PENSHIP Autonomous Surface Vehicle

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Abstract— **PENSHIP is an autonomous ship designed by a team of EEPIS to join Roboboat 2013 competition in Virginia. PENSHIP has adopted catamaran hull with four motors. PENSHIP has an ability of moving omnidirectionally. In order to accomplish the missions regulated in the Roboboat 2013, PENSHIP is equipped with an algorithm established in an embedded system based computer and hardware. The team's main focus in this year (2013) is to develop computer vision, navigation, and electronic system.**

Keywords-penship, autonomous survace vehicle;roboboat, navigation

I. INTRODUCTION

PENSHIP is one of the competitors of Roboboat 2013 and this is the first time for PENSHIP to join the competition. Ahead of this competition, in the same kind of contest in national level, PENSHIP had been proclaimed to be the winner. The journey of PENSHIP from the preparation of national to international contest has experienced some changes. The biggest changes is on the design of hull and vision system.

The number of hull of PENSHIP's first generation in the national contest was four, as shown in figure 1(a). With this hull design, the ship was able to move forward, backward, left, and right. However, the speed was decreased by water. In the international contest, it was modified to utilize only two hulls as shown in figure 1(b). This change is aimed at decreasing the blocking of water toward the ship and adjusting to the missions of the competition. In the competition mission, the ship often to move forward rather than to the left so that the hull design of the second generation of this ship is optimum.

Figure 1.(a) Hull design of first generation PENSHIP, (b) New hull design of second generation PENSHIP

The vision system of PENSHIP in this national contest only utilized distance sensor. The utilization of distance sensor has been proven to be effective in accomplishing the missions in the national autonomous ship contest. In this contest, vision system of PENSHIP utilizes camera. Image processing has become the main effective weapon in accomplishing the missions. The chosen missions are sneaky sprinkler, and shoot through hoop task.

II. MECHANIC DESIGN

The ship is designed with the shape of multihull or catamaran, as shown in figure 2, to avoid water stability problem on water surface for both calm and wavy water[1]. Besides that, it is considered more effective to avoid crash with ball. Ball is passable through the narrow space between the hulls. The hulls and frame are made easy and fast to disassemble. The hulls of the second generation has dimension of 2m x 1m x 0.5 m of Styrofoam. Styrofoam has got high buoyancy. The payload loadable by this ship is as much as 8 kg. the ship hulls are dark painted to result in beautiful mixture with the lake water and avoid the possibility of vision system failure. The center gravity of the payload which lays on the ship is placed in the middle. The height of the ship is optimized by considering the size of the ball and wind swash that interfere the ship movement. The frame of ship has got light aluminum hull. The frame of ship design with strong hull and size precision do affect the ship movement. The frame of ship design is very simple. Four aluminum rods that assemble the main frame are used to join the two hulls. From this main frame, it is installed a boxes to store hardware and rocket launcher mechanics.

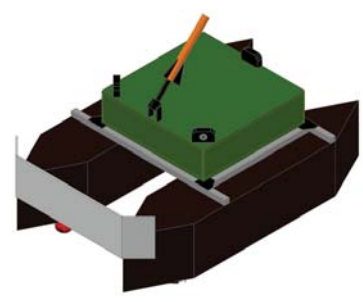

Figure 2. PENSHIP 3D design

In the front area of the ship is installed aluminum plat that functions to accomplish sneaky sprinkler task. The plat is designed wide enough to push the button. To accomplish the second mission, that is shoot through hoop, the rocket launcher is installed on the surface of the hardware. The rocket is launched by blowing with high pressure air. The mechanism of the rocker blow involves pneumatic wares.

In the hull, it is installed four thruster motors with each elevation 45 degree as shown in figure 3. This is on purpose that the ship can move omnidirectionally, or free to move to all directions. Therefore, this will be much easier for the ship to maneuver pushing the push button or launch the rocket to right aimed target.

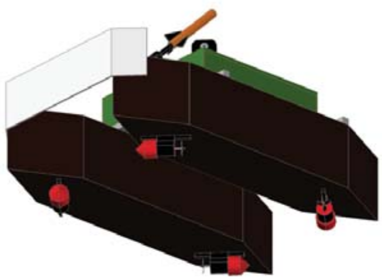

Figure 3. Motors placement of PENSHIP

The control algorithm is given more attention over the ship design. With good control algorithm, the ship movements are controllable easily.

III. HARDWARE PLATFORM

A. Main Control Board

The electronic system of PENSHIP is based on AVR Microcontroller Embedded System. It consists of two main parts; master microcontroller and slave microcontroller, as shown in figure 4.

