Analysis of an infrared interference antagonizing window tracking algorithm

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Abstract

Interference is an important issue in visual tracking. While most tracking algorithms are able to track well in simple condition, they usually fail when the objects have serious occlusion interference. This paper provides a surface type interference which has an excellent effect to disturb three common window tracking algorithms, includes fasten window algorithm, group windows tracking algorithm and adaptive window algorithm. This paper also proposes a series of experiment to find out the proper parameter of the surface type interference, and the results show this kind interference is a strong one against the window tracking algorithm.

1 Introduction

The window tracking algorithm is an important technology in visual tracking as it can do the space filtering with a limited time cost and resources cost. The window tracking algorithm uses a window which is a little bigger than the tracking target to enclose the target region and make the tracking can't be disturb by the interference outside the window. The adaptability to the interference is a certain capability to judge a tracking algorithm. So it is also important to find a strong interference against the tracking algorithm.

There are two kinds artificial interference: one kind serves as a fake target to allure the tracking equipment into another direction; another kind serves to destroy the tracking target to make the tracking equipment lose its aim. The tracking window can usually handle the fake target outside the target region, but it is difficult to deal with the second one. Hong Ming introduced an incoherent intense light interference which cut the optical circuit of the tracking equipment and misadvised it[1]. But this interference is more efficient to disturb the window centroid tracking algorithm. Wang ke-wei also analysed the tracking error model of the window centroid tracking algorithm.[2] Wang Falong discussed about the effect of smoke jamming in front of the tracking equipment to the window tracking algorithm and correlation tracking algorithm.[3] Li Baoning discuss about the performance and properties of the US surface type infrared decoy.[4] But these works do not have a strong experimental result to support their issues.

In this paper we provide a surface type infrared interference which has strong interference effect to the infrared window tracking algorithm on the sea surface. In section 2, we introduce some common tracking algorithms; in section 3, we discuss about choosing the parameter of this type interference. In section 4, we provide a set of experiment to verify this kind of interference have an efficient effort.

2 Window tracking algorithm

There are three kinds of infrared tracking window algorithm depending on the size of the window: adaptive window tracking, fixed size window tracking and group window tracking. As the infrared image is not real- color, so all these tracking algorithm based on infrared video is operate on the gray-scale image. We focus on the issue that a tracking machine try to find its target on the sea surface and when it locks on the target it will come toward the target. So there are some special characters in this issue:

1) The environment is simple. There is little other subject in the tracking scene, so the back ground is very clear and the target is easy to be catch up.
2) The target's scale changes in a big range. At the beginning, the tracking machine is far from the target, so the target will only occupy a small region of the tracking machine's focal plane. With the tracking machine continuing to approach the target, the scale of the target expands until the target fills the entire focal plane.
3) There will be some artificial interference during the tracking process. It is another difficulty that the artificial interference appears and moves unpredictably and very similar to the target and always damages the target's feature seriously.

No matter which tracking algorithm should be designed base on these characters. Next is introducing of each kind of the infrared tracking window algorithm.

The fasten tracking window algorithm can easily set its parameters and do not need lots of calculation, so it has been wildly used in most virtual tracking scene. The size of the window is set by the fore information of the tracking target, as a little bigger than the figure of the target. The central of the window points to the central of the target and moves to the forecast of position during the tracking. Since the scale of the window will not change during the tracking process, the tracking algorithm will change to suit when the target objects undergo large changes in scale.

At the beginning, fasten window usually uses the observation model for tracking frame by frame. First step, the

algorithm distinguish the foreground from the background and choose the most potential region from the foreground as the target region. During the tracking process, the algorithm will searching only inside the window, update the position of the window central by prediction until the tracking model's size crosses a threshold. Second step: when the foreground is almost full fills the searching window, the tracking algorithm will change its model from the whole target to some part of it. The second step is easier to be disturbed, because although a small interference can not cover the entire target, but it can easily cover a small part.

The window tracking algorithm is aimed to reduce the calculation and the interference outside the window. So the size of tracking window always sets as small as possible. A smaller window means limited searching area which can reduce the calculation complication and a smaller window can stop more interference outside the tracking window, while a big one could lose its target when the error is accumulated exceed a threshold. But because the second step is not reliable, the fixed-size window algorithm cannot accept such a small window which causes it to be disturbed more easily.

The group windows tracking algorithm is an adaptive algorithm based on fixed-size window algorithm. It uses a group fixed-size tracking windows instead of one, so it can get the more accurate edge of the target while suit to the scale variation. The size of each window is set before the tracking start also based on the prior knowledge. This means that the group windows tracking algorithm can get more accurate edge of the target but do not need more calculation.

