Design of Optimum Gating Using Multiple Hypothesis Approach

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Abstract:

This paper discusses the design of "non-anticipatory" gates for correlation based on multiple hypotheses based gating (MHG). The approach maintains dual track states and the associated error covariance corresponding to maneuver and non-maneuver gates. At all transition points, the approach adopts "wait-and-watch" approach to establish the transition from maneuvering to non-maneuvering phase and vice-versa. This minimizes wrong detection of transition points and brings down miscorrelation percentage. Since the nature of gates is non-anticipatory the gate sizes are smaller and the multiple hypotheses allow the tracking of high-g maneuvering targets with smaller correlation gates. The MHG based filter is tested and evaluated against the data collected during field trials of the radar and establishes the effectiveness in plot to track correlation.

key words: Tracking, MHG, Phased array, non-anticipatory gating

I. Introduction

Modern radar systems maintain several hundred of targets simultaneously. Phased array antenna paves the way for faster beam switching which helps in maintaining multiple tracks at variable update rates. In real world scenario, different targets transit from maneuver to non maneuver phase and vice-versa at arbitrary instances. Potential threat targets are those which are non corporative and tracking such targets accurately both during maneuvering and non maneuvering phases is a challenge. Conventional tracking approaches use anticipatory gates, as the approach expect target maneuver at all measurement instances thus accounting for maneuver potential[4]. This result in formation of broader correlation gates leading to larger percentage of plot to track miscorrelation when tracking is performed with dense clutter background[3]. Thus this approach is more error prone and non optimum. Further the gate size is also a function of update rate[4]. Higher is the update rate smaller will be gate window. To minimize miscorrelation of plot to track, the radar tracker must use optimum correlation gate sizes and meanwhile must track high-g maneuvering targets, which can occur at arbitrary time instance.

II. Interactive multiple model (imm)

IMM is a multi model approach developed to handle the changing dynamics of target in real time. Multiple models can be added to the IMM configuration where each represents the probable state of target kinematics. The novelty of IMM lies in the decision making where it selects the correct model using Markov model for state transition[1]. IMM filter automatically detects the maneuver and the model probability for the Constant Turn (CT) model becomes high. CT model dominates till the target is maneuvering[5]. To associate the correct measurement to the track gating is done. The gate defines the boundary value within which the measurement must be positioned. It is computed around the predicted state using predicted state error covariance and measurement covariance. But to detect maneuvers, an additional term of maneuver potential is added to the gate. This is added to anticipate the probability of maneuver. The gate so formed is able to capture maneuvers but at the cost of higher probability of miscorrelation. This problem can be solved using Multiple Hypothesis based gating, which is described in the next section.

III. MHG

In this section we describe the hypothesis based gating approach.

To perform hypothesis gating, for every target, in the database, we maintain identical instances of IMM filter parameters (IMM.NM and IMM.M). The difference lies in the gate sizes. The correlation gate computation in IMM framework using IMM.M parameters, maneuver potential is included while in case of IMM.NM maneuver potential is not included in gate computation. Their separate states (X_M

& X_{NM}) and respective error covariance (P_M & P_{NM}) represent the maneuvering and non-maneuvering predictions of the target dynamics. To perform non-anticipatory correlation we use multiple hypothesis. In the next paragraph this approach is described.

Hypothesis generation:

During initialization phase we initialize IMM filter and create two instances as IMM.NM & IMM.M for every track. IMM.NM is updated whenever there is a correlated measurement satisfying non-maneuvering gate, which is a stringent gate and its duality is maintained in terms of IMM.M . This is continued for ever until there is correlation fail with non-maneuvering gate. On occurrence of correlation fail with stringent gate, the measurement is gated against maneuvering gate. Under this condition IMM.M is filtered while IMM.NM is only propagated in time. Thus two hypothesis are generated at every correlation fail with stringent gate.

