Development of Auto Tracking and Target Locking on Static Defence Based on Machine Vision

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***Abstract*—Auto tracking and target locking are an automated weapon system. The system works by tracking and locking target automatically against targets selected. This system can replace the human role in a defence point. The existing technologies utilize radar and opto-electrical technology. These technologies are vulnerable against jamming and have a high degree of difficulty and the cost of procurement that is expensive.**

This research proposes an automatic system for target tracking and locking based on visual perception using camera. The camera on the system aims to acquire the visual information as image data. With the target reference in image selected by the operator, the image data is processed further to estimate and to track the target position in image representation. The estimated target position is used to generate motion command for the gun platform so that the gun direction aims at and lock the target. Then, the operator can take a decision on whether the target should be shot or ignored.

Results of the experiment conducted in this research are the system is able to track target of the human body within moving or stationary targets chosen by the operator. The difference of gun prototypes does not affect performance of the system. The shooting accuracy has been obtained from the firing test with various distance and the height of the target is approximately 100 percent.

Keywords—tracking system; machine vision

I. INTRODUCTION

In military, the use of human resources to perform tasks that demand high level of accuracy and precision gradually reduced and replaced with a system that can perform independently. Example of things that demand high level of accuracy and precision is the target tracking and locking.

This research does the implementation of automatic tracking and locking the target on a static defence based on machine vision. Machine vision technique is applied to perform visual processing and to provide the position information of the target. Based on visually tracking of target position, the motion control performs a control mechanism to the gun platform so that the target can be tracked and locked automatically. It is hoped that the system can cover the deficiencies that exist in humans to perform similar tasks. It is also intended to prevent unintended casualties or victims and to prevent the occurrence of errors that occur due to limitation of human abilities.

II. THEORETICAL BACKGROUND

A. Machine Vision

Machine vision is a process to extract image information to get important information of an object. The information will be further processed in accordance with desired objectives. In the field of industry, machine vision can be used as replace of traditional sensors. For the example of machine vision application is counting the number of bottles and sorting the bottles using machine vision rather than multiple sensors. By using machine vision that replaces multiple sensors, it would make process more efficient and cost-effective.

In the military field, machine vision can be used to detect the presence of enemies without direct contact of military personnel with the enemies. This can prevent unnecessary casualties on both sides. Machine vision is used for unmanned system that operated at far position from operator or frontline personals that make operator safer from direct contact with the hostile enemy.

B. Target Tracking

The target tracking is a process to estimate and track the position of a target in the sequence of images. Optical flow is a method that commonly use for the target tracking purpose. Optical flow is an estimation of the movement from a part of the image based on the derivative of the light intensity in the sequence of images. In two dimensions space, this mean how far an image pixel switching between two successive images frames, they are present frame and previous frame. Calculation of the derivative is based on changes in light intensities between present frame and previous frame. Changes in light intensity that occurs in the part of image can be caused by the movement made by the object, the movement of the light source or a change in the viewpoints.

The target tracking can be done by using optical flow method formulated by Lukas-Kanade with Lukas-Kanade pyramidal algorithm. At the beginning, this algorithm attempts to find a fast image registration technique by utilizing the spatial gradient intensity.

C. Human Detection

In the process of target selection for static defence application, to know what things are at in front of the camera will greatly help the operator to interact with it. Human detection can be used as one of feature to provide help for the operator. Human detection is a method for detecting presence or absence of human in the image sequence. The human detection can be conducted using Haar-cascade method.

D. Modular Advanced Armed Robotic Systems (MAARS)

MAARS is a powerful combat ready robot which can operate for reconnaissance mission, surveillance mission and target acquisition [1]. The presence of MAARS can make frontline operator in conflict area safer because MAARS can replace operator presence in dangerous area. MAARS can be regarded as one of example of a defence system. The model of MAARS is shown in Fig. 1.

III. SYSTEM DESIGN

In this section, the design of the Static Defence System is discussed. The system's block diagram is shown in Fig. 2. The system consist of Operator, Static Defence Equipment, and Target. The Static Defence Equipment in this system is placed in a static position which means it cannot move from its initial position. The Operator in this system is responsible to select the Target, and then the Static Defence Equipment will track and lock the Target which has been selected by the operator. The straight line in the figure means the process is running continuously and the dotted line in the figure means the process is not running continuously.

