A Maneuvering Target Detecting Method Based on Lifting Wavelet Transform Algorithm

Shi Jianfang, Qi Le, He Chengwei
College of Information Engineering
Taiyuan University of Technology
030024 Taiyuan, China
shijftyut@163.com

Abstract—**Signals which is composed of all kinds of different frequencies can be decomposed into different frequency domains by using wavelet transform to realize de-noising efficiently. Lifting wavelet algorithm has some advantages, such as simple computing, easy programming, and fast speed. A quick method of maneuvering detection based on lifting wavelet transform algorithm is proposed. Multi-resolution measure data can be obtained by using lifting wavelet transform in the algorithm which has the advantages of computing easier, maneuvering detection delay smaller and detection probability higher. A framework of five-layer lifting wavelet decomposition was used for target movement track, the out-put multi-resolution measure data are used to update the target state of interacting multi-model algorithm. Simulation result shows that the algorithm can extract the maneuvering of target from strong-noisy circumstance, and display maneuvering moment clearly. Tracking performance is improved.**

Keywords—**Maneuvering detection, Lifting Wavelet Transform, Target tracking**

I. INTRODUCTION

In the process of maneuvering target tracking, the maneuvering of target is an important factor that causes decline of tracking performance, which can be improved by detecting the moment of target maneuvering betimes and effectively. Traditional algorithm of maneuvering detection is to make the total error probability minimum, according to probability distribution of noise and signal with noise, by means of choosing detecting threshold reasonably. But the choice of threshold will cause the fail alarm rate. Hong [1993] applied multi-resolution to target maneuvering detection. By means of decomposing the measure data into lower resolution level and applying low-pass filtering feature of wavelet transform to de-noise effectively. So target movement track can be seen clearly and better detection effect can be obtained. But the method must decompose the observation data to the lower resolution level at first so as to detect maneuvering moment, and then backtrack to make sure the moment which maneuvering occurs. Because of its complex computing and long maneuvering detection delay, it may result target tracking in failure as models can't change in time.

Lifting wavelet transform algorithm constructs wavelet filters in the aspect of airspace, and gets rid of its dependence on frequency domain. The algorithm is simple and easily carries out fast algorithm. (Its speed is as twice as that of traditional wavelet transform). The inversion transform has the same complexity with positive transform. Transform signals can have random length (need not be 2n) and even computing at original bit is allowed, so the memory of the computer can be saved. It is easy to be extended to integer transform, and provide a kind of precise reconstruction. It is also easier to construct non-linear wavelet transform. In this paper, lifting wavelet fast algorithm is applied to maneuvering detection and a framework of five-layer lifting wavelet decomposition is used for target movement track. The out-put data are used to update the target state of interacting multi-model algorithm. Simulation results show that the algorithm can extract the maneuvering of target from strong-noisy circumstance, and display the maneuvering moment clearly, so the tracking performance can be improved

II. MANEUVERING DETECTION

Traditional maneuvering target tracking algorithms mostly are based on Kalman filtering theories, and their performances depend on the precise description of target movement state. While the state model of target matches its actual moving state, target tracking can be obtained precisely. But once model mismatches (which inevitably occurred when target maneuvering) it may cause failure of tracking. The algorithm is essential to make the total error probability minimum, according to probability distribution of noise and signal with noise, by means of choosing detecting threshold reasonably. Therefore detecting maneuvering betimes and correctly, changing target models timely are keys to maneuvering target tracking.

III. LIFTING WAVELET TRANSFORM ALGORITHM

There are three steps of lifting wavelet transform: split, prediction and update. In the discrete circumstance, when given a data set a_0, through a complete level of lifting process, it will be decomposed into two parts: scale coefficients $a_1$and wavelet coefficients d_1.

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First step is split; the process of split is to decompose a_0 to two sets $a_1$and d_1.There are some methods:

1) Defines odd number point set as a_1 and even number point set as d_1.
2) Distributes front-half data to a_1, and back-half data to d_1.
3) Distributes the sum of two near data to a_1, and difference of them to d_1.

Second step is prediction. The process of prediction is to remove the redundancy remained in first step and to give more strict data presentation. The purpose of prediction is to predict d_1 by a_1 and form a new prediction error d_1, as

$$d_1 \Leftarrow d_1 - P(a_1) \quad (1)$$

Here, P is a prediction operator; it is a fixed operation form, which is irrespective of data set.

