and individual distance calculations will ensure better results with less processing time. The instants shown in Fig. 9 will require optimal assignment solution by considering globally all the possible cases. The Munkres will find the optimal solution with better processing time compared to basic level assignment solution. The basic level optimal assignment solution finds out distance for all possible cases by increasing the time delay. The comparison of using Munkres and basic optimal assignment solution is shown in Fig. 10. The reduced processing time by proposed approach helps correlator to work on more load with the given hardware. The proposed method has disadvantage at certain instants. Consider a scenario where primary track with track identity 70 is correlated with secondary track with track identity 100 for about 10 scans making fusion count (n_{fc} = 10) in the fusion table shown in Fig. 6. After 10 scans of correlation the secondary track is lost and a new secondary track is created with identity 120. The correlator waits for m1 + m2 scans to initiate the new correlated track. The count m1 refers to the coasting of the correlated track when the required secondary track is not found. The count m2 is the fusion count which is used to initiate correlated tracks after 2

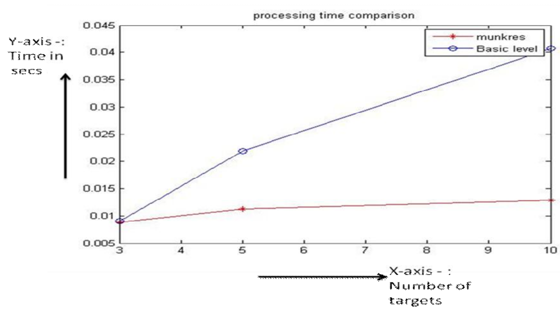

Figure 10: Processing delay comparison between Munkres and basic level optimal assignment solution

consecutive scans of correlation. In this paper m1 is 5 and m2 is 2 and totally 7 scans are needed for initiating the correlated track after a secondary track is lost and initiates new secondary track. This disadvantage can be reduced by modifying the contents of fusion table. A parallel counter can be added to the fusion table and is updated when the primary track doesn't get a required secondary track for correlation. The correlated track starts coasting whenever the primary track doesn't get required secondary track. If the secondary track of different track identity satisfies the distance criteria for 3 consecutive scans during coasting period then the fusion table is updated with the new secondary track identity and correlated track continues without going through the new correlated track initiation process and thereby reducing the number of scans. So the delay of formation of new correlated track can be reduced to 3 scans.

5 Real time scenario depicting correlation strategy

The data recorded on the live radar has been shown in Fig. 11. The primary tracks, secondary tracks and the correlated tracks are shown in Fig. 11.

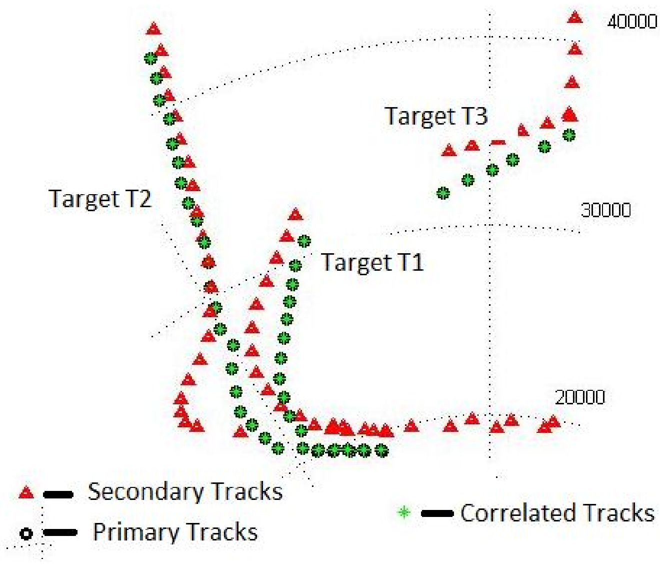

Figure 11: Real time scenario depicting correlation strategy

In Fig. 11 targets 1 and 2 are very near, and this may cause the secondary plots with garbled mode information. The secondary tracker will maintain the mode information without garbling based on previous history. The proposed approach uses the valid mode information from the secondary tracks and the updated table information for performing correct. The proposed approach is able to correlate the primary track with the correct secondary track and avoids miscorrelation by using secondary track instead of secondary plot.

IV CONCLUSION

This paper develops an efficient correlation strategy for primary and secondary tracks which keeps track identity intact. The proposed approach developed in this paper is useful in preventing the mis - correlations when targets are nearby and to have a better processing time. The mis - correlations are prevented by using correlation history along with track-to-track distance measurement as a parameter. Better processing time is achieved by employing Munkres algorithm for obtaining track-to-track correlation in an efficient way. The simulated results show the advantage of the proposed method. The proposed correlation approach in this paper is implemented in real time environment and verified.

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