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# Pan and Tilt Camera Object Tracking Using Ziegler-Nichols Method for Control PID

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**Abstract−** Cameras are widely used in video surveillance in observing and monitoring various conditions. The purpose are monitored, primarily for surveillance, security, and object tracking. Plant Pan and Tilt is part of changing the rotation of the horizontal and vertical axis of the camera to move to follow the object or as needed. Pan and Tilt movement control is carried out with three types of settings, namely (PID) proportional, integral, and derivative. To work properly, certain parameters, called constants, must be set in each case. Each parameter type has its own strengths and weaknesses. This research uses a technique that can be used for control, the closed-loop Ziegler-Nichols. The method is a heuristic method used in disturbance rejection. The control is carried out using Arduino as the actuator control command and python as the command on the camera with serial communication. The ziegler-nichols method is used as a way to set the PID close-loop. The Plant Pan and Tilt tracks the ball using a camera connected to a computer as a sensor, and a servo connected to an Arduino as an actuator. The results obtained by horizontal rotation get a value proportional 0.24, integral 1.371, and derivative 0.0105. vertical value rotation get proportional 0.21, integral 1.2, and derivative 0.0092.

**Keywords**: Plant Pan And Tilt, Camera, Proportional, Integral, Derivative, Ziegler-Nichols Method

## 1. INTRODUCTION

In recent years, cameras have been installed in various systems such as surveillance systems, security systems, mobile phones, and tablet computers, and the number of such systems is increasing rapidly. Image classification and recognition systems based on deep learning require large amounts of image data to improve prediction accuracy. Although the resolution and dynamic range of cameras continue to improve, the pan and tilt function that rotates simultaneously the cameras optical axis horizontally and vertically are still realized using mechanical worktable parts such as servo motors. It is used for mounting and fixing the camera equipment, and as a connecting device between the camera equipment and the supporting object, it has balancing and stabilizing functions.

(PID) propotional, integral, and derivative controller is one type of controller that is widely used and this system is easily combined with other control methods. Each PID parameter has certain properties, called constants, that must be set for proper operation. Each type has its own strengths and weaknesses. Object tracking is one of the expert system functions performed through image analysis[1], [2]. PID controllers are widely used in industrial processes with a variety of implementations, including standalone controllers and distributed control systems[3], [4]. For many controllers, most researchers use PID controllers as a powerful computational method, such as the Ziegler and Nichols method, the most widely used PID tuning method. These frameworks use a combination of computer vision algorithms such as image stitching, object recognition, and feature tracking with active control of Pan and tilt cameras. Principles of camera geometry to achieve expected performance. Pan-tilt-zoom camera to locate, track and identify objects of interest on construction sites. This automatic camera control system uses several image and video processing algorithms to detect objects and estimate their trajectory and speed, and then uses the extracted information to set parameters. camera movement, including direction and magnitude [5], [6].

In general, video surveillance system architecture starts with moving object detection. Now for tracking these objects along the sequence. This requires a pairing between the detected object in each image and the previously detected object. Object tracking is an application in which a program recognizes objects and tracks their movements in space or from different camera angles. Object tracking allows you to identify and track multiple objects in an image. Data obtained during the tracking phase can be used to analyze object behavior and extract advanced information. In motion conditions, in detecting the changing object, it is driven by an actuator that can change the vertical and horizontal directions of the camera. the movement is set with PID control in motion changes to produce a stable object movement value. The value is set with a method that can balance against disturbances that occur both from internal and external. In this paper, consider a self-tuning PID technique to obtain highly optimized gain values (Kp, Ki, and Kd). This gain value is determined during the process and additionally the system can update some parameters required for PID tuning. Experimental results show that the proposed self-tuning PID method not only achieves the desired output object tracking with minimal error, but is also more robust.




