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VISION MOBILE ROBOT SYSTEM WITH COLOR OPTICAL SENSOR

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ABSTRACT

A basic design and configuration of Vision Mobile Robot System (VMRS) using a camera with color optical sensor for FIRA event in RoboSot challenge is presented. As a result, VMRS called Color Optic Sensor Robot (COSBot) had been produced. A Pixy CMUCam5 with capabilities of remember seven different color signatures, find hundreds of objects at the same time, super-fast processing at 50 frames a second, and can synchronous serial data used by microcontrollers for communicating with quickly over short distances is adopted in this system as a color sensor and main device used in this system. The other hardware and software of the devices used in the VMRS are also explained. By carefully design and configure the optical part and electrical part with adopting a simple algorithm for color identification and image processing using C++ programming and Pixy Mon application software the COSBot realized with relatively high accuracy and reasonable speed. The results show that COSBot can be upgraded in term of model and material. Consequently it can be used as part of the color vision in intelligent robots and it can be applied to color quality monitoring in many industrial fields such services robotic application and others.

Keywords: color optic sensor, camera, vision mobile robot, arduino microcontroller, image processing.

INTRODUCTION

Nowadays many objects or machines are built-in with sensor to make things works more easily, smoothly and intelligently. Object with intelligently system that control by controller and support with vision sensors is called Vision Mobile Robot System (VMRS). There are many researchers have been used and applied vision sensor to the mobile robot system [1, 2]. This kind of robot can identify the surrounding environment as well as immediate movement can be determined to reach the intermediate or final goal. This because vision sensors are a low-cost sensor and provide a vast amount of information on the environment in which robots can move [3]. In addition they are passive so that vision-based navigation systems do not suffer from the interferences often observed when using active sound- or light-based proximity sensors [4]. The VRMS mostly used in services robotic application which is equipped with a camera that can be controlled from its visual perception using visual data to control the motion of the robot [5].

Now day many researcher were study VRMS for robot playing soccer [6, 7, 8]. Even for international level competition especially Federation of International Robot Association (FIRA) Roboworld Cup. They used vision sensor with suitable autonomous navigation algorithm to help robot react as well as a human in robot soccer event or tournament. They have proposed a variety of theories and methods for controlling, planning and so on. Now day at Politeknik Malaysia, they setup a robotic team at every Politeknik. They used this platform to prepare politeknik robot soccer team to compete in FIRA Malaysia Cup even FIRA Roboworld Cup every year. FIRA Malaysia Cup has many categories such as Androsot, RoboSot, Simurosot, MyBot, Mirosot and Hurocup. Base on each category they need a different type of robot. Especially for Robosot they need custom made robot for enter the challenge in FIRA Malaysia Cup or Roboworld Cup.

This paper presents the basic design and configuration of vision mobile robot system with optical color sensor includes hardware and software for FIRA event in RoboSot challenge. This VMRS called Color Optic Sensor Robot (COSBot). The method used for identify the surrounding environment is based on color signature setting and training using pixy Mon application software and pixy camera. Supported with simple algorithm, vision mobile robot will be able to identify the surrounding environment as well as immediate action will be taken to achieve final goals.

COLOR OPTIC SENSOR ROBOT (COSBot)

COSBot is a robot designed for the purpose of FIRA event in RoboSot challenge as well as teaching and learning methodology and understanding of the basic design and configuration of the VMRS. The COSBot is design and build based on hardware devices such as camera, microcontroller and motor driver. COSBot configuration is support with software application and simple algorithm using C++ programming. This robot will work based on color coding as configured using application software and camera. Basic concept operation of COSBot is software and hardware communication between the camera, microcontroller and motor driver. There is a camera as an input and motor driver as an output of microcontroller. First, camera will detect object's color, the result will be saved and processes in the image processing area build in camera. The result will then send to microcontroller by using Serial Peripheral Interface (SPI) or UART interface. The microcontroller will process the result and take action based on the program which is written in permanent memory (ROM) of microcontroller and send to the motor driver. The motor driver will turn the wheels to move forward, backward, turn left or right or pump around depends to the object located.

METHODOLOGY

This section will focus on design and build of COSBot. It design and build are based on hardware, software configuration and image processing on vision color optic sensor and also programming algorithm to detect the image object based on color signature.

