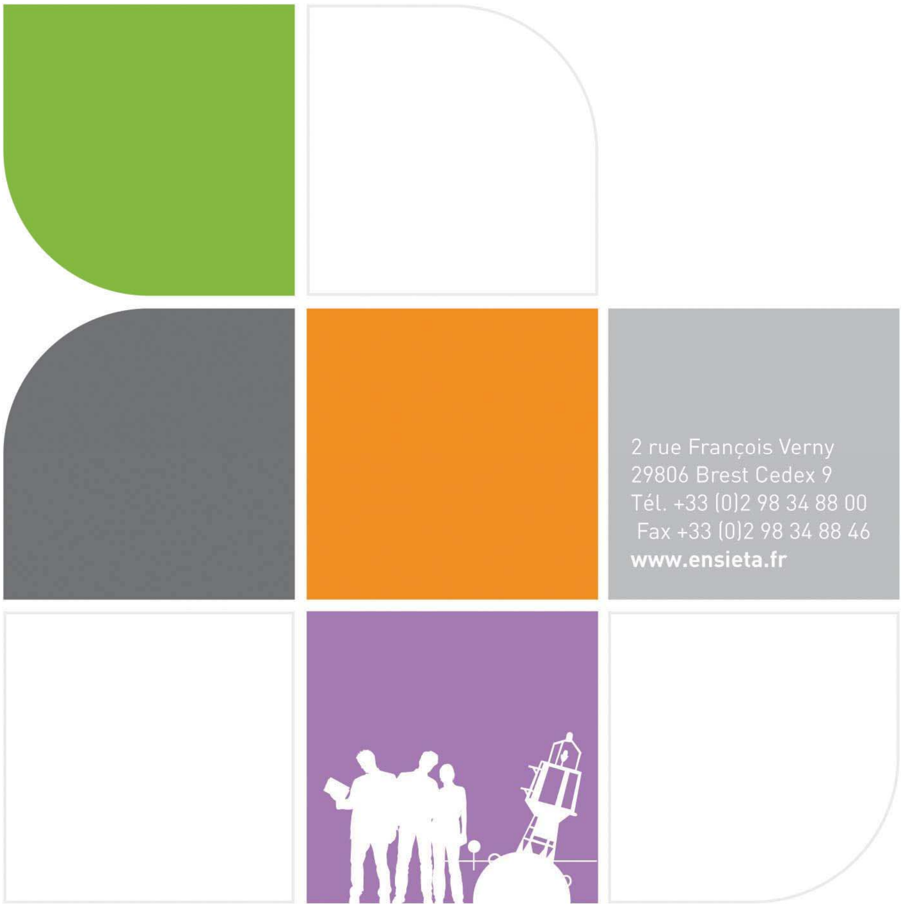

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SAUC-E 2009 Journal Paper ENSIETA

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ENSIETA
ÉCOLE NATIONALE SUPÉRIEURE D'INGÉNIEURS
FORMATION INITIALE - FORMATION CONTINUE - RECHERCHE

CONTENT

I. Executive summary

As last year and since 2007, the ENSIETA (Ecole Nationale Supérieure des Ingénieurs des Etudes et Techniques d'Armement) will take part to the SAUC-E competition. The actual submarine is roughly the same as in 2008 except in the computer part: it was mainly bugs in our programs that prevented it to succeed in some competition missions.

This year, we had some difficulties to find time and people to help us in the preparation of the robot. But as the main mechanical and electronics parts of the existing submarine were reliable, the work of this year was less important.

II. Introduction

The robot of this year shares the same basis with those of last years with a mechanical and electronic architecture that has been proven to be reliable. However, some changes were made in the computer science part. First, we will detail the physical architecture (mechanical and electronic) of our robot. Then, you will find our answers to the issues of autonomy and mission planning. A part about innovations made this year will follow. Finally, a financial summary and a risk assessment table will be provided.

III. Physical Description

External architecture:

The mechanical base of the robot was not changed this year. Indeed, an aluminium tube is a good choice for its resistance to pressure, its amagnetism, its resistance to corrosion, and its facility to prepare a watertight environment. Its size was reduced last year to ease its transportation and reduce its weight, as the space inside was sufficient to contain all the devices needed.

