A Tank Shooting Method Simulation Based on Image Analysis

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Abstract. A simulative tank shooting method based on image analysis is presented, it is an alternative to the existing laser system. The system is composed of an image acquisition system and an infrared strobe light system. Based on the strobe light, the ID of the target tank can be computed. Analyzing the characteristics of the target image, the position of strobe light is determined through image normalization, image segmentation and tracing boundary contours algorithms in turn; then the target ID is identified. Experimental results show that the proposed method can recognize the ID and hit location of the target tank accurately.

Keywords: training system, strobe light, target ID, image segmentation, tracing boundary contours.

1 Introduction

Tank is a tracked armored fighting vehicle, which has a strong direct fire, armor protection force and a high degree of cross-country mobility.Tanks are the main weapons of modern warfare on land, the main task of tanks is to combat with the enemy tanks and other armored vehicles; they can also suppress and eliminate anti-tank weapons, destroy fortifications, and annihilate the effective strength of the enemy.

Currently, the main training method of tank training is to emit laser instead of live ammunition. This simulative training system mainly consists of a laser transmitter and a detector[1]. Target tanks equipped with infrared laser detectors, when training, one's own tanks emit infrared laser, the infrared laser detectors analyze the received signal to determine that whether they have been hit or not.

The advantages of this training method are: do not use live ammunition, low cost, high security; but it also has many drawbacks[2]: whether the target tanks have been hit or not and the hit part can not be determined accurately, because laser will form a great spot in the distant tank; laser's time-of-flight do not match with the live ammunition, because it takes a few seconds for the live ammunition flies to the target tank, but the laser beam's speed is the speed of light; the flight path of the laser beam can not simulate the live ammunition, because the flight path of the live ammunition is a parabola, but the the flight path of laser beam is a straight line. A simulative tank shooting method based on image analysis is presented in this paper, this training method has a higher accuracy, more close to the live ammunition training.

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2 Principle and Design

In the simulative laser training system, there is no need to encode the target tanks, because the laser emitters installed on the firing tanks and the laser receiver on the target tanks can determine whether the target tanks have been hit or not. But in the tank shooting method simulation based on image analysis, sequences of images of the target tanks are got through a video camera; in order to distinguish every tank, to confirm its identity, the target tanks should be numbered. In order to identify the target ID, strobe lights flashing with different frequencies are installed on the target tanks, then combine the known ballistic data and the launch angle of the projectile to calculated the target tanks' hit parts[3].

The following figure is the processing unit schematic. The method includes image acquisition module, data processing center, and wireless communication module. The core problems are the acquisition of images and the design of the strobe source ID. Next these two issues will be further analyzed.

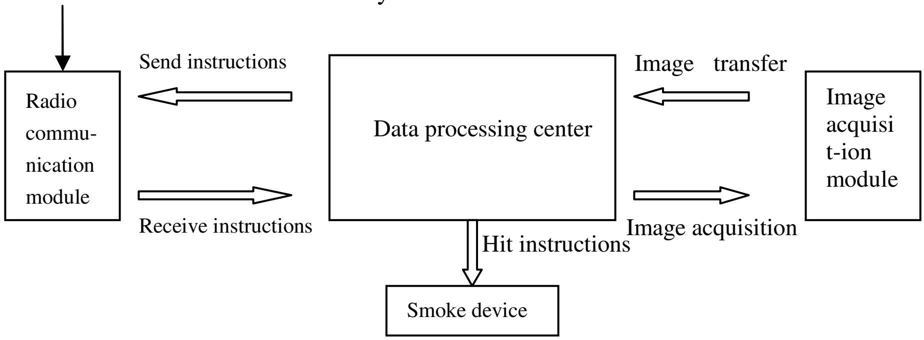

Fig. 1. Processing unit schematic

2.1 Image Acquisition

It is very important to select the appropriate video camera and filter, because images mainly come from the video camera, and the target tanks equipped with infrared strobe light.

Comprehensive consideration of the video camera on several factors, such as the angle of view, focal length, resolution, sensors, etc. 1280*960 infrared-sensitive video camera is selected, it can capture 50 images per second; focal length of 75mm lens is selected to get the clear strobe light,which is conductive to determine the identity of the target tanks.

