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A Study on Tracking and Trajectory Prediction of High-Speed and Long-Range Flight Target using Infrared Stereo Cameras

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Abstract: In this study, it suggests the method to track and predict the trajectory of long range target flying at high speed. Generally, it uses the laser or radar in order to gain the three-dimensional position information of target. However, in case of laser, it is very difficult to take aim at target of high speed, and radar is relatively correct, but very expensive. In this study, hereupon, it proposes the way to utilize the heat of flying target as tracking information, using infrared stereo cameras. The suggested method is calculated the three-dimensional position information of long range target, by building the stereo environment with long base line, and it finds the exact position of target in thermal imagery, by finding the leading part of heat source. Also, it predicts next trajectory of target using regression analysis and genetic algorithm.

1. Introduction

The tracking and prediction of trajectory for field target is regarded as important technology in areas of surveillance, robot, and military affair and is being actively studied. The way to track target is used as laser, radar, and camera, etc. The method to utilize laser is measured the distance, receiving laser reflected from target, after shooting laser for target. This is easy for stationary target to measure, but it has limitation of moving target at high speed to take aim[1].

The three-dimensional radar has the best accuracy, compared to other ways, in direction, distance, and altitude of long range target, but it has disadvantages of high cost and possibility to expose the location of observer[2].

For the manner to use camera, it exists various ways depending on kinds and formats of camera. CCD camera or infrared camera acquiring temperature data can be used for tracking target, it is very difficult to gain the correct three-dimensional information of target, only using single camera. Such limits can be solved by being suggested the stereo compatible method, with two cameras, using parallax data between two cameras[3]. On the contrary, this method is being utilized only for tracking target of short range, and not experimented for long range. Moreover, in case of stereo system with long baseline, it has limitation of much difficulty to grasp the geometric relation between two cameras, for places where spatial limitation exists. Besides, even though it gains the thermal imagery of flying target by two infrared cameras, it has errors of three-dimensional coordinates of calculated target, unless it detects the actual position of pertinent target correctly in thermal imagery[4][5].

In this thesis, we propose the method to detect the exact location of target and presuppose next trajectory of target, using the central part and direction of heat source which long range target at high speed generates on the system of infrared stereo camera with long baseline. In chapter 2, it suggests the method to track in detail and presuppose the trajectory for long range target at high speed, in chapter 3, it proves this by experiment. Lastly, it refers to the conclusion, in chapter 4.

2. Proposed Method

We propose the preservation method of geometric relation of stereo camera system for gaining the three-dimensional location data of long range target in section 2.1. It suggests the way for exact detection of target position in the acquired thermal imagery in section 2.2, and it proposes the method to presuppose next trajectory of target in section 2.3.

2.1 The Preservation of Geometric Relation of Two Cameras

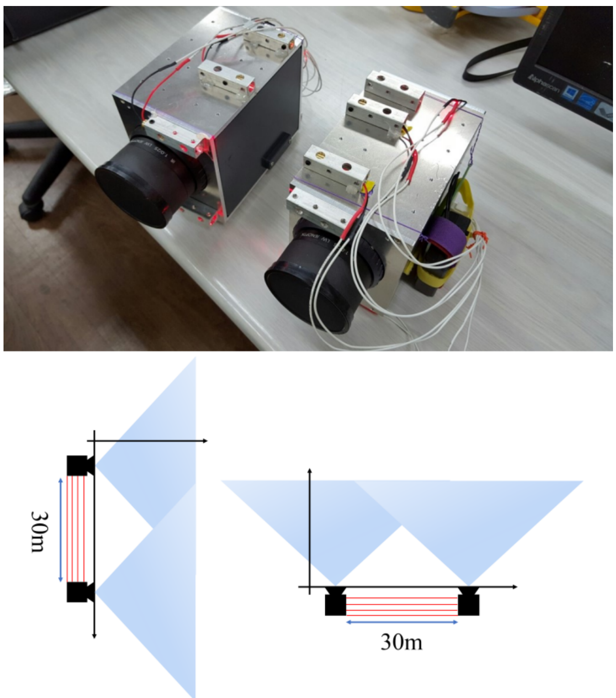

Figure 1. Infrared Stereo Cameras with Lasers.

