Automatic Collecting and Shooting Mobile Robot

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***Abstract*—Nowadays, automatic factory is the goal pursued by many industries. Therefore, transporting need is becoming more and more important. Using a mobile robot to transport between stations will substitute human to increase productivity. In this paper, an omnidirectional mobile robot has been established by aluminum extrusion and acrylic. Digital Signal Processor (DSP) is a main controller that commands the robot to move and transport. Visual identification is realized via a camera using a Single Board Computer (SBC) in a specified area and gets command to perform the task. Finally, the mobile robot can complete the related tasks autonomously. Furthermore, the modularizing robot can be easy to change the operating mode to perform various tasks conveniently.**

***Index Terms*—mobile robot, color recognition, shock absorption system, positioning system**

I. Introduction

During the past decades, manufacturers want to increase profits so that they have continuous pursuit of productivity, quality and low cost [1]. Cost pressure, competitiveness and the increasing turbulence of globalized saturated markets has been the driver for a variety of research activities in the field of production planning and control (PPC) [2]. Therefore, they gradually strengthen technology of automation in order to keep pace with the times. Produce products of small-volume and multiple-types are business aim because of consumer changeable demand. It is more necessary to rely on communicating and delivering between equipment that leads to promote the value of community logistic. Therefore, having an automatic guided vehicle (AGV) is indispensable.

AGVs are advanced material handling devices used to transport goods and materials between workstations and storage areas of an automated manufacturing system. AGVs involve at least one driverless automated guided vehicle and each vehicle travels on predetermined guide paths [3]. They increase efficiency and reduce costs across a wide area of applications, including distribution logistics. Operational control of AGVs in a distribution warehouse encompasses the task of routing the vehicles, i.e., navigating them through the warehouse, efficiently to optimize storage and retrieval processes [4].

The 22th annual Taiwan TDK Robocon competition presented a place to run tasks. The goal of the challenge was to develop an automatic mobile robot which transports the object in three minutes. The competition was hosted on Formosa University. We design, process and fabricate a mobile robot ourselves in order to complete this setting task.

Based on this working mode, we can use vision to detect the various the station position and add WIFI to get operational command of the station. Deliver work pieces and productions between the stations or station and warehouse by good planed path. In the future, the mobile robot will become AGV for logistic of production line. Let production system be managed efficiently.

II. Problem & Evaluation

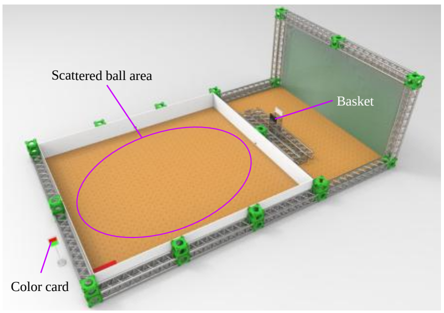

Figure 1. The schematic 3D field.

This competition rule is that the robot need to raise the right flag and pick up the correct color balls in the specified area is accorded to the color of the card, then, the correct color balls will be shot into the target basket in the destination area. The schematic competition field is seen as Fig. 1. Therefore, it needs to have omnidirectional

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moving, position moving and visual recognizing, and needs to complete the task within three minutes.

III. Machine Structure

A robot is drafted to simulate and design by the 3D Computer Aided Design (CAD), and is established and processed by computer numerical control (CNC). The machine diagram is shown in Fig. 2. We've divided my machine into eight parts, e.g. vehicle movement, position detection, visual recognition, flag raising, ball collection, ball conveyor, ball selection and ball shooting.

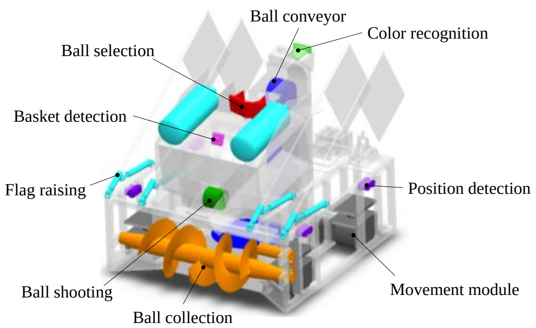

Figure 2. Machine simulation.

