The DIPO-BOAT - Autonomous Surface Vehicle Journal Paper (Diponegoro University Roboboat Team)

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Abstract: Dipo-Boat 1.1 is boat that designed by RoboBoat Team from Diponegoro University. This boat using autonomous system to compete in the anual competition in the Virginia Beach by Assosiation Unmanned Vehicle Systems International (AUVSI) 2012. DiBoat 1.1 uses responsive doublehull mechanism with a thrust motor and a rudder tube and an integrated system for the controller, sensors, and electronic component.

1. Introduction

Autonomous vehicle have purpose to help human. The Autonomous Surface Vehicle (ASV) have main goal to build a autonomous watercraft robot . This ASV project is for international competition in Virginia Beach. This ASV project or DiBoat 1.1 uses a boat that have two hulls. Controller, various sensor and programs of DiBoat 1.1 to make this boat can navigate in autonomous. Additionaly, it possesses a radio control backup system in case the vehicle become lost, allowing it to be manually controlled back to base port.

2. Detailed Design Description

2.1 Background Design

Kapuas river which divides pontianak still be the largest illegal timber smuggling routes in Indonesia. Each year billions of dollars due to the aggrieved government illegal logging case is. Pontianak is separated by Kapoeas Large, Small and Kapuas River Porcupine River with a width = 400 m, water depth between 12 s / d of 16 meters, while its branches have a width of 250 meters. Thus the city of Pontianak is divided into three parts. (http://pontianakkite.blogspot.com/2012_04_01_archive.html).

Therefore, one way to reduce illegal logging in khasus smuggled through Kapuas river, boats are made in reconnaissance to locate and wood smuggling points that are difficult to reach by land kendaranan by the police. Ship used in this ahun roboboat created a replica of the ship for ship surveillance in the river basin scale Kalimantan with 1: 10.

By knowing the geographic data of the river - the river on the island of Borneo, especially in London, then on to the ship's main dimensions are as follows:

Main dimentions	:		
Length Over All (LOA)	: 12,00 m	Koefisien Blok (Cb)	: 0,2
Load Water Line (LWL)	: 10,66 m		
Breath (B)	: 4,99m		
Hight (H)	: 1,7 m		
Draft (T)	: 0,8 m		

Existing data on the molded catamarans, with respect to plan lines, hydrostatic curves, stability, and hambata ship as follows:

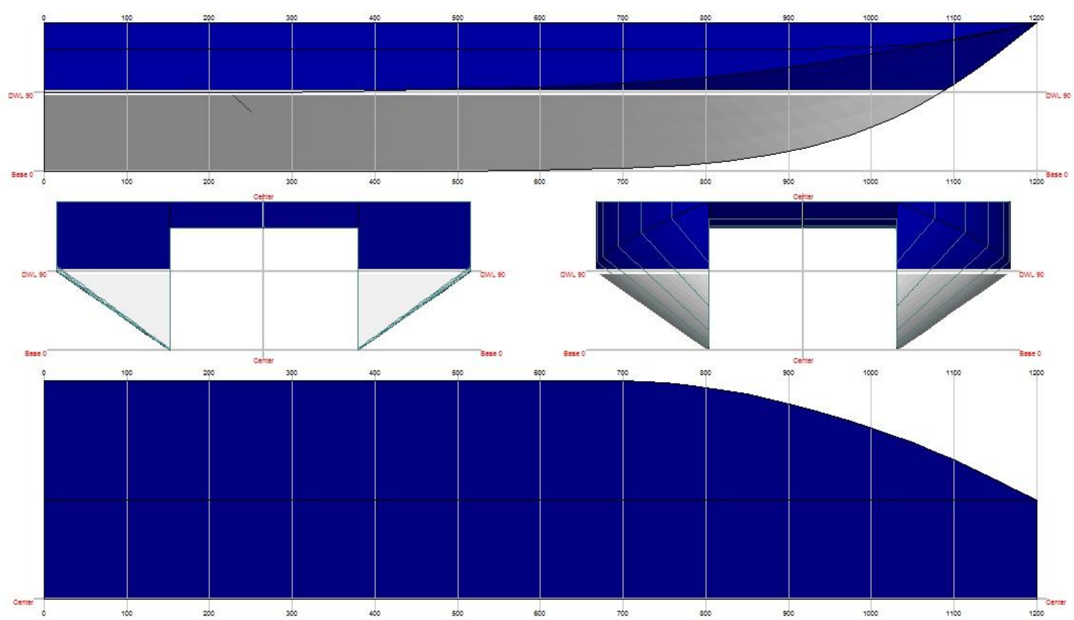
DESIGN HARDWARE

2.1.1 Lines plan

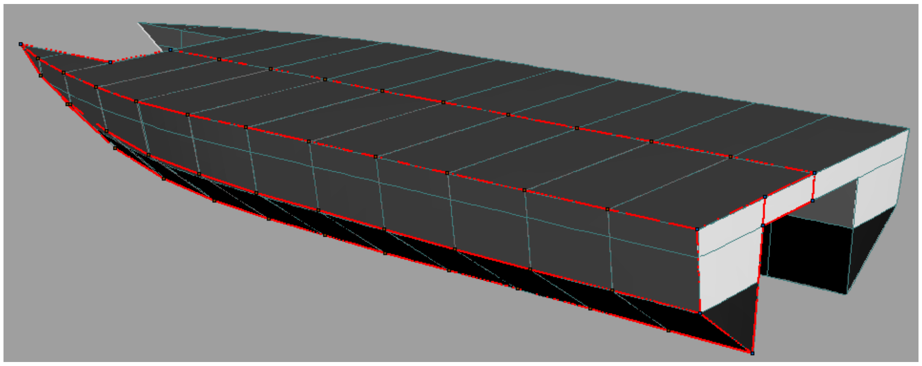
Design and determination of the ship's main dimensions of this comparison method, by comparing the size of the existing field and adjusted to the required size.

Lines plan of this vessel are as follows:

Volume properties		Waterplane properties	
Displaced volume	8.044 *m3*	Length on waterline	10.657 *m*
Displacement	8.044 *tonnes*	Beam on waterline	4.699 *m*
Total length of submerged body	10.657 *m*	Waterplane area	21.191 *m^2*
Total beam of submerged body	4.699 *m*	Waterplane area	21.191 *m^2*
Block coefficient	0.2008	Waterplane coefficient	0.4231
Prismatic coefficient	0.8550	Waterplane center of floatation	4.514 *m*
Vert. prismatic coefficient	0.4745	Entrance angle	0.000 *Degr.*
Wetted surface area	42.045 *m^2*	Transverse moment of inertia	62.265 *m^4*
Longitudinal center of buoyancy	4.283 *m*	Longitudinal moment of inertia	157.68 *m^4*
Longitudinal center of buoyancy	-16.114 *%*		
Vertical center of buoyancy	0.543 *m*		