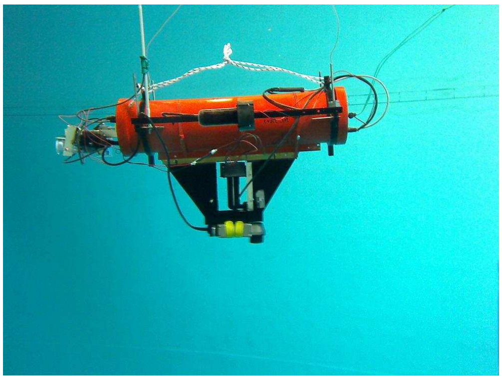


Figure 1 : The submarine in water

The watertightness of the tube is made by two aluminium plaques. There are waterproof connectors on each plaque for the various sensors and actuators of the robot. The watertightness is provided by three stainless fastener screws. The fixation of the screws is done with a pawn centre. The extraction of plaques is done with three extraction screws. Only one tape must be removed to extract the electronic part of the robot. This allows an easier maintenance.

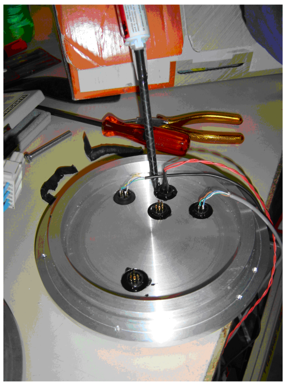


Figure 2: A plaque with its waterproof connectors (interior side)

A special structure was made to carry the horizontal thrusters.

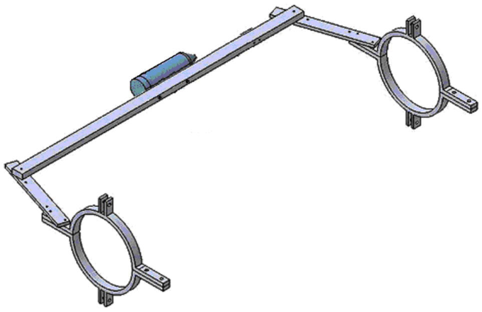


Figure 3: Structure that carries the horizontal thrusters

The roll and pitch are not controlled but are stable thanks to a weighted keel, what is also a support for the sonar and the vertical thruster. The keel is cut to put our vertical thruster in the center of the submarine, in order to keep symmetry.

Figure 4: Vertical thruster centered in the keel

The weight of the ballast keel is currently of about 630 grams. Additionally, we have a system to adjust the overall ballast of the submarine: breakthrough mass lead can be added on 4 threaded rods placed in the four corners of the submarine so we can reach the limit zone of buoyancy. As a result we just need a propelling force very weak to make the submarine go under the surface, and when the vertical engine is shut down, it goes itself to the surface.

Internal architecture:

Because dismantling or reassembling the submarine is a significant factor of loss of time and reliability, we have chosen to limit sharply the need to open one of the plaques that close the cylinder by bringing all the connections to the aluminium rear plaque of the submarine.

Rails with glue for aluminium enable us to drag a Plexiglas plate of 6mm width which is the main support base for the internal electronic devices of the submarine.

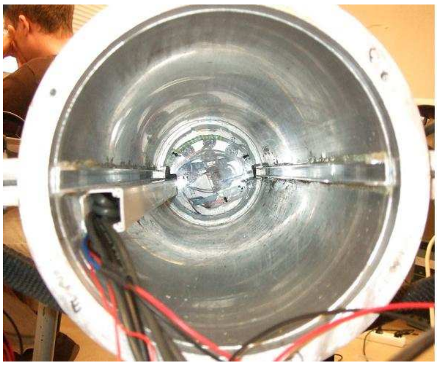


Figure 5: Rails inside the tube

Below the plate, another sliding support contains the batteries. Thus, we can readily access the batteries without having to touch any of the other electronic devices. These are put above the main Plexiglas plate.

