Automated Navigation System based on Weapon-Target Assignment

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Abstrak

Pengoperasian senapan pada tank masih digerakkan secara manual. Kondisi ini tidak ideal untuk operasi yang berbahaya. Diperlukan sistem pengendali otomatis untuk mengoperasikan senjata dengan tetap mempertahankan ketepatan target sasaran. Pada paper ini telah dirancang suatu sistem pengendalian senjata otomatis berbasis citra digital. Beberapa metode pengolahan citra digital digunakan untuk meningkatkan ketelitian arah senapan sehingga mendapatkan target yang dituju. Metode yang digunakan dalam pengolahan citra digital adalah penjejakan pergerakan Camshift. Metode ini dibandingkan dengan metode penjejakan pergerakan Lucas Canade. Perbandingan ini dilakukan untuk mendapatkan hasil yang lebih presisi diantara kedua metode tersebut. Hasil pengolahan citra digital ini digunakan untuk mengendalikan arah senapan sehingga menuju pada sasaran yang diinginkan. Hasil pengujian penelitian menunjukkan bahwa implementasi penjejakan pergerakan dengan metode Lucas Kanade pada alat simulasi tembak telah berhasil. Kinerja metode penjejakan pergerakan Lucas Canade lebih baik dibandingkan dengan metode Camshift. Penggunaan metode Lucas Canade untuk pengendalian senapan tank lebih baik dan telah memenuhi kebutuhan.

Kata kunci: *Camshift, Lucas Canade, pengolahan citra, penjejakan pergerakan, senapan*

Abstract

Operating of weapon on the tank is mostly by manually. It is not desired performance for a critical operation. An automatic control system is required to operate the weapon with the target while maintaining the accuracy. In this paper has designed an automatic weapon control system using object image proccessing. Various an image processing methods used to improve the weapon accuracy to obtain the intended target. The method used in digital image processing is the Camshift motion tracking method. This method is compared with the Lucas Canade motion tracking method. This comparison is conducted to found more precise results between the two methods. Results of object image processing are used to control the direction of the weapon that towards the desired goal. The results show that the implementation of the Lucas Canade motion tracking method using fire simulation tools have been successful. The performance of the Lucas Canade motion tracking methods is better than the CamShift method. Using Lucas Canade method for weapon controller is accordance with the purposes.

Keywords*: Camshift, image processing, Lucas Canade, motion tracking, weapon*

1. Introduction

The military weapons develop rapidly in several countries. A battle tank is among of combat arms that are often used in the land. In the tank there is a weapon that is essamblied on top. A weapon–target assignment (WTA) problem is to obtain a proper assignment of weapons to targets with the objective of minimizing the expected damage of own-force assets. Control to

the tank weapon was operated manually by humans. One of its advantage is the gun can be moved freely in accordance of the human and its disadvantage is operator saveless.

A previous research on modeling and algorithm of weapon target assignment (WTA) is conducted by Cai [1]. Several methods are used for solving WTA problem. Solving WTA problem by combining of ant colony optimization and the ability to cooperatively explore the search space and to avoid convergence have conducted by [2] and [3]. Wacholder [4] presented a neural network-based optimization algorithm for the static weapon-target assignment problem. A desired weapon profiles can be obtained by applying digital image proccessing for automaticity of the directed weapon. The camera can be used as sensors to identify objects that can replace the role of the humans sensing. The object that was captured by a camera sensor can be processed using image processing techniques [5], [6]. Motion tracking method such as Camshift and Lucas Kanade algorthms can be used for image processing.

Continuously Adaptive Mean Shift (Camshift) algorithm is an advance development of basic algorithm MeanShift performed repeatedly in order to search for a local probability density function (PDF) that approximates the empirical PDF [7]. While Lucas Kanade method is one of the Motion Tracking algorithms that perform searches based on color. The objectives of this paper are designing and implementing automatic rifle activator system in following a moving target using motion tracking with CamShift and Lucas Kanade method. Analyzing the performance of the system in capturing and following a moving target with a variety of objects, object size, speed and distance of objects moving objects on the camera and measure the response time since the determination of the target until the object is locked.