Figure-1 shows the block diagram of the COSBot system. This robot hardware system includes of Arduino UNO as a microcontroller, camera Pixy CMUCam 5 as a color optic sensor, L298P Shield V1.2 as a motor driver, servomotor and Serial Peripheral Interface (SPI) cable. Meanwhile the Pixy Mon software is used for color signature configuration in image processing or vision system.

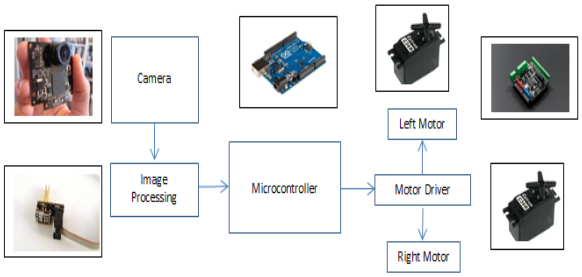


Figure-1. COSBot system block diagram.

Microcontroller type used in this system is Arduino microcontroller, which is an open-source computer hardware. This Arduino microcontroller system provide sets of digital and analog I/O pins that can be interfaced to various expansion boards ("shields") and other circuits. This boards features with serial communications interfaces and USB port for loading programs from personal computers. Arduino microcontrollers provides an integrated development environment (IDE) based on the processing project, which includes support for the C and C++ programming languages [9]. The first Arduino was introduced in 2005, aiming to provide an inexpensive and easy way for novices and professionals to create devices that interact with their environment using sensors and actuators.

The COSBot system supported with camera type of Pixy CMUcam5 as a vision sensor. This camera can program by only send the information you're looking for. The Pixy CMUCam5 also can exports its information in a variety of useful ways - UART serial, SPI, I2C, digital out, or analog out. The advantages of the Pixy CMUCam5 is it can remember seven different color signatures, find hundreds of objects at the same time, and is super fast - processing at 50 frames a second [10]. With Serial Peripheral Interface (SPI) pixy CMUcam5 can synchronous serial data used by microcontrollers for communicating with quickly over short distances.

Last but not less, motor driver L298P board are used in this system. This allows for motor control with Arduino right away. Stack up this shield on the microcontroller and possibly drive servomotors with higher power requirements. This L298P chip allows driving two 7-12V DC motors with maximum 2A current. This shield can be directly mounted onto standard Arduino microcontroller. Speed control is achieved through conventional PWM which can be obtained from Arduino's PWM output Pin 5 and 6. The enable/disable function of the motor control is signalled by Arduino Digital Pin 4 and 7 [11]. The Motor shield can be powered directly from Arduino or from external power source. But in this system the external power supply to power the motor shield are used. For betterment of the system a servomotor is used. This is because the servomotor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback.

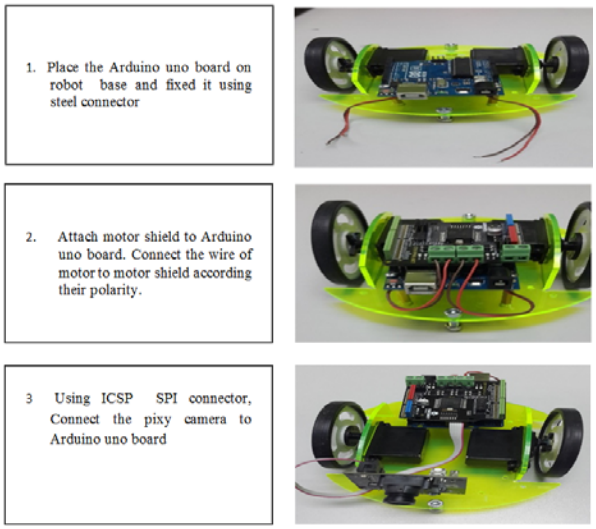
PixyMon is an software application as an image processing that allows to configure Pixy camera as see what it sees. It can runs on several different platforms including Windows. Details configuration of Pixy Mon in image processing will be discussed in the session below.

Hardware installation and pixy mon software setting

This section will be explained how the hardware and Image signature are setup. The hardware used in this system are pixy camera, Arduino uno board, motor shield, robot base, servo motor, 9v battery and power jack, ICSP SPI connector and cable as show in Figure-2.