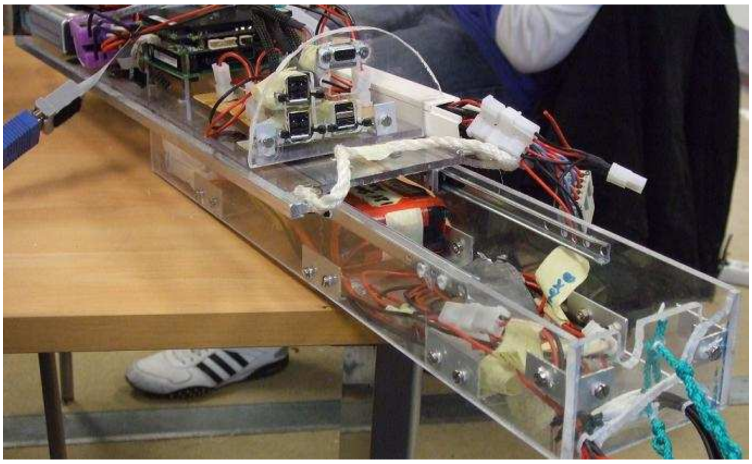


Figure 6: Sliding support

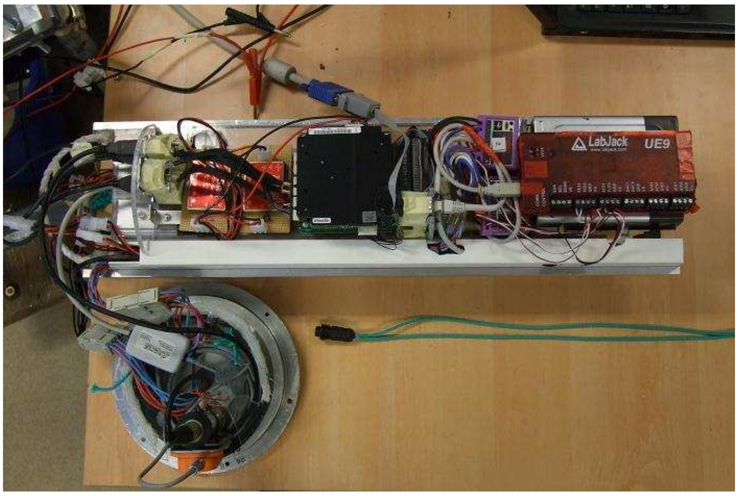


Figure 7: Internal devices

Electronic architecture:

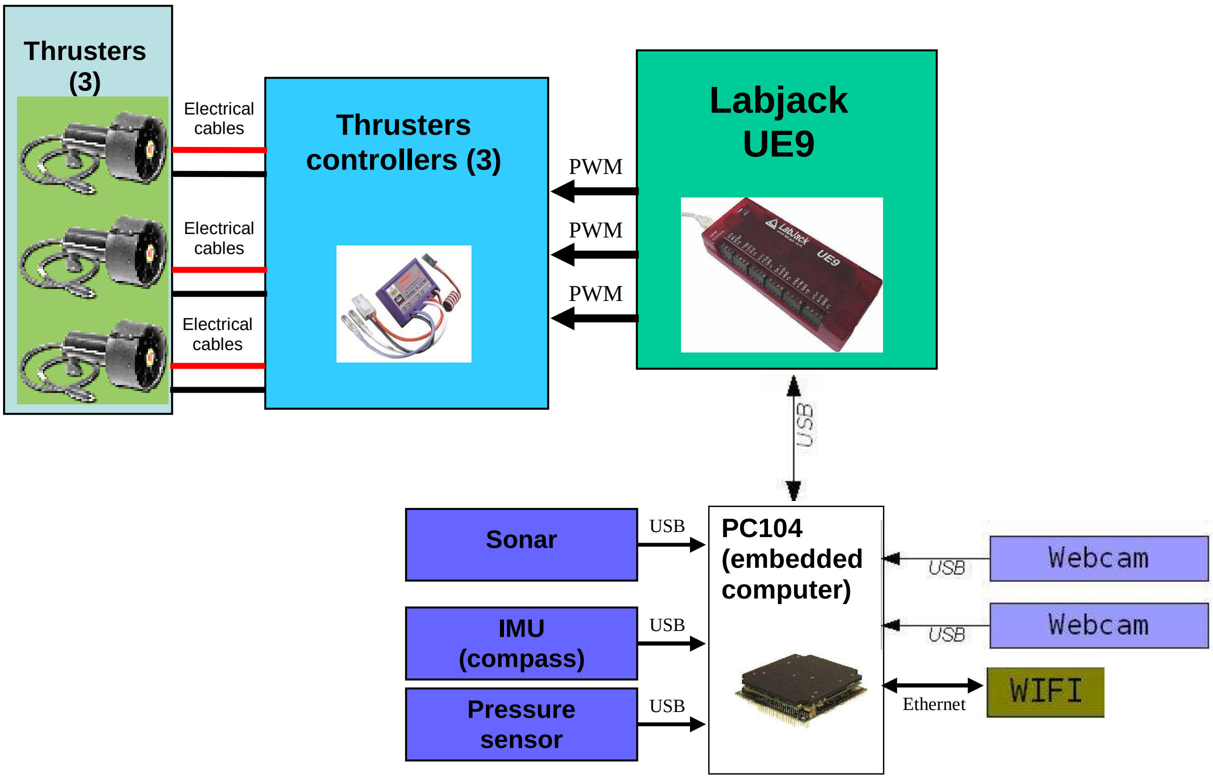


Figure 8: Electronic architecture

We use three thrusters STB150 from SEABOTIX, an American manufacturer specialized in ROVs (Remote Operated Vehicles) to make the robot move:

- 1 vertical thruster to adjust the depth of the submarine.
- 2 horizontal thrusters to control the speed and the direction.

They are delivered assembled and are made by professionals. Until now, they seem to be reliable because we never had any problem with them (especially watertightness problems like we had with the previous thrusters we used in 2007).

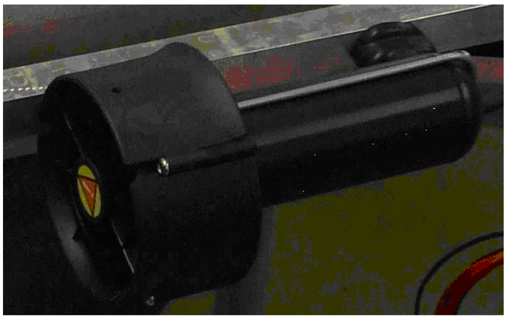


Figure 9: SEABOTIX thruster

To control the thrusters with electronic signals, we use a servo controller Robbe Rokraft.

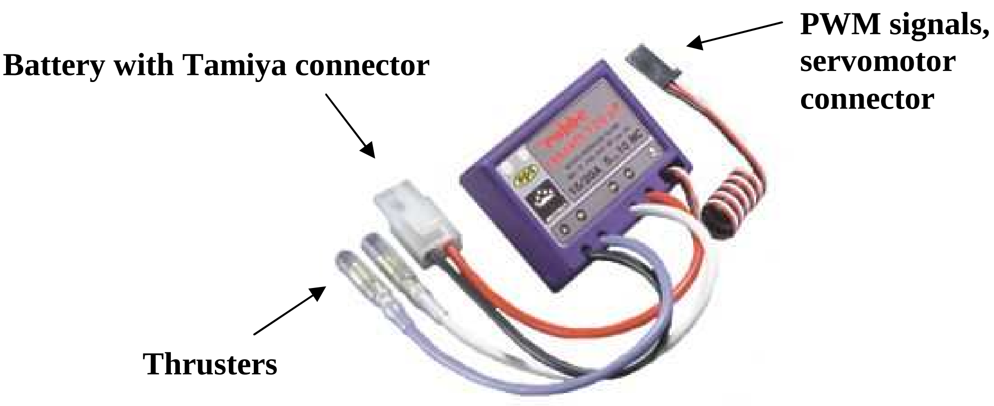
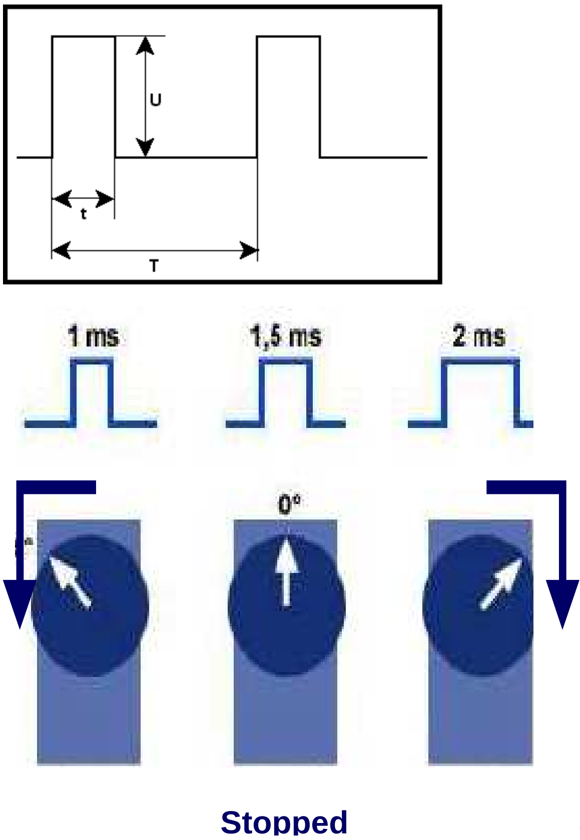


