ROBOTICS AT ENSIETA

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ABSTRACT: *The purpose of this paper is to discuss about the robotics development in our school. The robots developed in our school are a submarine robot, a swarm of ground robots a robotic sailboat and a flying robot. The purpose of building a submarine is to participate to the international AUV competition SAUC'E (Student Autonomous Underwater Challenge Europe). As for the sailboat, we are participating in two competitions. The first is the WRSC (World Robotic Sailing Championship) and the second is the Microtransat Challenge which purpose is to autonomously cross the Atlantic Ocean. The discussed subjects will be hardware, software and algorithms used for the different autonomous missions.*

Keywords: Robotics, AUV, Sailboat, Ground robot, Quadcopter, Interval Analysis

Introduction

With the development of electronics (computers, sensors), it is now quite simple to make a robot. In this paper, we will try to show an overview of the development of robotics in our school. The discussed subjects will be hardware, software and algorithms used for the different autonomous missions. The robots developed in our school are a submarine robot, a swarm of ground robots and a robotic sailboat. The purpose of building a submarine is to participate to an international AUV competition that is SAUC'E (Student Autonomous Underwater Challenge Europe: [site1]). As for the sailboat, we are participating in two competitions. The first is the WRSC (World Robotic Sailing Championship: [site2]) and the second is the Microtransat Challenge ([site3]) which purpose is to autonomously cross the Atlantic Ocean. The ground robots purpose is to participate in a local competition called CAROTTE which purpose is to develop autonomous ground vehicles (AGVs). While developing robotics we abide to several principles. The first is that we always try to participate to a challenge (be it international or national) because it is an important factor for boosting the motivation of the students participating in the projects. The second principle is to use COTS –Commercial Off The Shelf- components to ensure their reliability and reproducibility. The third principle is the KISS -Keep It Simple, Stupid- principle.

Sailboat

The sailboat was built for the Microtransat challenge which purpose is to autonomously cross the Atlantic Ocean while communicating its position through satellite communication. Many factors helped in the project creation. First, ENSIETA is located in Brest, a city on the North-West of France on the Atlantic Ocean shore. Moreover, our school is multidisciplinary since there are departments of informatics, electronics and mechanics and particularly the sub-department of naval architecture. As for our first challenges, we participated in the WRSC competition in Portugal and then we made our first little challenge of crossing the Brest

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Harbour with our first prototype (see figures below). We are currently preparing two new robotic sailboats for the transatlantic challenge.

Figure 1: Crossing Brest Harbour with "Breizh Spirit" sailboat

Mechanics

Our sailing robot design is based on the IMOCA Open 60 class design race boats, we only made the mast smaller in order to enhance its stability. In order to build the hull we used glass fiber mat bound together with a resin binder which we gave form using a mould made from plaster. The images below show the process. The tackle of the boat is maid using the same techniques as the real boats but using reduced size components.

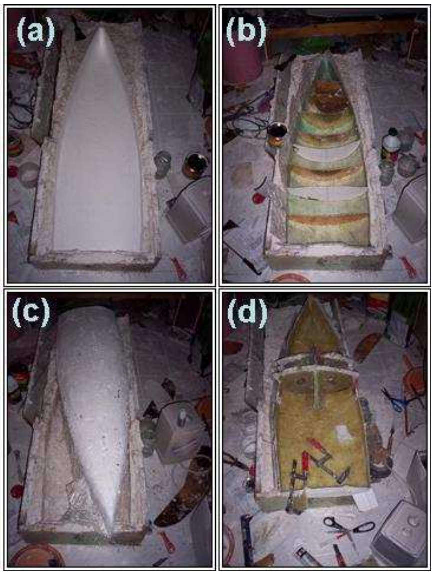


Figure 2: Hull construction

Electronics

The electronic architecture of the robotic boat is showed in figure 3.

