Isfahan University of Technology

Under Water Robotic Team

Project :

DENA

6th Annual International Student ROV Competition

Celebrating the International Polar Year: Science & Technology Under the Ice

Team Members

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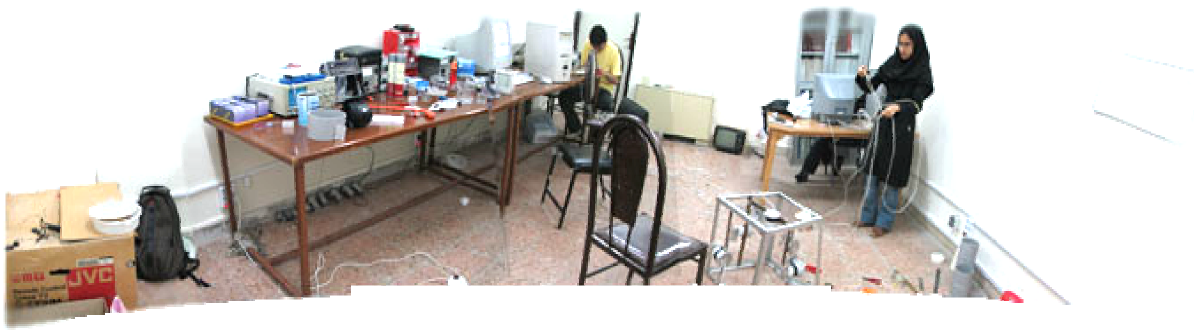
Abstract:

The Underwater Robotic team has been established since last year by a group of senior electrical and mechanical students of Isfahan University of Technology. The goal of the team is to highlight the importance of marine environment and related technologies. Our ultimate concern is to design a fully automatic vehicle (known as AUV). To begin, we decided to design and build a general purpose ROV as our first experience, and when the team was accepted as a participant in the MATE competitions, we focused on the competition missions and adapt our robot to the missions' circumstances.



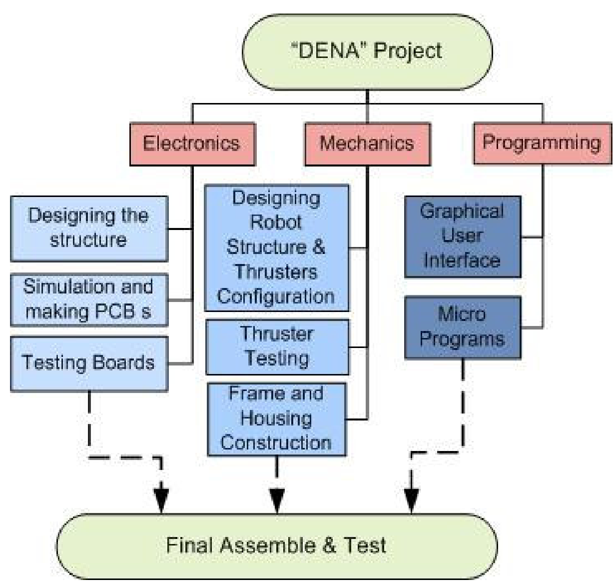
"Control research lab"

The control research lab is a place for the team to get together and to design and test electrical boards. This laboratory was founded at the same time the team started its work, it did not have enough laboratory instruments at first but it became better now.

Design of DENA had three major parts.

1) Mechanical analysis and simulation, performed by CAD soft wares like Catia and Fluent.
2) Electrical boards: design and simulation using Orcad, PCB design using Protel.
3) User interfaces design, using VB.NET.

In the following pages, you will learn more about our robot



Design Rationale:

Robot Configuration & thrusters

Frame:

In building the ROV frame, we used the aluminum parts, which are used in making doors and windows. Although the PVC pipes and other plastic materials are buoyant, advantage of using aluminum is simplicity in fixing the equipments. Aluminum also was preferred than steel because of its lower weight and hardness (the more hardness, the more difficulty to drill and fix it), even though steel is cheaper.

Maneuver:

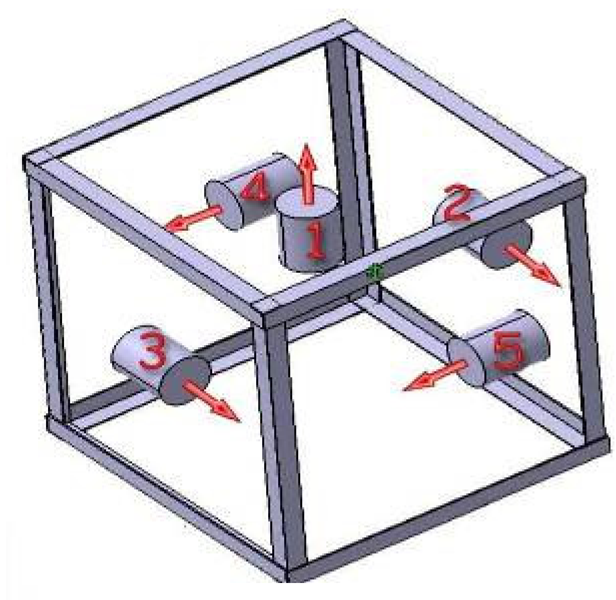
By considering the determined tasks for the ROV, we need these degrees of freedom: the straight motions in three directions and the rotation only around the vertical axis. In addition, we do not need the rotation around two other axis and motions like moving on a carved path.