Figure 10: Thruster controller

The power sent to the thrusters (and therefore their speed) depends on the PWM (Pulse Width Modulation) signal.



U : tension of the PWM (5 V)
t : pulse width (between 1 and 2 ms)
T : period (20 ms)

Motor state	Pulse width
Motor stopped	1.5 ms
Turn in a direction	1.5 to 2.0 ms
Turn in the other direction	1.0 to 1.5 ms

Figure 11: PWM signals

To generate these PWM signals from computer programs, we need an interface module between the computer and the servo controllers: the Labjack UE9. It is a professional USB device that provides several IO pins to connect to electronic devices.

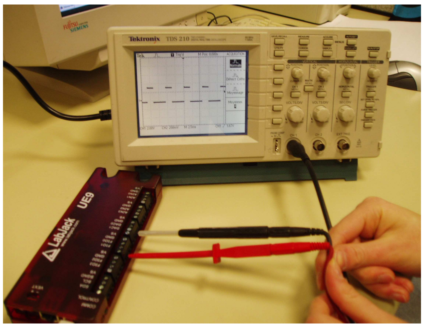


Figure 12: Labjack UE9 generating PWM signals

The embedded computer is a PC104 from EUROTECH with a Pentium M 1.4 GHz CPU and 512 MB of RAM. The operating system and the programs are stored on a hard drive 2.5 of 40 GB. 8 USB, 1 Ethernet, 2 RS232 and 1 VGA ports provide all we need to connect external devices and communicate with the computer.

Figure 13: PC104 CPU module

A power supply module (compliant with the PC104 standard) that provides 3.3, 5, +12 and -12 V has been added this year to power it directly from 12 or 24V batteries.

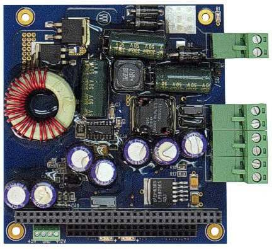


Figure 14: Power supply module for the CPU

To detect the objects in the pool (especially the moving red ball), we have 2 standard webcams Logitech Quickcam Pro 9000, that can get pictures with a very high resolution (1600x1200). Moreover, the common defaults in webcam pictures such as distortions and light or colour problems are automatically handled by its integrated filter.

Our 2 webcams were made waterproof by putting them in house water systems tubes with a Plexiglas window.

Figure 15: Webcams

To get the depth of the submarine, we use a professional pressure sensor Keller PAA33X connected to the computer with a RS485 to USB converter. The sensor is fixed on the back plaque of the submarine.

Figure 16: Pressure sensor

An IMU (Inertial Measurement Unit) Xsens MTi lent by the GESMA (Groupe d'Etudes Sous Marines de l'Atlantique) is used to get the orientation of the robot in the pool. It has a built-in fusion filter that uses magnetic data and gyroscopes to get a correct orientation even in case of magnetic disturbances. It is connected to the embedded computer via a RS232 to USB converter.

