# UTILIZING CAMERA SENSOR ON ANDROID SMARTPHONE INTO OBJECT FOLLOWER ROBOT

Muhammad Resna Rizki Pratama[1], Galih Hermawan[2]

[1,2] Teknik Informatika – Universitas Komputer Indonesia
Jl. Dipatiukur 112-114 Bandung
E-mail : resnarizki29@gmail.com[1], galih.hermawan@yahoo.com[2]

## ABSTRACT

*Nowadays, every manufactured smartphone can't be separated with a sensor named camera. The camera on the smartphone have the main function is to take a picture and record a video which can capture every moment of life into smartphone's storage memory. In addition to capturing photos or record a video, the camera on the smartphone have another ability to be used in other cases such as Augmented Reality, games, or controlling a robot.*

*The objective of this research is to try to take advantage of the camera on the Android smartphone as motion control for a robot which will be built with DFRobot microcontroller. The detection method that will be used in this research is Canny Edge Detection and Contour Extraction. Data obtained from the results of detection then will be calculated by PID controller algorithm. PID Controller is applied as a DC motor speed controller and steering wheel robot motion controller. Then finally after doing some calculation will get the value of speed and rotation direction for each DC motor on left and right side of the robot which will be sent to the microcontroller via Bluetooth.*

*Based on the results of tests performed, the robot can follow objects with a success percentage of 77%.*

*Keywords: Robot, Camera, Smartphone, Android, Microcontroller, Image, Control, PID, Canny, Contour*.

## 1. INTRODUCTION

Based on history, technology has been rapidly developed. Many of the technology creation have already become a supporting tool for helping human task and activities. Like smartphones and sophisticated robots which everyday support our productivity. A robot is now able to do some of the heavy works that human can't do them in a short time. Some examples of robots like Mobile Robot, Industrial Robot, Humanoid, and Competition Hobby Robot, etc. The function of the robot created even more diverse ranging from aiding the process of production of products, military, personal assistant, a game, or for the purposes of competition.

The sophistication of the robot can not be separated from several components that support each other. From some of these components are one of the senses of the robot, that is the sensor. There are many kinds of sensor that can easily found in the market. For a robot's vision, can use the camera. One of the basic information that can be obtained in the form of the value of Red - Green - Blue (RGB) of each dots to build the image. The information then can be further processed in order to obtain more information. At a later stage, can do the color filtering process, object detection, or using other detection methods to obtain the information from these images.

In research conducted by Ratnasari Nur Budi Laksono Rohmah and Prianggodo [1], applying the object detection system for moving the mobile robot. Using the Raspberry PI camera module to capture the image and then the image will be processed by the Raspberry PI board. The method used to detect the circle-shaped object contained in the captured image is Circle Hough Transform and HSV color filtering. Then, from the detection result, Raspberry PI sends command signals to the DC motor to move the robot.

In this research will use the camera found on Android smartphone. Object detection process will also be performed by the applications that run on Android smartphones. In addition, there is also a DFRobot board is used to control DC motors. Data communication between Android smartphones and board DFRobot Romeo BLE will be transmitted via Bluetooth 4.0. The object detection method that will be used in this research is the Canny Edge Detection and Contour Extraction. So this thesis entitled " **UTILIZING CAMERA SENSOR ON ANDROID SMARTPHONE INTO OBJECT FOLLOWER ROBOT**".

### 1.1 Limitation

This research will be limited by several constraints in order to keep the research to don't widen the scope of the problem. So that the research will become more clearer and focused. Limitations of this research are:

1. The robot will be built with DFRobot Romeo BLE microcontroller and DC motors to move the robot.
2. The smartphone will be placed at the top of the robot.
3. The smartphone that will be used in this research is Android Smartphone.
4. The smartphone have 13MP camera.
5. The data communication between smartphone and microcontroller will be transmitted via Bluetooth 4.0
6. The software development for Android application will use Android Studio for building the app and will use Java and C++ programming language.
7. Use Android Native Development Kit (NDK) to make Android Studio can compile C++ codes.
8. Data will be processed in android application.
9. The microcontroller will just retrive the data from smartphone and send the signal to DC motors.
10. Image processing will involve OpenCV library.
11. The software development for the microcontroller will be developed with Arduino IDE.
12. PID Controller will be used to gives speed control for DC motor on left-right side of robot.
13. The image detection method that will be used is Canny Edge Detection and Contour Extraction.
14. The object that will be used for the detection is orange Ping-Pong ball .
15. The robot will not use servo motor for rotating the position of smartphone .