A. Movement Model and Shock Absorption

The omnidirectional movement is necessary, so Swerve drives, Omni wheels and Mecanum wheels are our reference of the movement mechanism. Because they can keep the robot attitude moving agilely, the robot cans run on a better path. As author Alex Macfarlane and Theo van Niekerk point out on the principle of Swerve drives: the wheels are able to rotate about the drive motor, to generate traction, and the steering motor to generate steering. The system called for four separate drive units. This concept can be seen in Fig. 3 [5].

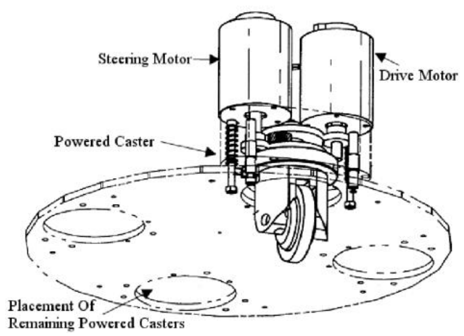

Figure 3. Original patent for the swerve drive system [5].

The design proposed in Fig. 3 called for four identical drive units. Each drive unit contained a drive motor and steering motor which brought the total amount of motors for a four wheeled system to eight. This was deemed expensive and uncompetitive when compare to other omnidirectional systems [5]. Rigidity and loading of Mecanum wheels are better than Omni wheels, and therefore we select Mecanum wheels to be movement models of the robot.

Use Mecanum wheels to move that needs a vector sum of speed of four wheels, so each wheel musts are on the ground. In order to avoid the robot slip because wheel musts be not on the ground. We design a mechanism. The mechanism diagram of robot movement is shown as in Fig. 4. The sliders let the movement model do up and down linearly. The spring bears the robot let each wheel is on the ground.

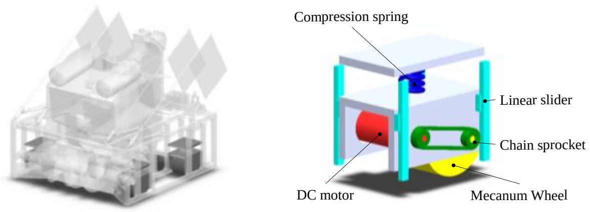

Figure 4. (Left) Movements model diagram. (Right) Shock absorption system.

B. Position Detection

The ultrasound sensing range is large is disturbed easily. The laser distance sensors consequently which are installed on our robot are shown as in Fig. 5. The laser distance sensors consequently are installed on our robot. The sensors sense near environment. They can assist the robot to correct moving attitude. Let the robot doesn't lose the way in running task.

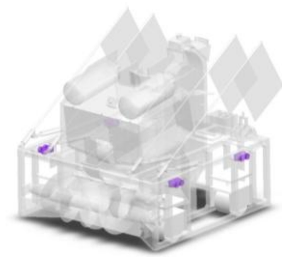

Figure 5. Position detection diagram.

C. Visual Recognition

Two individual webcams are adapted to recognize card and detect basket in order to pick up and shoot the balls from the diffusing balls area. One which recognizes the color of the card is shown as in Fig. 6 (Left). Another which detects the location of the basket is shown as in Fig. 6 (Right). In the visual system, when the SBC receives a started signal of recognizing card or detecting basket, the webcams will grab the images. Then, the SBC issues a command to the DSP about result of analyzing images.

Figure 6. (Left) Card recognition webcam diagram. (Right) Basket detection webcam diagram.

While enhancing the intensity or saturation component for high-quality color enhancement, keeping the hue component unchanged is important; thus, perceptual color models such as the HSI and HSV were used. Hue-Saturation-Intensity (HSI) is a public color model, and many color applications are commonly based on this model [6].

Both colors on the card and the basket are recognized by the color model of HSI in this system. In recognizing card, the robot recognizes colors with Hue and Saturation to get. In detecting basket, it recognizes with Intensity to get region of items from images, and detects center of items of area of setting range to know that the basket is where.