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# 2. METHODOLOGY

## 2.1 LITERATURE REVIEW

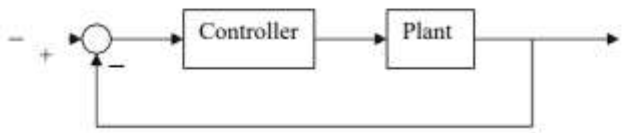
The method search was conducted using the Chinese National Knowledge Base (CNKI) academic information "pan, tilt, zoom" as keywords, and a document search rule model was adopted to combine and organize the search results, and 1,072 samples of Chinese academic documents were obtained [7]. One of system Pan and Tilt implementations is Object detection. It is one of the most important applications in surveillance systems. System design requires a model that is used in the compensator design process. Black-box modeling techniques are an empirical approach to obtaining input-output data from open-loop system responses while allowing mathematical models of the plant to be obtained without resorting to the laws of physics [8]. Some of researchs for implementation in robotic is widely use. Comparative control is a rapidly evolving field in robotics in the sense that it enables interaction between humans and manipulators. The main idea of cooperative control is to facilitate some tasks by combining human skills and robot characteristics for specific tasks [9]. Perspective Projection Augment Platform a fixed camera is used in combination with a motorized pan-tilt projector camera unit. Servo control of the steerable pan-tilt system allows continuous adjustment of the system to center the user's field of view on the projection surface [10].

The research for anomalies objectin video sequence by pan and tilt zoom camera specific scene pedestrian on a highway [11], [12]. The robotics implementation pan and tilt since existing inspection robot products cannot meet the needs of field inspection work, in order to better improve the working effect of substation intelligent indoor inspection robot, a flexible pan-tilt control method for substation intelligent indoor inspection robot is proposed [13].

## 2.2 PID CONTROL

PID controller is a widely used type of controller. Moreover, the system can be easily combined with other control methods such as fuzzy control and robust control. For a better regulatory system. This reserch is limited to systems with the Unity feedback system. Picture 1 System using for control feedback loop to manage every single condition input and output. The PID Controller actually consists of 3 types of combined control methods, namely P (Proportional). Controller, D (Derivative) Controller, and I (Integral) Controller. Each has certain parameters that must be set to operate properly, which are referred to as constants PID Controller response to constant changes follow in table 1. Constant changes will affect changes in other parameters.

These parameters are not independent, so the system may not respond as expected if one of the constant values changes. The table above is just a guide if you plan to make changes on a regular basis. Trial and error are commonly used to design PID controllers. Designers should therefore experiment with combinations of controls and their constants to obtain the best and simplest results [14]–[16]. The conditions change the input signal then can see how the system will respond when given a particular input signal. Different combinations of input signals and types of control actions produce different reactions. if the three parameters are combined optimally it will produce a good output response. The PID has an input in the form of an error signal "e(t)" and the controller output is a control signal "u(t)" . The relationship between the input and output of the PID controller is on (1).




**Picture. 1.** Diagram block for unity feedback system

**Table 1.** Response PID Controller

| Closed-Loop Response | Rise Time | Overshoot | Settling Time | SS Error |
|---|---|---|---|---|
| Kp | Decrease | Increase | Small change | Decrease |
| Ki | Decrease | Increase | Increase | Eliminate |
| Kd | Small change | Decrease | Decrease | Small change |



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$$u(t) = \mathrm{Kp}\left(e(t) + \frac{1}{\tau_i}\int_0^t e(t)dt + \tau_d\,\frac{de(t)}{dt}\right) \quad (1)$$

$$U(s) = \mathrm{Kp}\left(1 + \frac{1}{\tau_i s} + \tau_d s\right)E(s) \quad (2)$$

$$\frac{U(s)}{E\ (s)} = \mathrm{Kp}\left(1 + \frac{1}{\tau_i s} + \tau_d s\right) \quad (3)$$

In equation (2), Kp is proportional gain and τ_i is integral time and τ_d is differential time. The values of these three parameters can be determined. So, the PID controller transfer function is shown by equation (3). The proportional Kp controller type will have the effect of reducing the rise-time value but not eliminating the steady-state error value. Integral control $Ki$ will have the effect of eliminating the steady state error but reducing the transient response. Meanwhile, the derivative controller $Kd$ will have an effect on increasing system stability and reducing the overshoot value. Conventional controllers such as PID are commonly used because they have good performance in controlling linear systems.

### 2.3 CLOSED-LOOP ZIEGLER-NICHOLS METHOD

The Ziegler-Nichols law is a heuristic PID tuning rule that attempts to produce appropriate values for the three PID gain parameters Kp - the controller path gain, Ti - the controller's integrator time constant, and Td - the controller's derivative time constant, given two measured feedback loop parameters derived from the measured parameters Tu, Ku. The period Tu of the oscillation frequency at the stability limit, and the gain margin Ku for loop stability for good control (interference suppression). Tabel 2 shown P, I, and D gains depending on the type of controller used and behaviour desired.