### 1.2 Purposes and Objectives

The purpose of the research that will be done is to make the robot move automatically follow the object detected by the camera Android smartphone.

The aim of this research was to examine the extent to which Android smartphone is capable of detecting objects by using Canny Edge Detection and Contour Extraction and test whether the robot can follow the object properly.

### 1.3 Imagery

The definition of the image is a representation (picture), likeness or imitation of an object in the form of two-dimensional (2D) in length and width. The image of the image there are two kinds of discrete and continuous image. Continuous image is produced from an optical system that receives analog signals, such as the human eye and analog cameras. Discrete image generated through the process of digitalization of the continuous image [2].

### 1.4 Robot

The word robot was first introduced by Karel Capek in a stage play that was held in 1921 in the show R.U.R. (Rossum's Universal Robots). The word robot itself is derived from the word robota in Czech means slaves, workers, or porters. Another understanding of the robot is a device consisting of mechanical systems, electronic systems, and control systems that behave like humans that facilitates the work of man. From a variety of existing definitions, the definition is the most acceptable is from "Robot Institute of America", which defines a robot as a manipulator that serves plural which can be re-programmed and designed to move the workpiece, components, equipment or specialized devices with various tasks [3].

### 1.5 Arduino

Arduino is a single-board microcontroller which is open source. Arduino is developed by a team of people from various parts of the world. The core members of the team were Massimo Banzi, David Cuartielles, Tom Igoe, Gianluca Martino, David Mellis, and Nicholas Zambetti [4]. Arduino was designed in order to facilitate their use and the use of electronic prototypes in various fields.

In the Arduino board there is a main components which is microcontroller chip with AVR types. The microcontroller itself is a chip or IC (integrated circuit) that can be programmed directly through the computer of the Arduino IDE. Interest embed the program in microcontroller is that electronic circuits can read input, process the input and then generate the output as desired.

### 1.6 Proportional Controller

Proportional controller serves to reinforce the value of the driving error (an error value). Will issue a proportional control output value proportional to the error value (the difference between actual and desired value) [5].

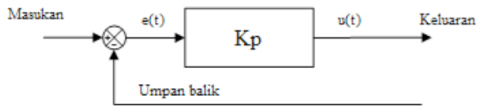



**Figure 1.** Proportional controller block diagram

The relationship between the value of the control output signal proportional u(t) to the error e(t) made by the equation:

$$u(t) = K_p e(t) \qquad (1)$$

The characteristics of the proportional controller can be described as follows.

1. If the value of K*P* is small, then the proportional control only able to do a small

error correction. so, will result in a slow system response.

2. If the value K$P$ raised, showing the faster system response reach a state of well being.
3. If the value K$P$ enlarged, reaching an excessive price, will result in an unstable working system, or the system will oscillate.

### 1.7 Integral Controller

Integral controller will eliminate the steady state error (offset) generated by the proportional controller. Integral controller will yield a value proportional to the large and ever error. Integral controller displacement accelerate the process towards the setpoint value (desired value) and eliminates the steady-state error that appears in the proportional controller. However, because the integral controller responds to the previously accumulated error value, then it can lead to overshoot. The integral controller as well as an integral characteristic. Output controller responds to changes comparable to the value of the error signal. The controller outputs a continuous sum of the change in input. If the error signal does not change, the output will keep the situation like before the change of input [5].

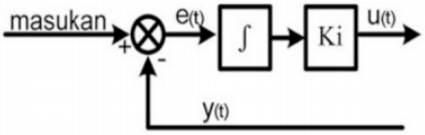



**Figure 2.** Integral controller block diagram

The block diagram above can be realized in the form of an equation that shows the relationship between the value of integral controller output signal u(t) with the following error e(t):

$$u(t) = K_i \int_0^t e(t)\, dt \qquad (2)$$

Integral controller traits are described as follows:

1. Output controller requires a certain time interval so that the integral control tends to slow down the response.
2. When the error signal value of zero, the controller output will last the previous value.
3. If the error signal is not worth zero, the output will show the error signal and the value K$i$.
4. K$i$ valuable integral control likely will accelerate the loss offset. But the greater the value of the constant K$i$ will lead to increased oscillation of the controller output signal.