D. *Flag Raising*

After the robot gets target colors, the equal color flags are raised by cylinders. The flag raising mechanism is shown in Fig. 7. It uses I/O to control cylinders in order to solve the PWM pin of controlling motor is not enough. Cam mechanism for raising flags is a reference that can obviously raise the flags for short elongation of cylinders.

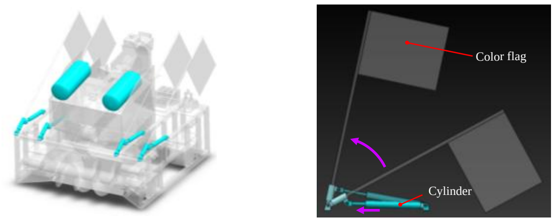

Figure 7. (Left) Flag raising diagram. (Right) Illustrate raising flag.

E. *Ball Collection*

Todays, road-sweeping vehicles are extensively employed in cleaning the highways and public areas. Most road sweepers use a set of brushing gear to sweep debris and utilize a suction unit to pick up [7]. Concept of road-sweeping vehicles for putting balls inside robot is imitated that improves the robot mechanism. The mechanism is shown as in Fig. 8. This mechanism with bidirectional spiral brush concentrates balls in the robot. That is seen in Fig. 9.

Figure 8. Ball collection mechanism diagram.

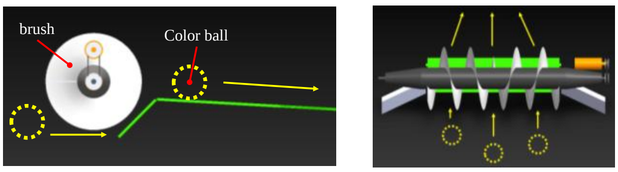

Figure 9. (Left) Illustrate picking up balls. (Right) Illustrate. concentrating balls.

F. *Ball Conveyor*

In order to pick up the correct balls and then shoot them into the basket. The collected balls will be transported one by one to the top floor and do following selection. The conveyer mechanism diagram is shown as in Fig. 10 (Left) and schematic diagram of transporting is shown as in Fig. 10 (Right). Conveyor track is only as wide as a ball is Fig. 11 (Left), and thus balls are blocked easily, but we add the turntable to flow the balls is Fig. 11 (Right).

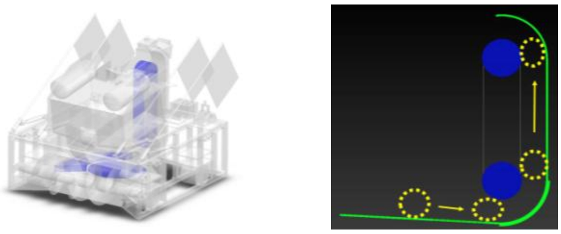

Figure 10. (Left) Ball conveyer diagram. (Right) Illustrate transporting balls.

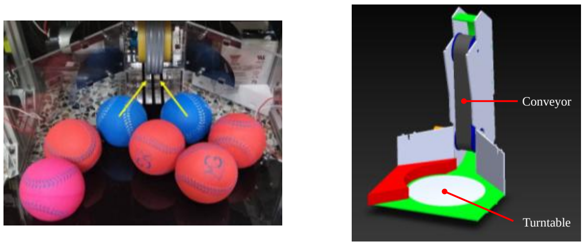

Figure 11. (Left) The balls being blocked. (Right) Mechanism of transporting of ball conveyer.

G. *Ball selection*

After the robot gets the required colors, it selects the balls about colors. We establish the mechanism is shown as in Fig. 12. When color sensors sense the ball, they will detect the color of the ball. If the color of the ball conforms to required, it will be stored in the robot. If it does not conform, it will be thrown out the robot.

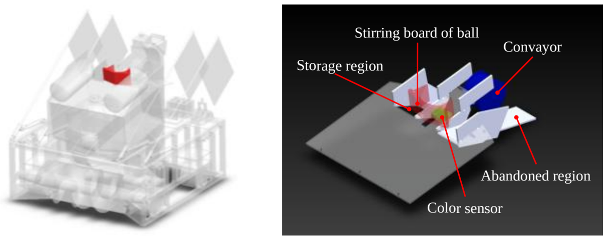

Figure 12. The balls selection diagram.