The adaptive windows tracking algorithm is more advanced algorithm. It chooses accurate edge of the target and set the windows border to the edge. As the window is small, the data which needs to do the calculation is limited so it can use the gray-scale image as the source for recognition. Unlike the above, it uses particle filter which predict the movement of a few target's points instead of setting the whole target as a model.

3 Surface type interference

In view of the infrared tracking algorithm continually enhanced, the infrared interference also improving its design to catch up. The point-source infrared interference cannot disturb nowadays tracking algorithm based on the infrared image: The new tracking algorithm can recognize the target by more feature, not follow the heat only. [5]Like the target's spectrum and the target's figure. Basing on that, the surface type interference has replaced the point-source infrared interference in recent years.

There are three key elements which affect the performance of the interference: the temperature of the interference, the scale of the interference and the strategy of it. We discuss about these key elements in detail in this section.

3.1 The highest temperature of the interference

The surface type interference release lots of hot particles which radiate more powerfully so that the target and region will be inhibited and the image of the target shows more fuzzy [3]. To achieve such effect, the surface type interference should guarantee its radioactive energy, but cannot blindly increase the interference radioactive lightness. As the tracking equipment will filter the objects which temperature equals a blackbody at 300 Celsius degree, the highest temperature can be calculated by the Equation (1)

$$T_{\max} = L^{-1}(\frac{L(T_0)}{\varepsilon\tau_a}) \qquad (1)$$

Where $T_{\max}$ is the highest temperature of interference, T_0 is the target's highest temperature, $L(\cdot)$ and $L^{-1}(\cdot)$ is the radioactive light function and inverse function which define as Equation (2), τ_a is the emissivity of the interference, is the atmospheric transmittance.

$$L(T) = \int_{\lambda_1}^{\lambda_2} \frac{2hc^2}{\lambda^5(e^{hc/k\lambda T} - 1)} d\lambda \qquad (2)$$

Where h is Planck constant, c is the speed of light, k is the Boltzmann constant, λ is the wavelength.

To show some examples, we give the different highest temperature based on different atmospheric transmittance and different distance between the interference and the tracking equipment.

Distance (R, km)	atmosphere transmittance τ_a	Highest Temperature $T_{\max}$ ($^\circ C$)
10	0.4218	625
9.5	0.4372	610
9	0.4533	595
8.5	0.4701	580
8	0.4877	565
7.5	0.5061	551
7	0.5254	537
6.5	0.5456	524
6	0.5669	510
5.5	0.5893	497
5	0.6129	484
4.5	0.6379	471
4	0.6643	458

Table 1 the highest temperature at different atmosphere condition. (The simulation is based on US standard)

3.2 The scale of the interference

The interference should be a potential tracking target not a noise point, so the interference must keep a certain size. Tracking algorithm generally use mean filter or median filter to remove the noise. The filters use template about 3×3 or 5×5 pixels, so if the interference wants to avoid being eliminated, it should keep the connected region more than 4×4 pixels. If the interference needs to maintain a certain

shape to be treat like a target, its scale should be larger than that.

It is obvious that the surface type interference will be more powerful if it can occlude more of the target. But it is difficult to calculate the proper scale of the interference, because the interference effect is a function defined by four combined factors (Equation (3)): t_{begin}, t_{end} is the existing time of the interference in the tracking window, ρ is the proportion of the target occluded by interference and P_{ro} is the character of interference, and C_l is the reliability of the tracking algorithm.

$$\mathrm{Re}\, s = f(t_{begin}, t_{end}, \rho = \frac{S_{\mathrm{int}erference}}{S_{target}}, \mathrm{P}_{ro}, C_l) \qquad (3)$$

There are a lots of elements affect these four factors which all need to be considered about: the position where the interference appears, the scale and the shape of the interference, the direction and the velocity of the target, the direction and velocity of the wind and the direction of the tracking equipment. The function is hard to be described by particular equation and the size of the interference is only one element. So we design an experiment which uses the simulation to get the proper scale which can still have a good effect.

3.3 The strategy of interference

The way of interference is destroy the updated model of tracking algorithm by influence the feature of the target. Since all tracking algorithms will select the target channel from the grey scale histogram, so our strategy focuses on occlusion part of the target disturb the tracking algorithm. Different tracking algorithm should use different interference strategy.