The stereo compatibility for having three-dimensional loca-

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tion data of target is used by two cameras. This study is to detect the long range target of a few km, so it should be composed by stereo system with long baseline of 30m. However, because it has many spatial limitation in stereo compatibility for long baseline, it executes the stereo compatibility without restrictions, and it builds the preservation system for geometric relation of two cameras through laser, shown in figure 1. By playing role of fixed axis between two cameras, laser can be composed the identical, geometric relation even for voluntary location.

2.2 The Detection of Target in Thermal Imagery

In figure 2, it shows the imagery to represent the taken target with the course of time, at the same moment with infrared cameras of left and right, respectively. Because the actual target is located at leading part, not slack tail part, among the taken imagery, it should be executed the stereo matching to detect the leading part of heat source necessarily, in order to gain the exact coordinates location of target.

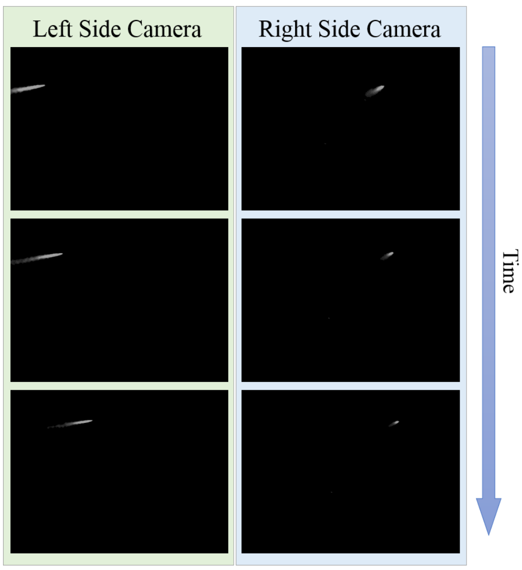

Figure 2. The Appearance of Taken Target with Infrared Cameras.

In figure 3, f_t means the bright pixels showing the appearance of target in current frames, and c_t represents the center by calculating the average of pixel positions. f_{t-1} and c_{t-1} shows the appearance and center of previous frames, respectively. P_t is the place where actual target is located in current thermal imagery frame, and the detection of leading part can be detected by making linear equation crossing c_t and c_{t-1} and investigating the location of pixels which reaches to pertinent straight line lastly.

$c_{t-1}$and c_t refers to (x_1, y_1) and (x_2, y_2) respectively, the linear equation crossing these two points is represented like formula (1).

$$f(x) = \begin{cases} \frac{y_2 - y_1}{x_2 - x_1}(x - x_1) + y_1 & \text{if } x_1 \neq x_2 \\ x_1 & \text{if } x_1 = x_2 \end{cases} \quad (1)$$

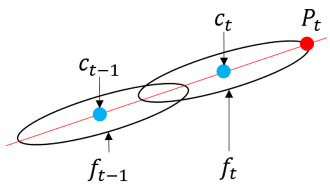

Figure 3. The Detection Method of Exact Position of Target in Thermal Imagery.

The bright pixel position which reaches lastly along linear equation of formula (1) is the position of actual target in thermal imagery.

2.3 Trajectory Prediction

In order to presuppose next trajectory of target, it uses the regression analysis and genetic algorithm[6][7]. In case target flies relatively gently, the presupposition through regression analysis may be excellent in speed aspect. On the other hand, providing target moves dynamically, the genetic algorithm producing various formulas will be more correct than the regression analysis method, even if it is slow.

In this test, regression analysis is executed the fitting by second polynomial, and genetic algorithm is fulfilled by having various formula node of ‘add, subtraction, multiplication, log, root, sine, cosine, and tangent’ without limitation of degree. The size of initial population of genetic algorithm is set up in 10,000, and the probability of mutation is 10%, that of crossbreeding 40%, that of being generated new entity 5%. In addition, it is established to evolve up to the maximum 500.