Hypothesis propagation:

If the correlation is a fail with narrower gate and the measurement satisfies maneuvering gate, the transition point is registered. To detect the transition points two flags are maintained indicating the Current State (CS) and Previous State (PS) of correlation window. The current flag is set when the correlation is a success with maneuvering gate and is a failure with non-maneuvering gate. The condition for reset is when the measurement satisfies non-maneuvering gate. CS helps in keeping track of transition between gates. During filter initialization CS is set to 0.

CS coupled with PS is used to determine the state of preserve flag (PF). Preserve flag indicates when to preserve one of the IMM.NM/IMM.M and filter the other. Table 1 represents the value of PF for each combination of PS and CS.

Table 1

PS	CS	IMM.NM	IMM.M	PF
0	0	Filtering	Filtering	0
0	1	No filtering	Filtering	1
1	0	Filtering	No filtering	2
1	1	Filtering	Filtering	0

Table 2 indicates the interpretation of the value of PF.

Table 2

PF	Condition
0	Do not preserve
1	Preserve IMM.NM
2	Preserve IMM.M
3	Preserve both

The IMM instance which is being preserved will undergo only prediction in time until the gate formed around its predicted position gets correlated measurement.

Hypothesis pruning:

The hypotheses were resolved after accumulating 5 to 8 consecutive correlated measurements. After transition is registered, for next 5 to 8 correlated measurements if the current state continues to remain in the changed state then the transition is successfully detected and redundant hypothesis is dropped. The