Motor configuration:

In order to find the best configuration for ROV's motors, the group members searched for hours in the net and analyzed the ROV's configuration. By announcing the missions and determining ROV's motion, eventually the decision was made as below: (the underneath configuration based on the ROV's maneuver)

For moving toward and backward, we considered two motors at the sides of ROV, because:

a) If we use two motors instead of one motor, it will be easier to control the rotary motion around the vertical axis, which is caused by unbalanced masses and forces.
b) The essential power for motion in any direction is divided between two motors, which cause requirement to smaller and cheaper motors.



"ROV thruster Configuration"

c) The rotation velocity around vertical axis is higher in comparison with working by means of one motor. As a result, the movement result decreases.

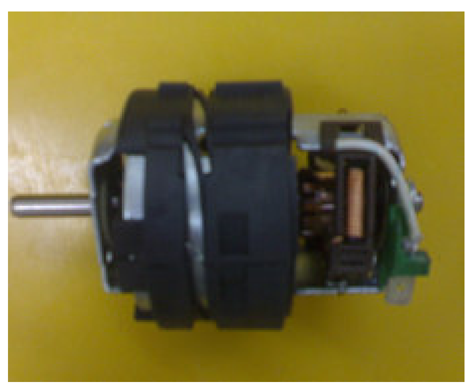
For the vertical movements we considered one motor in a center of ROV.
Because we have one motor for vertical motion if we consider one motor for lateral movement, the axis of these two motors (vertical and lateral motors) should pass mass center point and they may affect flows made by each other. Therefore, we decided to use two lateral motors.

Motor power:
The whole power, which can be used, is W=51(v)*40(A) =2040w
By assuming 840w for light, cameras, mechanisms etc, the available motor power is about 2040-840=1200w
The drag force in any direction movements is derived:

$$F_{D\max} = \frac{1}{2}\rho V^2 A C_D = \frac{1}{2}\times 1000\times 0.8^2\times 0.5^2\times 1.5 = 120N$$

($A=0.5^2\ m^2$ & $C_{D\max}=1.5$)
Therefore, the required power is about P=FV=120*0.8=96w
In addition, if we want the ROV to move in any direction by means of one motor (the motors outlet power is less than inlet), considering the power about 150w is appropriate. Also if we want to use just one motor in a direction, due to having the same motors (which leads to simplicity in making housings and sealing), it is better to use the same motors for all of them. This also increases the safety factor.

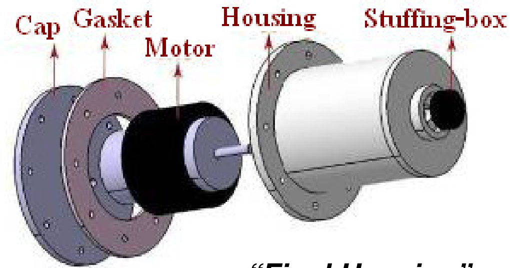
Motor choosing:
The main point for choosing motor was its voltage. Therefore, the group searched for 24v motors with high power. After search, we found some motors with 90w power and high cost, and because of that, the group was unable to purchase them. Afterwards we bought some 12v motors to use in our examinations. Then we realized that if we find an alternative part in automotive industry for each required electrical or mechanical part, it would be useful because lots of them are available with low price. This approach led us to find the 24v motors with about 130w power and 13$ cost. (These motors are used in trucks fan)



"24 volt truck fan motor"

Sealing:

During the work on ROV project, the group members got this point that in order to build any equipment, at first, it is better to design a cheap initial contour and analyze its challenges and problems. To make a housing, as you see in the pictures, at first we used the plastic container which fitted on motors by motorcycle tube and sealed by stuffing box. However, because of less accuracy they were failed. Next, we made some metal housing by aluminum, which was better than former plan. Due to using the thick metal sheet and the problem in TIG welding, again its accuracy was not very good. At last, we made the Teflon covers for motor, which has more accuracy and lower price, but unfortunately, it has lower heat transfer. Eventually we decided to make a Teflon covers with metal cap.



"Final Housing"

"Improvement of motor housing"

By using gasket between housing and its door, we sealed the end of motor and by means of heat glue, we sealed the outlet wires. The motors shaft was waterproofed by stuffing box, which is glued on the housing surface. In addition, we joined two metal parts to the motor and brought them out from the housing cap as away for better heat transfer.

Buoyancy:

The total ROV mass is about 10 kg and its volume is 8000 cm^3. In order to make the ROV buoyant we should add the very low-density material (such as air containers, foam, etc) with the approximately 2000-cm3 volume. However, because these ROV's are not built with high precision, it is better to designate the final buoyancy characters practically by adding and diminishing the foam parts.