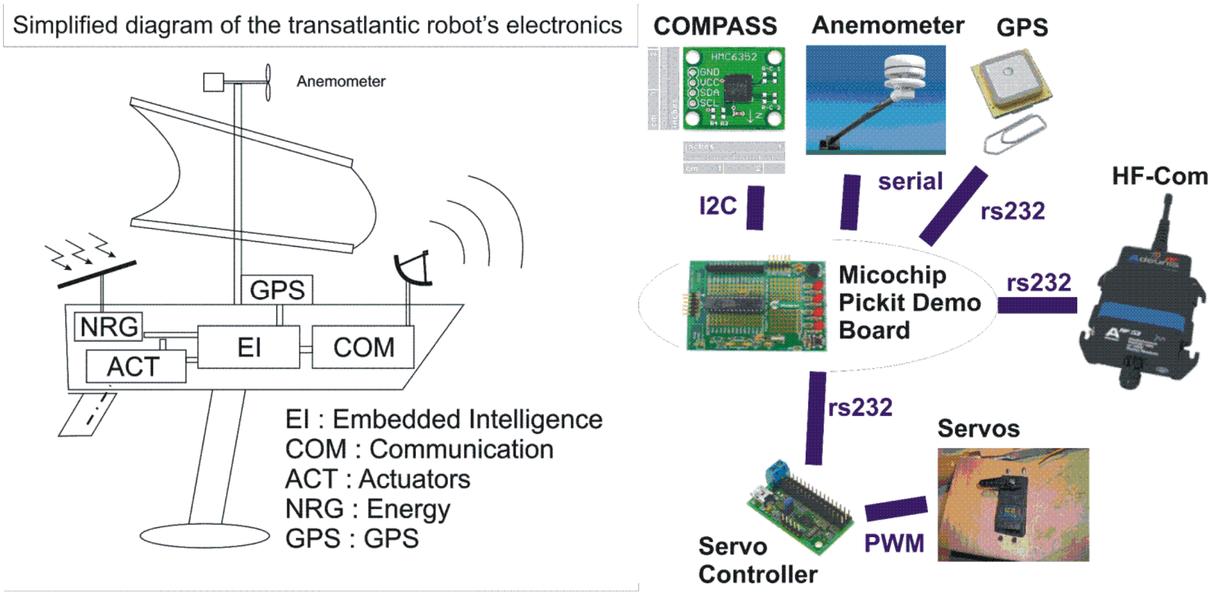


Figure 3: Sailboat electronics

The hardware references are listed in [hw1].

Sensors

As for the sensors, we used an Anemometer (wind sensor) a GPS and a compass. After several tests we concluded that the Anemometer is not a reliable device since it stopped working after a couple of month of testing. This is normal since the sensor is outside and is always subject to the harsh oceanic environment. We decided to develop sailing algorithms that doesn't need information about the wind.

Intelligence

As for the intelligence, we used a PIC microcontroller able to do floating operations. The advantage is first, power consumption and second, that there is no operating system, thus being simple and more predictable than a computer.

Energy

We used rechargeable batteries (LiPo) since the operation time is less than 24 hours. The transoceanic challenge is estimated to go on for more than 6 months thus we are obliged to use sustainable energies like solar power or wind/water turbines.

Communication

Even if the boat is supposed to be autonomous, we need a way to communicate with it for debug and configuration purposes. We used an HF-Communication module for that purpose. The range of the module is up to 6km. For the transoceanic challenge we plan to use SPOT messenger satellite module that will send us the position of the boat every 1 hour.

Figure 4: Spot messenger

Sailing algorithm

In our first sailing algorithm we assume that we know the direction of the wind since we have a wind sensor. The algorithm is based on human sailor techniques.

First, we have to be able to control the heading of the boat with the rudder and control the sail angle. The second stage of the controller is to take into consideration de fact that the boat can't go into the wind. We use simple technique described in the figure below.

