Pickup Strategy based on Table Tennis Pickup Robot

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Abstract. Due to the injuries and inconvenience that picking balls caused, a number of ball pickup robot showed up in recent years. The existing ball pickup robots have a common problem that is they can't complete the picking task at a fast speed for they are set to pick up all the balls. Put it another way, when facing multiple balls, their efficiency decreases to some extent. Different from their idea of picking all the balls, the new strategy in this paper aims to propose can balance efficiency and the degree of completion (picking enough balls) for the ball pick up robot. Taking table tennis as example, this paper first introduces the necessary hardware. And then it introduces the principle of detection, which is color recognition, and path planning, after which the collection structure is presented. Ultimately, the mode of data transmission is indicated. This paper offers a new way of thinking about ball pickup strategies for ball pickup robots, which contributes to the development of related robots.

Keywords: Ball pick up, robot, OpenMV, strategy.

1. Introduction

During the training of ball sports, players need to filled the empty basket with balls at intervals, which brings physical consumption and causes unnecessary injuries especially for teenagers. Aiming at replacing the process of picking balls to reduce the time of picking balls and extending playing time, related robots came into being in recent years. From tennis to badminton, such mainstream sports have their own pick-up robots like Tennibot for tennis picking. As a robot made for ball picking, efficiency, robustness and the degree of energy conservation are the main aspects that need to concern. In order to improve such performances, a good pick-up strategy is able to deal with this task. Due to the advantages that table tennis has (small volume, small working area, homogeneity of balls), this paper based on the table tennis pick-up robot to discuss the pick-up strategy.

To successfully collect balls, robots have two vital tasks to complete: detection and moving. For detection, using camera and deal with images is the mainstream of ball pick up robot. Keča, D concluded in paper that despite the fact that deep learning algorithms performed well on the test set, their predictions are still greatly influenced by the pixel values, numerical relationships, and features extraction procedure in the input data, which was shown in Table 1. Meanwhile, considering the microcontroller ball pick up robot generally use, deep learning algorithms is not a perfect choice [1]. (Time pred is the average image prediction time, and Time init is the average network initialization time. The sum of the initialization times is the total time)

Table. 1 Outcomes of the algorithms that the Raspberry Pi-powered teaching robot runs [1].

Encoder	RAM[MB]	loU	Time Drive	Total Time	Time Pred	Time Init	DICE
Hough 50-40-50	17.81	0.6651	2.44	4.71	0.17	0.22	0.7989
EFFICIENTNET-B0	52	0.5839	2.95	26.82	16.35	3	0.7373
MOBILENET_V3_LARGE_320	236	0.7482	2.17	12.74	4.69	5.33	0.8559
RESNET50	458	0.8016	2.18	158.71	148.27	17.62	0.8899
MOBILENET_V2	55	0.6126	3.81	26.22	15.28	3.28	0.7598

In comparison, Hough transformation is a better choice for its efficiency and robustness. For moving, F. Faizah, A. Triwiyatno used a simple way to lead the robot to the balls, which is fuzzy logic control [2]. It outweighs for its convenience in programming. In addition, S. Gu pointed out two ways to deal with the path planning problem. One was formulating it with the Travelling Salesman Problem (TSP) and another was using a regional traversal algorithm [3, 4]. But when facing the task of picking up the balls scattered all over the field, it spends more time and energy to pick up balls. All of them are not perfect in some ways. This paper aims to discuss a better strategy for table tennis pick-up robot.

The purpose of this paper is to provide a new idea for the manufacture of ball pickup robot and point out a new direction for the development of ball pickup robot, as well as solving the problems that the current ball pickup robot has, including the lack of efficiency, the high cost and so on. Ultimately, it can upgrade the ball pickup robot to better serve the user. The strategy is divided in five parts to introduce: hardware, ball detection, path planning, collection and data transmission. Hardware part is to introduce the example hardware used in table tennis pickup robot. Ball detection part is to explain the principle of ball detection and the reason why to choose it. Path planning part is to put forward a new way to acquire the path that the robot moves. Collection part is to point out the structure adopted to collect balls. Data transmission part is to explain how data processes and transmits between ball detection part and the robot itself.

