Ground Target Tracking Algorithm based on Prior Mode Set

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Abstract

Ground target is restricted by terrain information. In this paper, the character of ground target is analyzed, and then prior ground target mode set is constructed by associating the character of ground target with terrain information. Each mode in prior mode set corresponds with certain terrain. Based on the prior mode set, a new ground target tracking algorithm is proposed. The new algorithm switches the current ground target mode from prior mode set, according to the terrain where the ground target locates. Simulation results demonstrate that the approach yields drastic improvements over alternative techniques (Kalman filter, and Map-Tuned Variance method).

1 Introduction

Target tracking theory is initially developed from tracking airborne target. Most of the widely applied radar tracking systems still limit in resolving airborne target tracking. Ground target tracking is not so perfective as airborne target tracking[1-3]. To some sense, ground target tracking is more complex than airborne. Firstly, the environment of it is more complex, then, it has some special problem to deal with, such as geographical coordinates, terrain constraints. All of these is absent from airborne target tracking[1].

Valid usage of terrain information is valuable problem in ground target tracking[1,2]. By Analyzing the current ground target tracking algorithms[4-7], there are two approaches to utilize terrain information. One is electronic map modifying; the other is system model tuning. Electronic map modifying is to modify the measurement or tracking estimation by electronic map. System model tuning is to tune the system model of target for matching the practical target motion by certain terrain information.

In electronic map modifying algorithms, map preprocessing technique[2,5] projects the measurements to road. The key of the algorithm is confirming the modifying time. Unfit modifying will produce large error. map filter modifying algorithm[7] constructs statistical distance, and verifies the modifying by hypothesis. The precision of the algorithm lies on filter.

In system model tuning algorithms, map-tuned variance method (MTV)[2,5] decreases the process noise variance when target is on road, and increase the process noise variance when target is on the junction of roads. MTV is easy to implement, but it will produce very large error when ground target is in the transition of on road or off road. Curvilinear Model algorithm[5] use a curvilinear model when ground target is on the junction of two roads, but it couldn’t deal with the situation when the junction is crossed by more than two roads. HMM-based tracking technique[5] process the road information by HMM. The method results in large longitudinal error and small transversal error[2,5] by the cost of large computational burden. Variable structure IMM algorithm VSIIMM[6] establishes model to each road, and increases or decreases the model in model set. VSIMM is very complex and time consuming. Because of the lag of manoeuvre detection, the precision of tracking improves not so markedly.

In this paper, prior ground target mode set is constructed by associating the character of ground target with terrain information. Each mode in prior mode set corresponds with certain terrain. Based on the prior mode set, a new ground target tracking algorithm is presented. The new algorithm switches the current ground target mode from prior mode set, according to the terrain where the ground target locates.

2 Ground Target Tracking Algorithm based on Prior Mode Set

\[ \psi_M = \{\psi_i, i = 1,...,M\} \] is the prior mode set of ground target motion which is associated with certain terrain information, M is the number of mode in prior model set. \( \xi^k = \{\xi_1, \xi_2, ..., \xi_j, ..., \xi_k\} \) is the system model sequence, \( \xi_j \) is the system model in time j, and \( \xi_j \in \psi_M \). then the central problem is finding the relation of \( \xi_j \) and \( \psi_i \). If the relation is confirmed, system model sequence \( \xi^k \) will be confirmed.

Ground target tend to move along the road with almost const velocity[2,5]. When the ground target passes by the junction of road, the target will manoeuvre possibly, when the ground target is on the transition of on road or off road, the target will also manoeuvre possibly. We divided the ground target motion into such mode by terrain information: moving along road, passing by junction, getting into road, getting off road.
moving outside road. In this paper, we use CV model for system model, and different process variance levels represent the different model which refer to MTV. That means \( \psi_M \) instantiates process standard variances set \( \{ \sigma_p, \sigma_j, \sigma_w, \sigma_a, \sigma_k \} \). \( \sigma_p \) relates to moving along road, \( \sigma_j \) relates to passing by junction, \( \sigma_w \) relates to getting into road, \( \sigma_a \) relates to getting off road, and \( \sigma_k \) relates to moving outside road. \( \sigma_j, \sigma_w, \sigma_a, \sigma_k \) is no-directional noise which means noise in any direction will be equal. No-directional noise shows that the motion of target has the equal uncertainty in any direction. Because \( \sigma_k \) is related to moving along road, the uncertainty of along the road is more than orthogonal to road \( \sigma_a \). \( \sigma_a \) is directional noise that means \( \sigma_a^2 \gg \sigma_0^2 \) (\( \sigma_a^2 \) is the noise variance along road, \( \sigma_0^2 \) is the noise variance orthogonal to road).

To decide the current terrain where ground target locates, the judgment whether ground target is on road is necessary. Now, [5] presents measurement uncertainty judgment, and [6] presents prediction uncertainty judgment. We know that it is necessary to confirm echo before using measurements in practical application. So prediction uncertainty judgment is used in this paper for easily implement to practical application.

According to the prior mode set we construct, we choose the proper mode by the terrain information. When ground target moves along road, the process noise standard variance is \( \sigma_k \).

When ground target passes by road, the process noise standard variance is \( \sigma_j \). When ground target gets into road, the process noise standard variance is \( \sigma_w \). When ground target gets off road, the process noise standard variance is \( \sigma_a \).