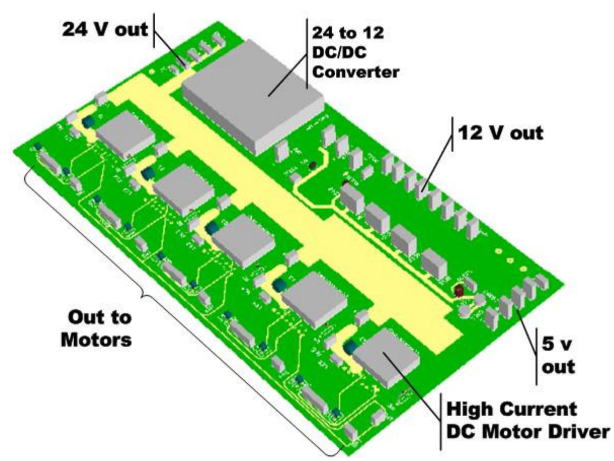
Stability:

It is better to increase the BG as we do not have any rotation around the horizontal axis. To derive the BG amount, we should know total mass and volume of ROV and their center points. By simple calculations and neglecting low mass or low volume parts, we found those center points. Mass center point is 10 cm higher than floor and has 5 cm distance from robot center in the back. Volume center is 10 cm below the top. Therefore, the BG is about 30.5 cm. Through consulting with fluid mechanic expert and by explaining ROV's task, maneuver and velocity, we were led to neglect dedicating and working on hydrodynamic point and surface waves (due to their low amplitude and frequency).

Velocity:
Because the distance that ROV should pass to reach the position of task is about 15 m and by considering going and coming back, we assumed the velocity to be about 0.5 m/s to have the ROV went and came back on one minute (except doing the task). Due to lots of different possible problems we increased it to 0.8 m/s. other visited ROV (through the net) did not have velocity more than 1 m/s.

Power Management

The power supply used in this project is a Phoenix Contact product, which has the ability to supply 24v DC voltage and up to 10A current from AC voltage between 110 and 220. Because we did not find any upper 10A power supplies, we were forced to parallel two of them to have 20A current (Fortunately Phoenix power supplies have this ability). We need 12-v line to feed our Grippers, Cameras and DC geared Motors used in Container boxes, so we used a 24 to 12 volt DC/DC converter to provide part of this need. In fact, we supply the Drivers and cameras by 12-volt line that is made by DC/DC converter and we used onboard battery to supply Grippers and lights 5 volt line is provided due to paralleling four 7805 regulators to Use in Control Board.



"Power Board"

On the power board, there are also five Drivers for controlling the main thrusters. We used L6203 because it can operate under 24 voltage and supply up to 5A current. They also have thermal shut down circuit, which prevents the Driver from being damaged during the Mission. Moreover, for the other motors, which drain less current, we used simple L298 drivers. We used 17 meters of 2 * 2.5 mm^2 cable for Tether .

Camera

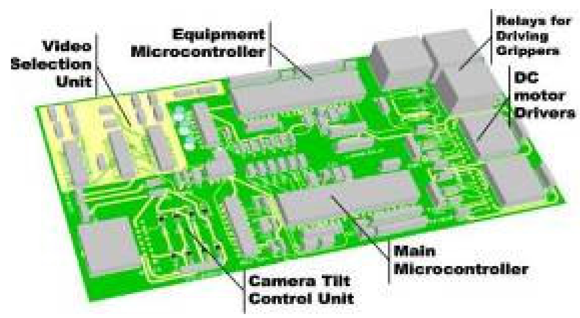
We used waterproofed CMOS camera for this robot. By testing these cameras we decided to improve their seal by glue to be assured of their work during the mission tasks. They have sufficient infrared sensors that improve the quality of video in dark areas. Camera selection unit in control board can handle up to 8 cameras.

"ROV camera"

Control system

We have two main microcontrollers on the control board, the reason for choosing two micros was to separate the motion commands from the other commands and to avoid complexity in programming them, and this selection of the control system will provide us the ability to add more sensors and special auto head & auto depth systems.

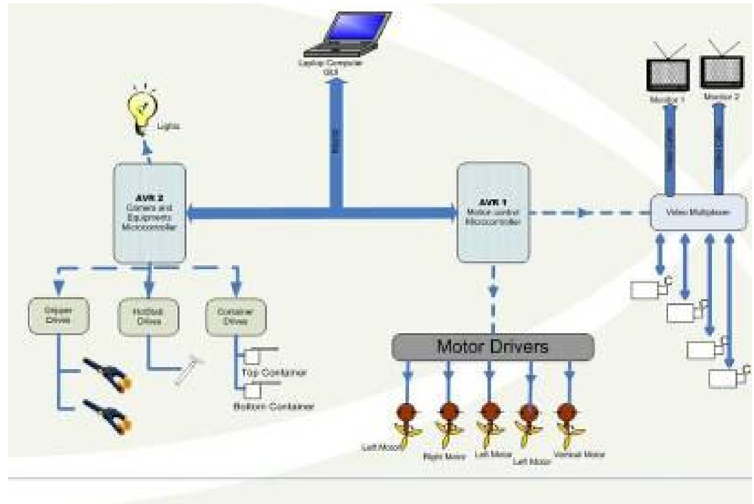
We have selected the AVR Atmega microcontroller series, because of their A/D converter channels, timers/counters with the ability to generate PWM pulses, and many other options. In addition, these micros provide a reliable mechanism (watchdog timer) to prevent noises from disturbing the system.