### 1.8 Derivative Controller

KThe output of derivatives controller have properties such as a derivative operation. Sudden changes in the control input will result in a very big change, and fast on the output [5].

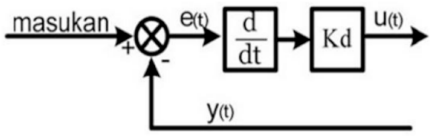



**Figure 3.** Derivative controller block diagram

The block diagram above is realized in the form of an equation that shows the relationship between the value of integral control output u(t) to the error signal e(t) as follows:

$$u(t) = K_d \frac{de(t)}{dt} \qquad (3)$$

The characteristics of the derivatives controller as follows:

1. These controllers can not produce output if there is no change in input (in the form of an error signal).
2. If the error signal varies with time, then the resulting output controller depending on the value of Kd and rate of change of the error signal.
3. Full derivative has the characteristics to get ahead, so that this control can result in a significant correction before generating the error becomes very large. So the control of plant derivatives can anticipate errors, provide corrective action, and tends to increase the stability of the system.

### 1.9 PID Controller

PID control is a combination of proportional control, integral control, and derivative control. The elements of the control of the P, I and D respectively overall aim to accelerate the reaction system, eliminating the offset and produce large initial change.

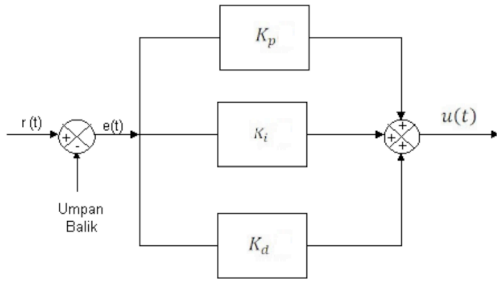



**Figure 4.** PID Controller block diagram

From the block diagram above can be obtained by the equation:

$$u(t) = K_p e(t) + K_i \int_0^t e(t)\, dt + K_d \frac{de(t)}{dt} \qquad (4)$$

## 2. THE CONTENT OF RESEARCH

### 2.1 Analysis of The Problem

Based on the analysis of previous studies, namely "Construction of Wheeled Robot with Object Tracking as the Basis Movement Control Robot" by Ratnasari Nur Budi Laksono Rohmah and Prianggodo of Surakarta Muhammadiyah University found that the resolution of the camera used will affect the results of the object detection. The greater the resolution used will be far distance of the object can be detected by the robot.

Based on the above, in this research the authors will make the follower robot (Object Follower Robot) by utilizing the camera that is on Android-based smartphone. Cameras on Android smartphones that will be used possessed a camera capable of taking quality images 12MP (megapixel). While the camera is used in the previous research Raspberry Pi camera module that can only take quality 5MP images.

### 2.2 Analysis of The Solution

Problem solving will be done by doing some of the detection process, and then from the detection result will be obtained coordinates of the center and great value contours of objects have been detected. From the middle of the object coordinates and great value contour of the object to be processed further using PID control algorithm to obtain the value of the steering robot and DC speed value.

The general description of the robotic system to be built is as follows:

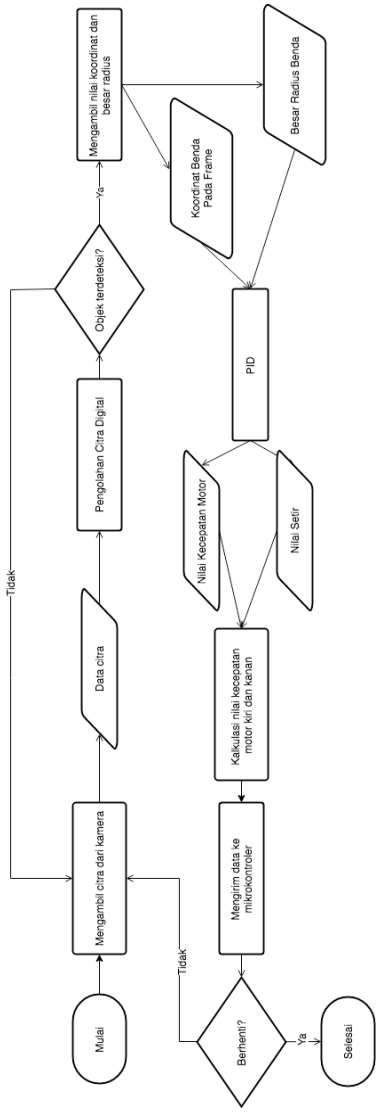



**Figure 5.** System Overview

### 2.3 Analysis of Detection Process

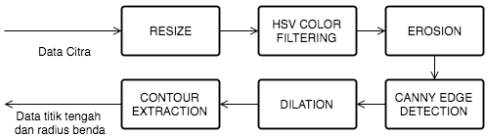



**Figure 6.** Detection Process Flows

Raw image taken directly from the camera has a resolution of a very large size. The amount of resolution will have an effect on memory usage and long image processing. It is necessary for downscaling or changing the size of the resolution of the image becomes smaller. In the first phase will be scaled down image taken resized to 320x240 pixels.



**Figure 7.** The image that's been scaled down

The next step is to change the color space of RGB (Red-Green-Blue) color space to HSV (Hue-Saturation-Value). This process is performed to segment the color easily.

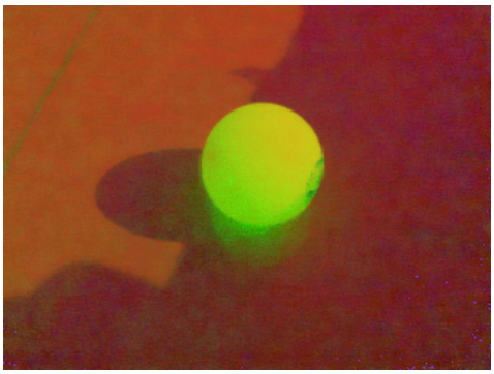


**Figure 8.** The results of the conversion to HSV color space.

After the color image is converted to HSV color space, then the next stage is to segment or color filtering. In this research, the objects that will be used to detect is orange ping-pong balls. As an example for the minimum value above the maximum of HSV to be used are:

$HSV_{MIN} = (0, 125, 150)$

$HSV_{MAX} = (60, 255, 255)$

Then the HSV values of each pixel in the image will be selected based on the definition of the HSV values. Then the results will be obtained is a binary image of each pixel value is within the limit values HSV.

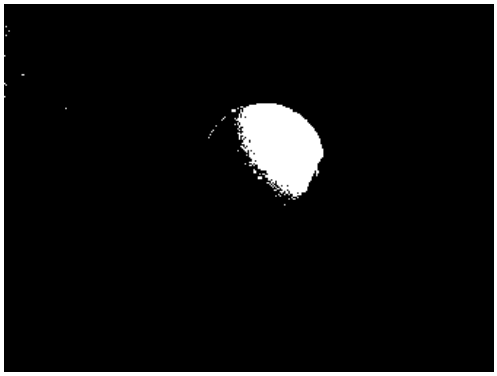


**Figure 9.** Results of Color Filters

The binary image obtained from the segmentation has some noises. It has small dots of white color outside the area of the ball. To eliminate the noise, then do the erotion process. Because of this erotion process, make every tiny dots will erode and disappear from the image.



**Figure 10.** After Erotion process

After that, the edge detection process will be carried out with Canny Edge Detection.

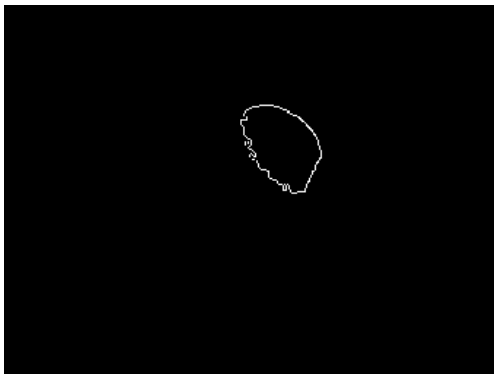


**Figure 11.** Results of Edge Detection

Having obtained the image with the results of the edge line is detected, then the dilation process is carried out to clarify the line.

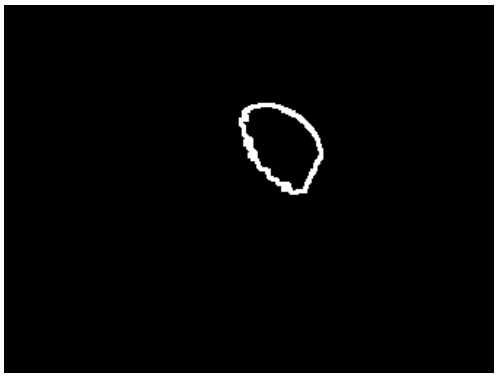


**Figure 12.** After Dilation process

After that, then proceed with the extraction of the contour (contour extraction). This process will be divided into several stages:

1. Contour finding.
2. Get the contour based with bigger size.
3. Take the central coordinate value and radius of contour.