Figure 17: IMU

The main sensor to get the position of the robot in the pool is the MiniKing imaging sonar from Tritech, lent by other people in our school. It is also connected to the embedded computer via a RS232 to USB converter.

Figure 18: Sonar

A wireless access point DWL G700AP in combination with an external antenna of 1m enables the robot to communicate with us (via a laptop) when it is near the water surface.

Figure 19: Wireless access point

The power supply is divided into three parts:

- The engines are powered by a 12 V battery
- The sonar needs a specific battery of 24 V.
- The PC 104 and the wireless access point (via the 5 V provided by the power supply PC104 module) are powered by an additional 12 V battery.

All the other devices (pressure sensor, sonar, IMU, Labjack, webcams…) are powered via the USB ports of the computer.

IV. Autonomy and mission planning

The autonomy of the robot is based on the combination of the localization and the image processing algorithms. Indeed, the robot needs firstly to know its environment and its state in it to know were to go. Therefore, we have chosen to work a lot on the localization of the robot in the pool, taking into account outliers due to sensors or objects in the pool.

First it is easy to get the depth of the robot thanks to its pressure sensor. This enables to have a depth regulation loop, which is most of the time independent from the position in the pool.

The most difficult is to get the x,y position. Except for some missions, the compass (the IMU) and the sonar are used to get it.

The compass gets the orientation of the robot with respect to the North and, as the pool does not move, we get the orientation with respect to the pool. This enables the robot to follow a particular direction (for example, to go in a straight line through the 3 gates…)

With the sonar, we get easily the distance to the first obstacle at a specific angle. But if we take into account outliers and consider that the orientation given to the compass is not always precise, the algorithm of localization becomes more complex.

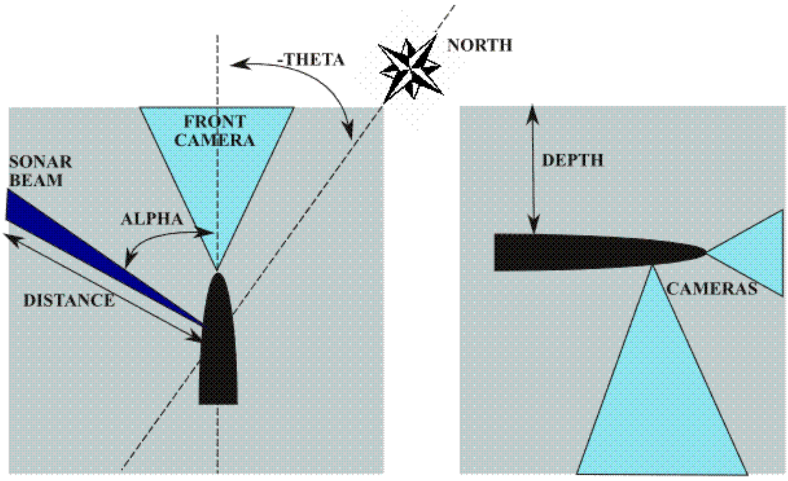


Figure 20: Localization and detection

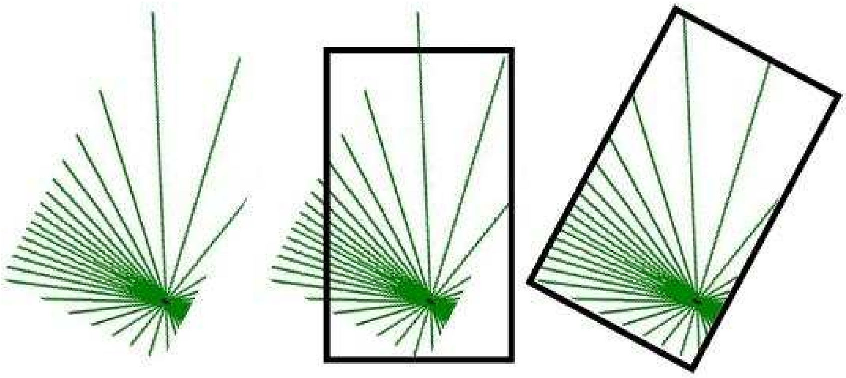


Figure 21: Sonar pings and localization in the pool

To follow the red ball target, we consider (for the moment) that it should be sufficient to stay immobile and wait for it to be in the range of our front webcam. A continuous change in the depth of the submarine could be needed if we do not know the depth of the target or if it changes. When it is visible on our webcam, only its position on the webcam picture should be used to control the position and the depth of the robot in the pool to follow it. An algorithm based on colour detection in water should be used.