2. Hardware

2.1. Main Haedware

2.1.1 OpenMV

As an open source machine vision module, OpenMV uses STM32F427CPU as the core and integrates OV7725 camera chip, which is shown in the Figure 1. On a small hardware module, the fundamental machine vision algorithm is effectively implemented in C and offers a Python programming interface. Simply put, it's a programmable camera and the camera itself has some built-in image processing algorithms that are easy to use. Its task is to gain the photos of the area to locate where the ball is and create a two-dimensional map in order to transmit the path data to the robot.

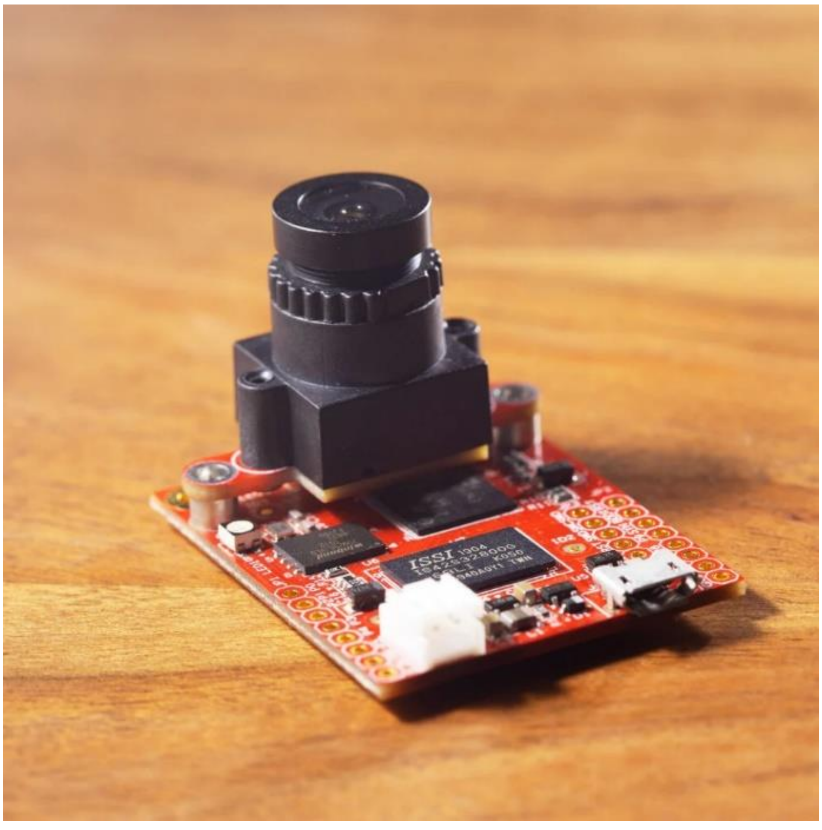

Fig. 1 OpenMV [5]

2.1.2 STM32

STM32 is a 32-bit microcontroller launched by ST. STM32 has the advantages of ultra-low price, ultra-many peripherals, rich models, excellent real-time, and very low development cost. It is used as the microcontroller of the robot. After receiving the data from OpenMV, it controls the robot to the balls.

2.1.3 YH-HC05

YH-HC05 is a Bluetooth serial module launched by Wildfire Technology, which uses Bluetooth 2.0 protocol, compatible with any version of Bluetooth communication, including Bluetooth-capable computers with Bluetooth, Bluetooth hosts, cell phones, PDAs, PSPs, and other terminals paired to achieve the serial port pass-through function. The YH-HC05 can be driven with just a TTL level standard serial port (5V/3.3V voltage is possible), and it supports a baud rate range of 4800 ~ 1382400. This makes it an excellent choice for single-chip systems looking to increase the capabilities of Bluetooth. It is used for the data transmission between OpenMV and STM32.

2.2. Other Hardware

Standard 12V servo motors are adopted in the robot for its power and remarkable control performance, which enable further improvements like adding PID. Additionally, L298N is chosen as motor drive module. Other hardware can be chosen according to the exact situation and personal needs.

3. Ball Detection

The detection part includes OpenMV and a YH-HC05.

Color recognition is the basic principle of the detection of the balls, which is widely used in related works, including D. Scaramuzza’s ball detection research and K. G. Hettihewa’s ball catching robot [6, 7]. After taking snapshot, it preprocesses the picture by wave filtering and so on methods to reduce image noise and improve image quality. Then image is converted from RGB color space to HSV color space, for which HSV color space is more suitable for characterizing colors according to Ganesan P and V. Rajini’s comparison in their paper [8]. Finally, the target color information can be obtained after processing.