H. *Ball Shooting*

The following three shooting methods had be proposed in [6]:

- Use spinning wheels to propel the ball, similar to a typical baseball pitching machine.
- Use compressed air to shoot the lacrosse balls, like a canon.
- Utilize a spring and lever arm to throw the lacrosse balls.

All three of these sketches can be seen in Fig. 13 [8].

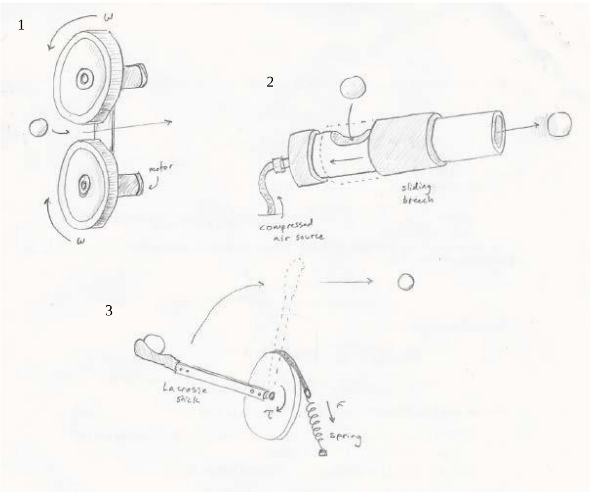

Figure 13. Concepts for launching the lacrosse ball [8].

First method that is more convenient than the second method to adjust the launch angle is due to differences of the velocity of the motors and this volume is smaller than final one's. We adopt this method as our shooting mechanism and improve it. We replace two motors with an adjusting card and a motor is seen in Fig. 14. This method can adjust the adjusting card to change the launch angle and is cheaper than two motors. The launch angle Schematic diagram is shown as in Fig. 15.

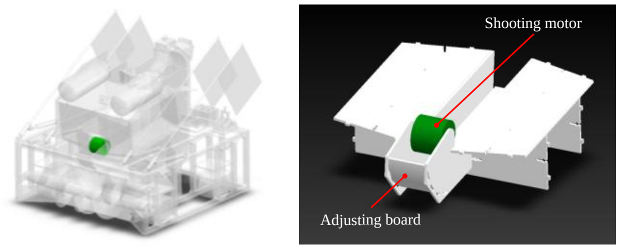

Figure 14. The balls shooting mechanism diagram.

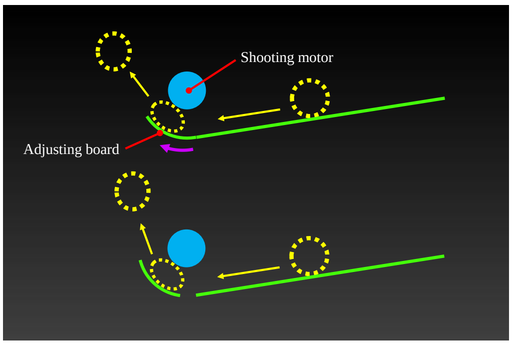

Figure 15. Illustrate difference launch angle.

IV. CONTROLLING

We use the DSP controlling the robot to move, shoot, pick up, recognize and raise the flags. The system is shown in Fig. 16. According to competition conditions, we plan the process flow is shown in Fig. 17. The distance sensor returns the position of the robot until the end of the task. The robot moves to the position of the command with distance sensors. First, control it to move to the card near area, and control the webcam grabs the image which is analyzed to recognize colors of the card. When the SBC gets the colors, the color signal will be returned to raise the same color flags. Then, it moves in specified area with planned path, uses a brush to pick up the balls in the path and selects the target balls from collection ones. The specified color balls are stored into the robot. The others are thrown away. Finally, it moves to detect the basket. While it gets the basket location, it will stop moving and shoot the balls.

