An Adaptive Interacting Multiple Model for Vehicle Target Tracking Method

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Abstract. In the field of traffic safety vehicle target tracking prediction as the background, this paper proposes an adaptive interacting multiple model tracking algorithm. According to the field of transportation vehicle movement state characteristics, based on the uniform(CV)and uniformly accelerated motion(CA)model, based on new information structure model of motion of the likelihood function, online adaptive adjustment model of the noise variance and the Markov matrix, realization of maneuvering target movement model and model set adaptation, not only improved IMM algorithm for tracking accuracy, and enhances the real-time performance of system, the simulation results show that, the algorithm for tracking precision compared to the traditional IMM method has bigger improvement.

Introduction

In traffic transportation field, when driving in the car swerves, acceleration, deceleration and other sports belongs to the target maneuver, especially when the vehicle target suddenly turns into the corner, the vehicle motion status will change more greatly than before at a constant velocity or acceleration linear movement, if not effectively tracking the target maneuvering state, easily causing the target is lost, and when the maneuvering target, it is the most prone to traffic accident moment.

The algorithm of a single model for target tracking has only good performance to the non maneuvering target. When the target maneuvers, the tracking performance of the system decreases, even lead to the target missed. In order to achieve the tracking of maneuvering targets, the need for maneuvering target motion features to establish a reasonable motion model. A typical motion model with Singer model, "current" statistical model, interacting multiple models (IMM). In the traditional IMM model[1,2], assuming that the target in different motion model between the transfer probabilities is fixed, this assumption is not sufficient to account for the movement model of selective, but the use of similar "hard decision "thinking model of transfer probability in a fixed value. In fact, when the target motion model is a trend, the traditional IMM algorithm only through the mediation of different observation vector under conditions of motion model the posterior probability weighting of motion model between the "comprehensive", and do not take into account the Markov transition probability matrix design is not reasonable. In the light of traditional IMM tracking algorithm using fixed Markov matrix of faults, this paper puts forward a kind of traffic carriage domain adaptive interactive multiple model for maneuvering target tracking method under complex environment, increase of vehicle maneuvering target tracking accuracy and real time of algorithm

Adaptive IMM tracking algorithm

In the field of automotive active safety, auto target maneuvering characteristics are different from the aerodynamic targets (such as fighter aircraft, civil aircraft, etc.) or a missile class target (ballistic missiles, cruise missiles, etc.). Aerodynamic target or missile class targets often occurred a large acceleration motorized or large corner maneuver. The maneuvering of automotive has obvious characteristics, usually linear motion (uniform linear motion, uniformly accelerated linear motion) or

turning motion. Therefore, the typical sports car class goals modeling using IMM tracking algorithm to judge and choose between a variety of sports model adaptive, in order to achieve stable tracking target. In mind the target motion model of uniform motion, target motion model of accelerated motion. IMM tracking algorithm for target tracking processing, can be considered a model of the interaction of the two movements, in order to get effective tracking of maneuvering targets

Assuming the uniform motion model of the automotive is expressed as $M_1(k)$, and uniformly accelerated linear motion is $M_2(k)$. IMM tracking algorithm for target tracking processing need to consider the interaction of the two motion models, which will be effective to track the maneuvering targets. In addition to the establishment of motion model, also need in the IMM motion model transition probability for the state between the various models. The probability of state transition can describe the probability of a certain time goals in the switching between pluralities of motion models. The two motion models, for example, which corresponds to the state transition probability matrix is expressed as

$$\mathbf{P} = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix} \tag{1}$$

When the target is in a state of uniform motion model, Markov transition probability matrix p_{11} shall be taken larger, p_{22} smaller shall be taken. According to the following relationship, this is expressed as

$$\sum_j p_{ij} = 1 \tag{2}$$

Uniform motion model is transferred to the probability of the uniformly accelerated motion model p_{12} should be set to a smaller value, while the uniformly accelerated motion model is transferred to a uniform linear motion model transition probability p_{21} should be set to a larger value, and vice versa.