Table tennis should be orange or white in accordance with International Table Tennis Federation (ITTF) regulations.The target balls are supposed to be orange shown in Figure 2.

Fig. 2 Table tennis [9]

A cross is drawn at the center of each ball in the image in order to locate the ball's location and Figure 3 is an example.

Fig. 3 Ball and cross [10]

4. Path Planning

Despite of the power of motors and the speed of signal transmission between detection part and robot, path planning is also vital for efficiency. Most of the research related focus on how to collect all the balls. But the truth is whether the balls are all picked up does not matter. The point is if the robot collects enough balls for training. Put it in another way, a few of balls scattered is allowed, which means it will save more time in collecting balls. Thus, the balance between collecting more balls and saving more time is the key.

Put it simply, the strategy is that the robot moving to the position where has a relatively number of balls and collect balls. Then it moves to the second one until most of the balls are collected.

To decide where has relatively more balls, image is divided into few grids, as it is shown in Figure 4. An array is created to store the number of the balls in each grid by gaining the coordinate of each ball and deciding which grid is the ball belong to. The division can be adjusted by the actual situation to control the collecting process. On one hand, the bigger each grid is, more time should the robot collect the balls. On the other hand, bigger grid means more time for the robot to collect balls in each grid. The number of the position, which is the center of the grid, that robot needs to go has two ways to set. One is choosing the number in the program and the other is setting a number of the balls that the grid should contain. In addition, the path is set to be a circle to avoid duplication of each route. After collecting the last grid's balls, robot will move to the destination and wait for the next collection.

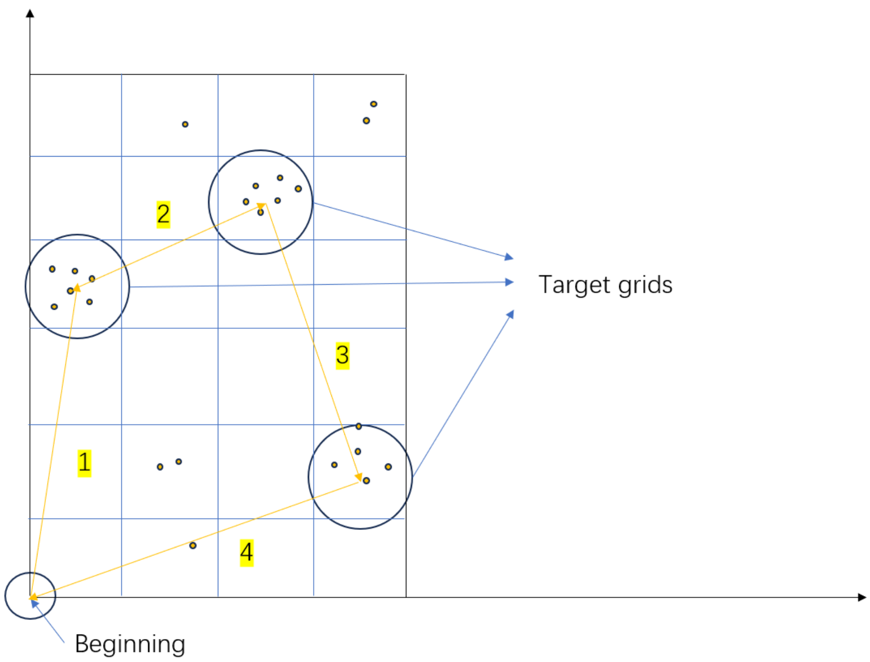

Fig. 4 Picking strategy (Photo credited: Original)

5. Collection

Roller table tennis picker is chosen as the collecting structure, which usually uses elastic material to maintain tension and ensure that the ping pong ball does not fall out easily. When table tennis picker touches a table tennis on the ground, the table tennis goes into the basket. The design of the table tennis picker allows the table tennis to slide easily into the basket while maintaining enough stability to prevent the table tennis from falling out. The collecting structure is shown in Figure 5.

