# A Novel Infrared Dim Small Target Detection Algorithm

Guangqiu Chen

School of Electronic and Information Engineering, Changchun University of Science and Technology, Changchun, 130022, China

## Abstract

Aiming at the pipeline size fixing in the traditional pipeline filtering algorithm,, when the size of the target is larger than the pipe diameter, the pipeline filtering algorithm based on the adaptive pipe diameter is proposed. The adaptive learning theory is introduced in this algorithm, which can modify the displacement of the pipeline center and the pipe diameter in real time according to the target location. The experimental results show that compared with the traditional method, this method can effectively suppress the influence of noise and effectively detect the trajectory of the small target.

## Keywords

Pipeline filtering Dim small target Adaptive pipe diameter.

## 1. Introduction

Pipeline filtering is one of the commonly used methods in infrared dim small target detection, which is taking the motion characteristics of small targets (motion trajectory space, motion velocity or acceleration) as a separable feature to detect the target. The basic principle of the algorithm is that: a spatial pipeline is established with the target as its center at the spatial location in *n* frame infrared video images (*n* is called pipeline length), the diameter of the pipeline (pipe is circular) represents the neighborhood size around the target, the length of the pipeline represents the required number of the image frames. According to the temporal and spatial continuity of moving target, if the target is detected in the pipeline with a specified length (such as *m* frames), is based on the theory of target track continuity and random noise correlation, it is considered that there is a target in the pipeline, whose theoretical basis is that the target trajectory is continuous and random noise is not correlated. The diameter in the traditional pipeline filtering algorithm is fixed, the relative motion between the target and the observer and the noise of the infrared detection system make the size of the small motion target changing, but the pipeline filtering algorithm can only detect the target with the diameter smaller than the diameter, and the diameter can not change with the target size. When the size of the target is larger than the diameter of the pipe, it will cause the target to overflow from the pipe. In this paper, a novel pipeline filtering algorithm is proposed, which can be adapted to the change the diameter of the pipe with the target size. The adaptive learning theory is introduced in this algorithm, which can modify the displacement of the pipeline center and the pipe diameter in real time according to the target location, which can effectively suppress the noise interference on the detection on target sequence[1].

## 2. Pipeline filtering algorithm with adaptive pipe diameter

Two important parameters are required in pipeline filtering algorithm with adaptive pipe diameter [2], which are the center coordinates of the pipeline and the target size respectively. Target diameter estimation and pipe diameter can be computed as following

$$\begin{cases} d = 2\sqrt{2}\sigma \\ D = 2d \end{cases} \tag{1}$$

Where $\sigma$ represents space scale, $d$ represents target diameter, $D$ represents pipe diameter. E.g. if $\sigma$ is equal to 1.4, the target diameter is 4×4, pipe diameter is 8×8.

The estimation coordinate of the pipeline center is that

$$\begin{cases} \hat{x}_i = x_{i-1} + m(x_i - x_{i-1}) \\ \hat{y}_i = y_{i-1} + n(y_i - y_{i-1}) \end{cases} \tag{2}$$

Where $(x_i, y_i)$ and $(x_{i-1}, y_{i-1})$ represent target center coordinate in *i*th and *i*-1th frame, $(\hat{x}_i, \hat{y}_i)$ represents pipeline center coordinate in *i* th frame[3]. The weighted values m and n are as follows:

$$m = \begin{cases} 0 & \frac{x_i - x_{i-1}}{R} < 0 \\ 1 & 0 \le \frac{x_i - x_{i-1}}{R} < \mu \\ \frac{C_x}{(x_i - x_{i-1})} & \frac{x_i - x_{i-1}}{R} > \mu \end{cases} \tag{3}$$

$$n = \begin{cases} 0 & \frac{y_i - y_{i-1}}{R} < 0 \\ 1 & 0 \le \frac{y_i - y_{i-1}}{R} < \mu \\ \frac{C_y}{(y_i - y_{i-1})} & \frac{y_i - y_{i-1}}{R} > \mu \end{cases} \tag{4}$$

Where $C_x$ and $C_y$ are constant, $\mu$ is controllable factor. The controllable factor $\mu$ can get in the *n*th frame and those in the (*n*-1)th frame is moving speed, so speed constraint is that

$$\begin{cases} u_i = x_i - x_{i-1} \\ v_i = y_i - y_{i-1} \\ \omega_i = \sqrt{u_i^2 + v_i^2} \end{cases} \tag{5}$$

Target speed variation constraint is that

$$\begin{cases} |u_i - u_{i-1}| < \alpha_u \\ |v_i - v_{i-1}| < \alpha_v \\ |\omega_i - \omega_{i-1}| < \alpha_\omega \end{cases} \tag{6}$$

Where $u_i$ and $v_i$ are moving speed in *x* and *y* direction respectively, $\alpha_u$ , $\alpha_v$ and $\alpha_\omega$ are the maximum moving amount of the target center between two adjacent frames. Candidate targets are considered to be correct only if the above three inequalities are satisfied. On the contrary, it is considered to be noise interference. If the target speed exceeds the constraint condition in the current frame detection, the center coordinate of the pipeline will not be updated, and still maintain the center coordinate of the pipeline in the last frame[4].