Figure-2. Hardware used in COSBot system.

Figure-3 show step by step installation of hardware used in COSBot.



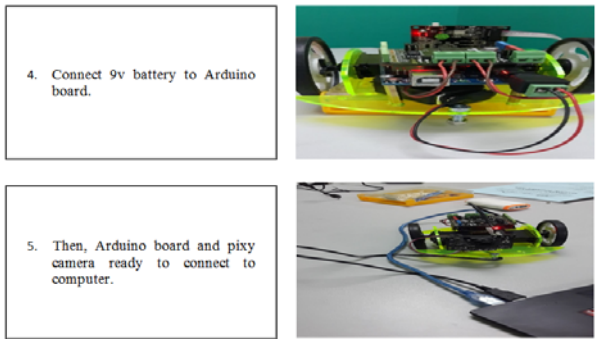


Figure-3. Step by step hardware installation.

After complete the hardware installation, next step of the building the system is fixed signature (image colour) setting using pixymon software and image detection algorithm programming using C++ programming. Combination of hardware, image signature and image detection algorithm, the system will be able to identify the image or colour as required by the vision system. Figure-4 shows the image signature setting using Pixy Mon application software.

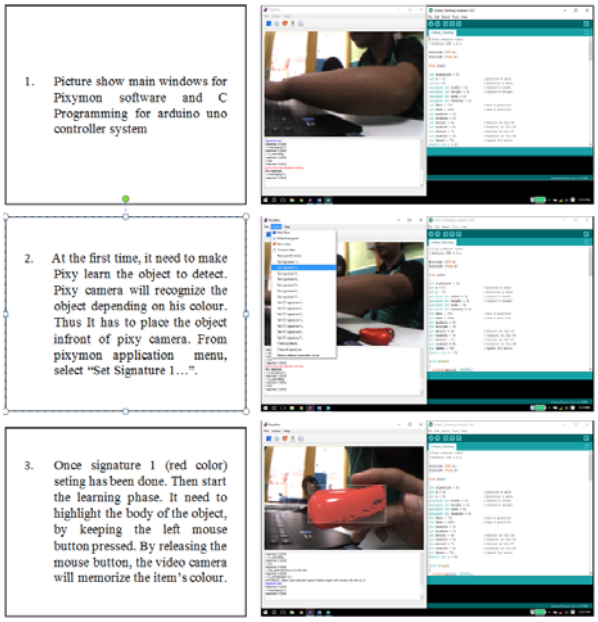


Figure-4. Image signature setting using pixy mon software.

Pixy Mon software is capable of memorizing up to seven different colors. For configure other colors, it need to train the pixy with different colors as well as setting signature number 2, 3, 4 and etc respectively. The advantage of the pixy video camera is it will keep the color in memory until they are deleted or overwritten. Thus disconnecting Pixy from the PC or from it power source will not cause the deletion of the learned items [12].

Planner based control architectures and programming algorithm flowchart for single image detection and processing

Control architecture provides the structure for the control of a system; it imposes constraints on the way a system should perform. There are several control architectures such as Planner-based, purely reactive, Hybrid and Behavior-based approaches [13]. However in COSBot system planner-based have been applied. This is because the model is used for the verification of sensory data, and generating actions based on the perception data. Figure-5 show the structure of a typical Planner-based system. The system is structured so that all processing, sensing, controlling and reasoning is performed centrally by Adruino uno microcontroller. This system is referred to as centralized intelligence.

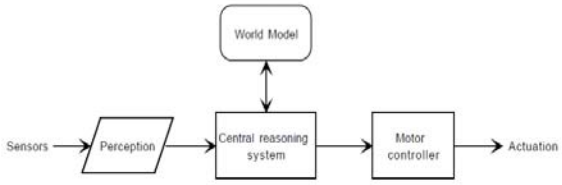


Figure-5. Planner based control architectures block diagram.

From planner-based architectures the algorithm flowchart programming are produced. Figure-6 show the programming algorithm to detect the image in COSBot Vision Mobile Robotic System. Robot will find the sensory data which is signature color (signature 1 - red) until success and action will be taken (move forward) to achieve the goal. Otherwise the robot will move around to left or right or backward until the robot identified the signature color (red). This algorithm can be updated to recognize two or more signature color until 7 colors as support by Pixy camera. This condition is happen in robot soccer challenge. For example first color with highest priority is the ball and the second color with the second priority is the goal. In this situation the game algorithm is to control the robot movement to achieve goal score. This will be based on the priority unless the robot will be loose and the game will be failed.

