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DESIGN OF OBJECT TRACKING FOR MILITARY ROBOT USING PID CONTROLLER AND COMPUTER VISION

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Abstract. *Control systems and vision-based robot technology have been used in the development of autonomous military robots. A sophisticated military robot should be needed by the military/police because it can be deployed to the battlefield or the eradication of terrorism in a remote or autonomous manner. PID controller is known as a reliable and robust control system for servo motors as an actuator of the gun. In this paper, we propose a prototype of a tank-based military robot with object detection and tracking using PID controller for simulation of shooting the enemy target based on the computer vision. The object tracker has been built for detecting upper body of the target using a library in OpenCV and the tank will track until it reaches the best position to shoot the target. The proposed methods were explained, and experimental results were presented.*
Keywords: Military robot, PID controller, Object tracking, Computer vision, Control systems

1. **Introduction.** The U.S. military inventory now comprises more than 12,000 ground robots and 7,000 UAVs. In addition to the United States, 44 other countries are now pursuing unmanned military systems included in Indonesia. What is happening now is the use of airplanes or armored vehicles: A technology that started out as abnormal and limited in use and acceptance is revolutionizing the tools we use to fight and rapidly becoming an everyday aspect of 21st-century military operations [1].

The Department of Defense (DoD) of the USA is increasingly interested in Artificial Intelligence (AI) for the robot. During a recent trip to Amazon, Google, and other Silicon Valley companies, Secretary of Defense James Mattis remarked that AI has "got to be better integrated by the DoD". What do we mean by the term AI? What does "deep learning" mean? What are the advantages, disadvantages, and risks of using AI? [2]. This condition is the same with the Indonesian government that really wants the implementation of Industry 4.0 in the defense sector by developing military robot.

Robots for military purposes, in general, called an Unmanned Ground Vehicle (UGV) are used to augment the soldier's capability. Many military robots were developed to maintain security and spies in conflict areas or borders based on cameras and firearms and missiles. The study of the military tank robot system has been carried out for example [3,4]. Object tracking in military robot is very important. A research focuses on a real-time system design, which can track (RGB) targets in dynamic environments with an active camera. The design consisting of three main parts that are object detection,

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mapping, tracking the object was proposed by [5]; unfortunately the robustness is still low because it is based on the RGB.

Image segmentation and object detection is an essential task in all applications of computer vision. It addresses the problem of partitioning an image into disjoint regions of interest according to their specific features (gray levels, texture, etc.). The accuracy of image segmentation significantly influences the results of image analysis performed in the following steps [6]. In developing of a military robot, to produce autonomous systems, the system must be able to track targets/recognize objects based on computer vision. Robots are also expected to be able to recognize faces/objects that can be enemies to be conquered. Uncertainty is very common in tracking objects based on vision, so the application of probabilistic robotics in the development of intelligent robots is very important [9].

This research is very important to produce models and methods of tank-based combat robots that can be controlled remotely or autonomously based on computer vision. Our system based on the object detection is more robust using upper body based on computer vision (detection of object not based on RGB). We present introduction in Part I, Part II as a concept of object detector, the proposed method in Part III and experimental results in Part IV then conclusion in Part V. Figure 1 shows the prototype of the robot.

Figure 1. Prototype of a tank-based military robot using computer vision

2. **PID Controller for Object Tracking.** PIDs are typically used in automation such that a mechanical actuator can reach an optimum value (read by the feedback sensor) quickly and accurately. The PID controller calculates an error term (the difference between desired set point and sensor reading) and has a goal of compensating for the error. The PID calculation outputs a value that is used as an input to a "process" (an electromechanical process). There are several prescriptive rules used in PID tuning. The most effective methods generally involve the development of some form of process model, and then choose P, I, and D based on the dynamic model parameters [7]. The sensor output is known as the "process variable" and serves as input to the equation calculated in the time domain t. Throughout the feedback loop, timing is captured, and it is input to the equation as well as shown in Figure 2.