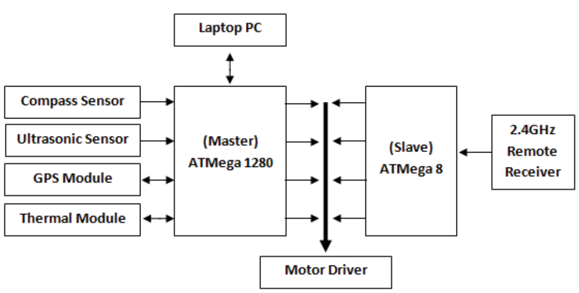

Figure 4. Block diagram of main control board

ATMega 1280, as master microcontroller, functions to runs command from the sensor or from PC and ATTiny 2313, as the slave microcontroller, controls the ship manually though remote control. When the remote control is not activated, the master microcontroller will work on controlling the ship, while the slave microcontroller is reading the signal from the receiver continuously. If the remote control is activated, the master microcontroller will be inactivated by the slave controller. Furthermore, the slave controller will control the channel of PWM motor based on the instruction from the remote control. By utilizing two microcontroller that works separately, the ship can be controlled manually in case that there trouble with the automatic system.

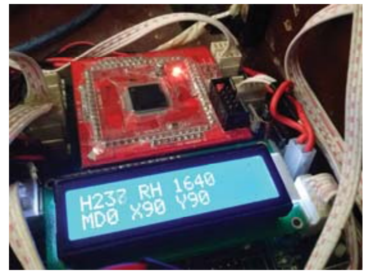

Figure 5. PENSHIP main control board

The communication between microcontroller and the module (GPS, Thermal, and PC) is using UART communication with baudrate 9600. However, the communication with PC is using baudrate 57600 bps. Selecting that baudrate is to reduce the load of master controller when executing the interruption. For the further development, it will be used microcontroller with clockspeed and bigger processing capacity to increase the performance of the ship's hardware system.

B. Data Communication Platform

PC and microcontroller communicate using UART. The data transmitted is shown in figure 6. The Data transmitted from PC is in form of command to move the ship while PC receives sensor data form the microcontroller. It is planted a simple artificial intelligence into the ship that generate decisions where the ship must go or move.

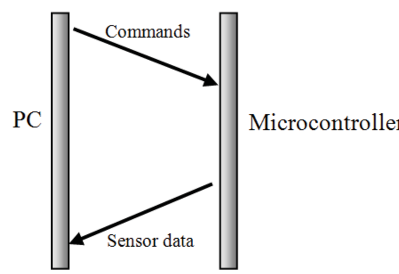

Figure 6. Data communication between PC and microcontroller

Considering the large amount of information sent and received in and out of the microcontroller, data packet is sent in form of ASCII which is then reparsed to take the needed data. The communication protocol built in the hardware system is divided into two kinds, they are:

- Data communication from microcontroller to PC.

  Data packet sent from microcontroller to PC is shown in figure 7.

!,[heading],[ultrasonic1],[ultrasonic2],[ultrasonic3],[ultrasonic4],[longitude],[lattitude],[push_button],[thermal_sensor],\n

Figure 7. Format of data packet sent from microcontroller to PC

- Data communication from PC to microcontroller

  Data packet sent from PC to microcontroller is shown in figure 8.

@,[mode],[setpoint],[power],[buzzer],[Digital_Out],\n

Figure 8. Format of data packet sent from PC to microcontroller

The serial data parsing in both microcontroller and PC is equipped with an algorithm of data checking to ensure that the received and processed data is not misconfigured or corrupted.

C. Hardware Box

The hardware box of PENSHIP covers all microcontroller needed by the ship, ranging from battery, microcontroller board, and PC laptop. Hardware box is designed water proof and efficient toward the need of wares room inside so that it will not increase load wholly. On the side of the box, it is utilized ventilation to avoid overheating on the driver motor and PC. The hardware box is positioned lower to reduce the effect of wind swash.

D. Sensor

To accomplish missions in the Roboboat 2013 contest, PENSHIP is equipped with some additional sensor including compass, ultrasonic, thermal, and camera.

- Compass Sensor (CMPS10)

  Ideally, in robotic navigation that use IMU (Inertial Measurement Unit) sensor in determining orientation and direction, PENSHIP is using compass sensor as to determine the ship orientation because it considers the existence of another additional system that is image processing. With the same price, compass sensor is more powerful in resulting and determining the orientation angle.

- Thermal Module Sensor

  Generally, heat detector application with precision and detail uses thermal camera. The price of thermal camera is considered very expensive, even for small resolution. Consequently, another alternative utilizable is non-contact thermometer sensor which is based on infrared emission measurement from the heat of an object. By moving the infrared thermometer sensor on two axis using pan-tilt servo, the sensor is able to detect the difference of temperature and recognize the angle of the heat source.

