A didactical electronic project for graduated students: Initiation to GPS localisation and navigation using a small-scale model electric car

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Abstract : In this paper, we explain first some major evolution in the student's behaviour. Then, we suggest here, an alternating teaching approach to better fit with the new student's needs: Indeed, far from the theoretical and difficult traditional courses, "learning by project" can be an interesting alternating practical way of teaching. We describe, as example, a GPS navigation project to illustrate this approach. Technical specifications and some design details are given. Finally, we show how Hermann brain modelling and team management tools are helpful to guarantee the success of this pedagogical process.

Key words: Pedagogical experience, Learning by project, Multi thematic electronic project, GPS navigation,

1. Introduction

1.1 ENSEIRB engineer school presentation

The "Ecole Nationale Supérieure d'Electronique, Informatique et Radiocommunications de Bordeaux" is one of the graduate national engineering schools, known as 'Grandes Ecoles', in France. It is also one of the oldest, as it was founded in 1920.
ENSEIRB has developed with the growth of information and communication technologies. The Computer Science Department was created in 1986 to complement the original Electronics Department and was followed in 2000 by the new Telecommunications Department.

1.2 The student's behaviour evolution

We have attended for a few years, a change of the behaviour students. The teachers are in front of a new kind of public and do not know how to manage behaviours which are not familiar. Among the major evolutions, we can extract the most important one's:

- The international origin and the diversity of social origin of our students increase the difficulties of teaching: level dispersion and cultural diversity is not anymore compatible with traditional lessons in full classroom.

- Most of the students have a lot of extra scholar activities such as sport, internet electronic games, and other leisure's. They are interesting from a personal development point of view, but they also generate a too big mental energy dispersion which is not favourable to a rigorous school work.
- A reduction of capacity of attention (inherent in human being and normally about 45 min with 1 hour) has also been observed. Thus, the efficiency of a traditional theoretical course of 1 hour is now poor, due to a progressive unhooking of the audience faster than before.
- At least, our students act now like consumers more than students: this "zapping" phenomenon is destabilizing for the teachers.

2. Learning by project

2.1 Introduction

If this concept is obviously not new, its introduction in scientific school is quite recent. The aim of this approach is to optimize the motivation and to develop the curiosity of the students by a practical approach and a "bottom up" teaching strategy.

Such approach avoids the abrupt and difficult theoretical courses and training which are often rejected by the students and makes the student more confident and responsible of himself. A funny project is also an opportunity for the student to develop his team work spirit and his management ability.

2.2 Application
The navigation of a small scale model electric car with a GPS module has been chosen to experiment this learning approach during training period for students in second year study in the GEII institute and in collaboration with ENSEIRB engineer school.

3. Description of the project

3.1 General description

3.1.1 Aim of the project
The aim of this project is to design electronic boards and embedded software to drive as simple as possible an autonomous small model electric car: It must reach a destination point (GPS coordinates manually entered just before moving) from the departure point using GPS localisation and compass modules. The trajectory must be linear as well as possible, and the velocity constant. In case of front obstacles, the car stops, go backwards and try to avoid the obstacles by turning left or right.

3.1.2 Mechanical characteristics of the small model car.
For this purpose, we use a mechanical frame from Tamiya company [11] as indicated in figure 1.

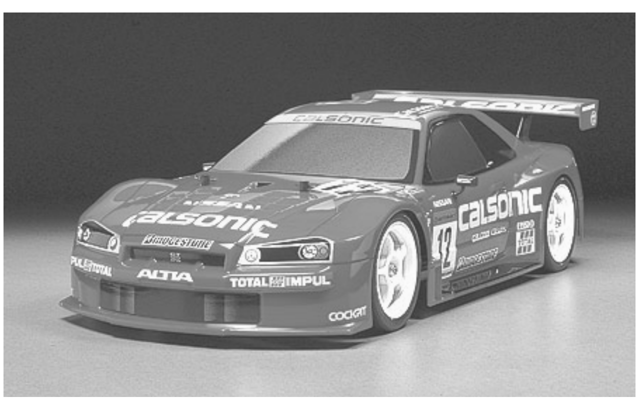


Figure 1: small scale 4x4 RTR Calsonic GT-R 2003 Tamiya 1/10

The main characteristics of this model are:
- 1/10 scale, Length: 441mm, Width: 185mm Weight: 1570g,
- Suspension: 4 Wheel Independent,
- Engine: Electric 7,2V 4A,
- Body Type: Polycarbonate Cut & Printed
- Differential Gear System: F/R 3-Bevel Diff,
- Tire Width: F/R both 27mm, Tire Diameter: F/R both 65mm.