When ground target moves outside road, the process noise standard variance is \( \sigma_k \). The remain question is to confirm ground target motion mode from prior mode set.

To judge that ground target passes by junction, we directly use prediction uncertainty method. To judge that ground target gets into road, we use historical decision value \( t_m \). If \( t_m < \delta_t \), we consider that target gets into road, otherwise, we consider that target moves along road. \( t_m \) is the accumulative value of judgment that target is on road, \( \delta_t \) is the time accumulative threshold. To judge that ground target gets off road, we use slide window logics \( M_{off} / N_{off} \). If \( M_{off} \) decisions that target is not on road in \( N_{off} \) judgments, we consider that target gets off road, the transition time is \( t - t_{off} - \delta_t \). \( t_{off} \) is the consuming time of \( N_{off} \) judgments, \( t \) is the current time.

Because the judgment target gets off road is confirmed after the event happens, we must filter repeatedly in \( t - t_{off} - \delta_t \). If the judgment does not satisfy above mode, we consider that ground target moves outside road.

The target position prediction is \( X_p \), covariance of \( X_p \) is \( P_p \), the set of roads is \( R \), the junction set of roads is \( J \), \( \sigma_k \) is the process noise standard variance, Formulation of the new method is described as follows,

\[
\sigma_w = \begin{cases} 
\sigma_j, & (X_p, P_p) \in \phi_j \{X_i, P_i\} \\
\sigma_w, & (X_p, P_p) \in \phi_w \{X_i, P_i\} \\
\sigma_a, & (X_p, P_p) \in \phi_a \{X_i, P_i\} \\
\sigma_k, & \text{others} 
\end{cases}
\]

\( \sigma_j \) is the event that target passes by junction, \( \sigma_w \) is the event that target gets into road, \( \sigma_a \) is the event that target gets off road, \( \sigma_k \) is the event that target moves along road.

The new algorithm divides the ground target motion carefully, and uses the mode which is more exact in prior mode set to be current system model. In the algorithm, we not only deal with moving along road and passing by junction, but also deal with the transition of getting into road or off road. The algorithm utilizes terrain information more sufficient than MTV, and decreases the error peak of MTV when target gets into or off road.

### 3 Simulation Results

This section gives the comparison of KF, MTV and the new algorithm which we present. Simulation scenario is as Fig.1.

![Fig.1 Simulation scenario](image)

In above scenario, there are four roads AJ, BJ, CJ, and DJ. J is the function of the four roads, the road ends are A(59, 58), B(58, 55), C(55, 51), D(51, 55), J(55, 55), the unit is km. J point is the junction of the four roads. The road ports are A(59, 58), B(58, 55), C(55, 51), D(51, 55), J(55, 55), the unit is km. A target(defined by truck) begin from S(57, 58), along SM, MJ, JN, NE. M(57, 56.5), N(55, 52.5) and the end point N(55, 52.5), the unit is km.
Suppose the sensor gets the periodic measurements, $T=1s$. Monte Carlo simulation times is 100, measurement noise variance is $\begin{bmatrix} 30^2 & 0 \\ 0 & 30^2 \end{bmatrix} m^2$. To Kalman filter, process noise standard variance is $\sigma_w = \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix} m/s^2$ (responding to common ground motion). To MTV, uncertainty threshold $\alpha = 9.27$ (responding to believing degree is 0.99), when target passes by junction, $\sigma_v = \begin{bmatrix} 10 & 0 \\ 0 & 10 \end{bmatrix} m/s^2$ (responding to the large manoeuvre).

when target is on road, $\sigma_v = \begin{bmatrix} 0.6 & 0 \\ 0 & 0.6 \end{bmatrix} m/s^2$ (responding to along road), otherwise, $\sigma_v = \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix} m/s^2$. To the new algorithm, uncertainty threshold $\alpha = 9.27$ (responding to believing degree is 0.99), $\sigma_j = \begin{bmatrix} 10 & 0 \\ 10 & 0 \end{bmatrix} m/s^2$ (target passes by junction), $\sigma_m = \begin{bmatrix} 10 & 0 \\ 0 & 10 \end{bmatrix} m/s^2$ (target gets into road), $\sigma_{off} = \begin{bmatrix} 10 & 0 \\ 0 & 10 \end{bmatrix} m/s^2$ (target gets off road), $\sigma_s = \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix} m/s^2$ (target moves outside road), when target moves along road, $\sigma_s = 0.6 m/s^2$ (along road), $\sigma_e = 0.001 m/s^2$ (orthogonal to road), time accumulative threshold $\delta_t = 8s$, $M_{off} / N_{off} = 3/4$. The choosing of above parameters is according to the practical ground target motion and reference [2, 3, 5, 6].
4 Conclusion

Ground target tracking algorithm divides the ground target motion carefully by analyzing the character of ground target, and constructs prior mode set by associating ground target motion with terrain information. The new algorithm chooses proper mode from prior mode set by terrain information judgment. In detail, we distinguish five ground target motion: moving along road, passing by junction, getting into road, getting off road, moving outside road. Then, we present the judgment of different terrain information, and tune process noise variance by the five type of target motion. Simulation result shows that the new algorithm gets the better performance than MTV, and KF.

In the future work, we will utilize the image information and target identification information of ground target to divide motion and argue the parameter design of the algorithm which is presented in this paper.

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References