The system is placed to defend an area. Emplacement of the Defence Equipment is in static configuration. The main Target of the system is human that possess threat to the area which defended by the system. Because the main target is a human, the Static Defence Equipment has designed with height lying between 80 centimeters to 120 centimeters. The Static Defence Equipment requires an Operator to operate the Static Defence System. When being operated, the Static Defence Equipment will display image captured by camera and show the presence of a human. If the Operator assumes the human possess threat to the defended area, the Operator can do the targeting against

Fig. 1. Modular Advanced Armed Robotic Systems.

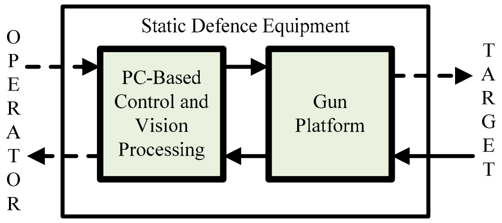

Fig. 2. Block diagram of the Static Defence System.

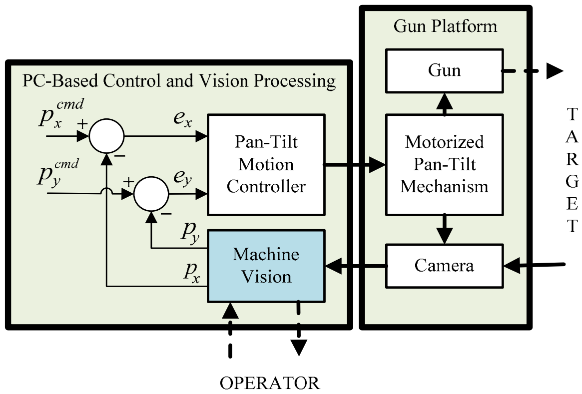

Fig. 3. Block diagram of Static Defence Equipment.

the individual suspected as threat and then the Static Defence Equipment will track and lock the motion of the Target which has been selected. Operator can change the Target with the new one and remove the previous target. If the Target is considered necessary to be shot down, the Operator can give a command to the Static Defence Equipment to shoot the Target. All process ordered by the Operator is done through PC-Based Control and Vision Processing without touching any defence hardware placed on defended area directly. So the Operator is far away from harmful area and located in a safe distance.

A. Static Defence Equipment

The Static Defence Equipment's block diagram is shown in Fig. 3. The Static Defence Equipment consists of the PC-Based Control and Vision Processing, and the Gun Platform. The PC-Based Control and Vision Processing use image from camera placed on Gun Platform as primary vision data to be processed. The Pan-Tilt Motion Controller is used to control the motion of Gun Platform through the Motorized Pan-Tilt Mechanism. The Gun Platform is also equipped with Gun to shoot the Target if necessary.

To achieve the adequate performance for the vision processing, the Machine Vision utilizes image pixel resolution of 640×480 pixels with image frame rates of 25 frames per second. The 640 pixels is designated for x-axis and 480 pixels for y-axis in image frame. The center position in image frame (320,240) is used as command positions (p_x^{cmd},p_y^{cmd}) for locking the target.

Fig. 4. Gun Platform hardware.

The Pan-Tilt Motion Controller utilizes 2 DC motor drivers to control the motion of the Motorized Pan-Tilt Mechanism which uses 2 DC motor to perform motion in pan and tilt direction. The x-axis and y-axis in image frame are used as reference for pan motion and tilt motion, respectively. The pan and tilt motion are determined by the control algorithm with inputs come from the command positions (p_x^{cmd},p_y^{cmd}) and the current positions (p_x,p_y) of Target estimated in Machine Vision. The standard Proportional-Integral-Derivative (PID) control algorithm is applied in the Pan-Tilt Motion Controller.

The hardware of the Gun Platform consists of a camera for image capturing, Personal Computer (PC), driver for DC motor, DC motor for pan-tilt movement, Pulse Width Modulation (PWM) signal generator, data acquisition module, and a gun. The gun types used in the gun platform are gun prototypes of SIG552 and M4 rifle. The gun prototype of SIG552 is made of plastic and its weight around 600 grams depends on ammo inside the prototype. The M4 rifle gun prototype has 1:1 scale, made of steel with the weight around 4 kilograms. The gun prototype of M4 rifle is same as the actual weapon in military. The hardware of the Gun Platform is shown in Fig. 4.