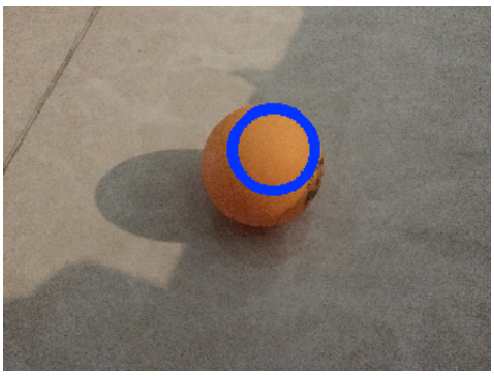


**Figure 13.** Final Result of Detection

Having obtained the central coordinate values, and the value of the radius of the detection process has been completed. As simulating the detection of these values can be used to draw a circle as shown in Figure 13. Then these values will then be used in the next process with PID controller algorithm.

### 2.4 Analysis of PID Controller Algorithm

PID controller or PID control system was essential to move the robot. PID control will adjust the speed of the robot to be built. The output of the PID control algorithm which is the value of the steering wheel and the maximum value of the DC motor speed. PID control works with the given setpoint value. This setpoint value is a reference value that we want. Distance and position of objects is an error. Error is a deviation between the variables measured value with a reference value. Cameras on the Android smartphone is used as a feedback element for mengumpanbalikan error.

PID control is the control that combines the advantages of the control of the P, I and D. If applied to the PID control system will improve response, eliminating error steady state, and provide a damping effect on the oscillating system.

PID control equation is given by equation (5) as follows:

$$u(t) = K_p e(t) + K_i \int_0^t e(t)\,dt + K_d \frac{de(t)}{dt} \qquad (5)$$

If the equation (5) discretize will be:

$$u(t) = K_p e(t) + K_i T \sum_0^t e_t + \frac{1}{T} K_d (e_t\text{-}e_{t\text{-}1}) \qquad (6)$$

When applied to the programming language then the equation becomes :

$$output = K_p{*}error + K_i(error + last_error){*}Ts + \frac{K_d}{Ts}(error\text{-}last_error) \qquad (7)$$

### 2.5 Analysis of Calculation of Speed for DC Motor

At this stage, the value of the steering wheel and the maximum speed value outputted from the DC motor PID control algorithm will be recalculated to obtain a value for the speed of a DC motor to the left and right of the robot. Differentiated speed value for the type of mobile robot that will be built in the form of a robot car that left and right movement of the DC motor speed is set on the left and right of the robot. To be able to turn to the left, the left engine had to move more slowly than the motor right. On the contrary, to be able to turn right, the right motor should move slower than the motorcycle left. But if you want to move straight, then the motor on both sides must move together.

To get the value of the left motor speed can using equation (8) and the right motor speed value can using equation (9).

$$LS[s,v] = \begin{cases} v, & s \geq 0 \text{ and } v \geq 0 \\ |v| - \left(|v| \left(\frac{|s|}{100}\right)\right), & (s < 0 \text{ and } v \geq 0) \text{ or } (s > 0 \text{ and } v < 0) \end{cases} \qquad (8)$$

$$RS[s,v] = \begin{cases} v, & s \leq 0 \text{ and } v \geq 0 \\ |v| - \left(|v| \left(\frac{|s|}{100}\right)\right), & (s > 0 \text{ and } v \geq 0) \text{ or } (s < 0 \text{ and } v < 0) \end{cases} \qquad (9)$$

S is the value of the steering wheel and V is the value of the maximum speed of a DC motor. If calculated by the second formula then the DC motor will slow in line with the given value of the steering wheel. Thus, the robot will be able to turn left and right.