3. Result and Analysis

The infrared stereo camera has the resolution of 384×288, focal distance 25mm, angle of view 30×23, pixel pitch 35um, average 50fps. The baseline is set up as 30m. The target moves fast at about 800m/s. Figure 4 shows us the correct coordinates position of actual target, by executing the stereo compatibility on the basis of the leading part of target detected by algorithm in section 2.2. It indicates the leading part of detected target in red circle.

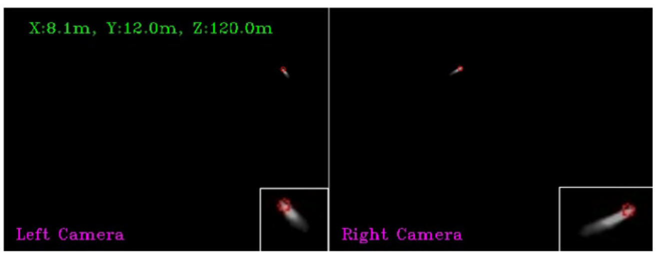

Figure 4. The Appearance of Exact Position of Target in Thermal Imagery.

The experiment is done by three times all, each target used in test is A1, A2, and B3. The location and presupposed result of gained targets through test are shown by figure 5, 6, and 7. Figure 5 is the graph for left and right(X-axis), and figure 6 and figure 7 represents altitude(Y-axis) and distance(Z-axis),

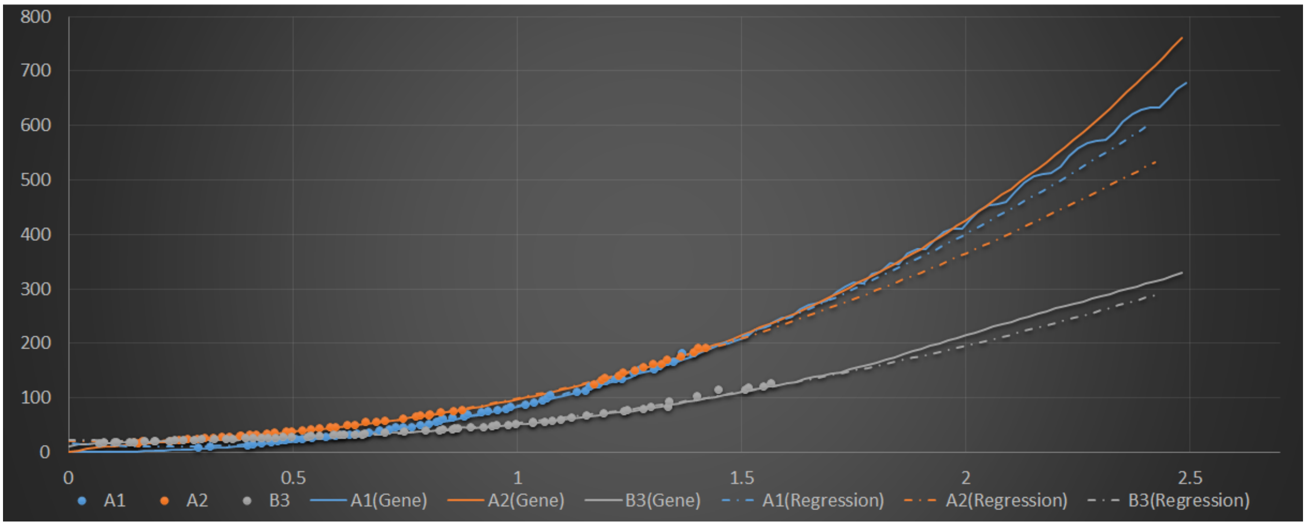

Figure 5. Graph Showing the X-axis Distance of the Target.