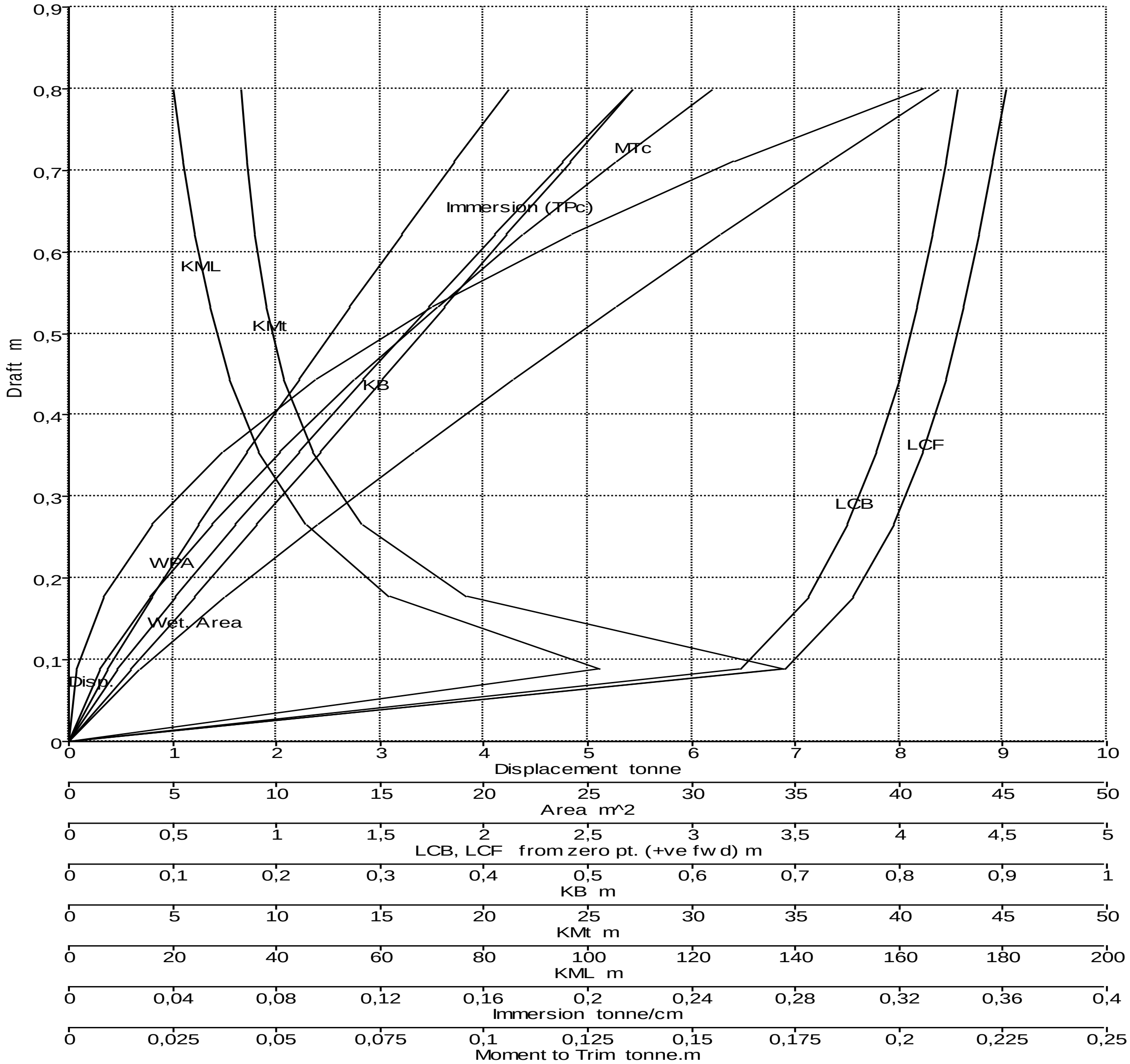


Perispective view :



2.1.2 Hydrostatic curves

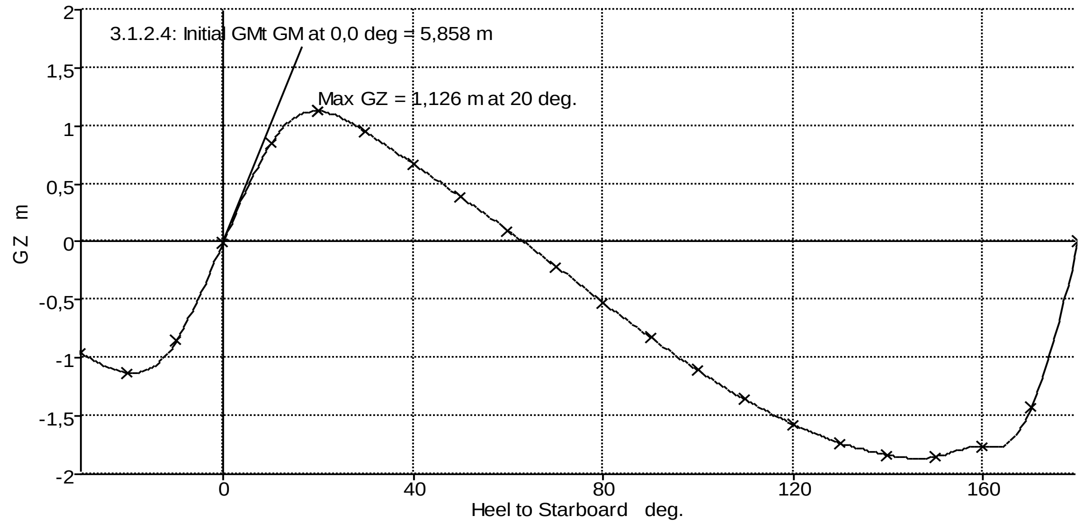
Hydrostatic curves are curves that show the characteristics of a submerged bilge water. Including the following:



Draft Amidsh. m	0,000	0,089	0,178	0,267	0,356	0,444	0,533	0,622	0,711	0,800
Displacement tonne	0,0000	0,0777	0,3408	0,8069	1,485	2,382	3,502	4,849	6,427	8,239
Heel to Starboard degrees	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Draft at FP m	0,000	0,089	0,178	0,267	0,356	0,444	0,533	0,622	0,711	0,800
Draft at AP m	0,000	0,089	0,178	0,267	0,356	0,444	0,533	0,622	0,711	0,800
Draft at LCF m	0,000	0,089	0,178	0,267	0,356	0,444	0,533	0,622	0,711	0,800
Trim (+ve by stern) m	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
WL Length m	4,063	7,933	8,698	9,178	9,540	9,830	10,082	10,295	10,486	10,660
WL Beam m	0,000	2,538	2,809	3,079	3,349	3,619	3,890	4,160	4,430	4,699
Wetted Area m^2	0,000	3,438	7,578	12,014	16,657	21,465	26,413	31,481	36,661	41,941
Waterpl. Area m^2	0,000	1,820	3,978	6,262	8,629	11,055	13,530	16,044	18,593	21,171
Prismatic Coeff.	0,000	0,796	0,796	0,793	0,790	0,787	0,784	0,781	0,778	0,775
Block Coeff.	0,000	0,398	0,398	0,397	0,395	0,394	0,392	0,390	0,389	0,388
Midship Area Coeff.	0,000	0,500	0,500	0,500	0,500	0,500	0,500	0,500	0,500	0,500
Waterpl. Area Coeff.	0,000	0,849	0,846	0,842	0,837	0,832	0,828	0,824	0,820	0,817
LCB from zero pt. (+ve fwd) m	0,000	3,237	3,562	3,755	3,892	3,998	4,085	4,159	4,224	4,281
LCF from zero pt. (+ve fwd) m	0,000	3,449	3,781	3,975	4,114	4,222	4,310	4,386	4,451	4,510
KB m	0,000	0,061	0,121	0,181	0,242	0,302	0,362	0,422	0,483	0,543
KG m	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
BMt m	0,000	34,356	18,985	13,934	11,469	10,036	9,119	8,497	8,057	7,739
BML m	0,000	102,037	61,433	45,277	36,387	30,689	26,698	23,724	21,421	19,576
GMt m	0,000	34,416	19,106	14,115	11,711	10,338	9,482	8,919	8,540	8,282
GML m	0,000	102,097	61,554	45,458	36,628	30,991	27,060	24,146	21,903	20,118
KMt m	0,000	34,416	19,106	14,115	11,711	10,338	9,482	8,919	8,540	8,282
KML m	0,000	102,097	61,554	45,458	36,628	30,991	27,060	24,146	21,903	20,118
Immersion (TPc) tonne/cm	0,000	0,019	0,041	0,064	0,088	0,113	0,139	0,164	0,191	0,217
MTc tonne.m	0,000	0,007	0,020	0,034	0,051	0,069	0,089	0,110	0,132	0,155
RM at 1deg = GMt.Disp.sin(1) tonne.m	0,000	0,047	0,114	0,199	0,304	0,430	0,579	0,755	0,958	1,191
Max deck inclination deg	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Trim angle (+ve by stern) deg	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

2.1.3 Stability

Stability is the ability of an object to float or float back to its original position after a force from outside influences. This ship stability calculations using the standard IMO A. 749 (18) ch 3, with the maximum stability Arm (GZ max) is 1.126 meters, the maximum stability occurs at arm tilt angle of 20 °

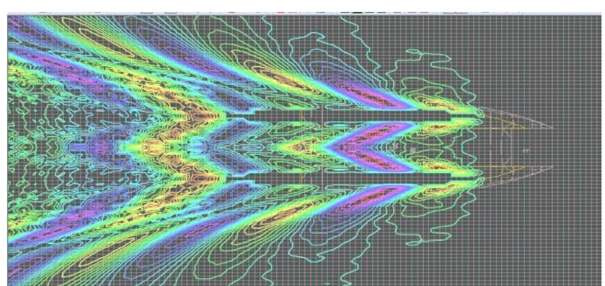


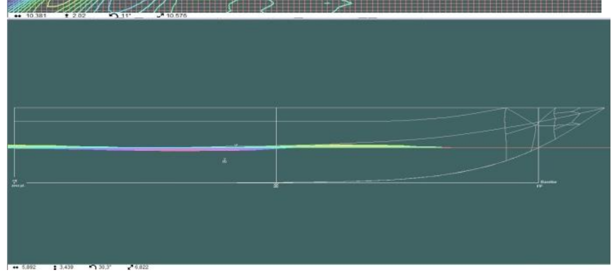
2.1.4 Resistance

The method used for this analysis is a slender body, by knowing the resistance vessels, we can know the power that is used in order to meet the desired speed

Speed (kts)	Slender body Resist. (N)	Slender body Power (W)
0	--	--
0.5	6.76	2.05
1	84.84	51.35
1.5	206.68	187.64
2	314.61	380.82
2.5	408.29	617.78
3	487.72	885.54
3.5	575.51	1219.11
4	641.31	1552.55
4.5	729.87	1987.82
5	838	2535.92
5.5	899.61	2994.59
6	957.73	3477.87
6.5	1063.77	4184.87
7	1206.22	5110.27
7.5	1362.03	6182.54
8	1517.13	7345.68
8.5	1669.03	8586.24
9	1819	9908.18
9.5	1969.05	11321.41
10	2121.45	12839.63
10.5	2277.19	14471.32
11	2438.57	16234.82
11.5	2606.04	18138.37
12	2779.06	20183.64
12.5	2958.88	22385.02
13	3144.82	24743.4
13.5	3336.69	27262.68
14	3535.98	29961.06
14.5	3740.59	32826.77
15	3951.48	35873.25

32	15.5	4170.12	39120.09
33	16	4392.98	42540.15
34	16.5	4622.06	46157.14
35	17	4858.82	49991.87
36	17.5	5099.32	54009.45
37	18	5346.81	58248.74
38	18.5	5600.04	62702.11
39	19	5859.59	67381.48
40	19.5	6124.59	72282.12
41	20	6393.35	77388.78





3. Electrical and Electronic

3.1 Electrical and Electronic Subsystem

According to the last year design we make an improvement, in software and hardware. But the improvement still make the system simple and powerfull. Because with simple system we avoid the error caused by complexity algorithm. Just make a effective and efficient design.