The variable e represents the tracking error, the difference between the desired output $r(t)$ and the actual output $y(t)$. The output loops back into the input. Also notice how

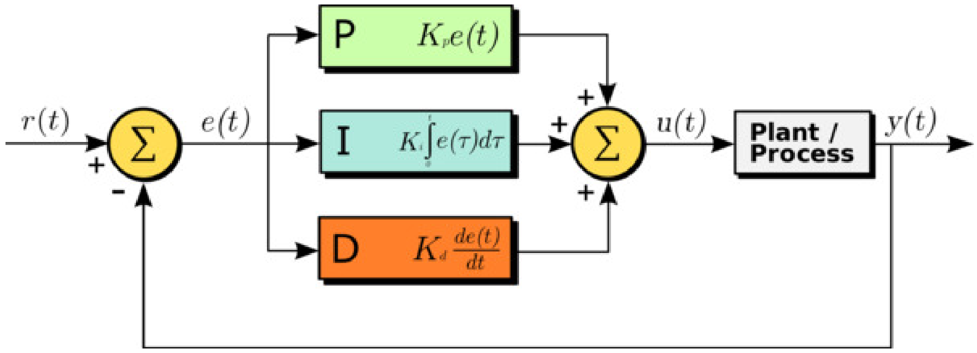

FIGURE 2. A PID controller used in this research

the Proportional, Integral, and Derivative values are each calculated and summed. The figure above can be written in equation form as:

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{de(t)}{dt}$$

where:

P (proportional): If the current error is large, the output will be proportionally large to cause a significant correction.

I (integral): Historical values of the error are integrated over time. Less significant corrections are made to reduce the error. If the error is eliminated, this term will not grow.

D (derivative): This term anticipates the future. In effect, it is a dampening method [8].

Object detection used in this system is based on the Viola-Jones object detection framework; it is the first object detection framework to provide competitive object detection rates in real-time proposed in 2001 by Paul Viola and Michael Jones. Machine learning approach was used for visual object detection which is capable of processing images extremely rapidly and achieving high detection rates [11]. The mean shift algorithm is modified to deal with dynamically changing color probability distributions derived from video frame sequences. For object tracking, we use CAMSHIFT. This method came from "OpenCV Labs" and it is called CAMSHIFT (Continuously Adaptive Meanshift) published by Gary Bradsky in his paper "Computer Vision Face Tracking for Use in a Perceptual User Interface" in 1998 [14]. It also calculates the orientation of the best fitting ellipse to it. Again, it applies the mean-shift with a new scaled search window and previous window location. The process is continued until the required accuracy is met. For face tracking, CAMSHIFT tracks the X, Y, and Area of the flesh color probability distribution representing a face. Area is proportional to Z, the distance from the camera [14].

3. **Proposed Method.** Many methods have been proposed by scientists for controlling the motor for tracking an object in computer vision. A digital controller utilizing the preview information of the desired trajectory has been proposed by [15]. In this study, we propose an autonomous tank-based military robot model that wants to be developed as shown in Figure 3, where firearms will be used to be able to shoot targets in long distances. This robot model can also be controlled remotely (teleoperated).

The author has conducted prior research for object tracking using a method of color-based object detection and Kalman filters that are adequate for tracking objects and develop a tank-based military robot using Arduino controller [13]. Programming a robot with a good algorithm and supported by artificial intelligence is an important aspect today [9]. The camera system on the robot will be used in this research to obtain the

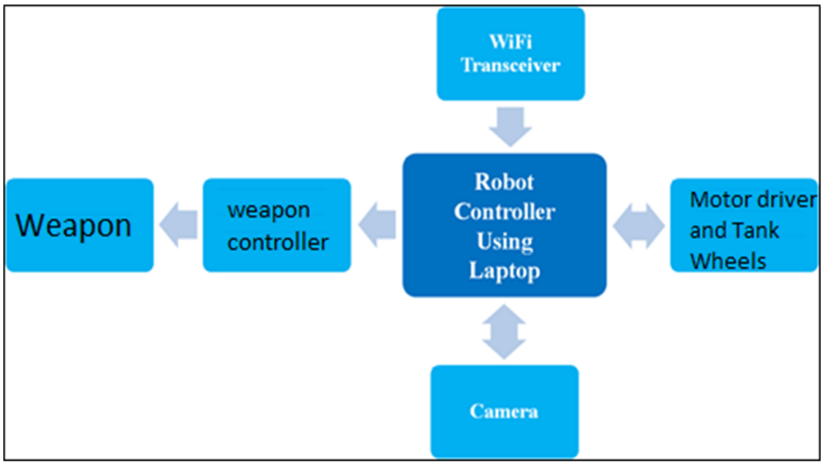

Figure 3. The architecture of tank-based military robot

visual of a target. We use high voltage 24 V and current 5 A in order that the DC motor and drivers of the tank are able to move with enough power [12]. Wi-Fi transceiver will be used in the future for controlling the robot using 2.4 GHz technology for long distance. We use a relay to activate the weapon. A single camera was connected to the laptop for processing video streaming.