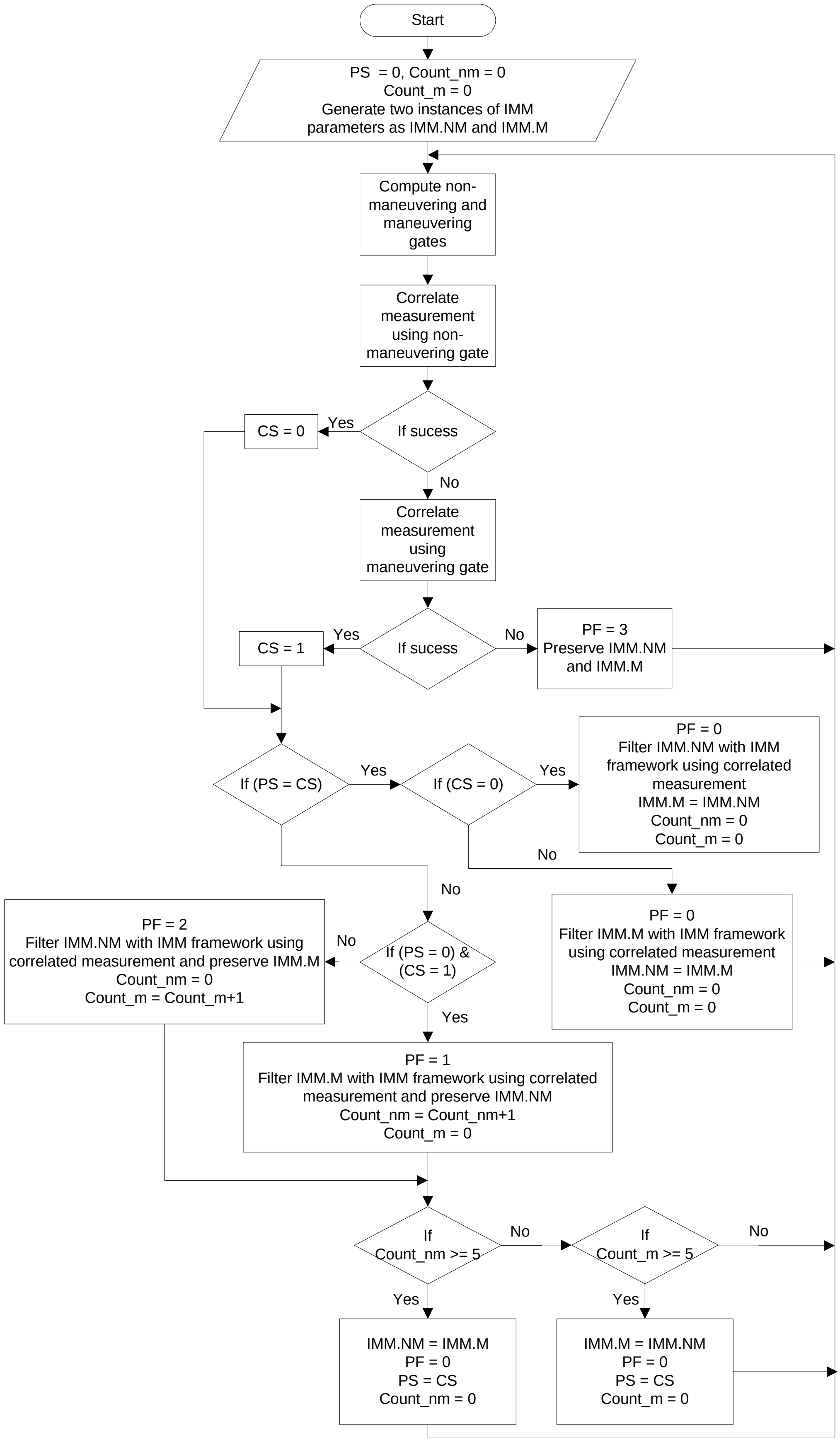

Figure 1 Flow chart of Hypothesis Based Gating algorithm

active state is one, which is updated even during the resolution of the hypothesis. The inactive state is one which was getting coasted during this period. On successful detection of transition active state is copied on to inactive state. This enhance the filter ability to maintain tracks with stringent gate window during maneuvering /non-maneuvering phase of target.

IV. Results

The performance of the purposed Multi Hypothesis gating logic is evaluated on the simulated data. The filter used for evaluation is an IMM based 3 model filter (CV, CA and CT)[2]. Radar measurements are R, u, v and $\dot{r}$, where r, u, v are measurements in sine-space coordinate system. Update interval varies from 500ms to 2sec.

CASE I: Comparison of tracking filter on simulated data with and without Multi Hypothesis Gating

Figure 1 shows the performance of the tracking filter without MHG logic. Radar measurements may have multiple plots for every look direction, out of which one might belong to the corresponding track. When gates are such that they always anticipate maneuvers, the probability of miscorrelation is high when actual detection pertaining to target is missing leading to track deviation and eventually track deletion. This is shown in figure 1, where Dedicated Track Beam (DTB) requests are shown diverging from expected position after a miscorrelation with wrong measurements and this divergence led to track break.

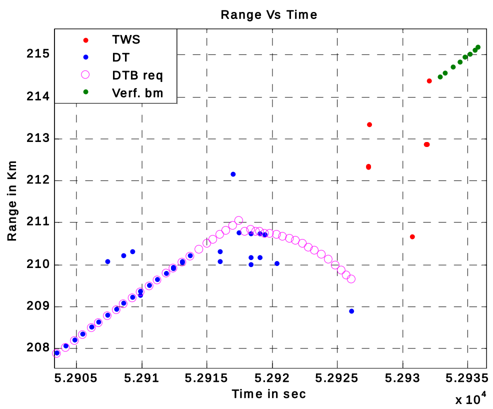

Figure 2 Range Vs Time plot

Figure 3 shows the performance of the tracking filter with MHG logic on the same data. The non - anticipatory gates minimize wrong detection of transition points and bring down miscorrelation percentage. At 211Km transition is detected and after 5 consecutive correlations the hypothesis accounting for maneuver failed and hence was dropped. The track was coasted ahead with non-maneuvering gate and was able to acquire the measurements after some time. This enabled in maintaining the track without any deviation.