2. Research Method
2.1 Digital Image
Digital image is an image f (x, y) that has spatial coordinates, and the discrete levels of brightness. The image is light which is reflected from an object. The f (x, y) function can be viewed as a function with two elements. The first element is the power source of light that surrounds our view of the object (illumination). The second element is the amount of light reflected by objects into our eyes (reflectance components). Both were written as a function of i (x, y) and r (x, y) which are incorporated as a multiplication function to form the function f (x, y):

$$F(x,y) = i(x,y) * r(x,y) \quad \text{Where } 0 < i(x,y) < \infty \text{ and } 0 < r(x,y) < 1 \tag{1}$$

Digital image is a matrix consisting of rows and columns, where each row and column index pair claimed a point in the image. The value matrix is expressed brightness values that point. The points are referred to as image elements, or pixels (picture elements).

2.2 RGB and HSV color model
RGB color model is a color model based on the concept of a strong increase primary light is Red, Green and Blue. Model HSV shows the color space in the form of three main components, Hue, Saturation and Value. A hue is the angle from 0 to 360 degrees. Usually 0 is red, 60 degrees is yellow, green is 120 degrees, 180 degrees is cyan, 240 degrees is 300 degrees is blue and magenta. A hue indicates the color type (such as red, blue or yellow) or shades of color, where color was found in the color spectrum. Red, yellow and purple (purple) are words that indicate hue. Saturation of a color is a measure of how much the purity of color.

2.3 Lucas Kanade
Optical flow is defined as a visible movement due to the image brightness (dark light image). Suppose I (x, y, t) is the image brightness varies with time as an illustration of a sequence of several images (image sequences). There are two assumptions: Brightness I (x, y, t) depends on x, y coordinates contained in a larger part of the image and brightness of each point of an object moving object does not change with time.

The two most important components of the tracking feature are the accuracy and toughness. Components relate to sub-pixel accuracy locally attached to the tracking accuracy. Intuitively, a small searching window will be better for leveling that is contained in an image. This is especially needed in the calculation areas within the image where two patches are

potentially moving with a speed that is very different. As for the components of resilience or robustness is related to sensitivity of tracking to the respect of any change to the light, the size of the image movement, in particular, in order to handle large movements, the better we choose to use a large integration window. By using optical flow equation for a group of pixels and assume that the pixels have the same speed, it will facilitate the process of computing to solve a linear equation.

2.4 CamShift

Continuously Adaptive Mean Shift (ChamShift) is the advance of Mean Shift algorithm. MeanShift algorithm essentially operates with finding an average (mean) of the function of solid opportunities a distribution of the image in the domain of x, y [8], [9]. For example, we assume a distribution f, Euclidean contains distribution of stage algorithms Mean Shift in Euclidean distribution is as follows: (1). The size of the predefined search window. (2). Initial search window locations that have been determined. (3). Calculate the mean area in the search window. (4). Position the search window to the middle of the mean as calculated in step (3). (5). Repeat step (3) and (4) until convergence (or until a shift in the mean area is less than the threshold/limit specified).

CamShift algorithm is a development of the basic algorithm MeanShift performed repeatedly in order to detect movement of objects from video imagery. MeanShift operates based on the probability distribution of the image. To detect color images on a video, then the color image should be represented in the form of probability distribution image with the help of image histogram. Color distribution of the video is always changing every time, then the algorithm MeanShift must be developed to be used to track objects on every frame.
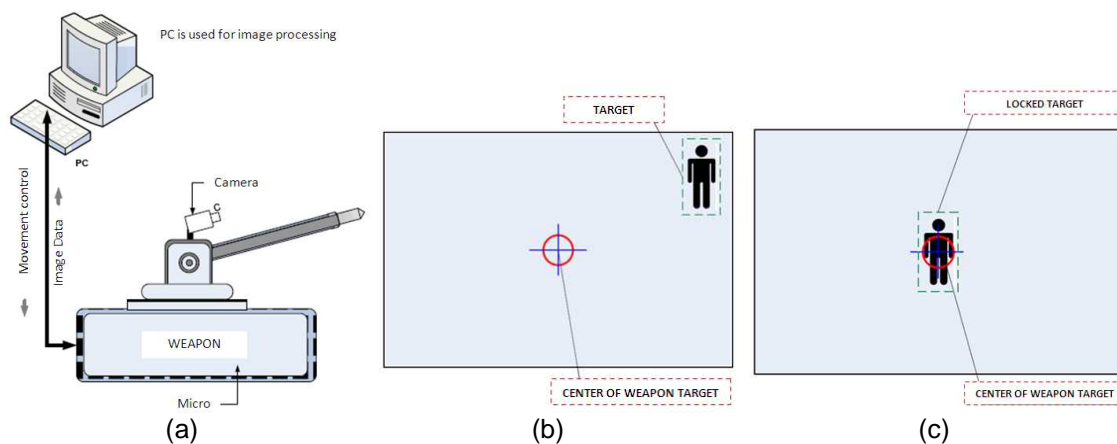

Figure 1. (a) Block Diagram System (b) initialisation of target (c) process to lock the target.