Explanation of the hardware:

1 = Gun prototype (SIG552)

2 = Camera

3 = DC Motor for tilt motion

4 = Proximity sensors

5 = PWM generator circuits

6 = Driver for DC motor

7 = Actuator circuit for gun shooting

8 = Multifunction IO Card (Advantech USB-4711A)

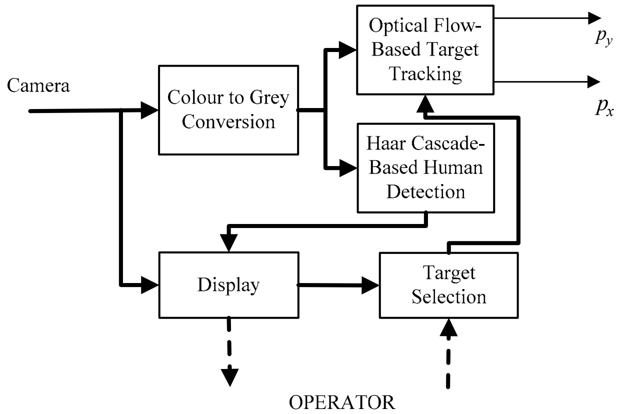

Fig 5. Block diagram of Machine Vision.

B. Machine Vision

The block diagram of the Machine Vision is shown in Fig. 5. Machine Vision's block in the PC-Based Control and Vision Processing utilizes the colour image captured from camera to be processed further. The colour image is displayed to the Operator and it is converted to grey image. The grey image is used as input of the Haar Cascade Based Human Detection to search the presence of human in front of the camera and then displayed to the Operator. Based on image on Display, the Operator can decide the order to select the Target if necessary. When the operator has selected a Target, then the grey image will be processed with optical flow method to track the current positions of Target in image frame. The current positions in x-axis and y-axis are denoted by p_x and p_y, respectively.

IV. System Results

Some of the experiments were conducted to verify the effectiveness of proposed system. The experiments results are explained in detail below.

A. Human Detection

The human detection experiment was conducted to verify whether the Gun Platform could detect human presence on the

Fig. 6. Experiment environment for human detection.

TABLE I. TRACKING PERFORMANCE

Test No	Tracking duration (seconds)	Target's colour
1	9	White
2	12	Blue
3	28	Red
4	40	Blue and black strips

TABLE II. PERFORMANCE OF SIG 552 PROTOTYPE

Test No	Tracking duration (seconds)
1	42
2	61

TABLE III. PERFORMANCE OF M4 RIFLE PROTOTYPE

Test No	Tracking duration (seconds)
1	43
2	48

outcome of the captured image from camera. The experiment conducted by rough search method resulted that the Static Defence System succeeded to detect every human presence in front of it. The experiment performed during the day with adequate light condition. The experiment environment is shown in Fig. 6.

B. *Tracking and Locking on Target*

The experiments of the tracking and locking on target were conducted with two prototypes, SIG552 gun prototype, and M4 rifle prototype. Condition of the experiment was same as shown in Fig. 6.

The first experiment was conducted to know how long the Static Defence System could maintain to track and lock the moving human with different shirt's colour as the Target. The experiment performed by SIG552 gun prototype and the Target was shirt's colour. The speed of the Target was average of walking person, around 3 kilometres per hour. The experiment result is shown in Table I.

The Static Defence System cannot perform well with the target's colour of white and blue because the contrast of target's colour and the background's colour behind the target was not high. The colour of background was dominated by white and blue.

The experiment was also conducted with two different gun prototypes, SIG552 prototype and M4 rifle prototype. In this experiment, the target's colour of black was selected. The purpose of experiment was to verify whether the different prototypes of gun affect the performance of the Static Defence System. The experiment result of two different gun prototypes is shown in Table II and Table III.

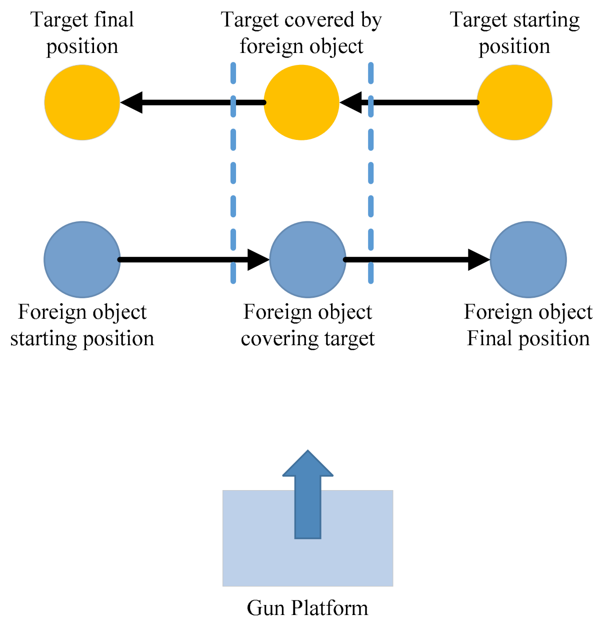

Fig. 7. The foreign object covering the locked target.