"Control Board"

The commands that are sent by the onshore laptop will be received by both the micros, but it is possible only for one of them to send data to onshore unit. All of the commands are encoded in a 5-byte form. For power saving, the microcontrollers are kept in sleep mode by default when they are idle. By receiving data from operator they will wake up and start to decode and execute the instructions. The motion micro (which has the permission to send data) controls the thrusters by PWM pulses; moreover, it converts the outputs of the sensors into digital form and sends them regularly. In addition to these tasks, it has the ability to change the angle of rotation of the primary camera.

Beside these tasks this microcontroller has the ability to control the angle of a rotating camera, which may be used in future, for this propose a complete Pan&tilt controller with its own low frequency oscillator is designed and implemented in control board. This micro controller selects 2 of up to 8 cameras by means of a decoder and analog switches prepared on the board. as a way to decrease the effect of noise on video signals, video lines on the control board are surrounded by grounded areas .



"ROV Control Diagram"

How about the second microcontroller? It controls the relays, lights, and the additional equipments drivers. The drivers, which have been selected for the additional equipments, are the L298 drivers, they can provide 2A current and each of them contains two H-bridges .the second micro also generates PWM pulses for these motor drivers.

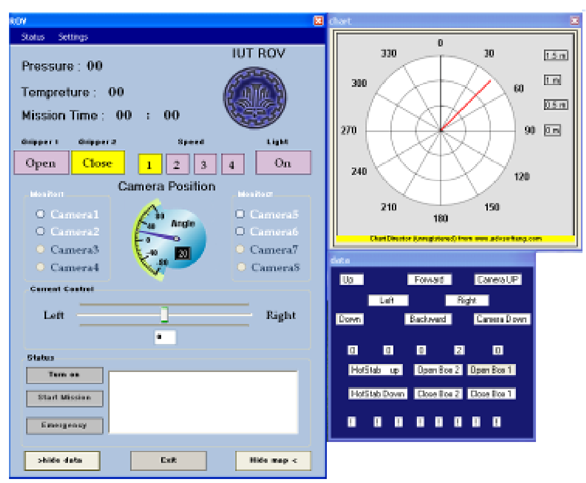
Surface control unit:

The Surface control Unit is playing the major rule in controlling the robot .the operator uses it to tell the robot what to do.
This part contains a program written in VB.Net; the main factor of choosing .NET is its simplicity and intelligible user interface.
Design of this program has three modules:

1) GUI
2) Interface
3) Software

GUI:

In the first stage, we have the forms & their information. ROV's information is gathered from the operator & then will be sent to the software layer. This information is displayed to the user simultaneously.



"GUI main and, Connection forms"

Main form:

In this form, the operator can control the ROV by means of special parameters. For

example, when it is needed to turn on or off the light, it is possible for the user to perform this task by changing the radio boxes or alternatively clicking related buttons.
In a small window at the bottom of the form, all of the events are recorded & displayed to the user. In addition, there is a chart for displaying the heading of pan and tilt camera and for displaying the estimated position of the robot in future!

Control form:
Two ways are available for the operator to enter commands: joystick and keyboard.
In keyboard mode, the user is allowed to choose his convenient keys from the control page. Moreover, it is possible for him to choose between joystick or keyboard mode.
In addition, in this form, we have a special possibility for the user to define a path for the robot, and then will follow this path automatically (but it is not available now, it is one of our future improvements).

"Control form"

Connection setting form:
In this form, the interface parameters such as serial port, baud rate, sending data intervals, are adjusted. Any improper changes in these parameters will lead to disturbances in connection between the robot and the onshore unit. Therefore these settings should be checked before starting a mission.

Software:
Although our program does not perform too many processes by now but it has the potential to carry out these computations. Therefore, it can use the collected data from different motion sensors & then calculates the position of the robot and sends it to the GUI for displaying to the operator.

Interface:
The main task of this layer is to establish a safe connection between GUI & the hardware. It has a timer & a serial port object. All of the data from higher layers will be sent to this layer & each time the generate function allows to send data, 5-byte data will be sent. On the other hand, after receiving data from the robot it will be sent to higher layers in supervision of the Receive function. (*See appendix for communication protocol*)

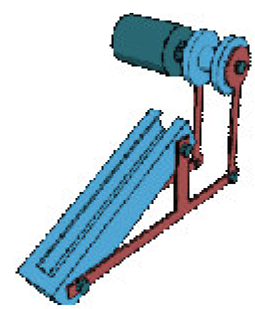
Additional Equipments

Our ROV includes five equipments, which are used to do different underwater missions there are two Grippers, two container boxes and a tool for inserting the hot stab

"Gripper made by car door lock actuator"

In our first Design of ROV, we decided to build a manipulator with two or three degrees of freedom, but after more estimation we found out that controlling such a manipulator under the unstable circumstances (conditions) in water, would be hard or maybe impossible for the operator .So we decided to design two simple Grippers.

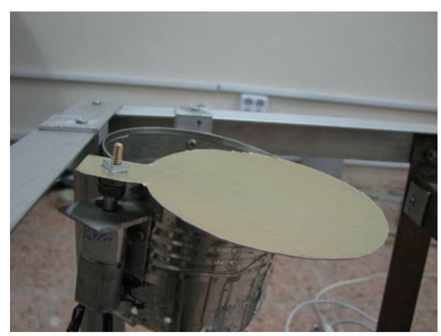
These Grippers have just two positions: Open and Close. Instead of converting the rotating movement of a motor to reciprocal movement, we used a Car door lock actuator activating by a relay.