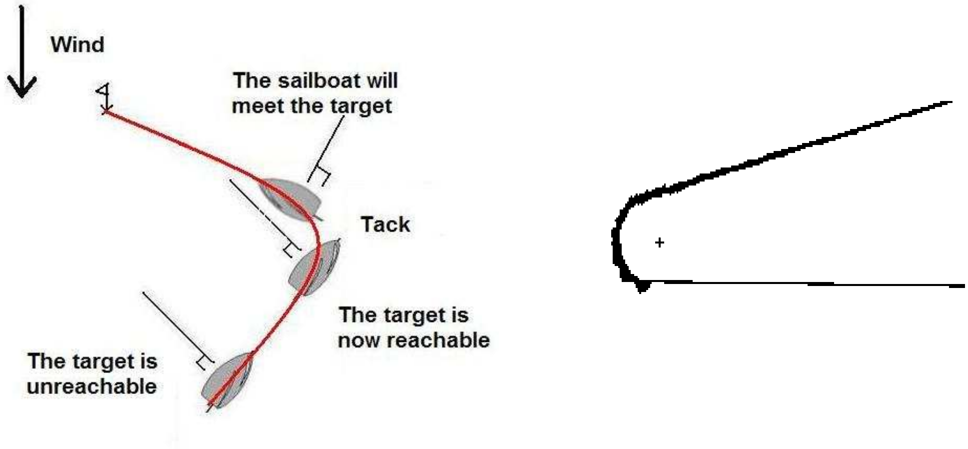


Figure 5 : Sailing strategy

To be able to go round a buoy with a circular trajectory, we developped an algorithm that uses no sensor history nor calculated route thus gaining in simplicity and reliability. The trick is to use the previous strategy while following a virtual point that is the intersection between the trajectory circle and the tangent to the circle passing by the boat.

The latter experience will show that the wind sensor is not reliable so we cannot use the previous strategy. Thus we created first method of sailing without knowing the direction of the wind Voronoi Diagrams [1].

Simulator

In order to simulate the sailboat we created a simulator where we compute the state of the simulated robot using state equations [2] [3].

AUV (Autonomous Underwater Vehicle)

This robot was created within the scope of the participation in the SAUC-E (Student Autonomous Underwater Challenge – Europe: [site1]) competition, which has been held for the last four years in France and England. This competition provides a challenge for students to present their ideas and their skills in the domain of robotics autonomous systems.

The goals of this competition are to advance the state-of-the-art of Autonomous Underwater Vehicles by challenging multi-disciplinary teams of students and engineers to perform an autonomous mission in the underwater environment and to foster ties between young engineers and the organisations involved in AUV technologies.

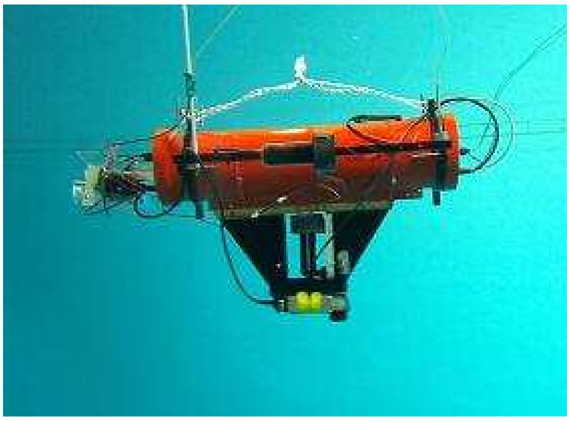


Figure 6: Saucisse AUV

Missions

Those are examples of missions to be performed by the AUV

- Detect and follow moving target
- Detect and dock into a docking box
- Pass through underwater gates in a specified order
- Detect bottom target and stabilise the AUV above it
- Follow a wall at constant distance using sonar

Mechanics

The mechanical base of the submarine is an aluminium tube with a plaque on each side of the tube to ensure water tightness for the inside electronics that communicates with the external sensors and actuators through waterproof connectors on the plaques. In order to control the robot, we need three thrusters. Two horizontal thrusters are used to control the horizontal position and the heading of the robot. The depth is controlled using one vertical thruster. There is no need for a powerful thrust since the robot weight is adjusted to be quasi null in water. The robot has a keel that’s purpose is to stabilise the roll and the pitch. The sonar is mounted under the keel and cameras and the WIFI antennae are mounted on the front (see figure 5).