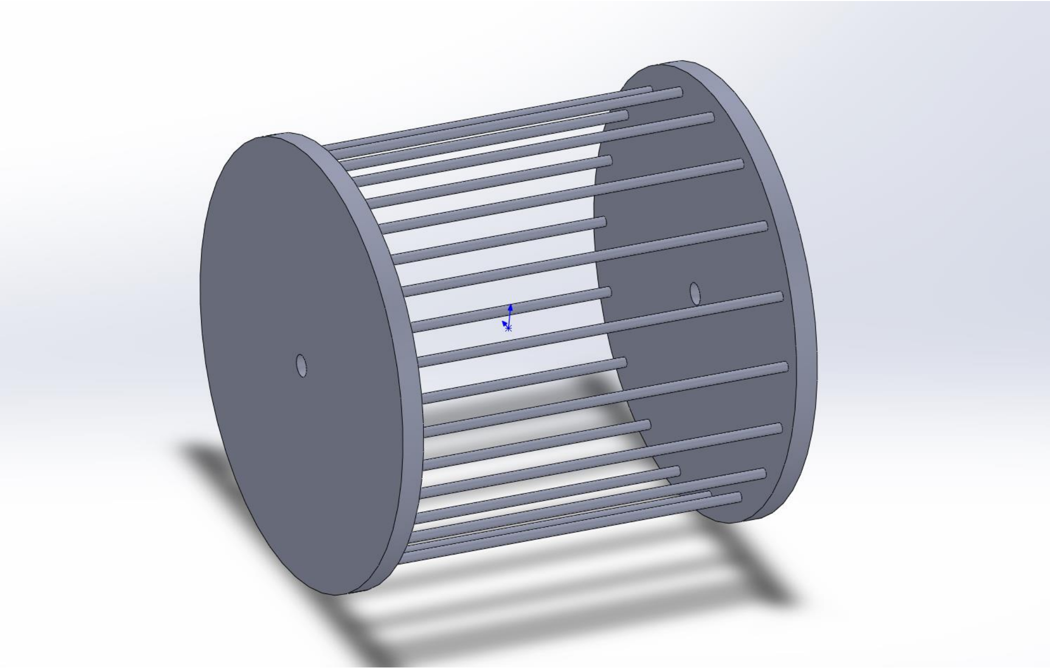

Fig. 5 Collecting structure (Photo credited: Original)

Due to the collecting structure used on the robot, collecting only requires the moving of the robot. The ball enters the collection part through the gap whose width is slightly smaller than the diameter of the ball when the collection part gives the ball enough pressure.

Initially, the robot is in the center of the target grid. Then it firstly moves to one side of the grid and moves through the entire grid to collect the balls, which is the easiest way to collect for which the grid has relatively small area.

6. Data Transmission

From image to actual moving, OpenMV takes the task of image processing. It figures out the balls and presents the coordinates of the balls in the image. Then it chooses which grids is the target and transfers the coordinates of the target grids into actual paths that robot needs to move. There exists a k that can figure out the crude distance between robot and the target grid. Suppose the robot is set to started in the bottom left of the area. Suppose the four edges of the image coincide with the four edges of the area in the image. x means the actual length on the direction of x-axis and y means the actual length on the direction of x-axis. The smaller rectangle represents the image, whose width and length can be equivalent to the max coordinate of x and y of the image.Finally, the actual moving direction and working time can be calculated according to the speed of the robot, which is sent to the robot though Bluetooth. The reason for choosing Bluetooth over WIFI has been suggested by K. Shahzad and B. Oelmann that Bluetooth is highly resistant to interference and has low power consumption [11]. Robot gets the data and moving as specified. After getting there, it moves in collecting mode mentioned above automatically. At last, it moves back to the setting place and wait for the next round. During the collecting process the robot can’t receive the data that detection part sends until detection part receives new command from user. Ideal situation and actual situation were shown in the Figure 6 and Figure 7, respectively.