"Hot stab inserting tool"

For inserting the hot stab the mechanism pushes the hot stab by means of releasing the rope through lower of a slope surface, which guides the hot stab in a correct way .it can be pulled up by gathering the rope connected to its end by means of a Geared DC Motor

In the Container boxes, we used a low voltage Geared DC motor and L298 drivers. When the Open command is received the door which is attached to the motor shaft will turn Clockwise to open the container box for collecting the sample when the sample is entered the box, the door closes and prevents the sample from getting out of the box. to boxes are same as each other except in size and place where they are mounted, one box in place on the top of ROV frame to collect the algae and a bigger one is on the bottom for jellyfish.



"Container box for collecting algae"

Challenges

Finding proper motors became the most time consuming problem the team faced, and the team could not find 24V DC motor with the desired torque and power until the last days. So the team decided to choose a motor from available 12V DC motors, because they did not want to lose the time, they started their experiments on a 12v DC motor in the overload condition (run it with 24v supply). This motor provided enough torque but it drained too much current. In addition, it was too dangerous for the motor to work in

overload condition continuously. However, the team could calculate mechanical factors (such as force) by these motors. Fortunately, the team members found appropriate 24v DC motors at about just 1 month before competition.
This problem occurred when the team needed high current motor drivers (L6203) and some other special ICs. They were forced to travel to Tehran (Iran's capital) to find them. Also for the power supply the ordered it and it took about five weeks to have it delivered.

Troubleshooting

There was a mistake in Control board design, we tested the control board and we found that the Camera selection unit does not work. By checking the ICs, we understood that the VCC pin of the Switches and the Decoder is not connected to the main VCC line! This problem came from the fact that in Protel, it is impossible to view the power pins of Logical ICs by default. These pins are connected to a Net Called VDD and the net we used for wiring the +5 volt in the board was VCC so they were not connected in routing stage. The problem was fixed by connecting these two nets on the board by means of wire.

Future improvements

We have many ideas about improving our vehicle. As we said before in the abstract, we wanted to design and build an autonomous robot. We think that after this competition we will have gained much more experiences. In addition, we can start our great challenge. We planned to implement closed–loop control systems on our robot to eliminate the effect of water current on the speed and controllability of the robot. It is necessary for autonomous vehicles to have their position regularly. Therefore, the robot should be equipped with various motion sensors (gyros, accelerometers, compass). In addition, we should improve our programming skills and invite AI programmers to become our team members.

Lessons learned

During designing ROV mechanism and equipment, we faced some contours and we found that we could not choose one of them without having any practical samples, which simplifies understanding problems. For example to design a gripper we have three choices, so we made a simple and cheep wooden gripper and through that we were able to choose the best one. Another example is motor housing that is described in waterproofing section. Overall, manufacturing simple contours helps us designating robot parts easier without loosing time and money.
Another point we realize is working by available industrial parts. Since we start this project, we faced many problems in finding suitable parts so we led to search in automotive industry. Because its parts are all available and cheap, for example we used

jacks that are used in car door lock, as actuator for grippers and truck fan DC motors, as main thruster motors.

Acknowledgments

We should thank all people and departments in our University helped us during this project, especially "Department of Electrical & Computer engineering" for providing team with place to work and some laboratory equipments. Also we should thank "Subsea Research and Development Institute" for some technical advises and the permission to use their testing pool.

Cultural, historical and social aspects of human life at poles

Humans have been living in the Arctic for at least 15,000 years. In the continuous expanse of land from Scandinavia through Eurasia to Alaska, Canada, and Greenland, native people developed sophisticated cultures and survival technologies. Because of their traditional dependence on hunting and fishing, arctic communities evolved near lakes, rivers and along ice-free coasts. Today, subsistence hunting and fishing remain an important component of daily life and cultural identity, although the major sources of income are oil, mining, and commercial fishing activities.

It has been proposed that the first people lived in Siberia during the Upper Paleolithic as early as 45000-40000 BC. Archaeological evidence indicates that the settlement of Siberia was a complex and lengthy process with migrations possibly originating from southern Russia and Eastern Europe, Central Asia, and Mongolia. In addition, there is evidence that cultural ties were established between the populations of western Siberia and Eastern Europe as early as the Neolithic period, and archeological findings of later periods testify to bonds between the populations of Siberia and the ancient civilizations to the West and South.

There are people of different cultures and backgrounds who live in the Arctic region:

Inuit people include the native cultures that continue to live on coastal areas of Arctic tundra in Canada, Alaska (USA), Siberia (Russia), and Greenland. Over this broad area, there are many different groups of people. Some share common ancestors, others probably do not, but most have similar ways of living in the Arctic. Inuit traditionally hunted for seals, whales, polar bears, caribou, birds and other animals from the ocean and the tundra. Inuit people invented the kayak and used these small boats to hunt for Arctic marine animals. Because of a great respect for these animals, Inuit have traditional customs that must be followed during a hunt.