**Table 2.** Ziegler-Nichols Method

| Control type | Kp | Ti | Td | Ki | Kd |
|---|---|---|---|---|---|
| **P** | 0.5 Ku | - | - | - | - |
| **PI** | 0.45Ku | 0.83Tu | - | 0.54Ku/Tu | - |
| **PD** | 0.8 Ku | - | 0.125 Tu | - | 0.10 KuTu |
| **Classic PID** | 0.6 Ku | 0.5 Tu | 0.125 Tu | 1.2 Ku/Tu | 0.075 KuTu |
| **Pessen Integral Rule** | 0.7 Ku | 0.4 Tu | 0.15 Tu | 1.75 Ku/Tu | 0.105 KuTu |
| **Some overshoot** | 0.33 Ku | 0.50 Tu | 0.33 Tu | 0.66 Ku/Tu | 0.11 KuTu |
| **No overshoot** | 0.20 Ku | 0.50 Tu | 0.33 Tu | 0.40 Ku/Tu | 0.066 KuTu |

The values proposed by this method try to achieve in the feedback system a step response with a maximum overshoot of 25%, which is a value Robust with good speed and stability characteristics for most systems. This method is used with the stages of tuning the PID, namely setting the value parameters kp, ki, and kd to zero, then increasing the kp value gradually until it produces an oscillating output when disturbance is given like picture 2 signal show.

### 2.4 OBJECT TRACKING PAN AND TILT CAMERA

This experiment was carried out using a MG966 servo motor on the vertical axis and horizontal axis. The 3d printer casis is used as a frame form of the servo and camera which will be connected to the microcontroller. The camera used is the Logitech C270 HD Webcam for detection object. Meanwhile, the motion regulator is controlled



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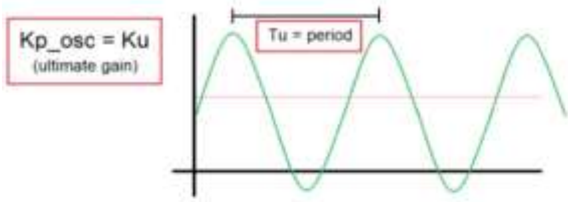
using Arduino Uno. wiring diagram on arduino for vertical servo data pin connected to pin 10 pulse width modulation (PWM), Ground pin to GND pin, and source pin to VCC pin. As for the horizontal servo, the data pin is connected to pin 9 (PWM), the ground pin to the GND pin, and the source pin to the VCC pin. Then connect the camera with the computer used. The PWM provided by the Arduino PIN will be processed in order to be set using serial communication on the computer and the setting command will be embedded in Arduino to be able to balance changes in servo motion in vertical and horizontal orientations.




**Picture. 2.** Ziegler-Nichols Mtehod Tunning PID

**Picture. 3.** Pan and Tilt Construction

## 3. RESULTS AND DISCUSSION

The camera communicates via serial with motion changes made by the actuator servo. The condition of setting the PID on arduino with a horizontal servo Kp_x = 0.24, Ki_x = 1.371, Kd_x = 0.0105, then on the vertical servo Kp_y = 0.21, Ki_y = 1.2, Kd_y = 0.0092, float Ts = 0.033. The settings that have been determined, changes are made with python code to make the trackbarsk min and max settings for image conditions. Displays the original image to see the results of changes in motion with the centeroid value of an object that is set. Displays the threshold in generating the value of the object to be detected as the main object. Picture 4 define the program with a different value or parameter and experiment to find the optimal value to determine the best parameter value. Parameter get value from v1_min, v2_min, v3_min, v1_max, v2_max, v3_max = get_trackbar_values (range_filter). Then calculate value use cv2.getTrackbarPos (‘r’,’controls’) to assign current trackbar position value to radius variable. Picture 5 shown how the position of the image with a certain area can be found the midpoint of the image. conditions for changing centroid data if there is a change in the contour of the object to be detected. This centroid will change the actuator motion where the servo on the vertical and horizontal sides changes when the object moves. Next in picture 5 shown as countour threshold each image object in the area of the camera that has obtained the centroid can be seen which color difference is based on the optimized color trackbar. when there is no object then the contour is not visible for analysis from an image.

In picture 7, 8, and 9 the ball object is given to the image by setting the v1 min parameter so that it can be seen in picture 7 the trackbar is set to increase even though in picture 8 the centroid has not detected the ball object yet, in picture 9 the threshold of the ball object has started to have a color change contour. The contour detected hand and the object ball not clear in monetize. Changes in objects can be seen from the gradation at the threshold which will limit the change in value of the RGB color contour. In picture 8 the color contour threshold of the hand visible when there is a change in v1_min. So that the centroid does not get the focus of the object to be detected. Centroid position worked in condition frame of picture and find object to get midpoint.