For our project, we removed the body and keep only the mechanical frame, in order to install our own electronic boards. And we disconnect mechanically the 4x4 motion option to reduce the power consumption.

3.1.3 Technical specifications
The electronic specifications for our project are:

- Power supply: 7,2V 2700mAh NimH battery cell
- Infrared detection of a front obstacle
- GPS module from Parallax company
- Microcontroller board: Basic Stamp from Parallax company
- Electronic compass module from Parallax company
- Front and back traction control (to be designed)
- Steering wheels control: servomotor FUTABA or equivalent.

3.2 The GPS module [4],[5]
This Parallax GPS module is one of rare module available on the market, with an easy access to the localisation data's and directly compatible with a classical micro controller. The main characteristics of the module are given in table 1 and 2 below.

Maximum Absolute rating	Value
Operating Temperature	-40ºC to +85ºC
Storage temperature	-55ºC to +100ºC
Supply voltage (V_{CC})	+4.5V to +5.5V
Ground voltage (V_{SS})	0V
Voltage on any pins	-0.6V to +(Vcc+0.6)V

Table 1 : GPS maximum ratings

Parameters	Symbol	Specification			Unit
Conditions		Min/Typical/Max			
Voltage supply	V_{CC}	4.5	5.0	5.5	V
Consumption	I_{CC}	80	115	135	mA

Table 2 : electrical ratings

The other important characteristics are:

- Refresh speed of GPS : 1 time per second
- Sensitivity: -152 dBm in search mode, -139 dBm in acquisition mode.
- The module contains a battery cell for the memory and Real time clock recovery.
- Average accuracy: plus or minus 5 meters in position and +/-0.1 meter per second for the moving speed.
- Data output format: NMEA [6] or ASCII character chain.

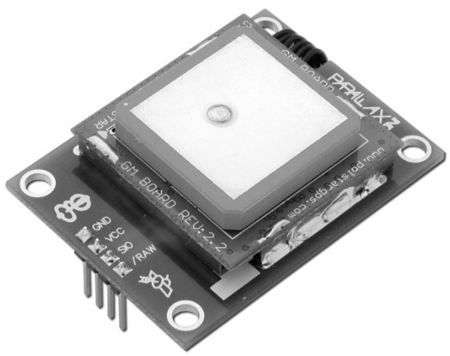


Figure 2 : GPS Parallax Module

An example of formatted data's returned by the module is given in table 3:

Parallax GPS Receiver Module Test Application

Hardware Version: 1.0
Firmware Version: 1.0
Signal Valid: Yes
Acquired Satellites: 8
Local Time: 23:28:45
Local Date: 09 MAR 2008
Latitude: 036° 35' 55.3" N (36.5986)
Longitude: 118° 03' 35.6" W (-118.0599)
Altitude: 1143.2 meters (3750.6 feet)
Speed: 33.8 Knots (38.8 MPH)
Direction of Travel: 338.1°

Table 3 : example of returned data's

3.3 GPS module and processing board

We use here a classical BASIC STAMP board [4] based on a micro controller PIC 16C57 and a "on board" BASIC language embedded software, to process data's from GPS Module (figure 3)

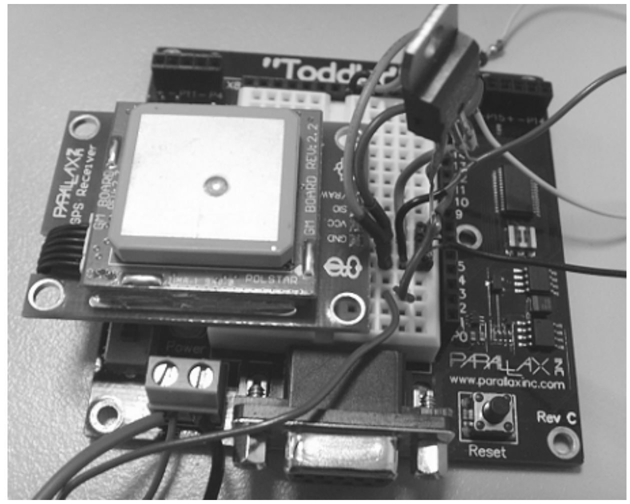


Figure 3: GPS module and BASIC STAMP Board

As a first experimentation of the module, we initialize it with the local coordinates and local time of our school ENSEIRB and then check with "google earth" the correct GPS point. (Figure 4)