Inuit myths were inspired by the environment that they lived within including the magical appearance of the aurora in the night sky, the long dark winters, and the icy Arctic Ocean.

Norse people were originally from Scandinavian countries. During the Middle Ages, between approximately 850 and 1066 AD, groups of Norse explorers and warriors called Vikings raided and colonized other regions within and near the Arctic such as Greenland, Iceland, and northern Russia (as well as warmer, lower latitude locations too). Today, many people living in these countries are descendants of the Norse people.

The Norse were excellent boat builders, crafting vessels out of wood called long ships, which could travel across large expanses of ocean. There were many oars along the sides of the boat and often one square sail. Vikings would row the oars and wind would fill the sail, propelling the boat. The Norse people, including the Vikings, were known to be excellent storytellers.

Their houses seem hardly adequate for polar winters, even though the temperatures in Greenland were warmer than they are now. The houses of these people were little more than skin tents with peculiar "mid-passages" or vertical stone slabs on centers of dirt floors. Here they stored meat and kept low burning fires of greasy musk-ox bones. Families appear to have almost hibernated through the winter, spending most of the 24-hour polar night sleeping under musk-ox skins near the warmed rocks of the mid-passage.

The end of the 18th century brought the intense cold of the "Little Ice Age." Norse settlers of Greenland, no longer able to farm, died out in the eastern and western settlements. In the eastern Arctic, the cold winters increased the extent of sea ice, diminishing the dependence on whaling. The Thule people left their permanent winter pit houses for temporary snow house villages on the sea ice, where they could concentrate on breathing-hole hunting. In time there developed a greater regional emphasis on locally available animals such as walrus, beluga, narwhal and caribou that ultimately led to the "tribes" of the modern Inuit.

Contact with Europeans and Yankees only started in 1825 on Alaska's Chukchi Sea coast. Frequent face-to-face contact started as late as the 1850s, with manufactured goods, especially any types of metal, still scarce in the 1870s. Many aspects of the Native way of life remained virtually unchanged until recently. When we excavate a tool or even an entire house, local people can often tell exactly what we are looking at, how it was made and how it was used. This is because they have heard detailed stories from their Elders, or because they saw these things in use, or, in some cases, because they have participated in their use.

At present, 31 native groups live in the territories of Siberia and the Altai. Although most populations differ in their origin, language, and culture, common types of economic activities characterize them: hunting, fishing, reindeer breeding and herding. Their traditional occupations are linked to their nomadic or semi-nomadic way of life and low population densities.

Human experience in the Arctic reflects both a successful adaptation to changing and often-harsh environmental conditions and the effects of modern development on small society's dependent on natural resources. Outside of regional centers like Anchorage and Fairbanks, communities in rural Alaska and other parts of the Arctic tend to be small and isolated. Most families rely on a mixed strategy of subsistence harvesting, wage labor, and commodity production. These communities use traditional knowledge while adapting to the global economy and modern technology. Change has become a way of life in the North. Economic development in the Arctic has brought new occupations and with that changes in wealth and income distribution, community and family patterns, and even health and safety.

Appendix

COMMUNICATION PROTOCOL

Main Micro 1:
This Microcontroller handles ROV navigation.

1st Received Byte:

O	Y1 Y0	X2 X1 X0	C11 C10

C11 C10	: Cameral select	(from camera 1 to camera 4)
X2X1X0	: In plane moves	(Turn left, turn right, Forward, Backward, No move)
Y1Y0	: Of plane moves	(Go up, Go down, No move)
O	: Turn On/ Off	

2nd Received Byte:

V1 V2	E	AD	NOP	Pt1 Pt2

Pt1 Pt0	: Pan & Tilt	(Going down, Going up, No move)
NOP	: No Operation	
AD	: AUTO Dept	(ON, OFF)
E	: Emergency Mode	(ON, OFF)
V1V2	: Move speed	(Gear1, Gear2, Gear3, Gear4)

3rd Received Byte:

PWM 0-6	Dir

Dir	: Side Motors Direction	(Left, Right)
PWM	: Side Motors PWM	

Main Micro 2:
This Microcontroller handles most ROV equipment.

4th Received Byte:

NOP	UB1 UB0	LB1 LB0	L	G2	G1

G1	: Gripper1 State	(Open, Close)
G2	: Gripper2 State	(Open, Close)
L	: ROV Lights	(ON, OFF)
LB1 LB0	: Lower Container Box	(Opening, Closing, No move)
UB1 UB0	: Upper Container Box	(Opening, Closing, No move)
NOP	: No Operation	

5th Received Byte:

E	RESERVED	C21 C20	X1 X0

X1 X0	: Hot Stab	(Going down, Going up, No move)
C21 C20	: Camera2 select	(from camera 6 to camera 8)
E	: Emergency Mode	(ON, OFF)