3. Result and Discussion
3.1 System analysis

System requirements consist of two parts, software and hardware. The hardware used to build this application consists of PC: Intel Core 2 Duo T5450, 1.66 GHz, HD 100 GB, 1.5 GB DDR RAM, VGA Card 256 MB, Keyboard and Mouse, Fusil: Logitech QuickCam S5500, Microcontroller ATMega 8535, Motor Driver, Motor DC 12 V. DB25 connector (male, female) data cable and Construction fusil (wooden boards, bearings, axles). Software is used to build application are Operating System Windows XP Home, Microsoft Visual Studio 2008, Intel open source Computer Vision Library.

The system was experimented in this paper is a directional control system based on a target rifle motion captured using a video image as input. The functionality of the system being designed is: Detecting objects as targets. The system can detect objects that have been targeted by the user from images captured by video. The system takes a target coordinates information and color. The system may lock taget by placing the coordinates of the target at the

center of the screen coordinates. From the information obtained from tracking the object, would produce a control that will move the rifle for tracking object is at the specified coordinates.

3.2 System Design
    Overview of functionality and interaction between the user's systems with the system are modeled in a Use Case Diagram. Based on Use Case Diagram on Figure 2. The system has three main action namely: tracking target, setting camera and setting control.
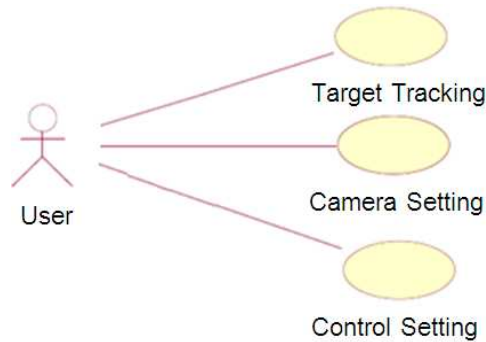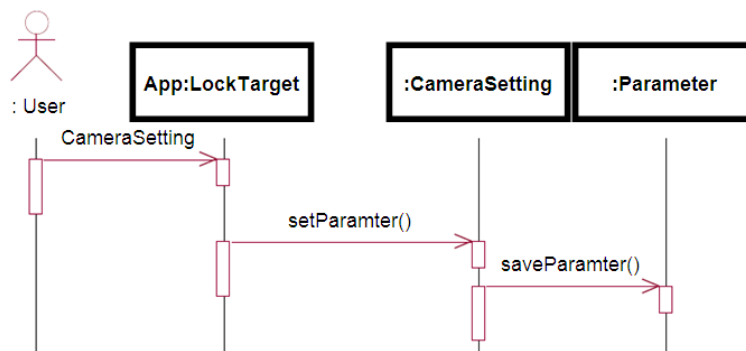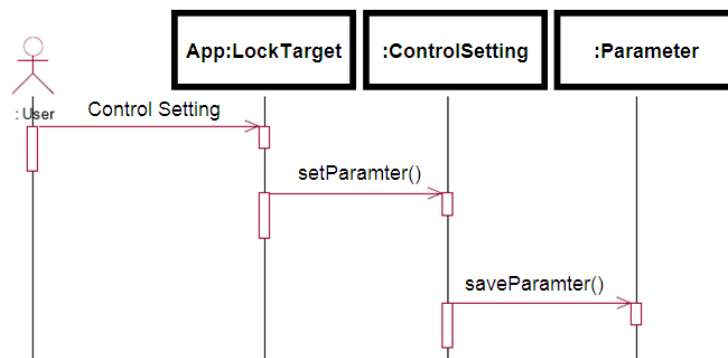

Figure 2. System Using a Case Diagram

    Sequence diagram shows how a process run in the system. Figures 3 and 4 show the sequence diagram of tracking target.