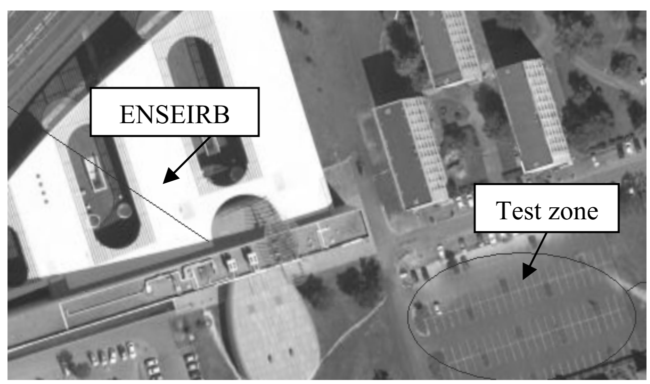


Figure 4 : GPS initialisation (google earth image)

3.4 Directional Servo motor

The front wheels of the vehicle are driven by a classical Futaba Servo motor. (figure 5a).

Figure 5a: servo motor

The figure 5b shows the control signal applied to the servo and the corresponding output rotation angle.

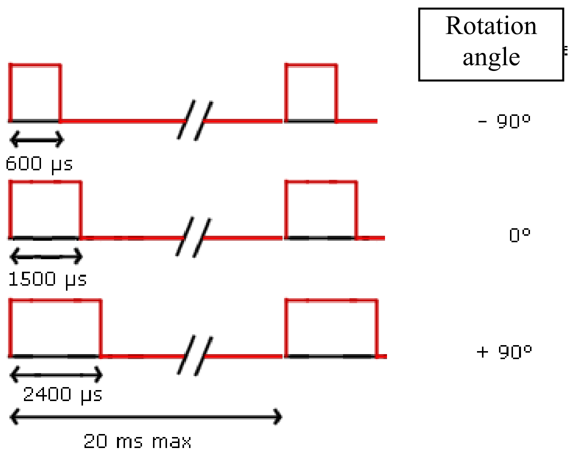


Figure 5b : typical PWM control signal

Power consumption of the servo during rotation is around 150mA depending, of course, of the friction resistant couple.

3.5 Traction DC Motor and PWM driver

In order to simplify the design, we decided to drive the DC motor with a basic H full bridge switching structure (NMOS IRFZ34N and PMOS IRF9540 power transistors [13] switched at 15 kHz and sized for 6A peak current) for forward and backward motion The driver is made of discrete components for pedagogical reasons: a classical NE555 for PWM generation, TC4420 MOS drivers with “hand made” dead time circuit R,C, diode to avoid cross conduction, enable and direction signals generated by the microcontroller. For a first try and as the “playing area” is supposed to be flat, we did not add any feed back loop for speed control. An input on the logical gate allows stopping the car in case of emergency or front obstacle detection during the motion.

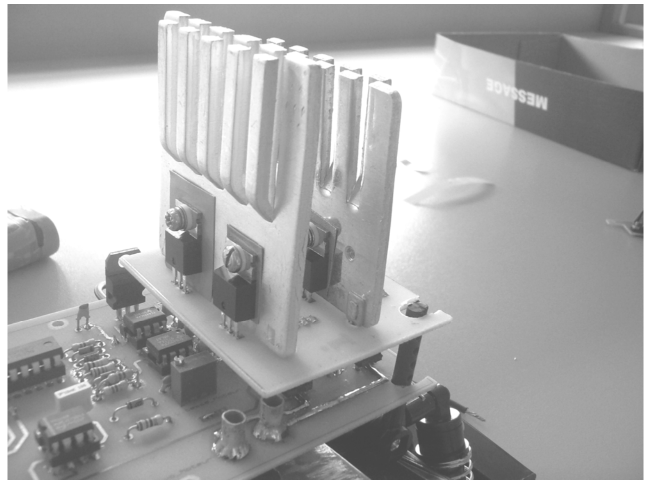


Figure 6 : Motor driver board

The figure 7 shows typical waveform we obtain with this motor driver.