Here is the overall electrical design:

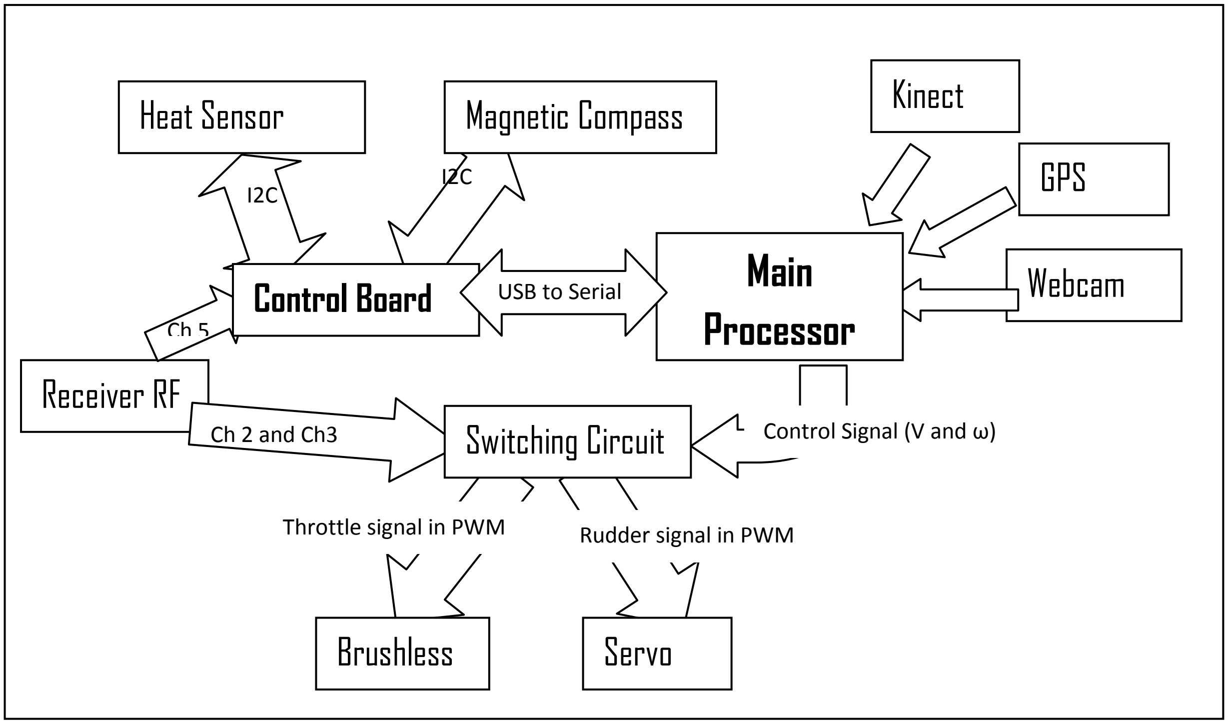


Figure Overall Electrical Design

The laptop Compaq with processor intel Core 2 duo and 2 Gb of RAM has been chosen as the main processor. The main processor will calculate the data of camera and kinect to get buoys position and convert it to the control signal throttle and rudder. The control signal will be transferred to the control board (8 bit microcontroller ATMega8535) through 8 bit data serial communication. The main processor also have to finished the TCP/IP task by using the internal wireless module, acquired GPS data and get the heat data.

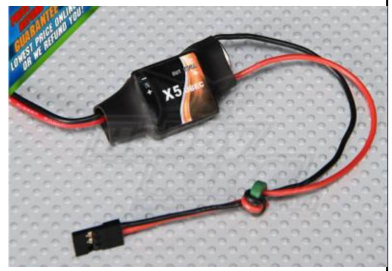
3.2 Power Distribution System

Two Lipoly Battery use for this robot. Turnigy Nanotech 3S use as the supply voltage of the brushless and Turnigy Nanotech 2S use as the supply voltage of the others. 5 A UBEC use as a regulator of 2S Lipoly so the electrical system can get well regulated 5 volt supply voltage.

We use separate supply voltage to avoid the error caused by lack of voltage. The brushless motor itself can drain the battery rapidly. So, if we joint the voltage source, it will be used up rapidly and will be lack of energy in controller series which is cause controller series become error.