Electronics

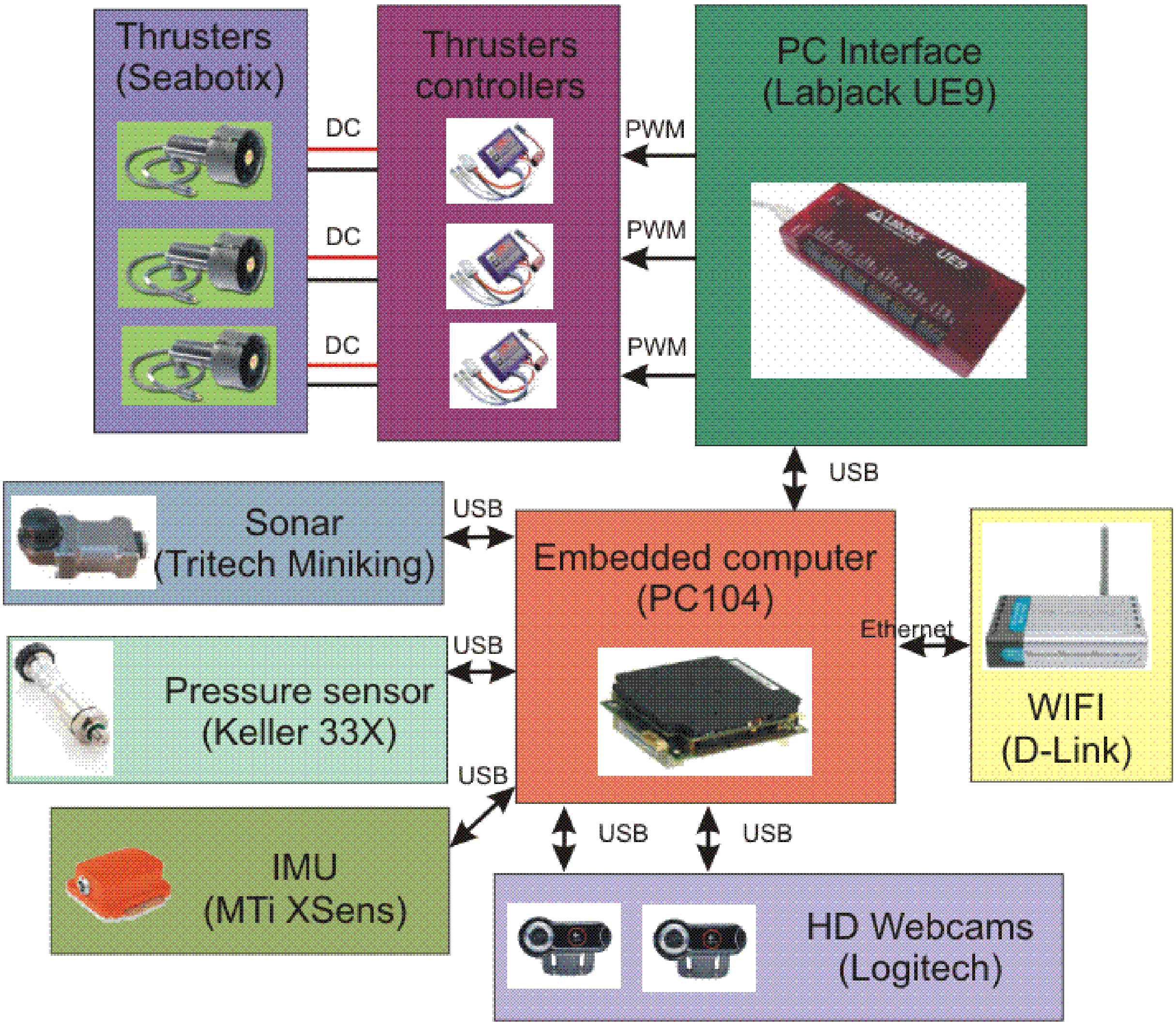


Figure 7: Saucisse's Electronic Diagram

The detailed list of hardware references are listed in [hw2]. As one can see, there is no custom electronics thus the reliability of the design. In fact, during the competition, we always have spare part for each component of the electronics.