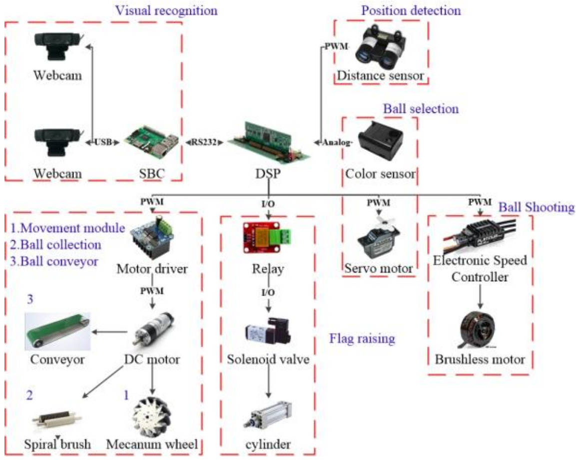

Figure 16. Robot System structure.

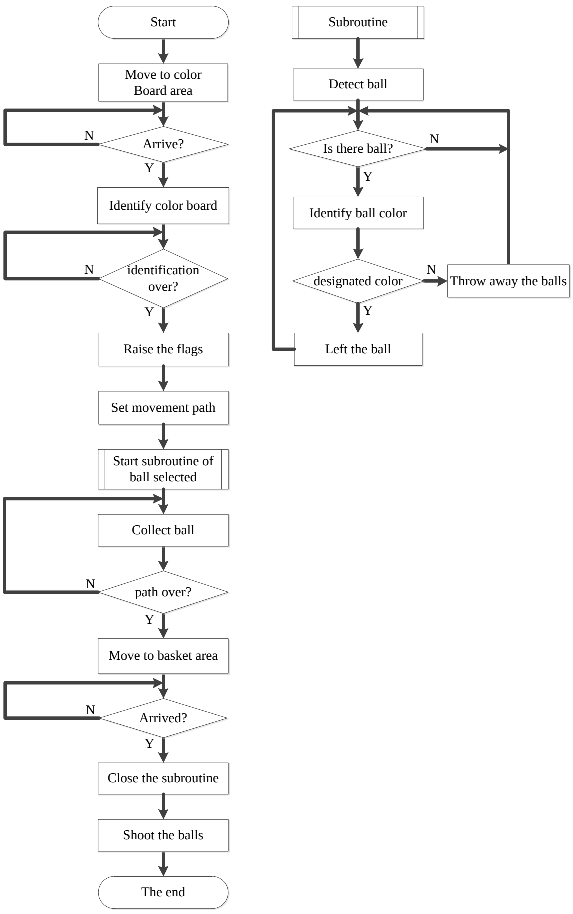

Figure 17. Process flowchart.

A. Moving Controlling

Indoor navigation technology has enabled the exploitation of mobile robots for transportation of goods and materials in industry facilities and warehouses [9]. Identifying the exact current location of a robot is a fundamental prerequisite for successful robot navigation [10]. The robot in navigation must move and obtain new data from the environment and make the motion decisions simultaneously [11]. In recent years, laser technology, sonar technology, visual function application that is more and more on the robot [12] often used to be tool of robot positioning [13-15]. We plan the simple motion path and positioning system to finish task since the competing time is only three minutes so that vision and path planning algorithm are not efficient. Based on these, we adopt laser to locate the location and correct attitude. We install sensors on three sides of the robot that is seen in Fig. 18. The robot can detect attitude of the robot to correct it. The robot detects the location of the robot that use the concept of coordinate to move to collect the balls is seen in Fig. 19.

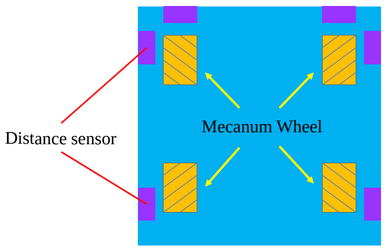

Figure 18. The sensors configuration.

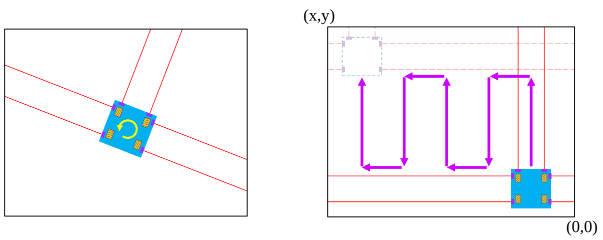

Figure 19. (Left) Illustrate incorrect attitude condition. (Right) illustrate using the coordinate of the robot to move.