Furthermore, to the direction of rotation left and right motors used equation (10).

$$D[v] = \begin{cases} Maju, & v \geq 0 \\ Mundur, & v < 0 \end{cases} \qquad (10)$$

### 2.6 Analysis of Data Serialization

The data of speed and direction of rotation of DC motors will be sent to the microcontroller via Bluetooth. Before sending the data, the data must be serialized to be sent. The amount of data to be transmitted are four, there are:

**Table 1.** Data of Speed and Directions of Motor DC

| No | Data Name | Data Type | Value |
|---|---|---|---|
| 1 | MotorKiriSpeed | Integer | 0-255 |
| 2 | MotorKiriDir | Boolean | 1/0 (Forward/Rewind) |
| 3 | MotorKananSpeed | Integer | 0-255 |
| 4 | MotorKananSpeed | Boolean | 1/0 (Forward/Rewind) |

The data will be sent to the microcontroller at a time with byte data type. For example, data to be transmitted is:

**Table 2.** Example of Data

| No | Data Name | Value |
|---|---|---|
| 1 | MotorKiriSpeed | 150 |
| 2 | MotorKiriDir | 1 |
| 3 | MotorKananSpeed | 150 |
| 4 | MotorKananSpeed | 1 |

Then the data will be converted into byte data type into:

**Table 3.** Converting to Byte Data Types

| No | Data Name | Value |
|---|---|---|
| 1 | MotorKiriSpeed | 0x00000096 |
| 2 | MotorKiriDir | 0xFF |
| 3 | MotorKananSpeed | 0x00000096 |
| 4 | MotorKananSpeed | 0xFF |

The entire value of the byte will be collected into a byte array type so that the data sent will be looks like [00, 00, 00, 96, FF, 00, 00, 00, 00 96, FF].

### 2.7 Interface Implementation

Interface has been implemented in the system:




**Figure 14.** Main Interface Implementation

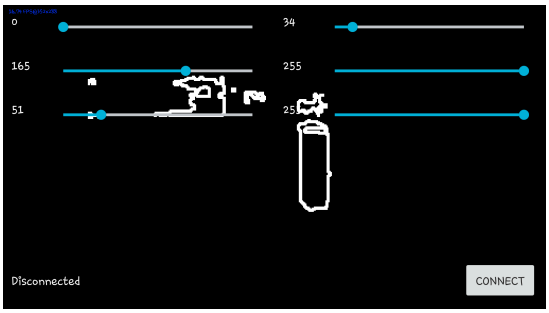



**Figure 15.** Settings Interface Implementation

### 2.8 Testing

**Table 4.** Object Detection Test

| No | Testing Item | Result |
|---|---|---|
| 1 | Directing orange ping pong balls | [√] Passed<br>[ ] Failed |
| 2 | Directing orange ping pong balls with dark lighting conditions. | [√]Passed<br>[ ] Failed |
| 3 | Directing orange ping pong ball in a long distance. | [√]Passed<br>[ ] Failed |
| 4 | Directing orange ping pong balls and at the back there are objects with similar colors. | [ ] Passed<br>[√]Failed |

**Table 4.** Speed Calculation Test

| No | Testing Item | Result |
|---|---|---|
| 1 | Directing pingpong ball very far. | [√]Passed<br>[ ] Failed |
| 2 | Directing pingpong ball close. | [ ] Passed<br>[√]Failed |
| 3 | Directing pingpong ball very close. | [√]Passed<br>[ ] Failed |

## 3. CLOSING

### 3.1 Conclusion

From the research, analysis, design, implementation can be concluded as follows:

1. The system can detect objects that orange ping pong balls under normal conditions.
2. The system is not fully able to detect objects when around objects that have a color similar to the color of objects.
3. The system detects non circular object as a circle if the color of objects included in the HSV color boundaries that have been set.
4. The system is able to provide the value of the speed based on the distance of objects.
5. The system is still difficult to be able to stop when objects are near the robot.
6. Robots can follow the detected object.
7. The frame size used was too small to be able to detect objects. So that the robot can not follow the object when the object suddenly changed position.

### 3.2 Suggestion

The system in this research there are still many shortcomings. Therefore it is necessary for further development and refinement. As for suggestions that might be applied to the next stage of development is as follows:

1. Using more reliable object detection methods.
2. Applying artificial intelligence such as object recognition for the system to freely detect the desired objects.
3. Adding a servo motor to drive the Android smartphone so that the camera can follow the ball freely so that the object detection area wider.
4. Using additional sensors such as ultrasonic sensors to detect the area around the robot.
5. Using a USB cable to transfer data between systems and microcontroller faster than using Bluetooth.

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