When original d_1 can be predicted entirely by a_1, and prediction operator P is an ideal prediction, the new d_1 is full-zero sequence. But the ideal prediction doesn't exist. If the original d_1 and a_1 have much relativity, d_1 can have low energy parting by prediction.

Third step is update. The process of update is to remain some whole character of a_0 which is in the last coefficient sub-set a_n. Define a scalar quantity operation $Q(a_i)$ and compute some whole variable of one sequence, such as mean-valued, as

$$Q(a_1) = Q(a_0) \quad (2)$$

In order to match unitary and inversion transformation, define an operator U , and update a_1 through $U(d_1)$ .The process of update can be described as:

$$a_1 \Leftarrow a_1 + U(d_1) \quad (3)$$

As is mentioned above, each level of lifting is made up of three steps. The split process of each level can be presented as follows:

$$\begin{cases} \{a_{j+1}, d_{j+1}\} \Leftarrow \text{split}(a_j) \\ d_{j+1} \Leftarrow d_{j+1} - P(a_{j+1}) \\ a_{j+1} \Leftarrow a_{j+1} + U(d_{j+1}) \end{cases} \quad (4)$$

While the process of inversion is:

$$\begin{cases} a_{j+1} \Leftarrow a_{j+1} - U(d_{j+1}) \\ d_{j+1} \Leftarrow d_{j+1} + P(a_{j+1}) \\ a_j \Leftarrow \text{join}(a_{j+1}, d_{j+1}) \end{cases} \quad (5)$$

Therefore, this decomposition mode accords with the thinking of discrete wavelet. The presentation mode of decomposed sequence is tighter. The different choice of split mode and prediction implement equals to choose different sets of filtering. The process of lifting and inversion shows in Fig.1. It's shown that only N point multiplication is needed. When using lifting algorithm to wavelet transform for N point signal sequence, while 2N point multiplication in Mallat algorithm. So the operation quantity can be reduced half.

Traditional wavelet transform is a transform in real number domain, that is to say, pre-analyzed-signal itself is an integer sequence, and corresponding coefficient of wavelet transform is also real number. As real number transform coefficients need float memory, larger memory space is needed. So there are some restricts while wavelet transform is applied to maneuvering detection. Generally speaking, in order to simplify computation and draw conclusions in a short time, the wavelet transform coefficients are expected to have an "integer-integer" wavelet transform when undetected-signal are presented by integer,. That is to say, map integer sequence with integer wavelet coefficients. The wavelet transform which possesses such characteristic is defined as integer wavelet transform.

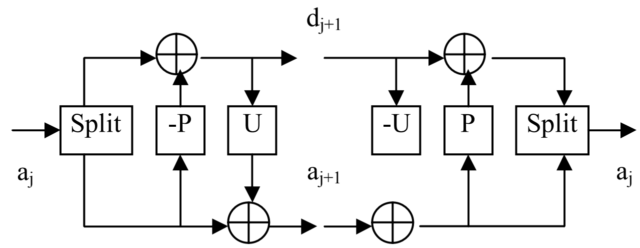


Figure1. Framework of lifting wavelet transforms

There are some methods to obtain wavelet integer transforms. The simplest method is an integer wavelet transform based on lifting algorithm. A complex wavelet transform problem can be transformed to a simple process of level-unite (cascade) lifting. The process of integer lifting wavelet transform is similar to that of lifting wavelet transform. The only difference is that the former joins rounding operation based on the latter.

IV. MANEUVERING DETECTION BASED ON LIFTING WAVELET TRANSFORM ALGOTITHM

The framework of multi-resolution measure lifting wavelet transform algorithm to detect maneuvering is showed at Fig.2.In the multi-resolution multi-model algorithm, first is to construct multi-resolution data structure, and then carry out independent multi-model tracking filtering based on different multi-resolution, and last synthesize maneuvering decision results in different resolution as to output filtering results of a certain model. Measure data and system multi-model are decomposed into layered data structure by multi-resolution measured lifting wavelet fast algorithm and carry out maneuvering detection on low resolution level. The final tracking output will be obtained on highest resolution level (original measure data level).