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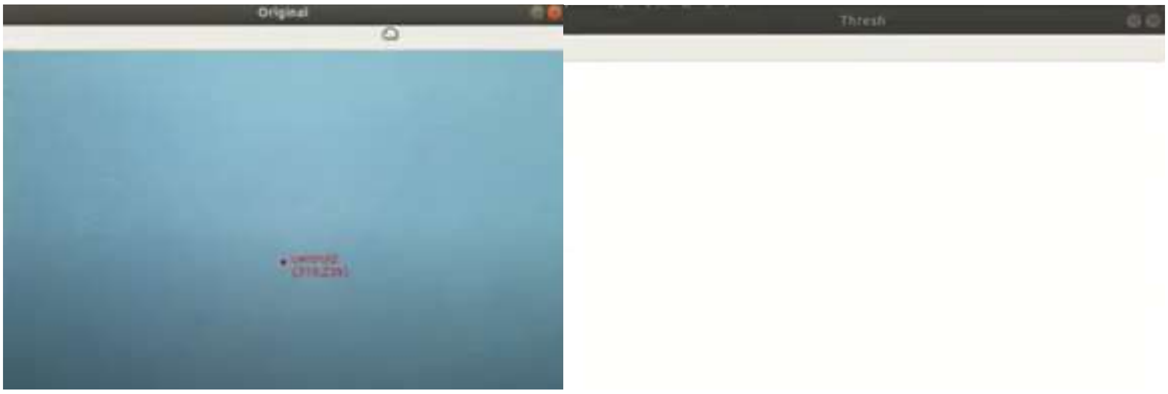
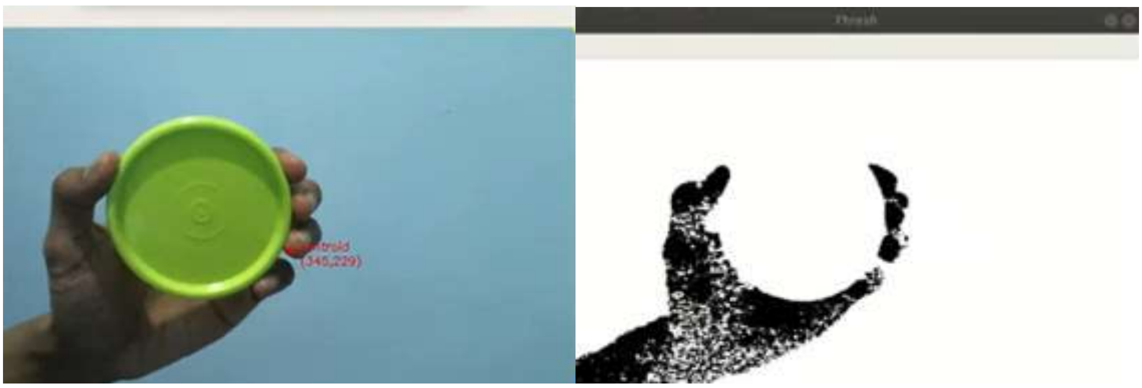
**Picture. 4.** Trackbars