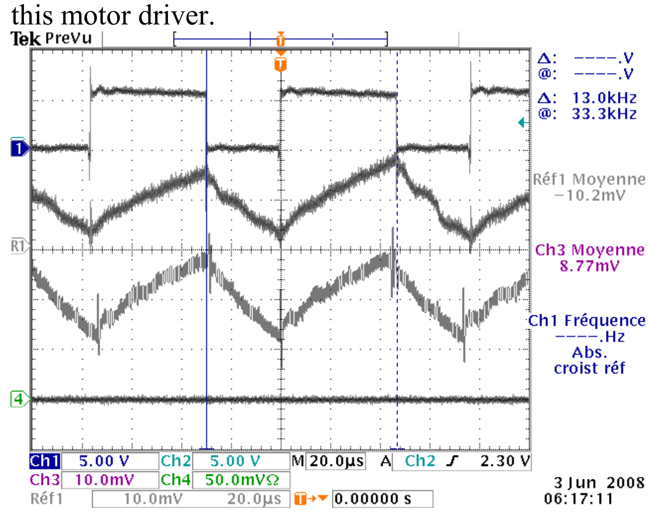


Figure 7 : experimental voltage and current waveforms through the driver board

Trace 1: logical control PWM signal
Trace R1 : Current through the motor (scale: 1A/div) (forward and backward)

3.6 Infrared sensors

A couple of IR emitter and receiver such as QEC113 (940nm) and PNA4602M sensor could be used to detect an obstacle using a 38 kHz carrier frequency generated by the processing board.
But we prefer to use a classical SHARP GP2D15 Infrared sensor as on/off detection up to 80 cm.

(Figure 8a). The threshold detection distance is set up to 25 cm (figure 8b), which is sufficient to slow down the car and to avoid the obstacle. The advantage of this second type of sensor is that it is not sensible to the reflectance properties of the obstacle.

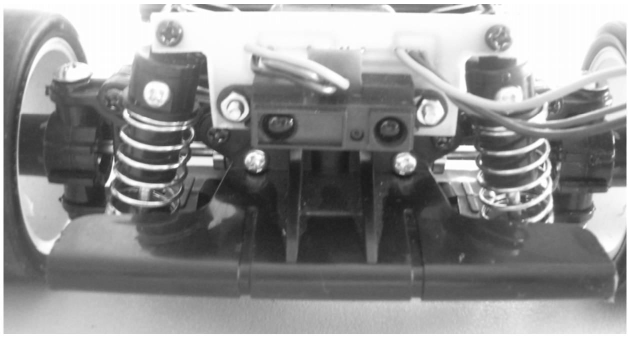
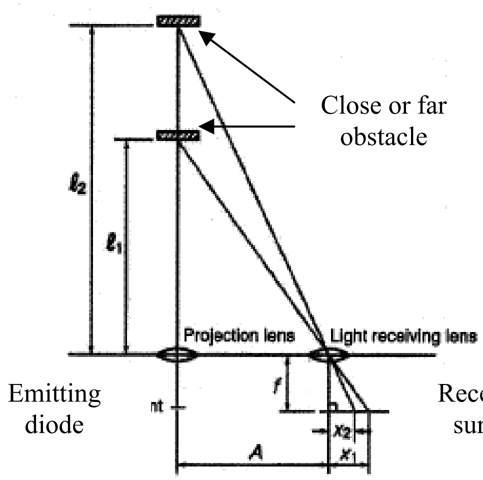


Figure 8a: infrared sensor Sharp GP2D15



Triangulation distance measurement principle [8]