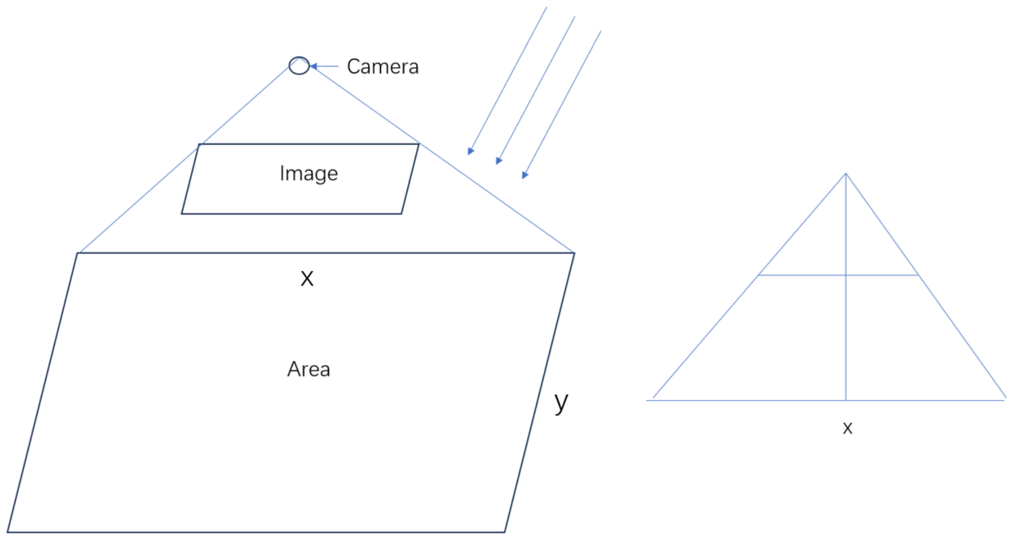

Fig. 6 Ideal situation (Photo credited: Original)

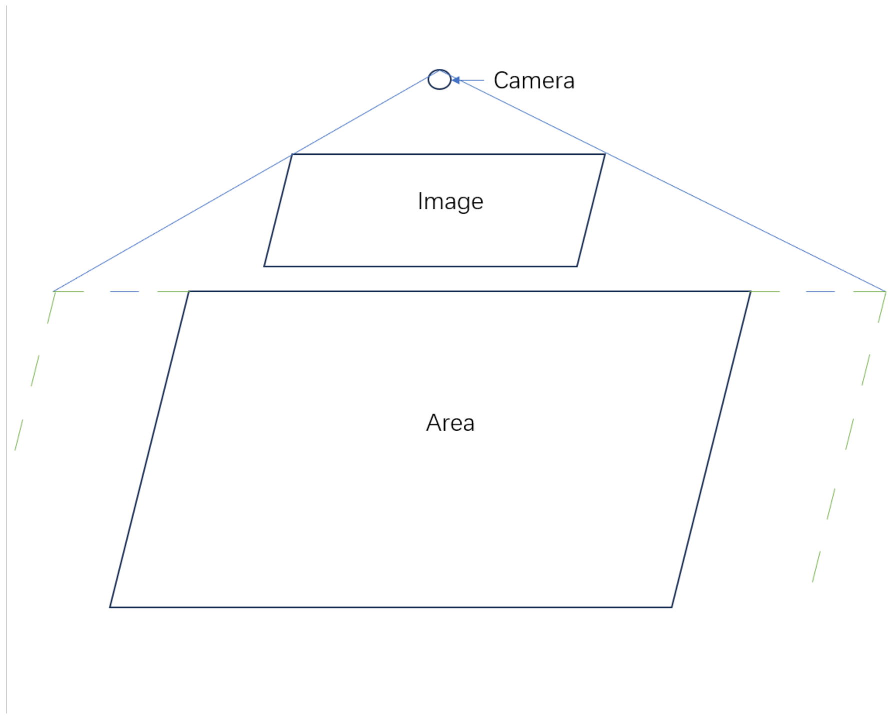

Fig. 7 Actual situation (Photo credited: Original)

7. Conclusion

As anticipated, the balls are scattered around the area and detection part starts to work after receiving the picking signal. Then the image is processed. Detection part gets the target grids, calculates the moving data and sends to the robot. Once the robot is moved to one of the target grids, the collecting program works and the robot moves through the entire grid to collect balls, after which it moves back to the center of the grid and ready to move to the next grid or back to the beginning. This is a complete ball pickup process if every part works as programmed.

This strategy provides a new idea for picking up balls for the ball pickup robot based on previous research, which considering the balance between efficiency and the degree of completion of the picking task. However, there still remain a few unsolved problems. First, the moving program for the robot has low robustness, for it is controlled by the working time of motors, which is open-loop control. The moving program of robot can be revised by combining it with PID and at the same time the data that detection part send needs to change a format to suit the revised moving program. Second, there exists another k2 when calculating the actual distance, which is the proportion of the camera scene and the actual area. It is caused by the truth that the four edges of the image may not coincide with the four edges of the area in the photo. Except for adjusting the camera, setting the four corners of the area as feature points is also workable, which can determine the coordinates of four corners and it is easier to get the k2 and calculate the k1.

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