Application of Adaptive UKF Algorithm in Multi-target Tracking and Positioning System

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Abstract. Adaptive filtering algorithm (FIR) is a design method of adaptive variable target tracking system based on probability density distribution model. The algorithm realizes the target movement in the global range by estimating the parameters of different regions in the image, which improves the real-time performance and effectiveness.

Keywords: Adaptive Filtering Algorithm, Multi-target Tracking, Positioning System

1. Introduction
Adaptive filter (SVM) is a passive neural network, its function is to process uncertain data information. The adaptive filtering algorithm is a non-minimum mean square error filter, and its ideas are mainly embodied in two aspects. Starting from the optimal target tracking algorithm, this paper analyzes the problems encountered by the classic ant colony optimization method in the process of target location. The algorithm realizes parameter estimation by modeling the target image and using the mutual mapping relationship between feature points [1].

2. Principle and method of target tracking filtering
2.1. Discrete kalman filter
In the discrete Kalman filter, the law of the target motion state changing with time is described by the state equation, and the relationship between the measurement vector and the state vector is described by the measurement equation [2]. The mathematical description in discrete linear systems has the following form:

The state equation is shown in formula (1):

\[ X_k = \Phi_{k\mid k-1}X_{k-1} + \Gamma_{k-1}W_{k-1} \]  \hspace{1cm} (1)

The measurement equation is shown in formula (2):

\[ Z_k = H_kX_k + V_k \]  \hspace{1cm} (2)

Discrete Kalman filter is a finite-dimensional linear discrete algorithm with a recursive structure, which is very suitable for computer implementation. Its main features:
(1) The discrete Kalman filter uses the unbiased minimum variance criterion to obtain the optimal estimate of the system;
(2) The signal model of the discrete Kalman filter is described by the state equation and the measurement equation. It can be applied to the state estimation of multivariable systems, time-varying systems and non-stationary random processes;
(3) The state estimation of the discrete Kalman filter is calculated by using the recursive method, that is, the current value of the signal is estimated only based on the previous estimation value and the latest measurement data. Therefore, the discrete Kalman filter data storage is small, the calculation is small, and the convergence speed is fast, especially this avoids the problem of high-order matrix inversion and improves the calculation efficiency;
(4) \( \hat{X}_k \) and \( \hat{X}_{k+l/k} \), \( P_k \) and \( P_{k+l/k} \) can be obtained at the same time, which are the accuracy indicators of state filtering and state one-step prediction;
(5) Discrete Kalman filter has good real-time performance and noise immunity [3].

Kalman algorithm quickly became the mainstream algorithm of tracking algorithm with its excellent characteristics. Now, people have created many algorithms with better filtering performance based on the classic Kalman filter. But in the final analysis, they are all Kalman filtering algorithms. For a long time, discrete Kalman filter has been regarded as the best choice to solve problems such as target tracking and data prediction.

2.2. Extended Kalman filter algorithm
The application of linear models in target motion is greatly restricted, because most target motions have great maneuverability [4]. The model is usually non-linear, such as high-altitude target flight trajectory measurement, trajectory tracking of water maneuvering targets studied in this paper, etc. Linearizing a nonlinear model is a basic method to solve nonlinear filtering, that is, an approximate method to describe a nonlinear system with linearization. The linearized filtering method of nonlinear filtering is expressed by a difference equation as shown in formulas (3) and (4):

\[
x_k = f(x_{k-1}, k-1) + w_{k-1} \quad (3)
\]

\[
z_k = h(x_k, k) + v_k \quad (4)
\]

2.3.Insensitive Kalman filter algorithm
Unscented transformation is the core and foundation of UKF algorithm. It is a new method of calculating statistical properties in nonlinear systems. The idea of UT transformation: select a set of Sigma points to make the sample mean and covariance consistent with the mean \( \bar{x} \) and covariance \( P_x \) of the state random variable, and then perform nonlinear transformation on these points to obtain the mean \( \bar{y} \) and covariance of the transformed points \( P_y \). Although the sampling points are not obtained by random selection, this deterministic sampling method extracts state-specific statistical characteristic information [5]. Suppose that the random variable \( x \) undergoes a nonlinear transformation as shown in formula (5):

\[
y = f(x) \quad (5)
\]

Here \( x \) is a Gaussian random vector with mean \( \bar{x} \) and variance \( P_x \), and the dimension is \( L \). Then the statistical properties of \( y \) can be obtained by the following UT transformation [6].