The servo motor is used for controlling weapon using PID. We develop a program based on Python and OpenCV for tracking an object and controlling the robot and weapon for tracking an enemy. We use USB port from controller to weapon controller using Arduino. First, program will detect a target using object detection method then if detected then robot will move forward to the target. The algorithm of object detection and tracking is shown in Algorithm 1.

Algorithm 1. Object tracking and PID controller for military robot

```
Declare variables
Begin
 Pid = PID (K_p = 1.0, K_i = 0.1, K_d = 0.05, setpoint = 1, sample_time = 0.01)
 # we have a system in controlled_system
 v = controlled_system.update(0)
  Detect a target
      If not detected, then
             Robot scanning to right and left
      Else
    # compute new output from the PID
    control = pid (v)
    # feed the PID output to the system and
    # get its current value
    v = controlled_system.update (control)
          move forward to target
          Robot stop and shoot the target
           If the target still detected, then
                   Shoot target again
           End If
           Else
                  Stop shoot
                  Move backward
      End If
```

4. **Experimental Results.** We developed a program for computer vision using a laptop, OpenCV and Python, and the controller of the tank using Arduino. The experimental result is shown in Figure 4.

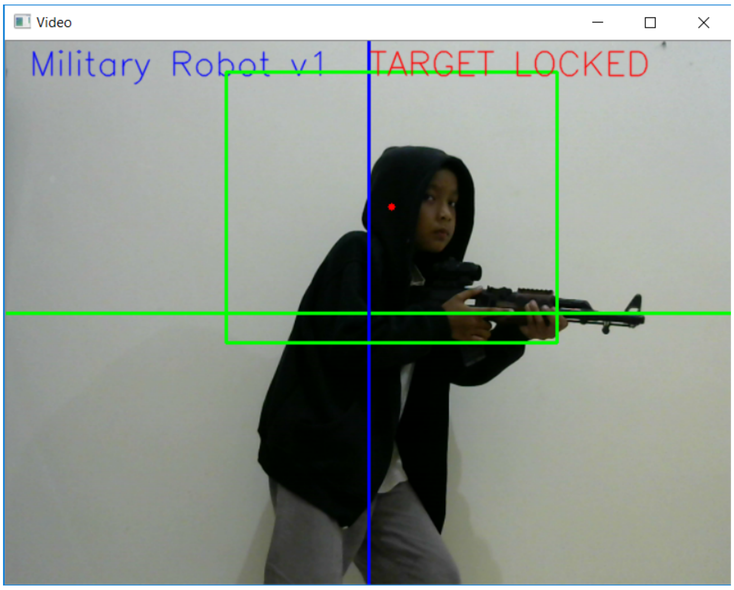

FIGURE 4. Results of the application using OpenCV

Based on the simulation, we got a better result in body detection rather than face detection. This is because the library in OpenCV easily detects the upper body of people rather than the face (if not frontal face). In previous work, we have developed a system for face detection using Haar cascade classifier and depth estimation for measuring distance of peoples as moving obstacles using stereo vision. The camera used is a Minoru 3D stereo camera, but it has limitation that it is only able to measure maximum distance of obstacle about 4 meters [10]. The weakness of the system is that they cannot track the moving objects that move very fast as shown in Table 1.

TABLE 1. Experimental results for object detecton and tracker

No	**Results from 10 times simulation**		
	Action	***Success***	***Not success***
1	Body detection	9	1
2	Face detection	8	2
3	Tracking moving object	7	3

5. **Conclusions.** In this paper, we propose a model of a military robot using computer vision with a focus on object tracking using PID controller where the servo that handles the gun is able to pan left or right. The ability of computer vision for detecting of the upper body as a target is enough good. A military robot is an important tool for combat. Combat robots will rapidly become an inherent part of our fighting forces within the next 10-15 years. Future warfare will involve operators and machines, not soldiers shooting at each other on the battlefield. For future work, we will propose a method for shooting a target with more precision and accuracy and using wireless technology.

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