Algorithms

In order to execute the missions, we implement vision and localization algorithms.

Vision algorithm

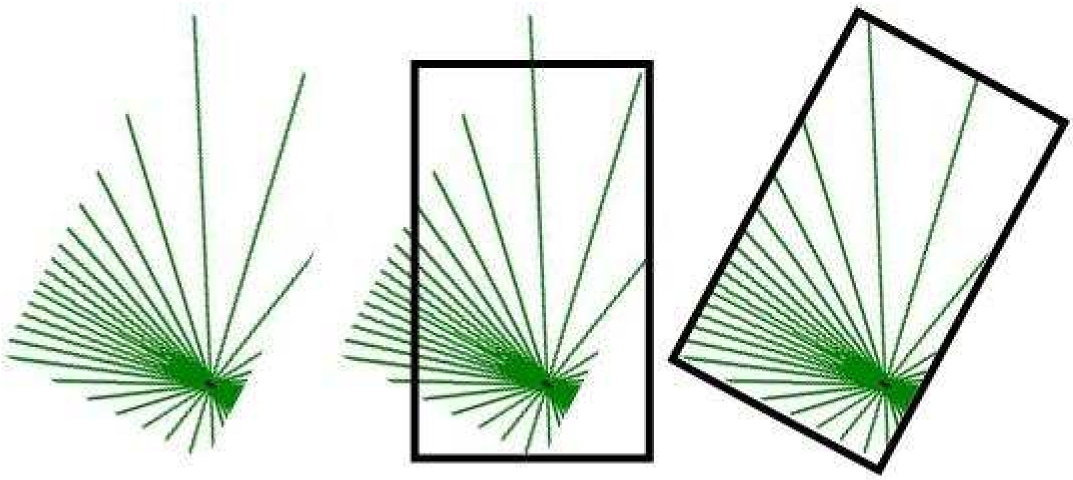
Figure 8: Underwater object detection based on color detection taking color fading into consideration

As for the vision, we have algorithms based on color detection taking color absorbtion in water into consideration. In fact, the red color is the most absorbed color in water. Those were the works of a Ph.D student [4].

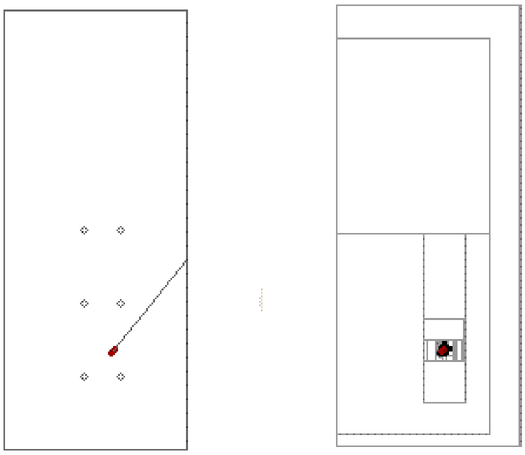
Localization

As for the localization, we use sonar and compass data and compute the position of the robot using set inversion methods from interval analysis [5][6]. Those methods are known for their guaranteed results.

The example below shows the overall principle of that kind of localization in a rectangular pool. On the figure are represented the pings of the sonar (distances to first obstacle measured by the sonar) in the robots workspace. In order to localize itself, the robot has to know the position of the pool in that workspace. The localization algorithm does that "matching" between the pool walls and the sonar images by bloc-testing of all the possible positions of the pool and rejecting the impossible solutions.



In the figure below you can see localization performed using simulated data and the RSIVIA algorithm [6]. As you can see the algorithm tests bloc by bloc and discards the impossible solutions leaving only the solution set (in black).