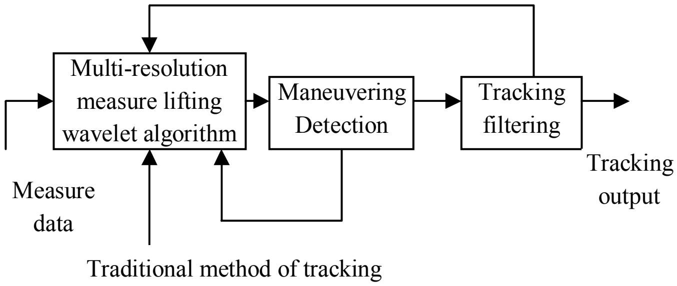


Figure2. Framework of target tracking method based on multi-resolution lifting wavelet transform algorithm

In the target tracking, state model and measure model are as follows:

$$X(k+1) = AX(k) + W(k) \tag{6}$$

$$W(k) \sim N(0, Q(k)) \tag{7}$$

$$Y(k) = CX(k) + V(k) \tag{8}$$

$$V(k) \sim N(0, R(k)) \tag{9}$$

Here X (k) is a system state vector, A is a state transform matrix from time k-1 to k, Y (k) is a measure value vector, C is a measure matrix, W (k) and V (k) is system noise vector and measure noise vector individually. Assume that W (k) and V (k) are all zero-mean-valued Gaussian white noise.

Assumes that there are q multi-resolution levels, then the measure value of i resolution level is given in the following formula,

$$Y_{i-1}(k_{i-1}) = h_1 Y_i(k_i) + h_2 Y_i(k_i - 1) \quad i = 1, 2, \cdots, q-1 \tag{10}$$

There into, k_i is sample time of level i , Y_i is measure data of level i , the measure data of level i （$i = 1, 2, \cdots, q-1$） can be obtained through a low-pass filter (wavelet transform) by original measure value $Y_q(k_q - 1)$ and $Y_q(k_q)$.Here (h_1, h_2) is a twain-taking low-pass filter.

Based on different resolution measure equations, in order to form multi-resolution data structure, state model and measure model need corresponding decomposition. The models of resolution i-level are as follows:

$$X_i(k_i + 1) = A_i X_i(k_i) + W_i(k) \tag{11}$$

$$W_i(k_i) \sim N(0, Q_i(k_i)) \quad i = 1, 2, \cdots, q \tag{12}$$

$$Y_i(k_i) = C_i X_i(k_i) + V_i(k_i) \tag{13}$$

$$V_i(k_i) \sim N_i(0, R_i(k_i)) \quad i = 1, 2, \cdots, q \tag{14}$$

Because the i level ($i = 1, 2, \cdots, q-1$) has no original measure value, the measure model of level i ($i = 1, 2, \cdots, q-1$) can be given by (10).

V. SIMULATION RESULTS

Constant-speed model, constant-acceleration speed model and constant-speed turning rate model are selected to set up interacting multiple-models to track target maneuvering. Assume process noise variance of simulation acceleration is 0.001, measure noises of X axes and Y axes are 50 meters, the turning speed is 750m/s, turning rate is 0.0524. Simulation scene is as follows:

Original position of target is at (0, 0), aviating at a constant speed along X axes and Y axes, the original speeds are 3m/s、4m/s individually. In the first 100s, it takes con-speed movement; between 100s and 200s, con-acceleration movement, accelerations are $3m/s^2$and $4m/s^2$ individually; between 200s and 400s, con-speed turning rate movement. The real track and noise track of target aviation in 400s by 100-times Monte Carlo simulations are shown at Fig.3. Lifting wavelet decomposition was applied to target movement track to detect the moment of target maneuvering by observing the small movement of the target. The track of target using lifting wavelet algorithm and track error curves along X-coordinate and Y-coordinate shown as Fig.4. The track of target using integer lifting wavelet algorithm and track error curves along X-coordinate and Y-coordinate shown as Fig.5.