In order to identify the ID of the target tanks, infrared strobe lights flashing at different frequencies are mounted on the top of the target tanks. Figure 2 is a spectrum, it can be seen that the wavelength of visible light is 400~700nm, in order to avoid the interference of visible light, to detect the infrared light source accurately, the 830~880nm infrared band pass filter is selected.

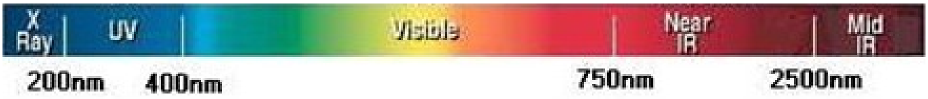

Fig. 2. Spectra

2.2 The Design of ID

The strobe light is flashing cycle in accordance with the encoding, different encoding represents different target tank. If the ordinary encoding is used,then only the circulataion bits of the encoding can be got,but not the real start and stop bits of the encoding. So a special encoding is used in this system, such as B8B7B6…B0, this encoding includes start and data bits, B8B7B6 are start bits, the others are data bits. At each training session, in order to facilitate the identification of the light source, the start bits of the encoding are constant[4]. The following table lists a group of encoding, each coding can be used to identify a tank.

Table 1. Light source encoding table (start bits are 100)

Tank No.	Data Bits	Tank No.	Data Bits	Tank No.	Data Bits	Tank No.	Data Bits
1	000001	10	001110	19	011111	28	111010
2	000010	11	001111	20	101010	29	111011
3	000011	12	010101	21	101011	30	111101
4	000101	13	010110	22	101101	31	111110
5	000110	14	010111	23	101110	32	111111
6	000111	15	011010	24	101111		
7	001010	16	011011	25	110101		
8	001011	17	011101	26	110110		
9	001101	18	011110	27	110111		

3 The Determinatioin of Impact Point

3.1 Image Acquisition

The video camera begins to acquire images when the gunner aims at target tanks; when the gunner prsses the button to fire, the imaginary shells start to fly; stop the acquisition when the shells reach the target (the fly time of shells: dt). A sequence of images $I_1,I_2,\ldots,I_b,\ldots I_e$ are acquired: I_1 represents the first image; I_b represents the image of the firing moment; I_e represents the last image. *dt* can be found from the mapping table, which is according to the target distance D and the kind of shells, from the table the angelφwhich is the elevation angle of the barrel to offset shells whereabouts by gravity during the flight can be got[5].

The sequence of images are passed to the processing unit, the processing unit according to the relative motion state between targets, to determine whether to match images or not. Assume that the sequence of matched images is $I_1,I_2',\ldots,I_b',\ldots,I_e'$. If one's own tank does not move, then there is no need to match, $I_1,I_2,\ldots,I_b,\ldots I_e$, is $I_1,I_2',\ldots,I_b',\ldots,I_e'$; if one's own tank moves while the target tank does not move, then I_e' is I[6].

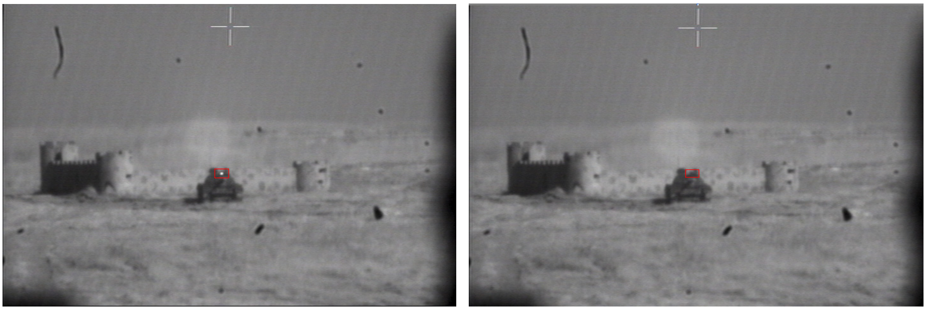

Fig. 3. The comparision images of the strobe light on and off

3.2 The Determinatioin of Impact Point

According to the horizontal angle α,φ, w_a, h_a, w_p and h_p of the video camera in image I_e,$\alpha$is the barrel title sensor measured horizontal angle of the camera, φ is the elevation angle of the barrel to offset shells whereabouts by gravity during the flight, h_p is the height of the image captured by the camera, w_p is the width of the image captured by the camera, h_a and w_a are the corresponding vertical viewing angle and horizontal viewing angle.