(a)

(b)

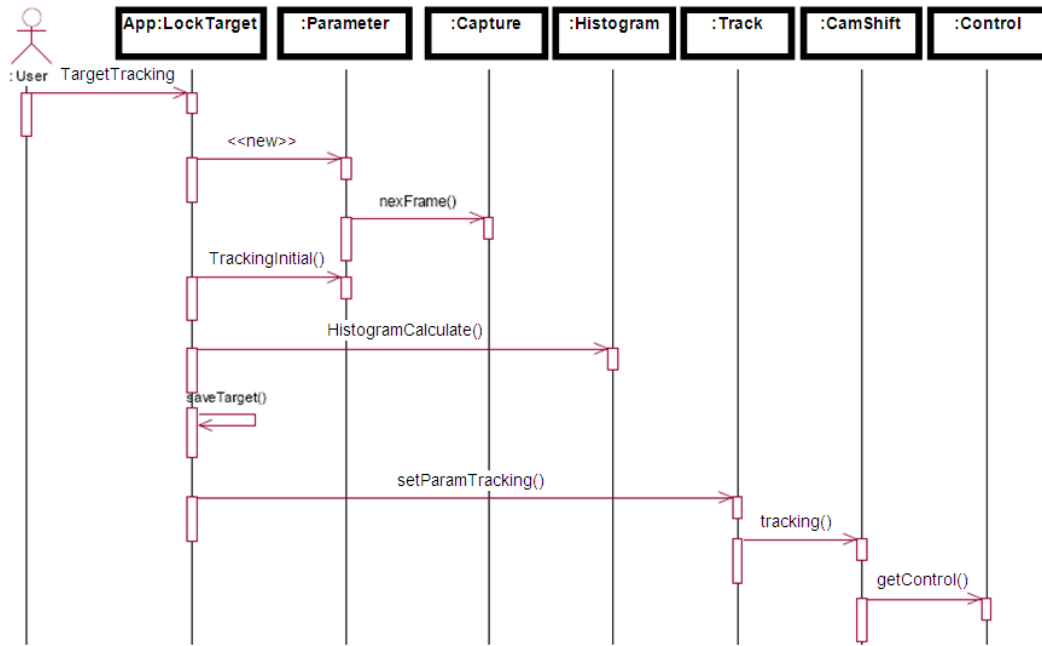Figure 3. Sequence Diagram of (a) Tracking Target and (b) setting control

Figure 4. Sequence Diagram of tacking target

4. Implementation and System Testing

Implementation of the system carried out in two different environments, a PC and a microcontroller-based hardware in the form of fire simulation tool. Input video image is taken from a sensor, camera.

4.1 Experiment scenarios

Scenario I: testing the accuracy and speed of the system in a stationary track objects. Tests carried out repeated 10 times, with variations of objects, distance and location. Tests conducted by putting some paper that has a different color difference to be used as a target.

Scenario II test the accuracy and speed of the system in tracking a moving object (Rifle and objects are both moving). Tests carried out repeated 10 times, with different variations of the object color, speed and direction of movement of the target. By direction of the rotating target, move up, down, right, left and moved irregularly. The variation of speed is done by beginning the movement slowly and then fast and slows again.

Secenario III is used to determine the maximum speed of movement of the target can still be captured by the system. Testing is done by conditioning the camera sensor is at rest, then take the target of repeated with increasing speed. The speed that can't be captured by the system that became the maximum capability in capturing the target system based on its speed.

Table 1. Testing result of Scenario 1 with Lucas Kanade

No	Frame number	Target coordinat				Dist (pxl)	Time(s)	Speed (Frame /sec)
		Init X	Init Y	Curr X	Curr Y			
1	22	80	80	160	121	89.44	3.407	6.46
2	35	46	184	161	115	130.74	4.828	7.25
3	51	258	73	161	118	108.69	7.36	6.93
4	49	249	45	162	120	253.78	4.172	11.74
5	67	8	163	155	115	157.97	4.86	13.79
6	22	176	47	164	118	177.37	1.906	11.54
7	33	272	211	161	121	144.31	4.516	7.31
8	46	58	161	159	123	74.03	7.125	6.46
9	47	294	185	163	122	148.93	5.578	8.43
10	41	220	191	165	120	223.79	2.625	15.62
	413					1509.0	46.377	8.91

4.2. Analysis of Testing Result

The results and test analysis after several testing, the results of the testing system is divided in 3 (three) sekenario is as follows: Table 1 presents the result and test analysis secenario using the speed of motion I motor vertical and horizontal with the speed constant temperatures, i.e. with 5π rad/second.

First test shows the location of the target in pixel coordinates is at the point (80.80) with a distance of 89.44 pixels from the center point of the target. In the first test target can be locked in a time of 3.407 seconds by taking 22 frames.