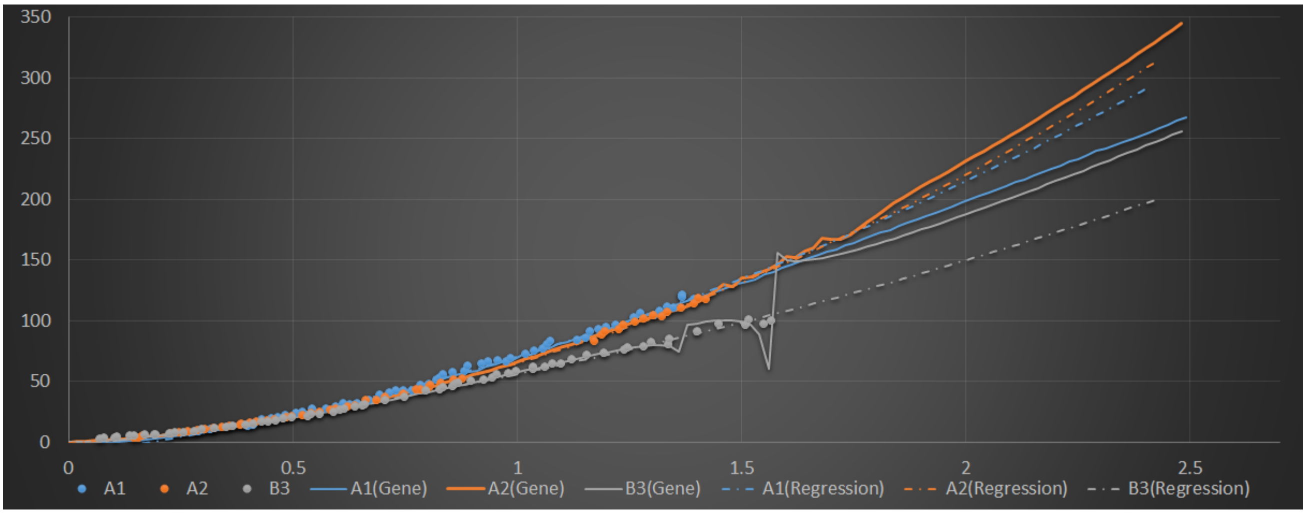

Figure 6. Graph Showing the Y-axis Distance of the Target.

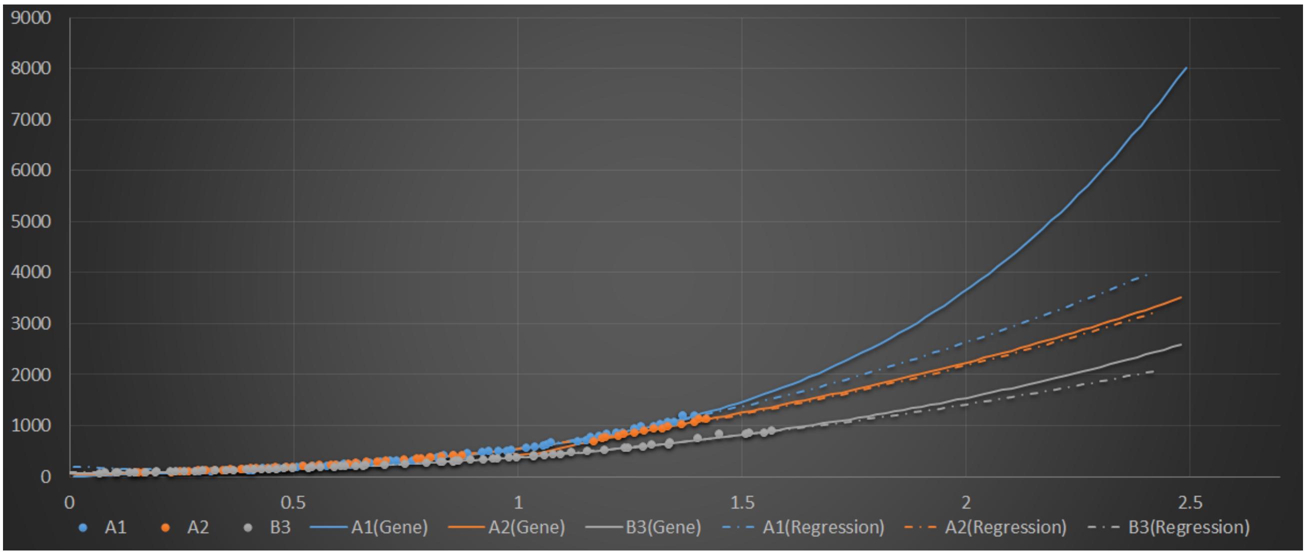

Figure 7. Graph Showing the Z-axis Distance of the Target.