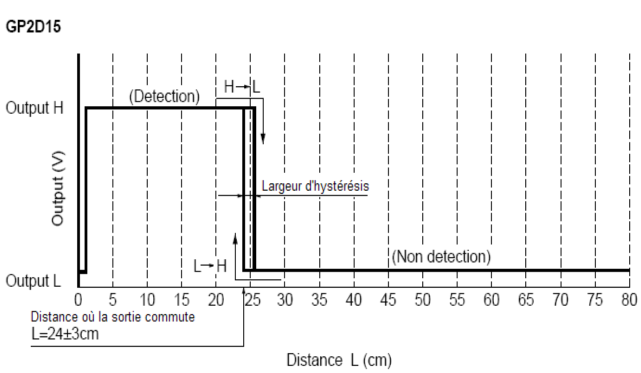


Figure 8b: infrared sensor threshold distance and hysteresis

3.7 Whiskers

In addition with the infrared detection, we added two tactile "whiskers" on the nose of the car in order to improve the protection against small or very low obstacles. They acts like mechanical switches, to shut down the PWM control signal of traction motor in case of emergency.

3.8 Compass module

Because of the relative "low" precision of GPS compared to the small size of the electric model car, we use a compass module for helping the car to find the initial header from the departure point.
This compass module consists of Hall Effect sensor Dinsmore 1490 (Robson company): it is built of a magnetic rotor inside a cavity with a very low friction coefficient, which turns on itself depending on the earth magnetic field.

Figure 9 : Compass module

The compass module returns a serial data coded on 4 bits as indicated in table 4:

Binary value	Header
0000	North
0001	North East
0010	East
0011	South East
0100	South
0101	South West
0110	West
0111	North West

Table 4 : header code

The compass precision allows guessing the main direction of the arrival point but nothing more: It is just used to set the car in the correct way at the beginning of the motion.

3.9 General synoptic

The whole schematic diagram of the embedded electronic is given in figure 10.

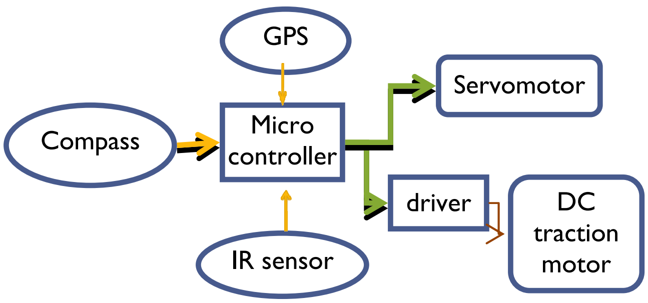


Figure 10: general block diagram

3.10 Programming the motion strategy

A very simplified strategy has been adopted compared to the commercial embedded powerful GPS system. It was just to move the car and to understand the complexity of navigation

At the beginning of the run, we enter the coordinates of arrival point in the program. Then, the GPS get the initial position and the processing board computes the initial heading.

Comparing the initial orientation of the car to the computed heading, the car turns until the compass module gives the right value.(figure 11a).

Then a periodic real time acquisition from GPS, allows correcting the instantaneous heading as shown in figure 11a.

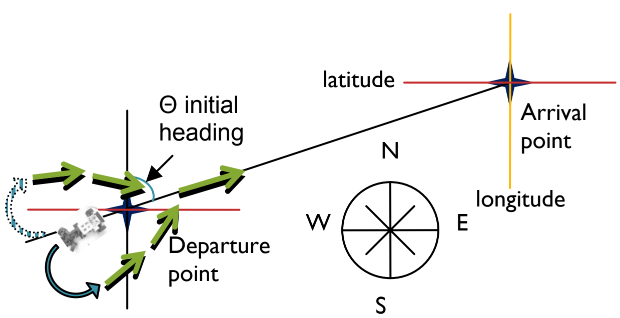


Figure 11a : initial motion

So the trajectory is not exactly linear but looks like segment of lines between departure and arrival points as indicated in figure 11b.

