Przemysław MAZUREK

WEST POMERANIAN UNIVERSITY OF TECHNOLOGY, SZCZECIN,
DEPARTMENT OF SIGNAL PROCESSING AND MULTIMEDIA ENGINEERING, 26. Kwietnia 10 St., 71-126, Szczecin

Track-Before-Detect filter banks for noise object tracking

Dr. Eng. Przemysław MAZUREK

Assistant professor in the Department of Signal Processing and Multimedia Engineering at the Faculty of Electrical Engineering, West-Pomeranian University of Technology in Szczecin. Author of more then 140 papers related to the digital signal processing, estimation of object kinematics, biosignals acquisition and processing.

e-mail: przemyslaw.mazurek@zut.edu.pl

Abstract

The Track-Before-Detect (TBD) filter banks is proposed for the processing of noise object that are additive to the background noise. Spatio-Temporal TBD algorithm uses the preprocessing of measurement. The modified moving standard deviation filter is applied. The correction of the results for the selection of the highest possible filter banks window is proposed. Monte Carlo test shows that all filter banks allow the tracking if the standard deviation of the background is below 1.3.

Keywords: Tracking, Estimation, Noise object, Track-Before-Detect

Bank filtrów śledzenia przed detekcją do śledzenia obiektów szumowych

Streszczenie

Algorytmy śledzenia przed detekcją, stosowane są do przetwarzania sygnałów jedno, dwu i więcej wymiarowych w celu detekcji obiektu oraz estymacji jego trajektorii (1a-1c). Cechą tej klasy algorytmów jest możliwość śledzenia obiektów, których sygnał jest poniżej poziomu szumów tła. Konwencjonalne podejście bazujące na detekcji a następnie śledzeniu nie może być wykorzystane z uwagi na niemożność dobrania poprawnego poziomu progu w algorytmie detekcji. Specjalną klasą sygnałów są sygnały szumowe, które łączą się z szumem tła, więc ich jest utrudniona i wymaga analizy statystycznej danych pomiarów. W publikacji [9] zaproponowano rozwiązanie polegające na wykorzystaniu estymacji odchylenia standardowego lub wariancji lokalnej, z wykorzystaniem przesuwnego okna o stałej szerokości (2). Zaproponowano rozwiązanie polegające na wykorzystaniu banku filtrów o zmiennym rozmiarze okna (Rys.1). W celu porównania wariancji dla różnych długości okna zaproponowano wykorzystanie średniej z całego sygnału, w celu eliminacji wpływu zmniejszonej ilości próbek. Do banku filtrów dodano wagi (3) mające na celu wybór wyniku z preferencją filtru o większej długości okna, ponieważ rozmiar obiektu jest stały, ale nieznany. Na Rys.2 przedstawiono wyniki testów Monte Carlo w celu określenia średniego błędu estymacji położenia dla przykładowego sygnału na podstawie 1000 testów dla różnych poziomu szumu dla każdego z filtrów banku z osobna. Największa efektywność jest dla szumu tła poniżej 1,3 odchylenia standardowego.

Słowa kluczowe: Śledzenie, Estymacja, Obiekt szumowy, Śledzenie przed detekcją

1. Introduction

The tracking algorithms are very important in numerous applications. The air, space, water surface, underwater surveillance applications are important for example. The tracking systems are very sophisticated. The main parts of systems are related to the detection, tracking and assignment. Most systems are related to the multiple objects tracking, so all parts of the signal processing parts need careful design and implementation. Typical tracking systems are based on the mentioned detection and tracking scheme [1-3]. The detection is based on the threshold algorithm (fixed or adaptive threshold level). The detected positions are processed by the tracking filters that are used for the signal-to-noise ratio (SNR) improvement. The noise measurement gives quite low SNR values so multiple false detections and missed detection occur. Tracking filters use the knowledge about the motion model so reduction of the influence of the noise could be obtained. The assignment algorithm is applied to the tracks maintenance. The observation should be assigned to the appropriate track, new tracks should be created if a new object is in the range and the removal of the tracks for objects that are outside of the range is necessary.