1) To the fasten window tracking algorithm and group windows tracking algorithm, since they use binary image as the source and radiation of surface type interference is close to the target, the surface type interference would be considered as part of the foreground. So if we put the interference in front of the target at the beginning, the tracking algorithm will take them as a whole target, and with their individual movement, it's not difficult to mislead the tracking equipment into a wrong direction as Fig.1.

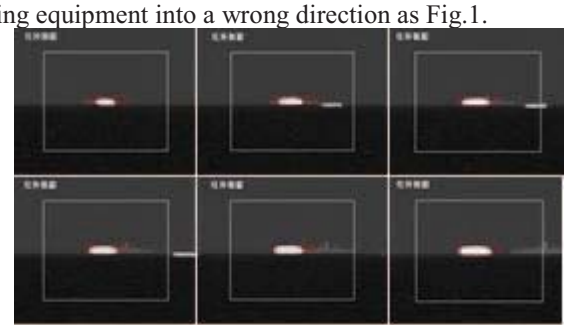

Fig 1 the example of successful interference

2)Some adaptive window tracking algorithms are just like the above, but others can choose the accurate grey scale region of the target by clustering algorithm.[6] To the sea surface scene, there are three obvious peaks on the grey scale histogram corresponding to the sea, the sky and the target region. It is easy to choose the target region. To these algorithms, there are two ways that the surface type interference can work with.

a) If the surface type interference is big enough to cover most of the target region, the distribution of the grey scale histogram would be damaged extremely. A new peak related to the interference region appears while the old peak of the target becomes flat. So the surface type interference becomes the target and leads the tracking equipment diverging from the former target.

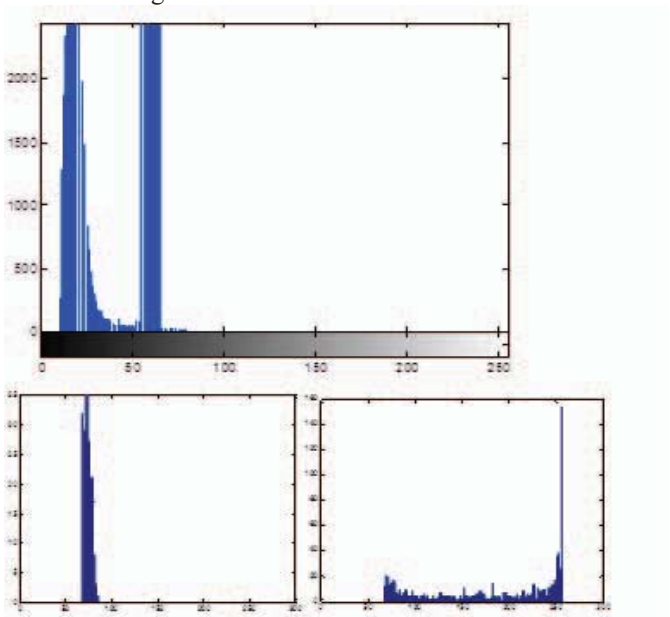

Fig 2 the histogram (top: the whole pic, bottom left: without sea and sky, bottom right: after interference without sea and sky)

b) If the surface type interference fails to substitute the target, it will be considered as part of the back ground interference. So when it occludes part of the target, the tracking equipment will think the target is turning small and the tracking central turning away cause of that. In this time, the accurately edge selected by the adaptive window algorithm now becomes a weakness point. As the fourth picture of Fig.4, the fasten window algorithm will still get the rest of the target in the right of the interference while the adaptive window algorithm determine the target is minifying to only left part of it. And finally, the algorithm will lose its target. The Fig.4 is the whole process of how the surface type interference works, yet it also needs the right movement of the target and the wind which pushes the interference move.

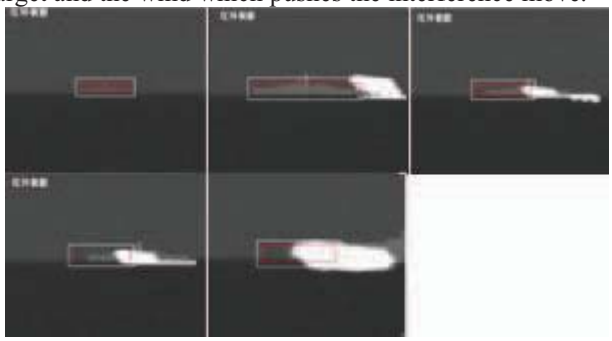

Fig 3 the example of the second type of interference

The selection of different strategy means different position where the interference appears which defined by Equation 4. (Assume 0 is the central of the target)

$$Pos = \begin{cases} 0 & \rho > threshold \\ \pm long_{target} / 2 & \rho \le threshold \end{cases} \quad (4)$$

4 Experiment result

To test and verify this surface type interference, we design a series of experiment to estimate the accurate parameter of the surface type interference. The experiment uses a simulation platform developed by us. The platform simulates the real sea surface scene convincingly by load the environment model which contains the wind with random velocity and direction, the sea model which contains the movement of the ocean wave and the radiation of the sea, the sky model which contains the different radiation at different time under different weather and the target model includes its shape, its radiation distribution and its movement. The simulation platform can load different tracking algorithms to do the test.