Embedded software

Operating System

Once again the design is simple. We use normal Windows XP on the embedded computer i.e. the same environment we develop software in. It means if the program works on our PC it will work on the robot. Another useful trick is to use the remote desktop connection in order to remotely communicate with the robot while it is on the surface of water. This approach enables us to control the robot and place it in the initial zone, to configure the new program, to test the sensors using proprietary software.

Code modularity

The code is made modular in order to make the code easier to understand and to be able to make a framework for the students that make parts of the code.

CAROTTE Robot swarm

This year, our school will participate in a national competition called CAROTTE (CArtographie par RObоT d'un Territoire: [site5]) organized by ANR (French National Research Agency) and DGA (French Department of Defence) which aim is to develop autonomous ground robotics. We have decided to create a robot swarm using robots as shown in the figure below. Because the robots will know their relative positions the swarm of robots could be considered as one “flexible” robot. This helps in the localization of the swarm and in the mapping of the area. As an example, the outside robots could localize themselves using their GPS position and thus localizing the complete swarm. Robots will be actually not of the same type. The base is the same but the sensors will vary (some robots will have a laser telemeter).

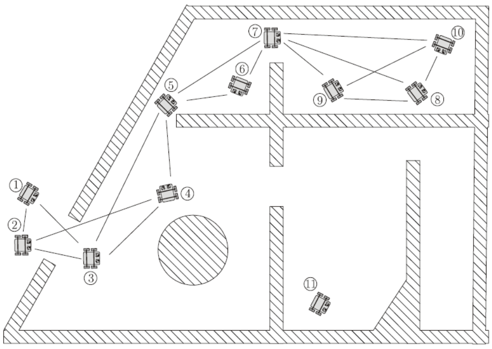


Figure 9: Robot swarm in a building and the robot itself

In the figure below you will find the electronic architecture used for the ground robot.