5 V 5A UBEC 2-5S Lipoly

Input: **6V-23V (2-5S Lipoly, 2-6S Li-Fe or 5-15S NiXX Battery Pack)**
Output: **5V/5A (Less than 50mV peak to peak voltage @ 2A)**
Dimension: **44.6mm x 14.3mm x 20.4mm(LxWxH)**
Weight: **11g (wires included)**



Lipoly Turnigy Nano tech 3S 2200 mAh
Capacity: 2200mAh
Voltage: 3S1P / 3 Cell / 11.1V
Discharge: 25C Constant / 50C Burst
Weight: 187g
(including wire, plug & case)
Dimensions: 106x35x24mm
Balance Plug: JST-XH
Discharge Plug: XT60

3.3 Sensory Subsystem

3.3.1 Main Camera (Webcam Logitech)

We used webcam Logitech C270 as our main vision sensor, which uses the RGB color space for data output. The Logitech C270 is capable of 3 mega-pixel resolutions for video output. The camera resolution is scaled down to 640x480 pixels to enhance processing speed and reduce computational power requirements. The resolution of the camera controls the amount of video frames per second that can be processed. Since pixels are processed in a matrix form, the more pixels, the longer processing time required for each frame.

Logitech C270 camera is used for object detecting from its colour. This colour filtering have purpose to differ the buoy colour and it's used for navigation system in the primary mission. And also we used the camera to playing card recognizing.

For the colour detection algorithm we used Euclidean algorithm because it is the simplest and powerfull algorithm. Also we use some modified vision algorithm that was taken from Visual Odometry paper to optimize the object detection algorithm. For the card recognizing algorithm, we use template matching class as a cluster and color segmentation as a color clustering . By using Visual Studio 2010 from Microsoft, all of the visual task is done. This design uses reference from AForge.Net.

The camera is placed paralelly with the boat so the field of view can be optimal

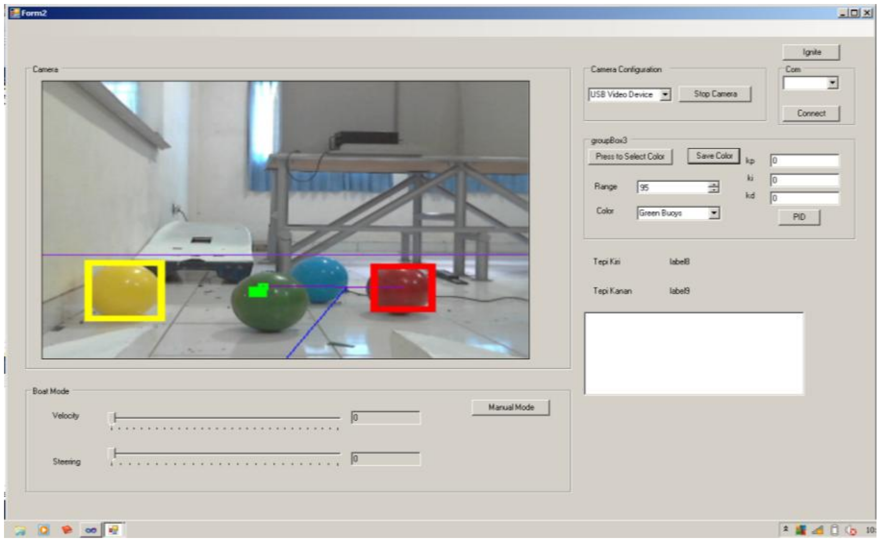


Figure Buoys Colour Detection

3.4 Second Camera (Kinect Sensor)

Kinect device is the controller of the Xbox 360 that makes the user able to use their body as the controller of the game. The main component of kinect sensor are RGB camera, Multi Array Depth Sensor,microphone, tilt motor and three axis accelerometer.

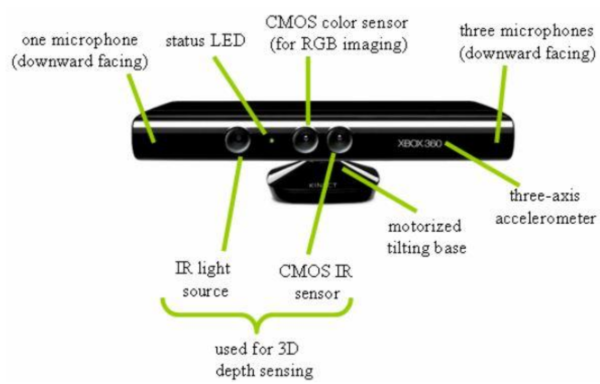


Figure Kinect Sensor

We use Visual Studio 2010 and Microsoft Kinect SDK 1.0 as the development program and some library such as Coding4Fun Kinect Toolkit, Aforge.Net.