The experiment result shown that the difference between gun prototypes did not affect performance of the Static Defence System. The Static Defence System performs well on both of gun prototypes.

Another experiment related to target tracking and locking was the influence of interference from foreign object to the

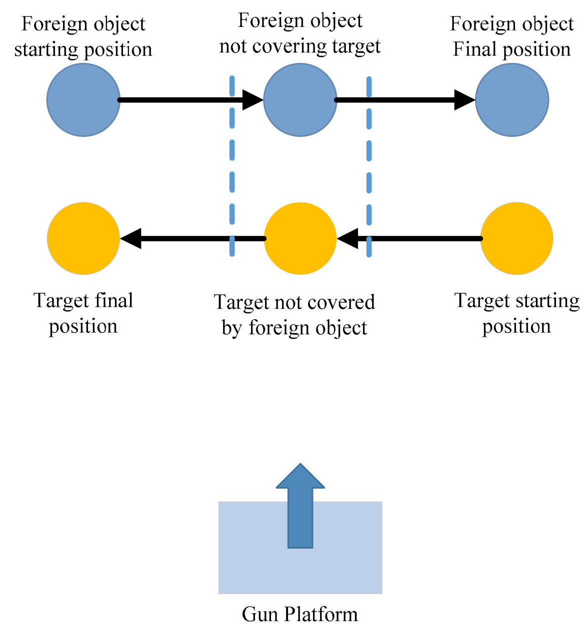

Fig. 8. The locked target covering the foreign object.

locked target. There were two types of interference condition. Firstly, the foreign object moved in front of the moving locked target. Here, the locked target was bypassed by foreign object, which make a condition that the foreign object covering the locked target in the line of sight of Gun Platform. The scenario of the first type of interference condition is described in Fig. 7.

Secondly, the locked target moved in front of the moving foreign object, the interference condition was the opposite of the first one. Here, the foreign object was bypassed by locked target which made the locked target was not covered by foreign object in line of sight of Gun Platform. The scenario of the second type of interference condition is described in Fig. 8. Both of experiments for first and second type of interference condition were conducted in the same place and condition.

The first interference condition shown the Static Defence System was unable to maintain the target locking. It was because the Gun Platform line of sight to the locked target was disturbed by foreign object. The locked target was suddenly covered by foreign object and then the Static Defence System lost the target and was unable to track and lock the target. In the second case where the foreign object moved behind the target, the Static Defence System still maintained to track and lock on the target because the Gun Platform line of sight to the locked target was not disturbed by foreign object.

C. *Gun Shooting*

The gun shooting experiment was conducted to assess the accuracy of the Gun Platform to shoot to the target. The experiment was done by utilize different distance of the target and with the height of the Gun Platform at 120 centimetres. The target was a circle with diameter of 20 centimetres. The target is in accordance with the standard of shooting regulation of ISSF (International Shooting Sport Federation) for shoot a target within 50 yard (45.72 meters) for the pistol weapon. The shoot was calculated as shot on target if the gun platform was able to hit the circle target. The environment of gun shooting experiment is shown in Fig. 9.

The experiment was started with locking the target by the Static Defence System which was the center of the selected target (center of circle). After the Static Defence System was able to lock the target, then the operator gave command to shoot the target. In this case, the Gun Platform (as part of Static Defence System) shot 4 times to the target. The parameters of the target used in this experiment is shown in Table IV, and the result of the gun shooting experiment is shown in Table V.

Fig. 9. The environment of gun shooting experiment

TABLE IV. TARGET PARAMETERS

Test No	Distance of target	Height of target
1	5 meters	120 centimeters
2	3 meters	120 centimeters

TABLE V. PERFORMANCE OF GUN SHOOTING

Test No	Bullet count	Shot on target
1	4	4
2	4	4

The experiment result of gun shooting shown that whether the distance of the target was changed, the performance of the Static Defence System to lock the target and then to shoot on target was still accurate enough. No bullet shot that hit out from the mark used as target.

V. CONCLUSION

Based on experiments results, the performance of the Static Defence System can be described as follow:

- The target's colour affect to the tracking process in image frame. If the colour blends with the background, the Static Defence System is unsuccessful to track and lock the target.
- The accuracy of gun shooting with variation in distance and height of the target is approximately 100 percent.

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