As introduced in section 2, we used three types of window tracking algorithm to test the effect of the interference: fasten window tracking algorithm, group windows tracking algorithm and the adaptive window tracking algorithm. The tracking target is a ship which moves with a constant velocity and speed of wind is defined as a random value from 0 m/s to 15 m/s from a random direction. The tracking equipment is coming from about ten kilometres away and toward the ship at about 300 m/s.

Firstly, we test about the suitable scale of the interference and the suitable temperature of the interference. Setting the surface type interference at 300 centigrade degree, we try different sizes of interference to see whether they would be recognized as a target of the tracking algorithm. Its size is defined by pixels. Then choosing different temperature of the 10×10×10 cubic pixels interference to see what temperature is the minimum temperature the tracking equipment will allow as a target. From table 2, the minimum temperature(T_{min}) should be 400 centigrade degree with the size of 12×12×12 cube pixels.

attack algorithm	T_{min} (10×10×10)			Minimum size (300 度)		
Parameter	100	300	500	$4^{\times 4\times 4}$	$8^{\times 8\times 8}$	$12^{\times 12\times 12}$
adaptive	30%	90%	100%	0%	10%	100%
fasten	30%	50%	80%	0%	50%	100%
group	50%	50%	70%	0%	50%	100%

Table 2 the result of parameter test

Secondly, we try to figure out the proper size of interference. We find out the best position for the surface type interference which can occlude 40 per cent of the target under a series of tracking conditions. Different tracking condition has different velocity and direction of wind and the target escaped to different direction. Then we change the size of the interference and record the rate of successful interference. The result can be seen in Table 3, which shows that when the surface type interference covers about sixty per cent of the target, it would have an efficient effort of each algorithm.

	The size of the interference			
Adaptive algorithm	20%	33.33%	46.67%	60%
Successful rate	39.31%	64.01%	66.90%	91.03%
fasten algorithm	The size of the interference°			
Successful rate	41.00%	65.33%	83.33%	92.46%
group algorithm	The size of the interference			
Successful rate	33.00%	65.67%	78.00%	83.33%

Table 3 the proper size of the interference

From the result above (see from Table 3), when the interference occludes over 60% of the target, the tracking equipment has over 80% probability to fail to track.

5 Conclusion

This paper proposes a surface type interference which has an efficient effect to nearly all kinds window tracking algorithm. Three key elements of the interference have been discussed in this paper. The minimum of parameters of this interference is verified by calculation and experiment result and probable ways the interference can work against different tracking algorithm based on the different size of the interference. Another potential of our surface type interference is using it as a benchmark to test the reliability and robustness of tracking algorithms, as it is a real challenge to face.

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References

[1] Hong Ming, Liu Shang-qian, Wang Da-peng,Gao guo-wang. “The jamming mechanism for intense light bomb antagonizing infrared imaging guided-missiles”. Jounal of Xidian University. Vol 34. 6. (2007.12).

[2] Wang ke-wei, Ma Chao-jie, Chen Wei, Zhang fan. “Error analysis for gate centroid tracking algorithm of infrared imaging. Journal of applied optics”, Vol.30 No.2. (Mar. 2009).

[3] Wang Falong, Tao Xi. “Analysis on smoke jamming to IR imaging guidance system”, Aerospace Electronic Warfare, Vol 24(5), (2008).

[4] Li Baoning, Xie Jipeng, Li Chaorong. “Development Analysis of the US Surface type Infrared Decoy”, Ship Electr onic Engineering. (2009.7).

[5] Wang Jian-xun, Zhang Dong-yang. “Analysis of the IR Active Jamming Technology”, Guidance & Fuze, Vol 24, No.2 (Jun. 2003).

[6] Guanhua Su, Huimin Ma, Yu Hou. “A Robust Approach for Anti-Jamming Target Tracking in Forward Looking Infrared Imagery”, International Conference on Image and Graphics (ICIG), (2011).