Conventional approach fails if the noise level is high and the signal values related to the object are low. The object is hidden inside the noise floor and the tracking is not possible. Alternative approach, based on the opposite scheme is necessary. The track-before-detect (TBD) approach allows the tracking of such objects, even if SNR<<1 [3,4,10]. The number of computation is huge, because all hypothetical trajectories should be verified, even if there is no-one object in the range [8]. The cost of conventional approach is linear function of the number of observed object, quite often. Accumulative approach applied in TBD algorithm allows the filtering of the signal related to the every trajectory [4].

2. Spatio-Temporal Track-Before-Detect Algorithm

The Spatio-Temporal TBD algorithm is recursive algorithm for multidimensional signal processing [6-9]. The formula (1a) is the initialization of the state space. The formula (1b) is the motion update responsible for the prediction and noise suppression. The formula (1c) is the information update responsible for the balance between new measurement and predicted values.

Start

$$P(k=0,s)=0 \qquad (1a)$$

For $k \geq 1$

$$P^{-}(k,s)=\int_{S} q_k(s \mid s_{k-1}) P(k-1,s_{k-1}) ds_{k-1} \qquad (1b)$$

$$P(k,s)=\alpha P^{-}(k,s)+(1-\alpha)X(k,s) \qquad (1c)$$

EndFor

Stop

k – iteration number, s – particular space,
q_k – Markov matrix, X – preprocessed data,
P^- – predicted TBD output, P – TBD output,
α – weight (smoothing coefficient), range: 0-1.

This algorithm allows the suppression of the zero valued noise and enhancement of positive or negative signals. The noise object is special case of signal – the mean value is zero and values are random. Such signal cannot be processed by this algorithm. The stealth technologies are quite often applied to some objects, so weak signals are observed. The noise difference between object and the background should be applied for the tracking of such objects. High differences between object and the background cannot be observed, unfortunately. Long time measurements and special TBD algorithms allow the detection and tracking.

The application of the variance/standard deviation estimator for the preprocessing of measurements is proposed in [9]. Fixed size of the object (number of samples) and the fixed size of the moving window are applied.

$$X(k,s) = std(M(k,s-L)...M(k,s+L)) \quad (2)$$

The measurements *M* are preprocessed using window size *2L+1*. Another solution is proposed in [5], based on the chi-square statistic for the detection of the difference between global and local distributions of the noise.

3. Filter bank TBD

The standard deviation is an interesting estimator that could be applied for Gaussian background noise and the additive object Gaussian noise signals separation. The size of the object could be variable, so detection should be based on the variable window size.

The computation of the standard deviation is based on the computation of the local mean value. The correction constant is necessary for the comparison of standard deviations for different number of samples. The standard deviation is related to the radius of hypersphere, where the number of samples is the dimension. The smaller number of samples is related to the subset of the hypersphere in lower dimension, with the same radius. The most important problem is that signal is random. The computation of the standard deviation is based on the local mean value, so subset has not identical mean value. It is a result of the radius change. The proposed technique is based on the computation of the mean value for higher dimension (longest window size or all samples). The mean value is applied for the computations of standard deviation for the smaller sample sets. It is also computationally important. Instead formula (2), new proposed formula is applied:

$$X_{bank}(k,s) = k_{bank}\sqrt{\frac{1}{2L+1}\sum_{i=-L}^{L}\left(E - M(k,s+i)\right)^2} \quad (3)$$

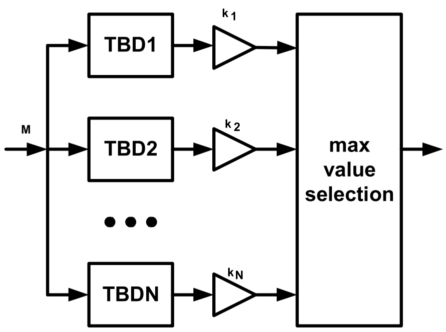
The k_{bank} correction constant is the value dependent on the filter. The value E is the mean value for all samples, not only inside the moving window. Each filter is assigned to the different window size so longer window size filter should be preferred. The following relation should be applied:

$$k_1 < k_2 < \ldots < k_N \quad (4)$$

for example:

$$k_i = 2L + 1 \quad (5)$$

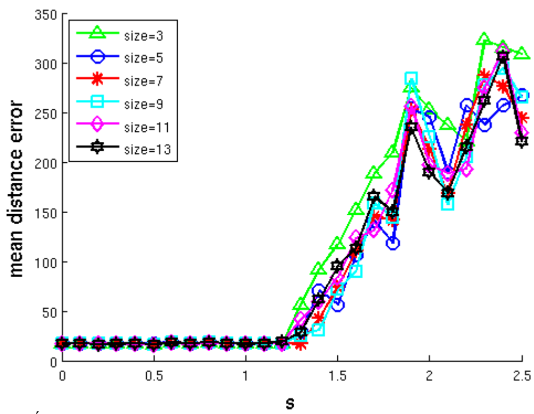
as a weight value dependent on the window size. The Spatio-Temporal TBD is linear transformation of signal, so correction constant could be added not to the input measurement transformation, but for TBD output result. The selection of the maximal value could be used as data fusion operation, but other approaches are possible also.



Rys. 1. Schemat banku filtrów
Fig. 1. Filter banks schematic

4. Results

The Monte Carlo test is assumed for the performance analysis of TBD filter banks. There are 1000 positions and 11 velocities. The 1D signal is processed and the standard deviation of the object is 1, the standard deviation of the background noise is variable (0-2), but fixed for single test. There are 1000 tests for every TBD filter. The signal has correct window size equal to the 7. Mean distance error is depicted in Fig.2 after 80 iterations, for α=0.95.



Rys. 2. Średni błąd odległości
Fig. 2. Mean distance error

5. Conclusions

The proposed filter bank allows the processing of the signal of noise object with unknown length. The filter banks response for all TBD filters gives very good results (mean position errors about a few samples or pixel). The threshold value is about 1.3 of the standard deviation of the background noise. The size of the object is rather small. The Monte Carlo test allows the estimation of the performance of TBD filters.

6. Acknowledgements

This work is supported by the UE EFRR ZPORR project Z/2.32/I/1.3.1/267/05 "Szczecin University of Technology - Research and Education Center of Modern Multimedia Technologies" (Poland).

7. References

[1] Bar-Shalom Y.: Multitarget-Multisensor Tracking: Applications and Advances, vol. II, Artech House, 1992
[2] Blackman S.: Multiple-Target Tracking with Radar Applications. Artech House, 1986
[3] Blackman S., Popoli R.: Design and Analysis of Modern Tracking Systems, Artech House, 1999
[4] Boers Y., Ehlers F., Koch W., Luginbuhl T., Stone L.D., Streit R.L.: Track Before Detect Algorithm, EURASIP Journal on Advances in Signal Processing, 2008
[5] Mazurek P.: Chi-Square Statistic for Noise Object Tracking in Track-Before-Detect Systems, Poznań University of technology Academic Journals – Electrical Engineering", no. 72, 1787-184, 2012
[6] Mazurek P.: Comparison of Different Measurement Spaces for Spatio–Temporal Recurrent Track–Before–Detect Algorithm, Advances in Intelligent and Soft Computing, vol. 102 - Image Processing and Communications Challenges 3, Springer Verlag, 157-164, 2011
[7] Mazurek P.: Hierarchical Track–Before–Detect Algorithm for Tracking of Amplitude Modulated Signals, Advances in Intelligent and Soft Computing, vol. 102 - Image Processing and Communications Challenges 3, Springer Verlag, 511-518, 2011
[8] Mazurek P.: Optimization of Bayesian Track-Before-Detect Algorithms for GPGPUs Implementations, Electrical Review, R. 86 no. 7/2010, 187-189, 2010
[9] Mazurek P.: Track-Before-Detect Algorithm for Noise Objects, Measurement Automation and Monitoring, vol. 56 no. 10, 1183-1185, 2010
[10] Stone L. D., Barlow C. A., Corwin T. L.: Bayesian Multiple Target Tracking. Artech House, 1999