Kinect is placed in front of the ship because the visibility of the camera is only 8 feet, and only capable of detecting the depth of the image at a distance of less than 4 meters. We use the spike and edge detection algorithms. First we determine the minimum and maximum line of depth image to be scanned. After found the distance of each pixel, we compare with the previous pixel. If the result is negative, it will be considered as the left edge, if the result is positive, it will be considered as the right edge, of course the result must more than 500 of threshold.

Kinect becomes the second sensor for determine the buoys position. Data from the kinect will complement the camera data. So it can increase accuracy of the buoys position data.

3.5 TPA 81

The TPA81 is a thermopile array detecting infra-red in the 2um-22um range. This is the wavelength of radiant heat. The Pyro-electric sensors that are used commonly in burglar alarms and to switch on outside lights, detect infra-red in the same waveband. These Pyro-electric sensors can only detect a change in heat levels though – hence they are movement detectors. Although useful in robotics, their applications are limited as they are unable to detect and measure the temperature of a static heat source. Another type of sensor is the thermopile array. These are used in non-contact infra-red thermometers. They have a very wide detection angle or field of view (FOV) of around 100° and need either shrouding or a lens or commonly both to get a more useful FOV of around 12°. Some have a built in lens. More recently sensors with an array of thermopiles, built in electronics and a silicon lens have become available. This is the type used in the TPA81. It has a array of eight thermopiles arranged in a row. The TPA81 can measure the temperature of 8 adjacent points simultaneously. The TPA81 can also control a servo to pan the module and build up a thermal image. The TPA81 can detect a candle flame at a range 2 metres (6ft) and is unaffected by ambient light.

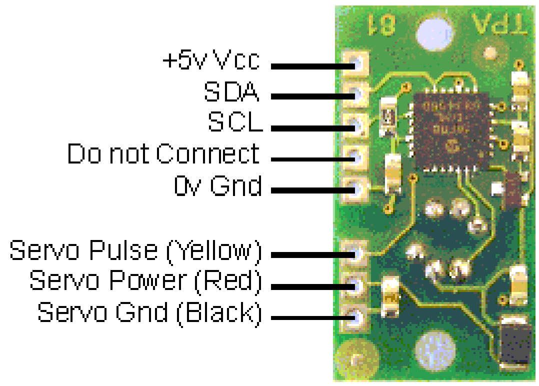


Figure TPA Sensor

The response of TPA81 is typically 2um-22um and is shown below:

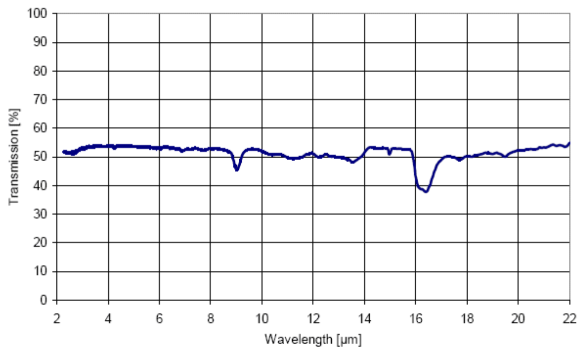


Figure TPA Response

3.6 CMPS03

The magnetic compass needed to aid the navigation of the robot. In this case we used CMPS03 because it’s easy to purchase and easy to use.

The specification of CMPS03 is shown below:

a. Supply voltage : 5 VDC
b. Current consumption : 15 mA
c. Interface : I2C or PWM
d. Accuracy : 3-4 degree
e. Resolution : 0,1 degree
f. Time conversion : 40 ms or 33,3 ms can be choosen by changing the register.

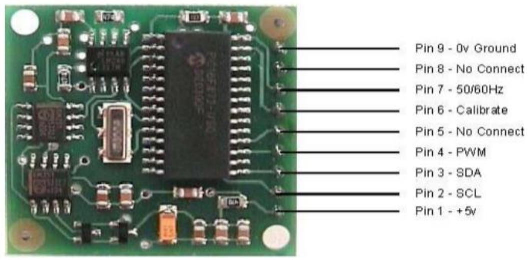


Figure Devantech Magnetic Compass

3.7 GPS PMB 648

Figure GPS Parallax PMB 648

The PMB-648 GPS module provides high performance with a SiRFstarIII chipset and integrated patch antenna. See our GPS Comparison Chart to evaluate this model side-by-side with the very similar PMB-688.

The PMB-648 GPS features 20 parallel satellite-tracking channels for fast acquisition of NMEA0183 v2.2 data for robotics navigation, telemetry, or experimentation. There is a built-in patch antenna; rechargeable battery for memory and RTC backup; cable for power, TTL and RS-232 connections.