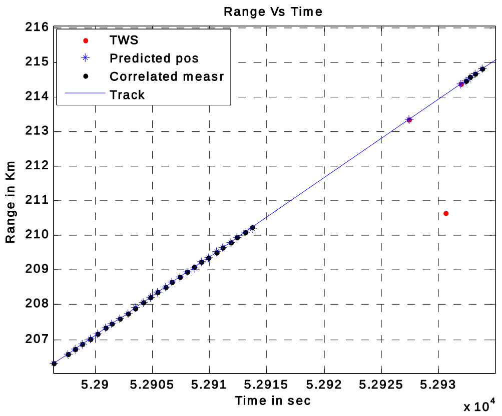

Figure 3 Range Vs Time plot

CASE II: Anticipatory and Non- anticipatory gates

Hypothesis gating was checked on the data simulated for a target carrying out multiple maneuvers.

Figure 4 shows PPI plot of the data. The fighter aircraft carried out maneuvers with their maneuvering intensity varying from 2g to 6g. In total 20 maneuvers were planned in trajectory. All of them were tracked without a track break i.e. maintaining single track identification.

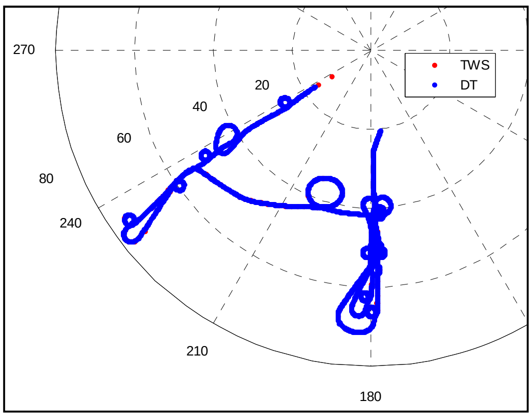

Figure 4 PPI

Figure 5 shows the gate transition during a 5g maneuver. Range rate Vs Time plot is shown to bring out the non-maneuvering and maneuvering gate sizes. Before the beginning of the maneuver presence of stringent gate indicates that gates computed using IMM.NM were able to capture the measurement. At the beginning of maneuver the stringent gate failed due to absence of maneuver potential. Thus hypotheses were formed, where IMM.NM instance of IMM parameters was propagated in time without filtering while IMM.M was filtered with the correlated measurement. Once the transition was confirmed after 5 consecutive measurements in maneuvering gate the redundant hypothesis was pruned. Once the maneuver was confirmed all of the IMM.M parameters were copied to the IMM.NM such that IMM.NM becomes able to correlate the measurement. The newly formed gate from IMM.NM were able to correlate future measurements till the next correlation failed happened. This is shown by reduction in gate size after maneuver was confirmed. Thus filter was able to track the maneuver with smaller gates thus further reducing the probability of miscorrelation during maneuvers.

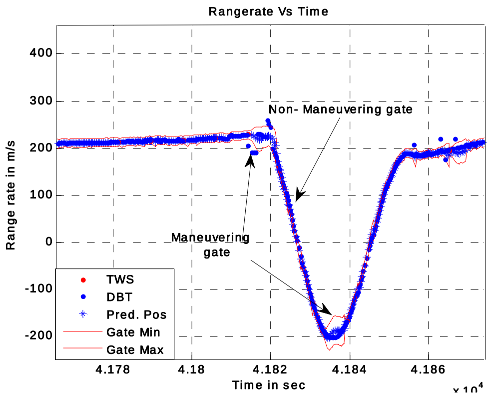

Figure 5 Range rate Vs Time

V. Conclusion

The Multi Hypothesis Gating technique has enhanced the ability of tracking algorithm to sustain track in dense clutter environment by substantially bringing down the probability of miscorrelation with wrong measurements. Also this technique made it possible for the filtering algorithm to sustain maneuvering targets with stringent gate sizes.

VI. Refrences

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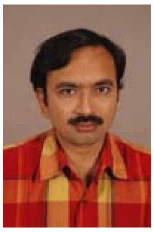

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