The specific steps of the pipeline filtering algorithm with adaptive pipe diameter is following

(1) Pipeline parameter initialization. Set the diameter and length, length N is determined by the requirements of the detection task

(2) Input sequence image. The first frame image is the starting image, and continuous input $N$ frame images in the stack mode.

(3) Establish a pipeline for each candidate target, when the pipeline is filled with $N$ frame images, start detecting the pipeline image in turn, then new image is entered by first-in first-out and the old image is removed.

(4) Speed constraint condition discriminates, counter updates. All the candidate targets in the current frame are observed that whether there are suspicious targets in their pipeline area in the next frame, If there is a suspected target, target appears counter plus 1, otherwise plus 0. To determine whether the target location is changed, then update the target position change counter.

(5) Update pipeline parameters. If the small target in the pipeline meets the constraints, the diameter of the pipe and the center coordinates of the pipeline are updated according to the formula (1) and (2).

(6) Distinguish between true and false target. After $N$ frame image processed, the output value of each counter is observed. If the value of the counter is greater than or equal to $K$ and the value of the target position change counter is less than or equal to $R$, the candidate target is determined to be a true target, otherwise it will be regarded as a false target.

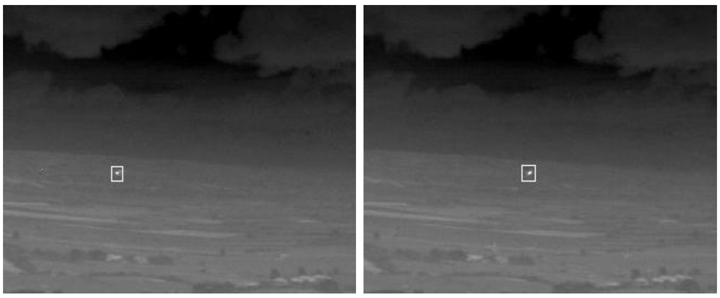
(7) Updating the pipeline image until all the image sequences are processed.

(8) Output target trajectory.

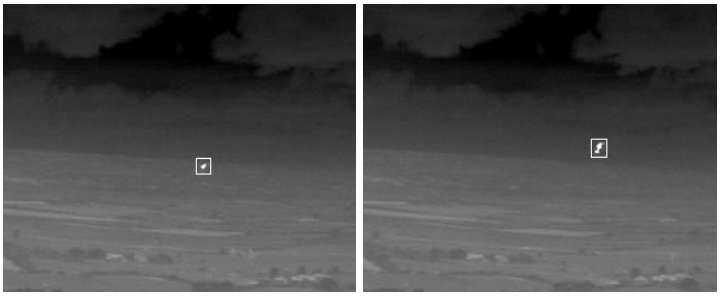
## 3. Simulation and result analysis

For demonstrating the effectiveness and stability of the proposed algorithm, the proposed algorithm is used to detect dim small targets airplane in a set of infrared video image sequences, as can be shown in figure1. The airplane in the video image sequence gradually becomes larger in the field of view, the length is 50 frames, the size of the image is $320\times240$. The original video image is shown in figure 1 (a)-(f), the residual images are shown in figure 1 (a)-(f), the target trajectory images of the classical pipeline filtering algorithm and the proposed algorithm are shown in figure 3(a)(b).

(a) The 10th frame (b) The 15th frame



(c) The 25th frame (d) The 30th frame



(e) The 35th frame (f) The 45th frame

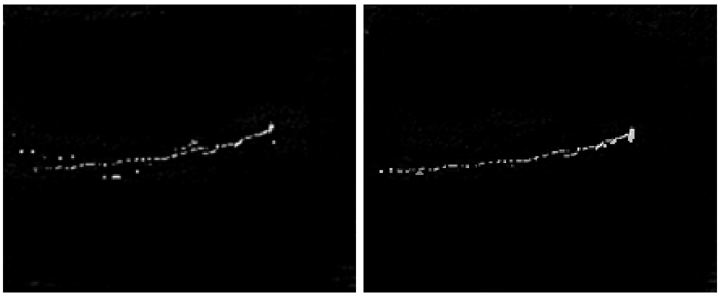
Figure 1 The different frames captured from the original video image

(a) The 10th frame (b) The 15th frame

(c) The 25th frame (d) The 30th frame

(e) The 35th frame (f) The 45th frame

Figure 2 Residual image obtained by background suppression



(a) Traditional pipeline filtering (b)The proposed algorithm

Figure 3 Target motion trajectories by the different filtering algorithm

As can be seen in the above experimental results, the fixed position noise is still retained in the result obtained by the traditional pipeline filtering algorithm. The leakage alarm rate increases with the size of the dim small target gradually becoming larger. The proposed algorithm can suppress the edge noise and the fixed noise in the pipeline, the target can be captured when the size gradually become larger with the small target from far and near

## 4. Conclusion

In this paper, aiming at the defects of the traditional pipeline filtering algorithm in infrared dim target detection, an adaptive pipe diameter filtering algorithm is proposed, which can effectively restrain the edge noise and the fixed noise. When the size of the dim small target in the field of view gradually becomes larger, the target can be effectively captured. Experimental results show that the proposed algorithm is superior to the traditional pipeline filtering algorithm in small target detection.

## Reference

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