In order to obtain the adaptive Markov transition probability matrix, we need to make the judgment about the tendency of every model. The target is more inclined to the uniform motion or uniformly accelerated motion. In fact, in the Kalman filter theory [3, 4], the innovation of the filtering result reflects the difference between the target true and predicted values. When the target motion model conforms to certain assumptions, and the observation noise is small, the innovation of the filtering result is also smaller. In general, it is assumed that the measurement noise and process noise for a Gaussian random process, and is easy to know that the innovation filtering is also a Gaussian random variable [5], the auto-correlation matrix can be calculated by the formula (3).

Based on the innovations can configure target motion model likelihood function, defined as

$$p_{M_i}\left[\mathbf{v}_i(k)\right] = \frac{1}{(2\pi)^{\frac{N}{2}} \left|\mathbf{S}_i(k)\right|^{\frac{1}{2}}} e^{-\frac{\mathbf{v}_i^{\mathrm{H}}(k)\mathbf{S}_i^{-1}(k)\mathbf{v}_i(k)}{2}} \tag{3}$$

Where N is the number of dimensions of innovations vector.

The likelihood function of Motion model reflects the difference between the current model filtering results and the true target motion model. The innovation filtering result indicates the greater the probability of filtering model from the true motion model, and vice versa.

So, the likelihood function of two motion models can be used to construct likelihood ratio function, when greater than a certain threshold $M_1(k)$ is discriminated as a model, and vice versa $M_2(k)$ is determined model, which is expressed as

$$\frac{p_{M_1}\left[\mathbf{v}_1(k)\right]}{p_{M_2}\left[\mathbf{v}_2(k)\right]} \begin{array}{c} > \\ < \end{array} T \quad \begin{array}{c} M_1(k) \\ M_2(k) \end{array} \tag{4}$$

The above is Neyman-Pearson judgment. The threshold can be calculated according to the judgment of the false alarm probability.

In the actual system, in order to further reduce the false alarm probability, transfer processing can be executed after the model transfer likelihood ratio function continuously several times through the decision threshold. Theoretically, according to the likelihood ratio function, this can calculate the variables in the Markov transition matrix, which is expressed as:

$$p_{12}(k) = f\left(\frac{p_{M_1}\left[\mathbf{v}_1(k)\right]}{p_{M_2}\left[\mathbf{v}_2(k)\right]}\right) \tag{5}$$

Experimental

The following is an example of uniform motion and accelerated motion adaptive IMM tracking algorithm for maneuvering targets in the field of automotive active safety tracking process.

Consider the following scene, at first the target moving for linear motion, then steering movements (analog car target curve driving). The above simulation scenario simulates a typical case of the car straight into the corners. Here mainly discuss the impact of different tracking methods, therefore, in order to simplify the observation vector and state vector are selected as a Cartesian coordinate system. Assuming a target moves speed of 72km / h uniform linear motion (simulating car in a straight line with the case), and then enter a radius of 80m corner. Assume the rms of the observation noise at 1m, and the rms error of the drive noise at 1m.

Experiment comparing the adaptive IMM tracking methods (including CV and CA model), traditional the IMM tracking method, Method based on the Kalman filter model of uniform motion, Method based on Kalman filter model of accelerated motion to analysis the performances of tracking algorithm.

In order to measure the effect of the different tracking algorithms, we use the rms error is used as an evaluation index, which is defined as the mean square value of the error between the filtered results with the true results. For reducing the impact of random error, the experiment uses 1000 Monte Carlo simulation results for average processing. Figure1 shows the result of the experiment.