Simulation results indicate that low-pass filtering effect of lifting wavelet transform algorithm can extract the maneuvering of target from strong-noisy circumstance. The maneuvering moment can be seen clearly and the detection of maneuvering is much easier. So models can be switched in time and the tracking error can be maintained in a low-level. Tracking effect can be obtained accurately. Besides, as integer lifting wavelet transform joined with rounding operation, the operation speed is much faster than that of lifting wavelet transform. So the moment of maneuvering can be detected betimes.

VI. CONCLUSIONS

As lifting wavelet transform algorithm has the advantages of simple computing and easy programming, it is applied in maneuvering detection of aviation target. The problem of large delay brought by multi-resolution decomposition is solved effectively. The algorithm can be combined with other maneuvering target tracking algorithm (such as multi-model algorithm) to detect target maneuvering and switch models in time to realize accuracy tracking of target.

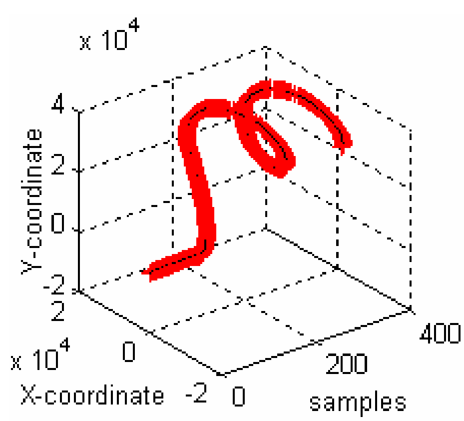
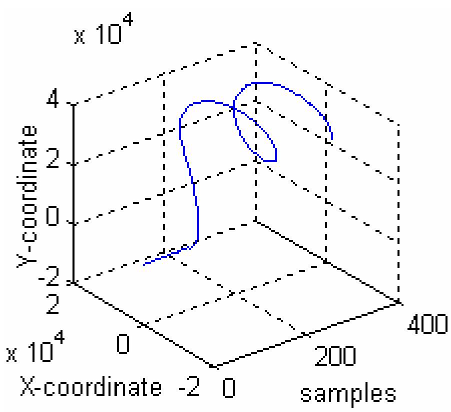
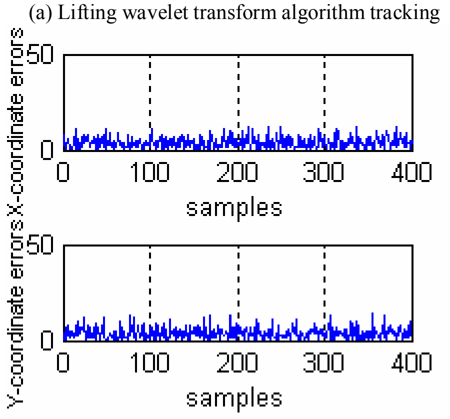


Figure3. Original track and track including noise

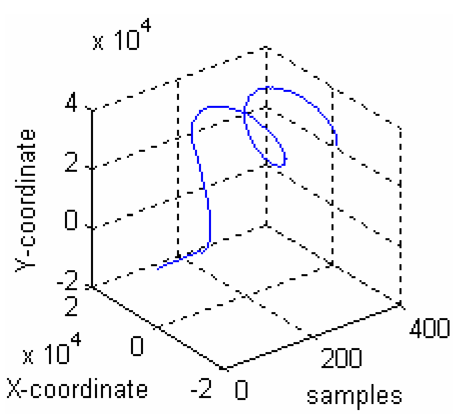


(a) Lifting wavelet transform algorithm tracking

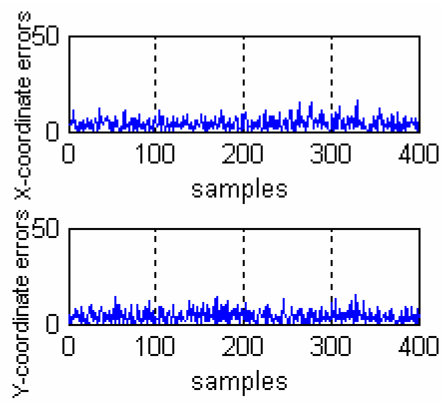


（b）Tracking errors

Figure4. Lifting wavelet transform algorithm tracking results



(a) Integer lifting wavelet transform algorithm tracking



(b) Tracking errors

Figure5. Integer lifting wavelet transform algorithm tracking results

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