- Ultrasonic Sensor

  Ultrasonic sensor is used to detect obstacles in front of the ship or in the side of the ship. Although it is not as effective as when using LIDAR that is relatively much expensive, the result of the detection of ultrasonic is considered sufficient in this application. Ultrasonic sensor is also used to detect gate.

IV. CONTROL SISTEM AND IMAGE PROCESSING

A. Control Method

The basic control method used in PENSHIP is conventional PID method as shown in figure 9. Conventional PID method is able to provide good response in controlling the heading of the ship. The implementation of conventional PID method does not require high computation system[2]. Therefore, it is implementable in hardwares based on embedded system in the PENSHIP.

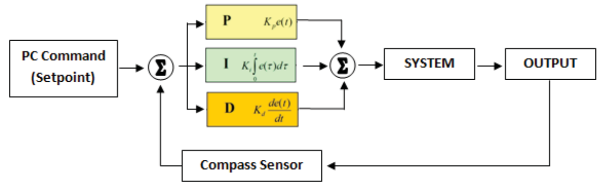

Figure 9. PID control of PENSHIP

PID control system receives input in form of heading set point command form PC. Furthermore, the value of the ship heading that is captured from the compass sensor is compared to the set point. Then, the error value will be captured. This error value is then need to be fixed by the PID control system so that the ship heading correspond with what is instructed by PC.

In some experimentations that have been done, control *I* holds an important role considering that the characteristic or response of DC motor that is often adjusted. With the combination of control *P* and *I* it is obtained better stability. In the further developer, PID control will be used totally to increase stability of the ship in keeping the heading both in the condition of steady state and transient with fast response [3].

There are four types of control PID in four movement modes, they are forward, shift right, backward and left motion. The technique of controlling motor of the four modes of movement is shown in table 1.

TABLE 1. MOTION CONTROL TECHNIC OF PENSHIP

MODE	FUNCTION	MOTOR CONDITION			
		FL	FR	BL	BR
1	Forward	*Cont	*Cont	OFF	OFF
2	Shift Right	*Cont	OFF	*Cont	OFF
3	Backward	OFF	OFF	*Cont	*Cont
4	Shift Left	OFF	*Cont	OFF	*Cont

*Cont : Controlled
FL : Front Left Motor
FR : Front Right Motor
BL : Back Left Motor
BR : Back Right Motor

Controller PID with sampling rate 50Hz adjustment, it is obtained a responsive output toward external disturbance as shown in figure 10.

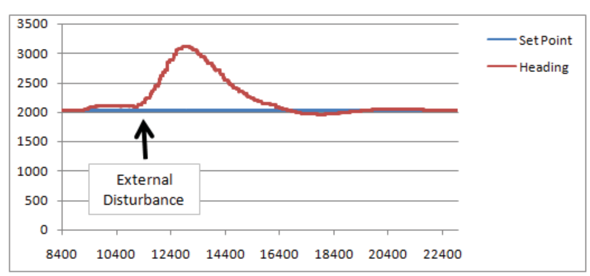

Figure 10. PID controller experiment result

B. Software Management

The software configuration of PENSHIP consists of some important part like shown in figure 11.

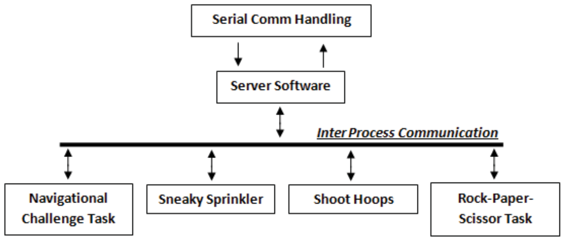

Figure 11. Process of software management for PENSHIP

To make it easy in developing the software in the future, it is designed a software that runs autonomously doing it's jobs specifically. The software exchanges information both data and flag through File Mapping IPC (Inter Process Communication). File Mapping method is used because the method doesn't behave like FIFO does (first in First Out) so that value of the captured variable does not lose. Figure 12 shows one of program debugs of the software configuration result.

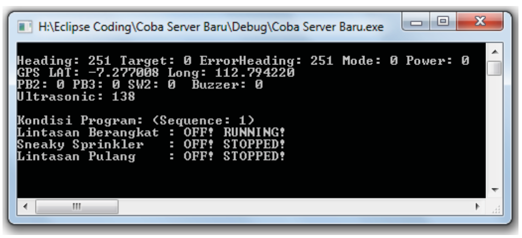

Figure 12. Debug of software management for PENSHIP

A main software, that is a server responsible of the main and basic functions that communicate with microcontroller through serial port and control any software that is permitted to run at the time. Therefore, the software is able to run synchronically and respectively.