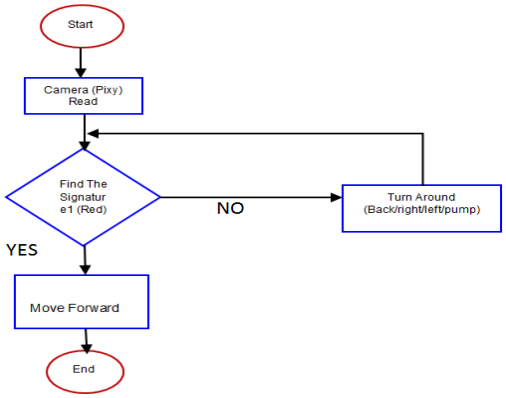


Figure-6. Algorithm flowchart programming.

Figure-7 shows coding in C++ programming for detect signature 1 and significant action will be taken when the test is match with the status of the image.

```
if(signature == 1)
{
newarea = width * height;
if (x < Xmin)
{
right();
}
else if (x > Xmax)
{
left();
}
else if(newarea < minArea)
{
backward();
}
else if(newarea > maxArea)
{
forward();
}
else
{
Stop();
}
}
else
{
Stop();
}
}
```

Figure-7. Coding in C programming for detect and image processing.

First of all, the robot will get the signature 1 (red color) and identified the size of the image (newarea). If the newarea is less then minimum size (Xmin) then robot will turn right. Otherwise the robot will check for second condition, if the newarea is more the maximum size (Xmax) then robot will turn left. This mean no image will match with the image detected (newarea). So the third condition will be tested, if newarea is less then MinArea then the robot move backward, otherwise the image (newarea) are detected and the robot move forward to get the object. This routine will be repeated until the robot system is shutdown. For more complex situation may be two or more object will be deteced. This routin should be modified and complex algorithm with priority should consider.

RESULTS AND DISCUSSION

In this section, preliminary results are presented. The experimental result of single image detection and processing will be highlighted and discussed. In addition the result of algorithm two images with priority are also presents.

Figure-8 shows the picture and video of COSBot under testing for single image color (red) detection respectively. It shows that the COSBot is successfully detect one tracking robot (red object) and move forward to the object as presents in Figure-8. In addition the speed of robot movement in a video is very pass as pass as movement of the object. These indicate that the algorithm used in programming is success to manipulate the data from vision system (camera) with the hardware system response in a real time especially for education purpose.

Figure-8a . COSBot detect single color.
Figure-8b. COSBot move to single image color.

Figure-8a show photo of COSBot Detect Single Color (red) and Figure-8b show foto of Video COSBot Move to Image Single Image Color (red)

Table-1 shows the result of algorithm two images with priority. The first priority is move forward (red color) and the second priority (green color) is turn left.

Table-1. Result of algorithm two images with priority.

TRIAL COMMAND	RESULT	NOTES
FORWARD	1	1st Priority
REVERSE	0	Ignore
LEFT	1	2nd Priority
STOP	1	Ending

In Table-1 with 2 objects are created in one condition. The condition is tracing the second priority after first priority object detected. When the object in first priority was detected then second priority object will be detected. This condition can be refer to how Robosot movement on 2 or more objects in one time.

CONCLUSIONS

The results discussed above indicated that VMRS with camera Pixy CMUCam 5 as a color optic sensor, Arduino UNO as a microcontroller, L298P Shield V1.2 as a motor driver, servomotor and Serial Peripheral Interface (SPI) cable optical sensor or camera were functioning as required. The speed response of hardware design in real time is reasonable and adequate to serves for education purpose as well as RoboSot challenge and lightweight industrial need. The most importantly, this project managed to success with using color optical sensor Pixy CMUcam5 as a main hardware component support with Arduino Uno as main controller as well as Pixymon application as a main image processing software and assisted by C++ programming as simple algorithm to manipulate the data and control the system. As a result this COSBot has potential to serves for education purpose as well as RoboSot challenge and commercialize for lightweight industrial with modification on the model and type of material used.

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