**Picture. 5.** Original Picture for Centroid Position and Threshold object countour


Picture. 7. Trackbar setting



Picture. 8. Centroid Object Ball and Threshold Object Ball

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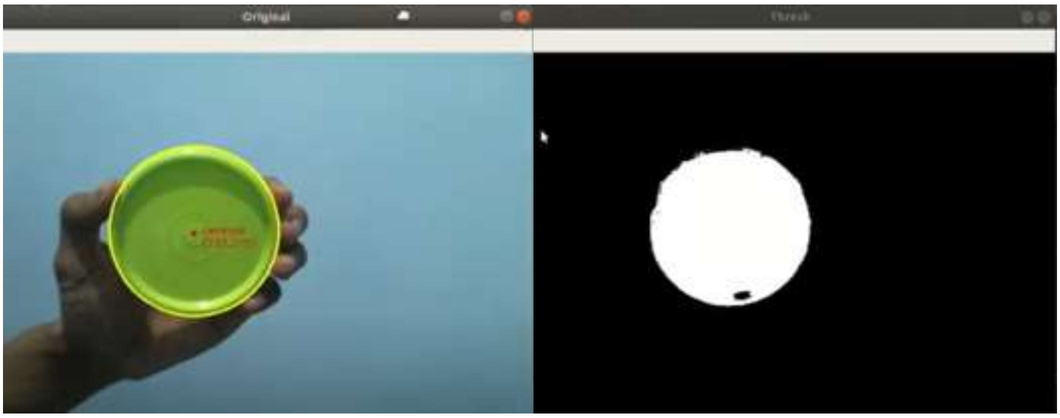
In picture 10 and 11 v1_min, v2_min, v3_min, v1_max, v2_max, v3_max set up in trackbar for better result object detection. By the fault range traceback from 0 to 255 using RGB parameter set up. The value every single point are v1_min in 31, v2_min in 135, v3_min in 97, v1_max in 71, v2_max in 222, v3_max in 255. The object can be detected object circle and find centroid of ball. The contour threshold can be seen as a detailed color change scale of the detected parameter object. centroid finds the midpoint of the ball which will be followed by the servo through the image area on the camera. Find contours in the mask and initialize the current (x, y) center of the ball. Two concept for find the object only proceed if at least one contour was found and only proceed if the radius meets a minimum size. In picture 13, 14, 15, 16 shown the condition of motor servo moving follow direction of object ball. In picture 13 and 14 changes in the movement of the servo when a ball object is directed downwards. In picture 14 changes in the movement of the servo when a ball object is directed leftwards. In picture 16 changes in the movement of the servo when a ball object is zoom in. Then in picture 17 changes in the movement of the servo when a ball object is zoom out. This condition explains that there is a change in the servo motion following the centroid point of the object that has been detected stably. These changes follow from the PID control that has been set with a nominal setting following the Ziegler Nichols method.


**Picture. 10**. Trackbar setting



**Picture. 11.** Centroid Object Ball and Threshold Object Ball



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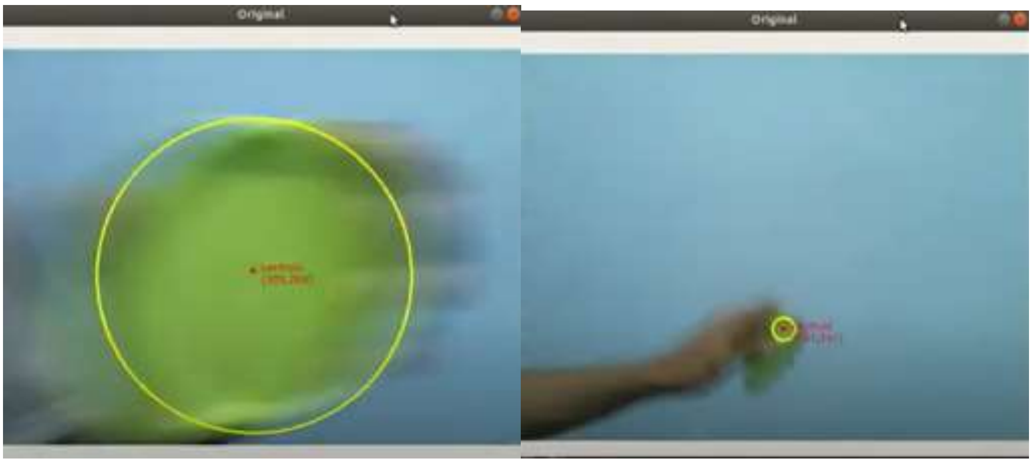
**Picture. 13.** Moving Object Ball Down Side


**Picture. 14.** Moving Object Ball Down Side and Moving Object Ball Left Side




**Picture. 16.** Moving Object Ball Zoom In and Moving Object Ball Zoom Out



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# 4. CONCLUSSION

Identifying PID tuning using the Ziegler Nichols method provides an overview of obtaining the best results in the process of detecting objects on Pan and Tilt camera motion. Best result for setting parameter setting the PID on horizontal servo Kp_x = 0.24, Ki_x = 1.371, Kd_x = 0.0105, then on the vertical servo Kp_y = 0.21, Ki_y = 1.2, Kd_y = 0.0092, float Ts = 0.033. This parameter will set the changes that are given when an object is detected. The change process is carried out by a traceback parameter which will make the parameter value used to find the object specified with the object contour parameter. Detection objects are described through parameter settings, namely values that do threshold settings from v1_min, v2_min, v3_min, v1_max, v2_max, v3_max range filter. This filter will determine the desired threshold to reach the centroid point of the detected object.

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