(a) real track of target motion

(b) likelihood ratio function

(c) The traditional IMM algorithm and adaptive IMM algorithm results contrast

(d) Adaptive IMM algorithm and model matching Kalman and the model matching Kalman filtering results contrast
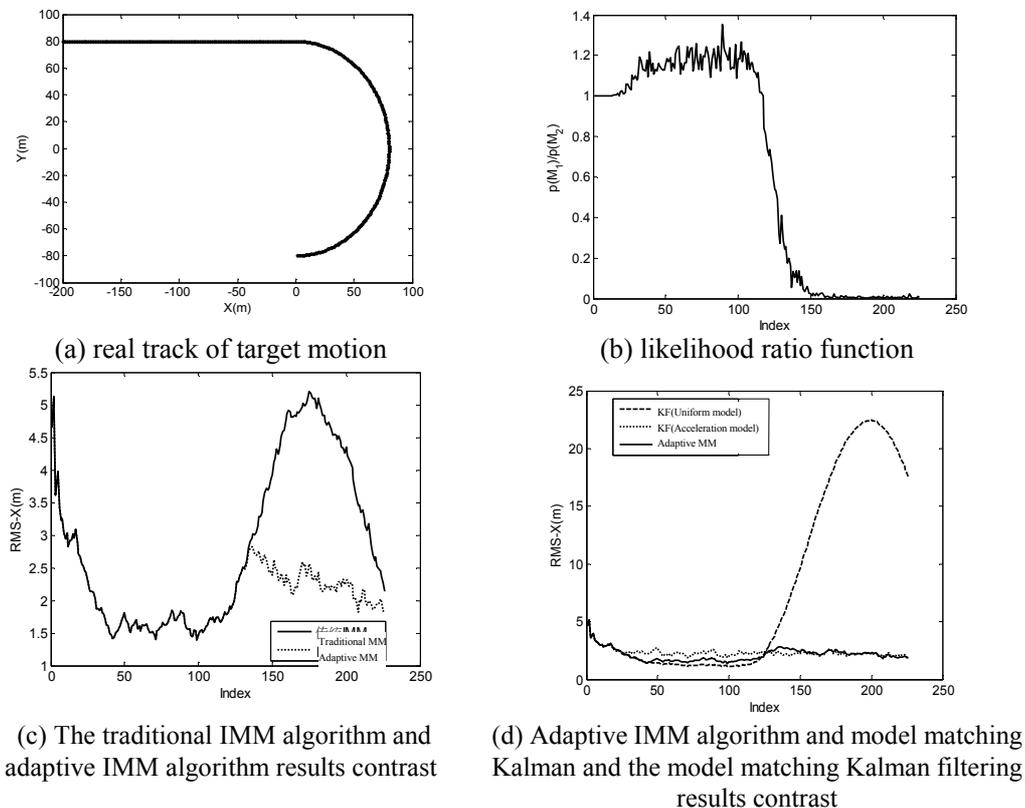
Figure 1 Adaptive IMM algorithm processing results contrast

From the figure 1(a) we can see the target move at the uniform linear motion stage between point 1 to 120, and the target move into the corner stage from point 120 to 226.

Figure 1(b) shows the likelihood ratio function value of two motion models, which can be seen, during the linear motion stage and the curve movement stages, the likelihood ratio function of motion models having significantly different values. according to the value of the case with a reasonable threshold (for example, the experiments selected for 1), we can judge the target motion model and make the parameters of Markov transition matrix to be adaptive selected, further getting more optimal model matching

Figure 1(c) shows the adaptive IMM algorithm in the target linear motion stage or stages of moving in the corners can be accurate and stable tracking maneuvering target, and adaptive IMM algorithm of tracking results superior to the traditional method of IMM.

Figure 1(d) shows the method based on the Kalman filter model of uniform motion can track the target only in the linear motion stage; when the target turn into corner stages, the method can not track the target effectively, and resulting in a larger tracking error. The method based on Kalman filter model of accelerated motion shows well performance during the stages of the corners, but the tracking error is higher in the linear motion stage. The adaptive IMM method can be better to follow the target motion model change, and be satisfied with the maneuvering target tracking results.

Summary

The paper focuses on the vehicle motion characteristics of the field of transportation, which establishing the model sets of uniform velocity (CV) and constant acceleration (CA) the motion model, not only reduces the complexity of the model and movement pattern matching, while improving the real-time nature of the system running. This paper using the likelihood ratio function of motion model, which bases on the innovations filtering structure, conduct online adaptive noise variance adjustment model and Markov matrix achieve adaptive adjustment maneuvering target mode model set. The method improves the tracking accuracy of the IMM algorithm. Simulation results show that the tracking performance of the algorithm is superior to the traditional method of IMM.

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Advanced Measurement and Test III

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