C. Gate Detection Algorithm

PENSHIP has got a simple algorithm to detect gate like shown in figure 13. Initially, it thresholds the image based on certain range for the needed color segmentation. The kind of color used is Hue, Saturation, and value (HSV) because they are effective to differentiate among colors compared to the other kinds of color[4]. This is because HSV is more sensitive in detecting colors in the camera input which its light intensity changes. The result is object in green and red depending on the threshold range. The output is stored in the matric which is then changed into contour and measured the height and the width using aproxypoly. Only objects with more height and more width that are considered as gate. The other objects are only considered as noise and will not be processed.

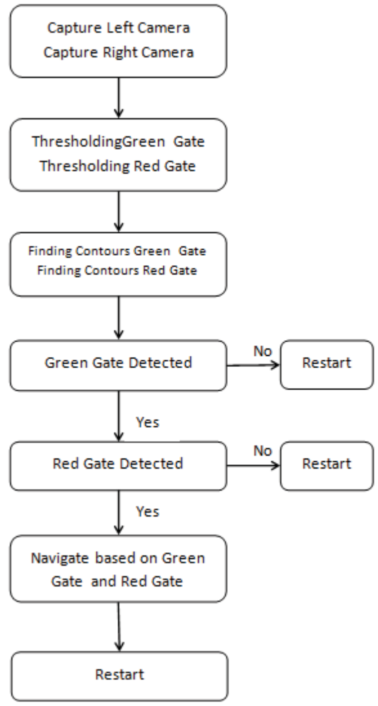

Figure 13. Gate detection algorithm of PENSHIP

D. Ball Detection Algorithm

PENSHIP utilizes simple algorithm to detect ball like shown in figure 14.

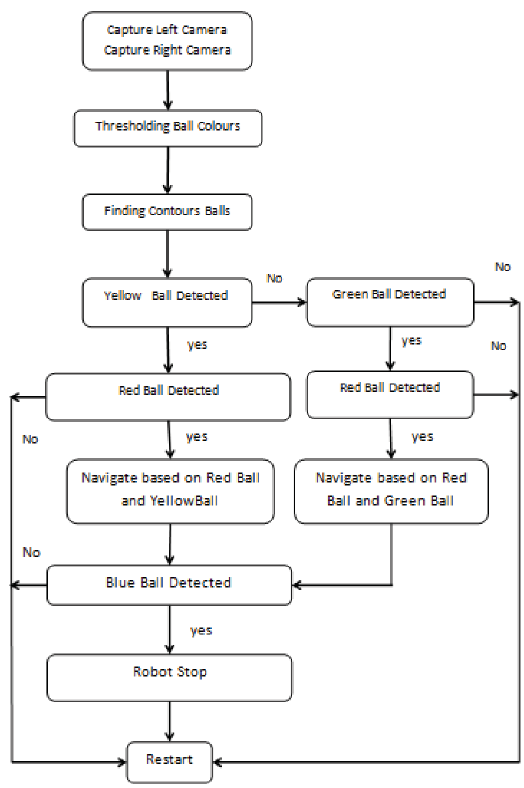

Figure 14. Ball detection algorithm of PENSHIP

To detect balls, the algorithm used is almost the same as the algorithm to detect gate. The difference is on the object. Object with certain diameter will be considered as ball, while the other object will be considered as noise and will not be processed.

E. Navigation Challenge Task

One of missions that can be accomplished by PENSHIP is navigation challenge task in which the ship can follow the determined track. The track is limited by red and green ball but there is obstruction that is yellow ball. Figure 15 shows the appearance of PENSHIP vision when navigating following the track.

Figure 15. Vision view of PENSHIP to follow the ball track

PENSHIP will move through between the two balls when detecting red ball with green ball or red ball with yellow ball. If there is only one ball detected, PENSHIP will move further straight according to the heading compass. Additionally, when detecting blue ball, the ship will stop for a while and ready to continue the next mission.

F. Sneaky Sprinkler Task

Another mission that has become the target of PENSHIP is sneaky sprinkler task. The ship will locate the position of the button and push the button precisely like what is shown in figure 16.

Figure 16. Vision view of PENSHIP to detect button

After the blue ball is detected, the first mission to be accomplished is Sneaky Sprinkler. If the distance between object and camera is considered still far, the object to find first is the black box. Whereas, if the object is already closer to the camera, the object to be found is circular object in red.

V. DISCUSSION

This year, we began with a goal to design a that can accomplish the Roboboat 2013 mission. We try to find the best hull and vision system. Difficulties encountered is how the ship is able to adapt to changing outdor light. Image processing parameter settings should always be changed according to changes in outdor light.

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