Otherwise the target end point is locked at the point (x, y pixels) (160.121). Figure 5 shows the target movement towards the center point.

The figure 5 shows the change in the center of the target per unit time. Where X and Y values will change with the movement fusil down then move to the left. Figure of fusil movement towards the target are presented in Figure 5.
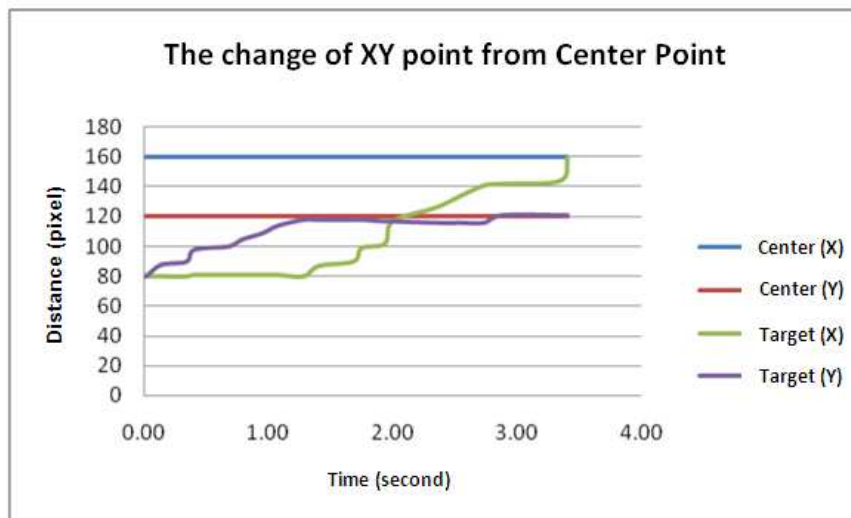
Figure 5. Changes to the xy from center point per unit time.

The testing results of the system in scenario I of stationary targets with movement controls the direction (right, left, up, down) get a better accuracy. Proven at every lock the target on a different location always finds the correct result (the final coordinates of the target is in the tolerance of the center point shot). Test results with two-way control can be shown in Table 2.

Figure 6. The movement in central point target distance per unit of time to target silence.

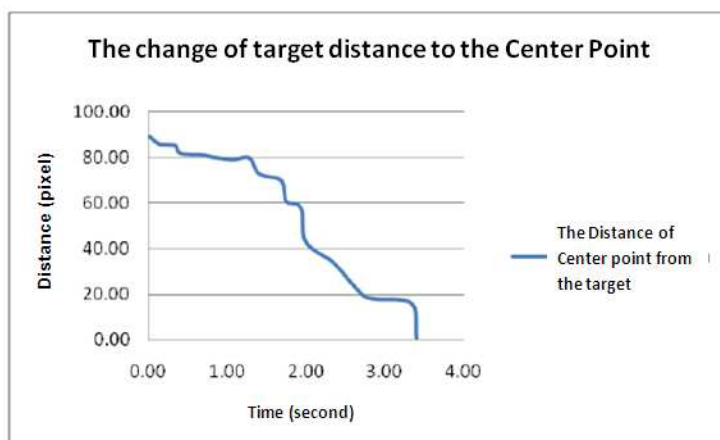On the other hand, the test result the scenario I under control of the direction and control of two-way towards the target in a stationary condition is proven to lock the target well. Control two-way give a more subtle movement of the control using one-way. Change the value of dx (x target - x center) with value change(target y - y center) is not always walk in balance. If the value of dx> dy dy will be faster toward the central y value. This is because vertical movement fusil (y) and horizontal (x) has the same speed, so if dx and dy have different values will result in the achievement of targets against xy xy center requires a different time.

Table 2. Test results Scenario 1 Analysis and control of two-way Lucas Kanade

No	Frame number	Target coordinat				Distance (pxl)	Time (s)	Speed (Frame/sec)
		Init X	Init Y	Curr X	Curr Y			
1	48	305	71	160	118	153.06	3.219	14.91
2	48	24	199	165	124	157.28	3.219	14.91
3	32	236	53	162	118	101.32	2.016	15.87
4	34	17	130	159	118	143.35	2.203	15.43
5	17	100	132	157	125	61.19	1.282	13.26
6	17	183	202	162	120	85.16	1.265	13.44
7	89	288	176	161	124	139.71	5.938	14.99
8	78	50	58	160	116	126.27	5.219	14.95
9	45	279	178	161	116	132.38	2.969	15.16
10	24	56	146	160	119	107.20	1.688	14.22