Figure 4 is a tank firing schematic, the central position of + is the impact point *(sx,sy)*.

$$sx = cx \pm \sin\alpha \times \frac{wp}{wa} \times \phi . \qquad (1)$$

$$sy = cy \pm \cos\alpha \times \frac{hp}{ha} \times \phi . \qquad (2)$$

There are two camera's installation methods on the tank, on the muzzle or on the barrel. *(cx,cy)* is a coordinate of the shell axis in the image: if the camera is installed on the

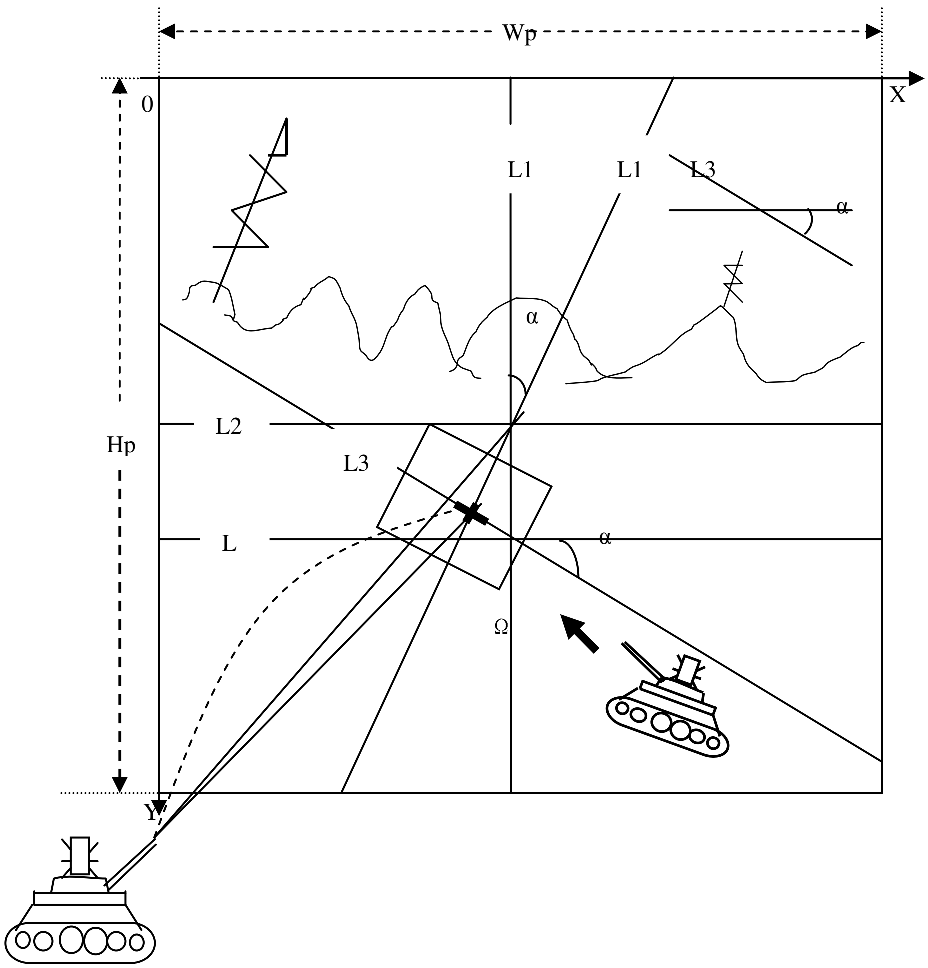

Fig. 4. Tank firing schematic

muzzle, *(cx,cy)* is the coordinate of the center of the image; if the camera is installed on the barrel, *(cx,cy)* is the coordinate that *dy* meters vertically downward shift of the center of the image, *dy* is a known constant. *wp/wa* is the number of columns in each angle of the image, *hp/ha* is the number of rows in each angle of the image. If the camera is titled to the right, the formula takes "+"; if the camera is titled to the left, the formula takes "-". So that (*sx,sy*) which is the coordinate of the impact point of the virtual shell in the image can be calculaite.