A matrix \( x \) containing \( 2L+1 \) vectors \( X_i \). Here, let \( \sigma_i \) be as shown in formulas (6) and (7):

\[
X_i = \bar{x} + \sigma_i \sqrt{P_x}, \quad i = 0, 1, \ldots, 2L
\]

\[
X_{i+L} = \bar{x} - \sigma_i \sqrt{P_x}, \quad i = 0, 1, \ldots, 2L
\]
The 3.1. filtering interactive multi-model probability. From the difficulty of the multi-target tracking, the IMM (Interacting Multiple Model) filtering algorithm is used to improve the positioning accuracy [7]. This can combine the IMM algorithm with the UKF algorithm. The IMM-UKF algorithm is used to improve the filtering effect.

2.4. IMM-UKF filtering algorithm
When the tracked target is maneuvering, due to the uncertainty of the maneuvering motion model, it is difficult to describe the actual target motion state with any single target motion model. Interactive multiple model (IMM) realizes the tracking of maneuvering targets by introducing multiple target motion models and weighting the state estimation of each model according to a certain probability. From the perspective of the motion model, a multi-model method is used to improve the positioning accuracy [7]. This can combine the IMM algorithm with the UKF algorithm. This is the multi-model insensitive Kalman filter (IMM-UKF) algorithm. In this way, the advantages of the interactive multi-model algorithm and the UKF filtering algorithm can be combined to obtain a better filtering effect.

3. Multi-target tracking system based on adaptive UKF

3.1. Basic principles of multi-target tracking
The principle of multi-target tracking is shown in Figure 1 below. First, by adopting the cross positioning method, the passive positioning system can obtain multiple cross points at the same time, and output the positioning points after processing the ghost wave points, and then it will delete these positioning points through the tracking gate. Tracking gate is a decision threshold, but it provides a tool. How to use this tool reasonably is the problem to be studied by the data association algorithm. Next, the candidate points in the gate are correctly paired and associated with the corresponding target through data association. Data association is also an important part of multi-target tracking. The quality of the data association algorithm determines whether the positioning point track and the existing target track can be correctly associated and paired, which greatly affects the tracking performance of multiple targets. There is no target track at the beginning, so the first step is to start the target track first. This is the first and most important part of target tracking. Therefore, this link can directly determine the accuracy of the follow-up tracking target. If the initial trajectory is
incorrect, the follow-up tracking target must be wrong. When the multi-target trajectory is successfully initiated and confirmed, many stable target trajectories are formed. After that, the number of basic moving targets and basic functional parameters can be determined, and then they can be transmitted to the target tracking filter and the target trajectory can be maintained. When the target loses track due to some reasons, the tracking of the target must be terminated in time according to certain judgment rules, otherwise the correct tracking effect will not be obtained, and the amount of data processing will increase. Finally, the processed track is displayed on the monitor in real time.

![Figure 1. Schematic diagram of multi-target tracking](image)

3.2. The hardware design of the system
The system structure block diagram is shown as in Figure 2.

![Figure 2. System structure block diagram](image)

3.3. System software design
System software flow: Based on the unique dual-core architecture of the system hardware, its software development is divided into two parts: ARM and DSP. ARM is responsible for the entire DM6446 system control and data acquisition and storage; DSP is responsible for processing the video data [8].

The essence of target tracking is to extract moving targets from the video sequence, and compare them with similarity, and finally get its moving trajectory. The specific flow chart of this algorithm is shown in Figure 3 [9-10].

![Algorithm flow chart](image)

**Figure 3.** Algorithm flow chart

4. Conclusion
With the rapid development of modern technology, computer technology and network communication technology have become increasingly mature. As a new and highly practical automatic control device, the multi-target tracking system has attracted more and more attention. This paper proposes a multi-target tracking system based on adaptive filtering algorithm, which has been widely used in many fields. It is believed that with the emergence of more algorithms and technologies, this will bring more progress to the development of multi-target tracking systems.

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