Table 3. The results of second scenario with Lucas Kanade method

No	Frame Number	Target coordinat				Time (s)	Movement
		Init X	Init Y	Curr X	Curr Y		
1	373	150	152	161	125	27.39	Free moving
2	219	234	84	163	124	16.875	Free moving
3	149	170	190	164	117	10.062	Free moving
4	164	73	110	164	122	10.937	Free moving
5	177	106	124	155	121	11.875	Free moving
6	546	194	46	157	115	37.594	Circular moving
7	143	159	136	162	123	10.391	Up - moving
8	185	169	109	154	115	13.141	Down - moving
9	180	182	133	157	125	13,016	Right - moving
10	142	185	125	161	123	10.078	Left - moving

Test Results and Analysis scenario scenario II Testing conducted on a dynamic target. From the results obtained on the testing there are several conditions at the time of locking the target. Fusil speed used was 5 cm/sec.

In the test scenario II - 1 test results indicate that there is a process lock as much as 18 times in 27.39 seconds, and 18 times in a state tracking. The condition was caused of the movement and speed of the target does not regular to allow the status of the target which is already in locked state and then add a speed that exceeds the velocity of fusil, giving rise to the distance between the center of the target which can change its state to a tracking. Table 3 shows the results of second scenario with lucas kanade method.

In test II - 6, the results are obtained from these tests that the initial velocity (below 5 cm/sec) target can be locked properly, after a speed is more than 5 cm/sec, the target changed to tracking the status of the target. This is due to the limited speed of motion of gunshot tool. Table 4 shows the results of second scenario with Camshift method.

On scenario II found ambiguity in detecting of the target system. It is found when the target has the same color as the color of objects that are on adjacent coordinates. From the data obtained during tracking a target that has a color (R = 182 | G = 169 | B = 180) moving through the objects that have the same color in RGB (R = 182 | G = 169 | B = 180). The system can still find the object that is considered a target by matching the color characteristics.

The color matching system does not make mistakes but the object is locked by the system but not the initial object that have characteristics similar to the target color. This is due to either CamShift or Lucas Kanade algorithm is motion tracking algorithm, which searches based on color. Color equation is the fundamental weakness of this system. Table 5 shows the results of third scenario with Lucas Kanade method.

Table 4. Test results Scenario 2 with the method CamShift

No	Frame number	Target coordinat				Distance (pxl)	Time (s)
		Init X	Init Y	Curr X	Curr Y		
1	298	93	54	160	115	94.05	36.95
2	199	127	159	156	120	51.09	30.22
3	172	163	182	158	122	62.07	12.03
4	127	249	59	160	115	107.90	8.52
5	389	119	70	155	118	64.66	37.16
6	192	155	143	159	119	23.54	12.95
7	202	107	98	161	120	57.38	13.64
8	221	160	126	163	117	6.00	14.70
9	34	103	99	156	116	194.40	2.31
10	18	160	88	165	120	32.00	1.25

Table 5. The results of third scenario with Lucas Kanade method

No	Init x	Init y	Curr x	Curr y	Time	Distance	frame/sec	frame number	pixel/sec
1	28	159	97	155	0.625	69.12	16.00	10.00	4.32
2	62	129	276	129	1.765	214.00	15.30	27.00	13.99
3	74	140	85	141	0.5	11.05	16.00	8.00	0.69
4	80	131	239	126	1.218	159.08	15.60	19.00	10.20
5	71	122	244	88	1.032	176.31	15.50	16.00	11.37

The objective of the third testing scenario is to get the maximum speed limit of moving objects that can still be tracked by the system. Based on the data obtained from the experiment a maximum speed of movement of the system is 11.37 pixels/sec.

5. Conclusion

Based on the anlysis of the result we conclude that Image-based motion tracking controller can be used as a rifle in the direction of motion do locking the target. The velocity gunshot effect the success of locking the target. Fusil velocity with the speed of image processing on the PC must be balanced. Response time specification using by Lucas Kanade method is faster than using CamShift, due to Lucas Kanade feature color take on a pixel so the search window becomes smaller. Locking colors using CamShift and Lucas Kanade algorithm has a weakness, namely when the target is in an environment that has the same color value.

There are many future works: the control system on fusil refined to obtain high precision motion and like using a conservative and intelligent control method and improved image processing capability per frame for the system to capture a more rapid movement.

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