From the registration relationship which is obtained in the previous, φ which is the corresponding region of Ω in the image of I_e can be calculated. Set the width is φ_w, the height is φ_h (unit: pixel). Obviously, the coordinate of the impact point of the virtual shell in the region φ is $(\varphi_w/2, \varphi_h/2)$. Assuming that the strobe light pisition is *(Lx,Ly)*, through calculate the distance between *(Lx,Ly)* and $(\varphi_w/2, \varphi_h/2)$ can determined whether the target is hit or not.

According to the type and the distance of the target, by looking for the morphology and database of different targets and different distances, according to the different types and the distances of the dfferent targets, the size and shape of the target in the imageφ can be got, and compared with the imageφ, then the hit parts can be got.

4 Identification of the Target ID

4.1 Image Normalization

Firstly, the images need to be preprocessed: grayscale normalization and contrast normalization. Through the grayscale and contrast normalization can correct the brightness and contrast of the image, eliminate the light changes and sensor photosensitive changes, increase the difference between background and target, stress the target[7].

4.2 Establish the Light Source Model

The grayscale of the target light source is alternating light and dark dramatic changes, but the grayscale of the other background portion in the image is substantial consistent[8].Extract the maximum value (m(x)) and the minimum value (n(x)) of each position in the image simultaneously, the maximum value image and the minimum value image are got.The difference image is calculated: $p(x) = | m(x) - n(x) |$.The light source model is got from the difference image threshold segmentation. The formula as follows :

$$B(x) = \begin{cases} 0 & background \quad (p(x) < T) \\ 1 & foreground \quad otherwise \end{cases} . \tag{3}$$

4.3 Select the Threshold

In order to separate the light source from the background the image needs threshold segmentation. The light source can not be separeted if a fixed global threshold is used to segment the whole image, because the images are got in outdoor, the scene is complex and there are a lot of interference.So adaptive threshold segmentation is used in this system, the formula as follows:

$$T = average + k * \mathrm{var} . \tag{4}$$

T is the segmentation threshold, *average* is the mean value of the image, *var* is the standard deviation of the image , k is the correction factor.

Mean value formula:

$$average = \frac{1}{width * height} \sum_{y=0}^{height-1} \sum_{x=0}^{width-1} f(x, y) . \tag{5}$$

Standard deviation formula :

$$\text{var} = \sqrt{\frac{1}{width * height} \sum_{y=0}^{height-1} \sum_{x=0}^{width-1} \left(f(x,y) - average\right)^2} \tag{6}$$

f(x,y) is the grayscale value of the coordinates *(x,y).*

4.4 Positioning the Strobe Light

The image obtained after the preseding process contains noise[9], the noise does not have a specific size and shape. So through the target has a particular size and shape to determine the position of strobe light[10].

A contour tracking algorithm[11] is used in this system: gray image is scanned from up to bottom, from left to right; if adjacent pixel gray jumps from 0 to 255, means a new outer contour is discovered, track and mark it; adjacent contour points are searched in turn from eight directions, until return to the starting point, and the points connected with the starting point of a contour line have all been tracked, end of the algorithm. A complete outline which can be expressed as chain code is got; the contour perimeter, the target area and the center position can be calculated. As the distance is known, the approximate size of the light source can be calculated, so the target contour perimeter and area of the light source are limited, compare them with the expected size, too large or too small disruptors can be eliminated, then the light source position is determined.