B. Vision System

When the SBC receives a started signal of identifying, the SBC will command the webcam to grab images which are identified. The identification process of the card and the basket is similar, so take the identification blue on card as an example. First, the robot captures the image is seen as in Fig. 20 (Left), and converts the original image to three pictures of the HSI model are divided into hue, saturation and intensity. Second, execute binary processing for the saturation to reduce hue to retain the domain of demanding chroma is seen as in Fig. 20 (Right). Third, execute binary processing for the domain of demand to distinguish to retain the domain of demanding color is seen as in Fig. 21 (Left). Finally, according to the area size, to capture the range size area is shown as in Fig. 21 (Right).

Figure 20. (Left) Original image. (Right) The domain of demanding chroma.

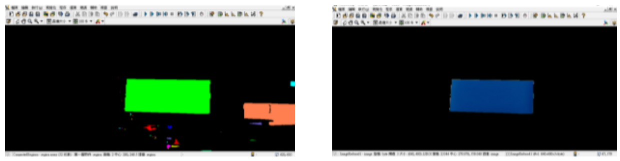

Figure 21. (Left) The domain of demanding color. (Right) is range size and correct color area.

C. Color Selection

The balls which are transported by ball conveyor are classified by color sensor. Then, the robot uses a servo motor to whirl stirring card to stir the balls are stored or thrown away. The color sensor, we adopt to detect the ball colors, has three modes of RGB. We use each RGB mode to filter suture and add an LED to stabilize the sensed color results. The schematic of ball features and the selection is shown as in Fig. 22.

Figure 22. (Left) Ball features. (Right) Selection schematic.

V. Conclusion

The automatic collecting and shooting mobile robot which is seen as in Fig. 23 had been finished successfully. The DSP is the main controller of the robot. The SBC assists DSP in visual recognition and task to complete color identification and basket detection. The robot with motion mode of the Mecanum wheels cooperates with the distance sensors to move agilely and accurately to target location is seen as in Fig. 24 (Left). It can collect various color balls and select them to store in it. In the final, it shoots the correct balls into the basket in the specified area that is seen as in Fig. 24 (Right).

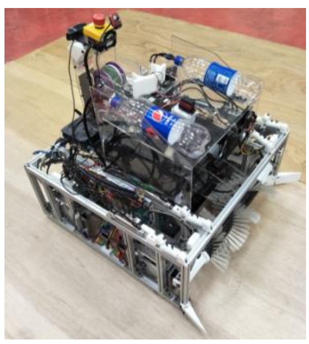

Figure 23. The overall of machine.

Figure 24. (Left) is moving schematic. (Right) is shooting schematic.

In this paper, the robot with omnidirectional moving, location, visual recognition will be available to simulate AGV to transport between stations and warehouse that promote efficient in performing tasks. In the future, the proposed software modules can be used alone or combined with different modules. The hardware modules, which are shown as in Fig. 25, can flexibly perform different operations by replacing the related components, e.g., ball classifying/shooting module, collecting module, robot arm. In addition, remote communication will be developed to let robot be controlled on process.

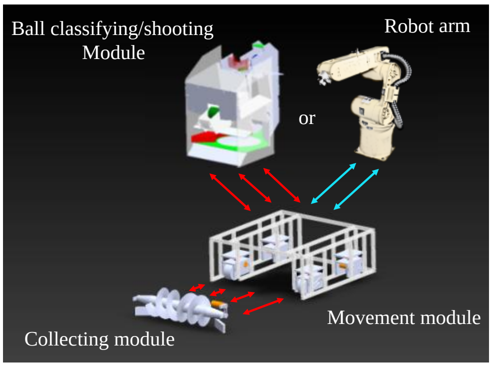

Figure 25. Module assembling.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Jeng-Dao Lee is the corresponding author of this research work. He was in response for conceptual generation, research planning, problem solving, and final editing of the manuscript; Chun-Chi Hung conducted the research, hardware design and implementation, mechatronics, and wrote the paper; Hung-Yu Hsu, Wei-Chuan Li provided software revision and integration; Cheng-Yi Li assisted experiments and paper revision; Moreover, all authors had approved the final version.

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