Features:

- High sensitivity
- SiRFstarIII chipset
- 20 parallel satellite-tracking channels for fast acquisition and reacquisition
- Built-in rechargeable battery for memory and RTC backup
- Supports NMEA0183 V2.2 data protocol
- Includes cable for power, TTL and RS-232 connections

Key Specifications:

- Power requirements: 3.3V - 5V DC @ 65mA
- Communications: TTL or RS-232 asynchronous serial @ 4800 bps
- Dimensions: 1.25 x 1.25 x .35 in (32 x 32 x 9 mm)
- Operating temp range: -4 to +158 °F (-20 to +70 °C)

4 . Mechanical Transmission

Here, all of the governing equations and vectors are expressed in the Inertial Reference System (IRS) and for a Control Volume (CV) moving with an arbitrary speed of *m uv* . In order to capture the interface between two phases, a transport equation is implemented (Volume of Fluid-VoF Method) [2]:

$$\frac{d}{dt}\int_V \alpha \, dV + \int_A \alpha \vec{c} . \vec{n} \, dA = 0$$

This design of Catamaran is researched and developed, because have more advantageus :

1. Shear Resistant of this catamaran is smaller because have value block Coeficient 0,38 and the bow of the boat needing a sharp entry point to move the rest of the hull through the water.
2. This Catamaran is classified as high craft boat.
3. 0,5 meters for the hull widht was chosen because increased of freeboard.
4. Space of deck catamaran more widht than monohull, so the location of equipment easily.

Fig.4.1 Brushless DC Motor

The chosen of propulsion is used Azimut of propeller.

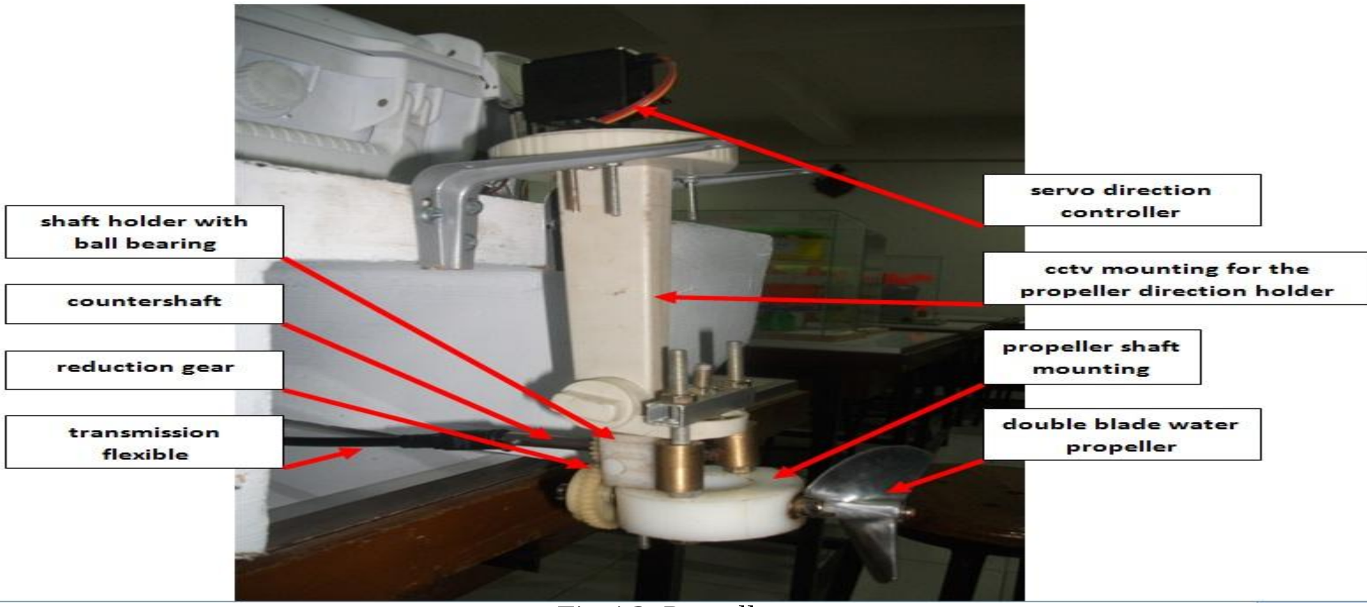


Fig.4.2 Propeller

Conclusions

Dipo-Boat 1.1 is autonomous surface vehicle designed and manufactured by Engineering students at Diponegoro University which assembled from various department such us, Naval Architecture, Electrical Engineering, Computer System Engineering and Mechanical Engineering. Despite this competition having various challenge, we will to be completed to have a fully autonomous boat.

We have been tried to coporated each system, hull design, propulsion system, rudder system, vision and compass. We developed a product that will be reasonably competitive in this year's ASV competition. The Dipo-Boat 1.1 team is presently continuing to develop the capabilities of the system in the lead up to the 2012 competition and hope can provide great benefits, especially in the field of Autonomous Surface Vehicle.

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