To detect the bottom target and the docking box, a combination between sonar data and front or back webcam detections should be used. The robot should follow different predefined waypoints to be sure to scan all the pool.

The detection of the wall to follow should be made by the sonar. We could put our sonar in a sector scan mode pointed at the wall in order to speed up its data stream.

V. Innovation

This year, we decided to focus on improvements in the computer science part of the robot. Indeed, we worked on the simulation of the robot, the GUI and the correction of the bugs in the devices communication. The autonomous part of the code was rewritten to provide more flexibility to be able to deal with unexpected changes.

2 students worked on the update of a 3D simulator (in OpenGL) that was released 2 years ago. The goal of this simulator was to show the robot on the screen as if it were in a real pool. In particular it had to:

- Communicate with the intelligent part of the code (objects detection, localization in the pool...)
- Simulate the physics behaviours of the robot in water

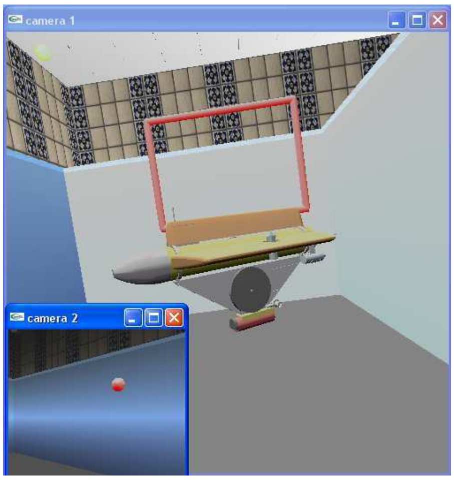


Figure 22: 3D simulator

Until now, the GUI was based on TCP servers running on the robot's computer (with Mandriva) and TCP clients on a laptop (with Windows), connected with WIFI. This year, we decided to eliminate the network part of our programs by using a remote desktop connection to the robot. This simplified our code, where many bugs were caused by the attempts to handle the network communication, as this part was now handled correctly by the remote desktop connection software.

We also changed from Linux to Windows on the robot's computer for the following reasons:

- Windows has good built-in remote desktop connection software
- Most of the devices we use has official drivers and programs for Windows whereas the manufacturers do not always provide support for Linux. As a consequence, we can use official tools to test our devices in real conditions (e.g.: test the sonar and the inertial measurement unit in a pool) without having to develop our own software to try to find all the capabilities of our devices.
- In combination with the remote desktop software, it is easy to develop directly on the robot's computer a GUI with Visual Studio, C++ Builder...

The real innovation is in our localization algorithm (static and dynamic) that uses interval methods to compute the position of the submarine.

VI. Financial summary

We got 25000€ this year for the project.

Products	**Prices (€)**	**Purpose**
PC104 Pentium M Eurotech	1000	Embedded computer to replace the previous one
PC104 Core 2 Duo Digital Logic	2000	Embedded computer to test and in case of problem (but not ready to use)
10 Webcams HD Logitech Quickcam Pro 9000	700	Webcams used for tests and in replacement
Various media readers, storage and converters and various tools	300	
IP68 waterproof connectors	650	
Pressure sensor Keller	550	In replacement in case of problem
D-Link DWL-2100AP High Speed Wireless Access Point	100	In replacement in case of problem
Labjack UE9	400	In replacement in case of problem
Servo controllers Robbe Rokraft	600	In replacement in case of problem
Servo controllers Parallax and Pololu	100	To test and in replacement in case of problem
Trip	5000 ?	

VII. Risk assessment

Risk	**Precaution**
Loss of control	Power switch, positively buoyant
Recovery needed	Central lifting cord
Sharp edges	Diving gloves
Frontal collision with a wall	Bumper in front of the frontal webcam
Electric shock	Only low voltages and intensities
Thrusters hazard	Propeller protected