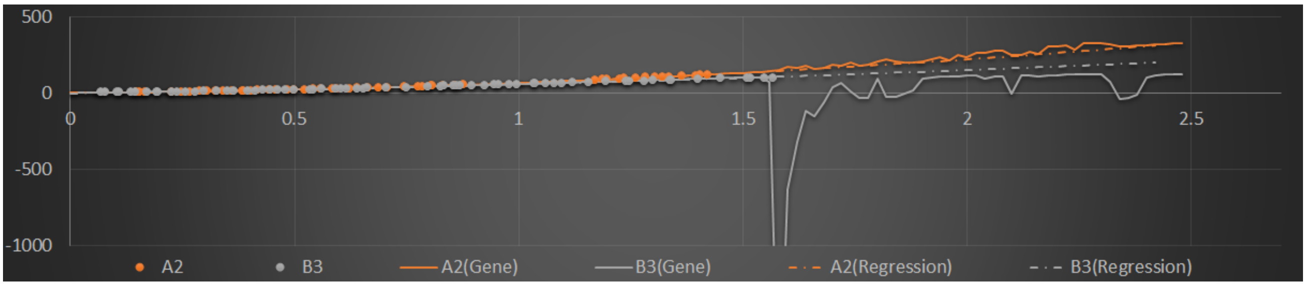

Figure 8. Overfitting Case: Graph Showing the Y-axis Distance of the Target.

respectively. In each graph, thick dot is the observed data of actual target, and the horizontal axis means time(unit:sec), vertical axis distance(unit:meter).

In table 1 and 2, we know the result of assessing accuracy for presupposition acquired by regression analysis and genetic algorithm, respectively. It shows us the average of error(η) and standard deviation(σ) between the presupposed formula by X, Y, and Z each and actual observed data.

Table 1. The Assessment of Presupposed Result using Regression Analysis.

	X		Y		Z	
	η	σ	η	σ	η	σ
A1	2.01	1.80	1.63	1.14	18.46	14.77
A2	1.47	1.48	0.71	0.63	11.16	12.04
B3	2.53	1.65	1.76	1.08	11.40	9.90

Table 2. The Assessment of Presupposed Result using Genetic Algorithm.

	X		Y		Z	
	η	σ	η	σ	η	σ
A1	1.58	1.36	1.27	1.12	13.36	10.73
A2	0.86	1.02	0.70	0.75	4.52	6.41
B3	2.48	13.26	1.25	2.13	5.90	9.52

By result of table 1 and 2, the genetic algorithm has more accuracy of average 30% than regression analysis. Nevertheless, in terms of speed, the regression analysis has much more excellent ability than genetic algorithm. Whereas the regression analysis takes average 0.1 seconds in computer with i7-4790K CPU, 32GB RAM, the genetic algorithm takes about one hour.

In figure 8, it shows the case of failure due to overfitting phenomenon of genetic algorithm. In this figure, the average error and standard deviation calculated by genetic algorithm is 0.59 and 0.52, in case of A2, and it has extremely low error of 0.91 and 1.19, in case of B3. However, the actual result of presupposition is extremely wrong. When flying target is 1.6 seconds, it moves rapidly about for 0.1 seconds more than 1km, less than -1000m at +100m spots, and it is because genetic algorithm produced the presupposed formula which the actual speed of target itself is not considered. Such error is expected to be solved, if the presupposed formula generated by genetic algorithm, considering the actual speed of flying target, verifies whether differs from the speed of actual flying target.

4. Conclusion

In this thesis, it described the tracking method using heat source which long range target at high speed generates, on system of infrared stereo camera. It suggests the preservation method of geometric relation of two cameras with long baseline, and described the detection way of the correct target location in thermal imagery taken target. Rather, it presupposed the trajectory of target using regression analysis and genetic algorithm. In this study, it considered the simple location data according to flying trajectory of target, but it requires more study on this, because it is possible to track target more precisely and presuppose trajectory, if it considers even flying trait and weather condition of target, itself.

Acknowledgement

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