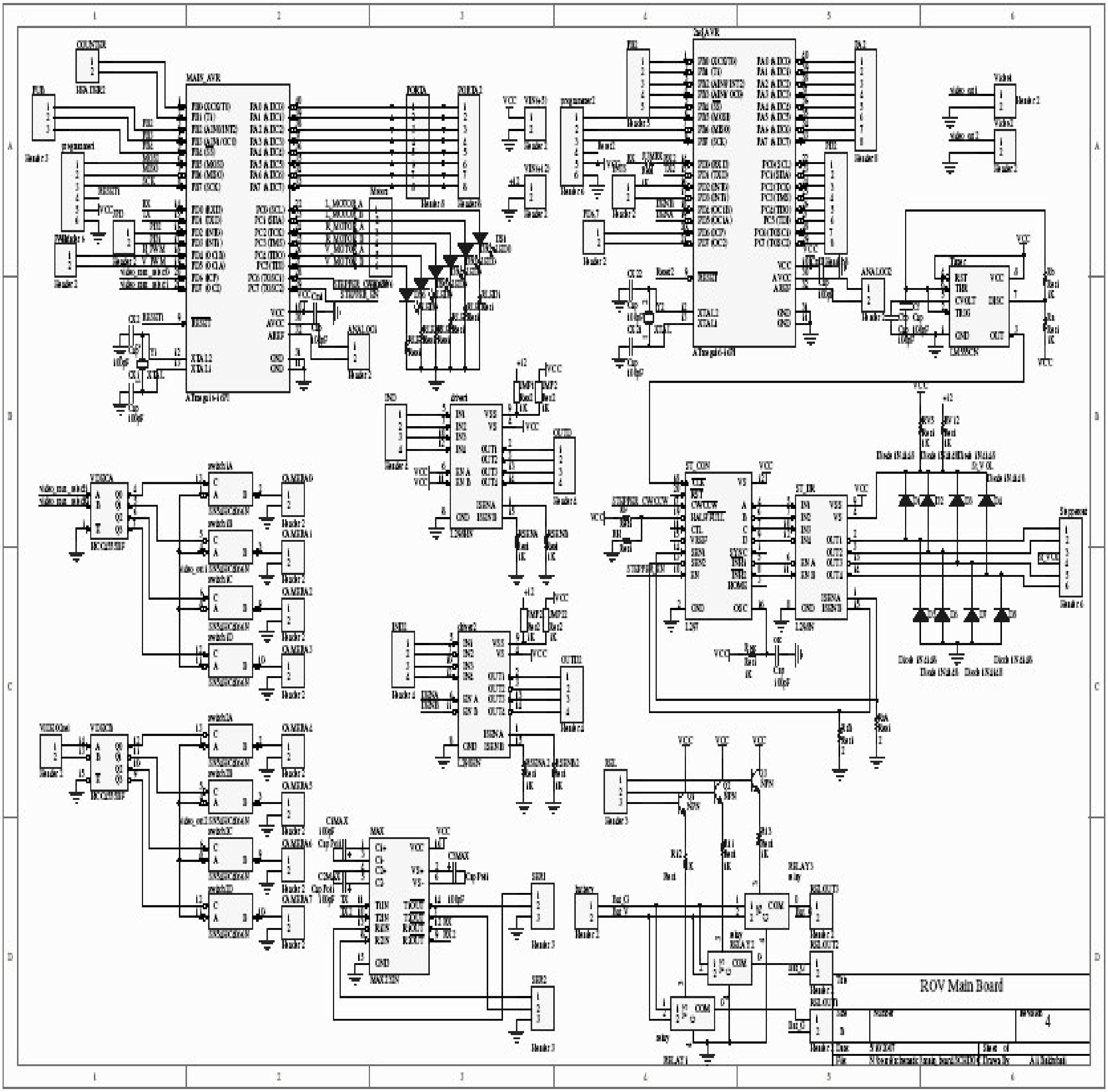
Other bits are reserved for future improvements.

Sent Bytes:

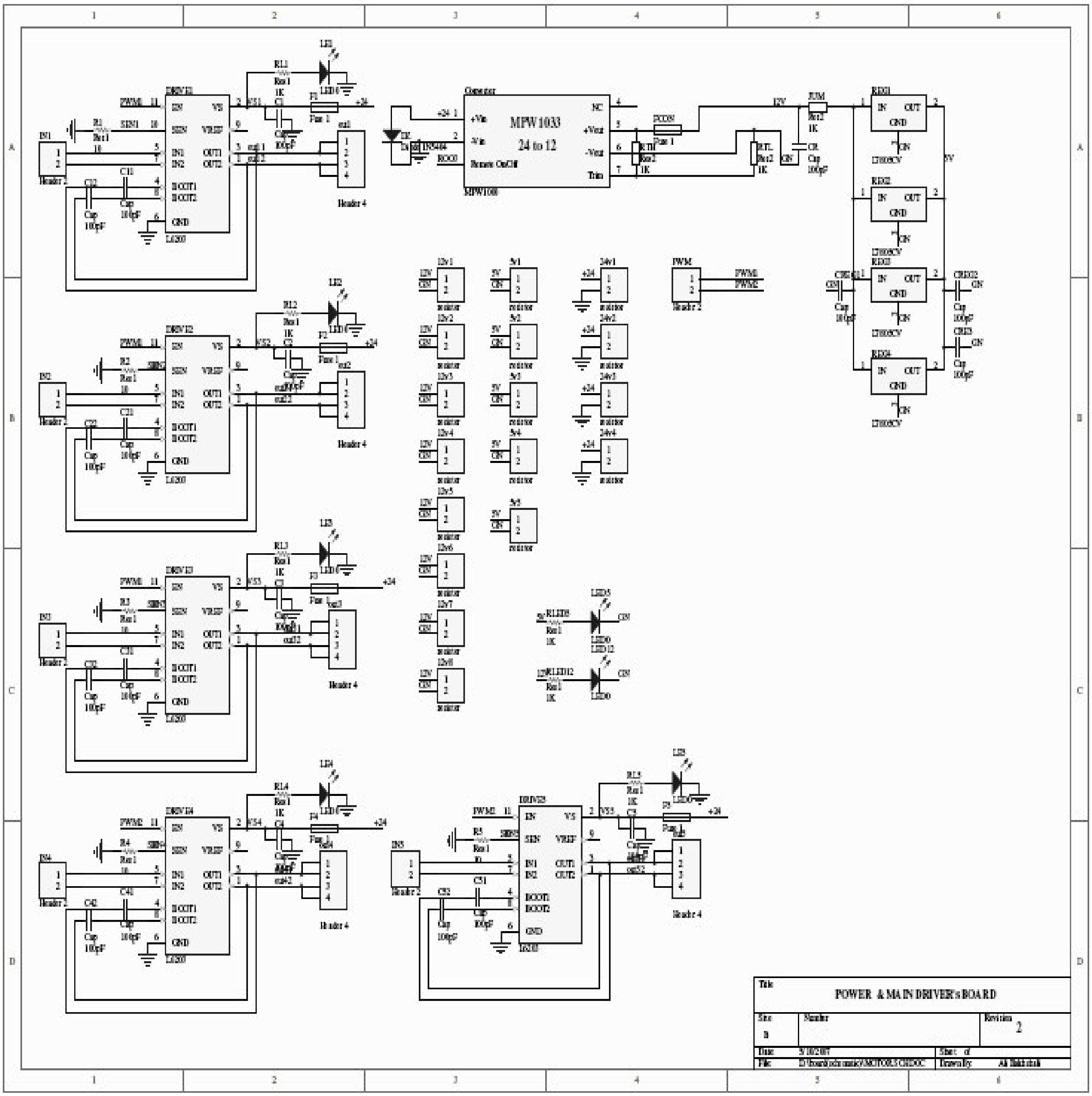
Sensors Data

After receiving all 5 Bytes, Main Microcontroller send 1 Byte for each sensor which includes Digital value of the sensor, obtained by internal ADC of AVR.

ROV Control board Schematic:



ROV Power board Schematic:



Budget List

Most of the team expenses was in Toman which is the usual currency for trades in Iran after Rial , (10 RIALs = 1 Toman)
We first calculated our expenses in Tomans and then converted them to US $ which is about 920 Tomans .

Donations	T	US $
Sub sea Research and Development Institute	10,000,000	10,870
Electrical & Computer Student Scientific Society	500,000	543
Isfahan University OF technology Administration of Research	300,000	326
TOTAL Budget	10,800,000	11,739

Electrical & Electronics	Cost (T)	US$
10 * L6203 DC Motor drive	35,000	38
5 *L298 DC motor drive	40,000	43
PCB Connectors	5,000	5
Final PCB Construction	30,000	33
4* ATMEGA16 Microcontroller	15,000	16
Power Cable	50,000	54
USB Joystick	10,000	11
Temp Sensor	5,000	5
Other ICs and Electrical elements	30,000	33
40 meter video cable	20,000	22
Data Cable	9,000	10
MPW1033 DC/DC Converter	40,000	43
2* 24 Volt Phoenix Contact TRIO power supply	312,000	339
4* Analog Camera	72,000	78
1* Analog Waterproofed camera	50,000	54
Waterproofed Box for Electronics	15,000	16
2* Optical Shaft encoder	8,000	9
USB to Serial Adapter	16,000	17
6” Video Monitor	25,000	27
TOTAL Electrical osts	787,000	853

Mechanical	Cost (T)	US $
6 * 24 volt Truck fan Dc motor	70,000	78
4* 12 volt Dc Motor	56,000	61
2* Small DC motor	10,000	11
Stepper Motor	15,000	16
Housing for motors (8 motor)	30,000	33
ROV Frame Construction	20,000	22
O-ring, Glue for sealing	20,000	22
2 * Car Door Lock for Grippers	10,000	11
Mechanical tools for frame Construction	30,000	33
Force Gauge	5,000	5
Foam	8,000	9
Blades (Including Blades for Test)	15,000	16
Motor Couplings	30,000	33
Total Mechanical costs	319,000	350

Travel Costs	Cost (T)	US $
Ticket to Saint Johns (5 Team Member)	8,000,000	8,696
Housing In Memorial University(5 Team Member for 6 Days)	300,120	326.22
Meals (5 Team Member)	492,000	534.78
Cost Of Shipping ROV to Memorial University (+ Return)	320,000	347.83
Total Travel Costs	9.112.120	9.904.83

TOTAL COSTS	T	US $
Electrical & Electronics	787,000	853
Mechanical	319,000	350
Travel	9,112,120	9,904
TOTAL COSTS	10,218,120	11,107

Balance	T	US $
TOTAL Budget	10,800,000	11,739
TOTAL Costs	10,218,000	11,107
Balance	582,000	632