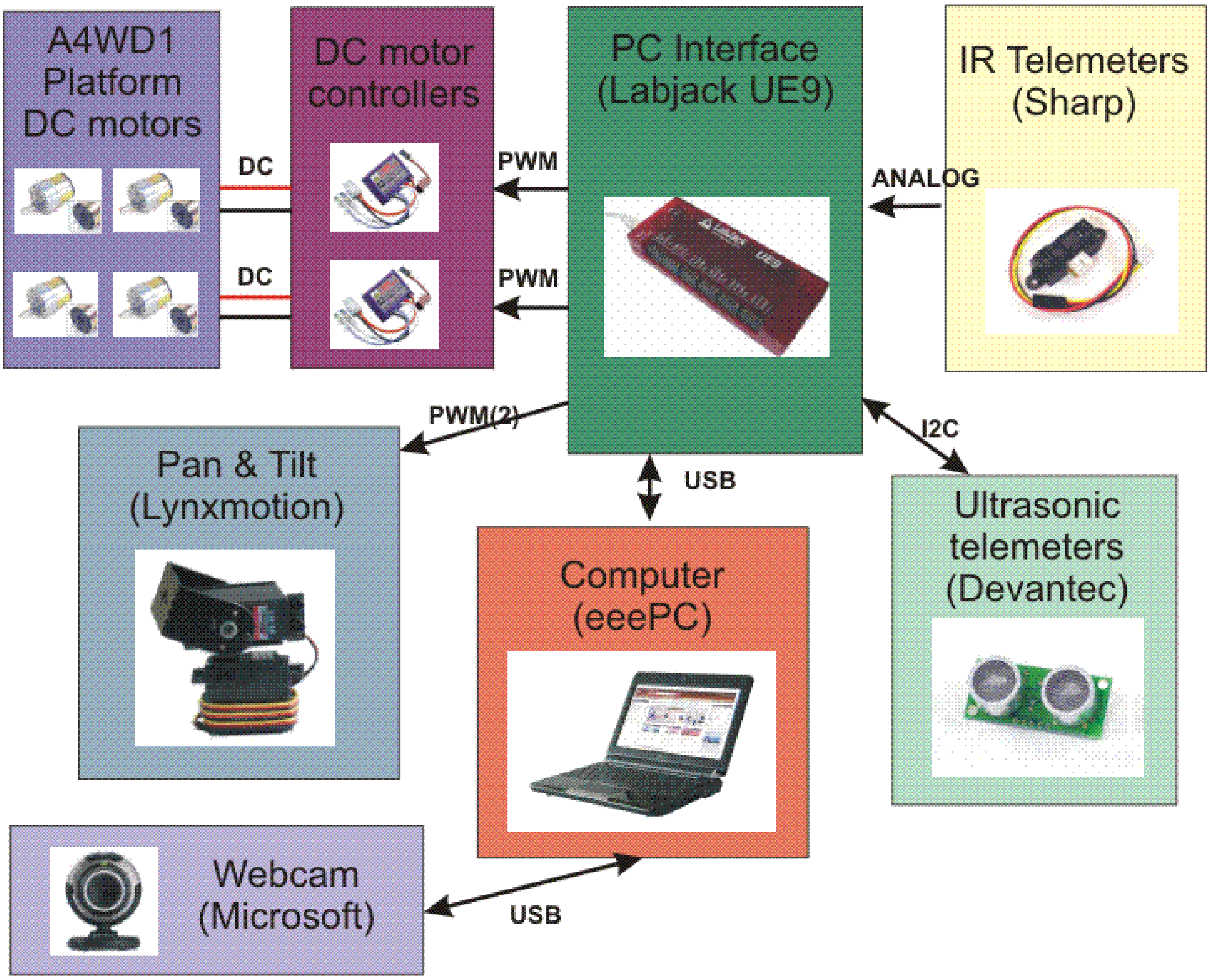


Figure 10: CAROTTE Ground robot electronic architecture

As usual we try not to make any custom electronics to have more reliability. We did not yet implement electronics used for other robots localization.

Algorithms

On the robot we will implement computer vision algorithms and SLAM (Simultaneous Localization And Mapping) algorithm similar to the one we used in the AUV. The SLAM will be performed using interval analysis which is well suited for CSP (Constraint Satisfaction Problem) Solving.

QUADCOPTER

This year we begin a new project that is the autonomous UAV (Unmanned Aerial Vehicle) project. The purpose is to build a flying robot capable of performing autonomous missions indoor and outdoor. We failed to find a competition to participate in this year so the robot will serve as a support for the ground robot swarm described in the previous part. It will help the ground robots to “see” the high places and to have a global view of the current situation from above. Our reference model is the German MicroKopter [site4].

Figure 11: An example of a quadcopter

Conclusion

In this article we showed different robots developed in our school. The purpose is to demonstrate that creating working robots is easy these days. The main problem is to create efficient and robust algorithms to give them intelligent behaviour.

References

Articles

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[6] L. JAULIN**,** *Robust set membership state estimation; Application to Underwater Robotics*, 2009, Automatica, Vol 45, Issue 1, pages 202-206. URL<http://www.ensieta.fr/jaulin/publications.html>

Hardware

[hw1] Compass: *HMC6352*; Anemometer: *CV7 ultrasonic anemometer from LCJ Capteurs;* GPS: *EB-85A;* HF-Communication: *Adeunis ARF53;* Servo Controller: *from POLOLU*

[hw2] Thrusters: *Seabotix SBT150*, Thrusters controllers*: robbe rockraft 120uP*, PC Interface: *Labjack UE9*, Sonar: *Tritech Miniking*, Pressure sensor: *Keller 33X series*, IMU*: MTi Xsens*, HD Webcams: *Logitech Quickcam Pro 9000*, WIFI Router: *D-Link DWLG100AP*, Embedded Computer: *PC104 from EUROTECH ref: CPU1472*

Internet Sites

[site1] *http://www.dstl.gov.uk/news_events/competitions/sauce/09/index.php*

[site2] *http://www.fe.up.pt/wrsc*

[site3] *http://www.microtransat.org*

[site4] *http://www.mikrokopter.de*

[site5] http://www.agence-nationale-recherche.fr/AAP-240-Carotte.html