4.5 Identification of the Target ID

The light source coding has nine bits (three start bits and six data bits), the light source cyclical changes according to the coding. When the bit is the start bit, then start coding to get the right nine bits. In the coding, 1 for the light source bright, 0 for the light source out, decoding every light source respectively, algorithm is as follows:

(1) According to the N-bit binary data stream, code on the i th bit is Bi.
(2) Remove the front several bits to avoid the beginning of the image acquisition unstable, resulting in the decoding error. Choose the ninth bit to start decoding, continue to seek the code until meet the coding i which is different with the ninth bit, coding it Bi.
(3) Continue to seek from i, until find a coding j which is different with Bi, calculate the number of binary codes which is same with Bi: Num.
(4) $f(x) = (Num-1) * t1 / t2$ ($t1$ is the exposure time of the video camera is 30ms, $t2$ is every light source coding time occupied is 70ms). By the above formula, m=f(x) can be calculated, ifmm is an integer, n=m; if m is not an integer, n=$\lceil m \rceil$.
(5) Make i=j, repeat (3)(4), until get nine bits codes. Then cycle shift nine coding, move the start bits to the beginning of the coding, then the light source ID is identified.

5 Experiment

Since there are too many experimental images, listed below are several images of two experiments .The first group images are the distance of 1200m, the second group images are the distance of 600m (with smokescreen).

The first group:

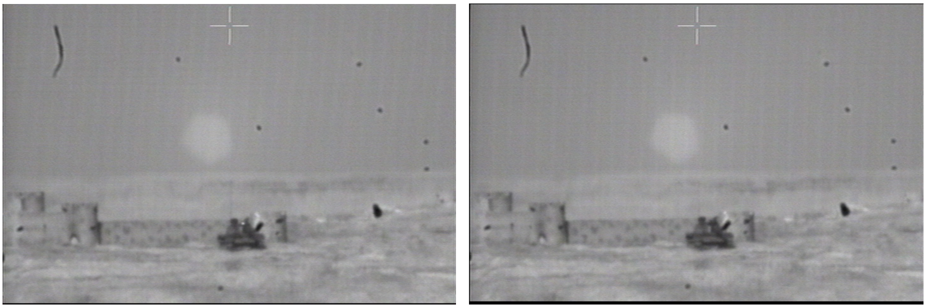

Fig. 5. From left to right : the 10th frame, the 22th frame

The second group:

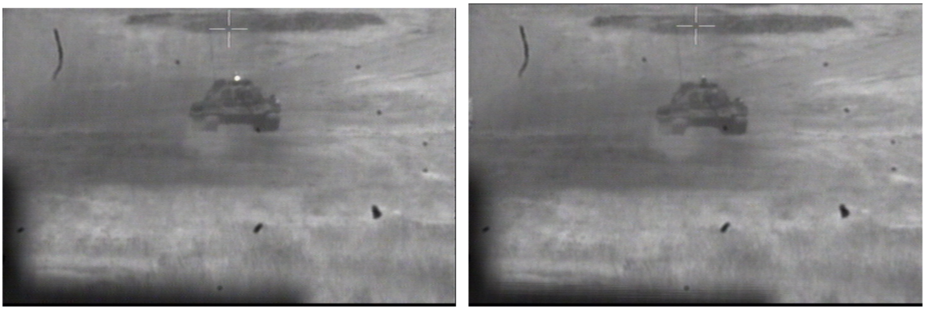

Fig. 6. From left to right : the 15th frame, the 30th frame

Listed below are two key images in the process of the first experiment:

Fig. 7. The target image with noise after threshold segmentation

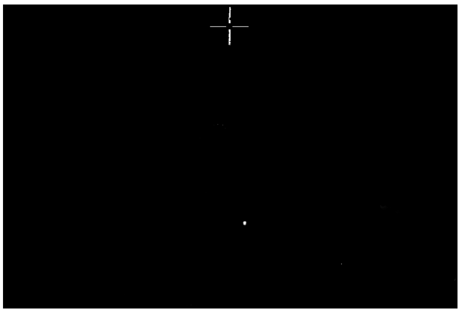

Fig. 8. The target image

50 images are used in this experiment, the full codes got from the experiment are: 1001111111111001110011001111111111001100011001111111, after recognition algorithm shows that the ID number of the target is 010101111.

6 Conclusion

Currently, the most widely used tank training system is simulative laser training system. For some disadvantages of laser training, this paper presents the tank shooting method simulation based on image analysis. This training system is more in line with the flight time of live ammunition, can determinate the ID of target tank more accurately. This training method can improve the level of tank training, improve tactical synergy and coordinate capability of tank training.

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