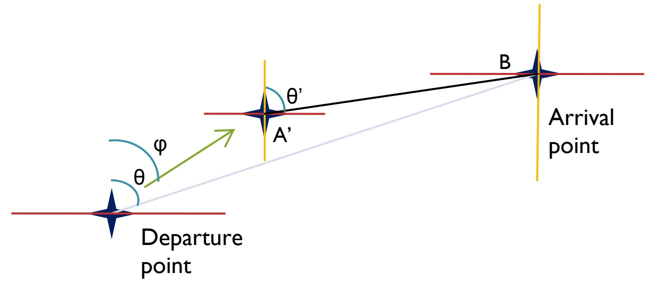


Figure 11b : moving strategy

In case of front obstacle, the car first stops then moves back, turns to avoid the object and computes a new correct heading.

The whole strategy is summarized in figure 11c.

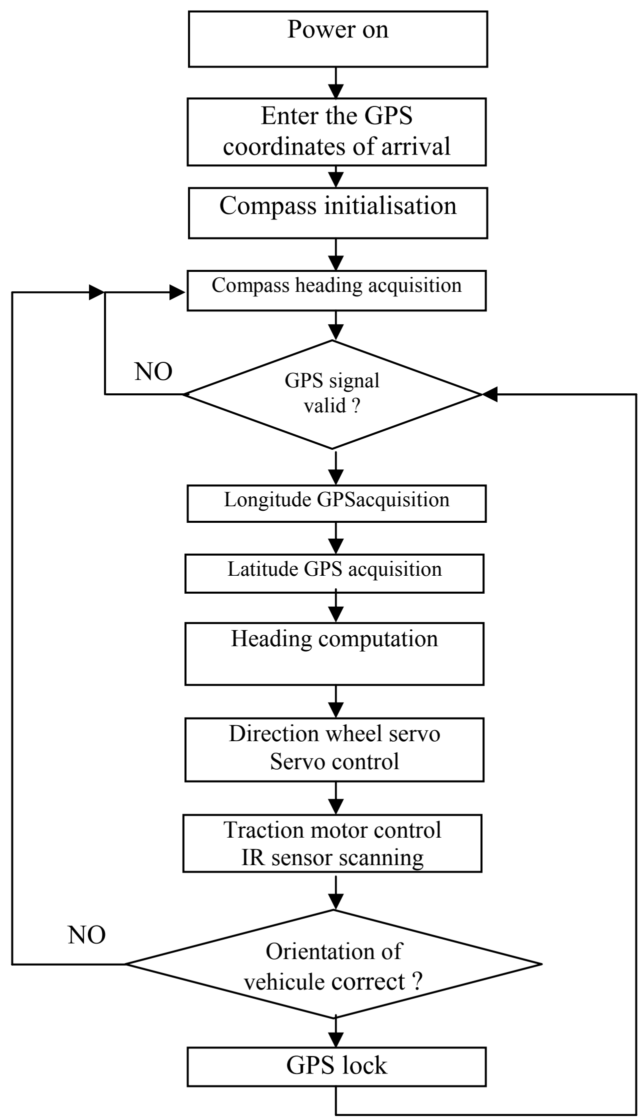


Figure 11c : software organisation

Programming this strategy represents around 450 lines of PBASIC code.

3.10 Full equipped small scale model car

The full equipped car is shown in figure 12a and figure 12b:

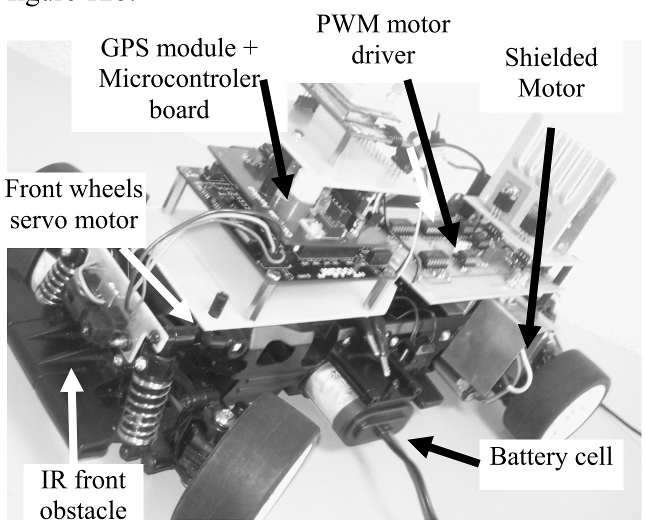


Figure 12a: model car opened

When the car is in action, the motor generates some electromagnetic perturbations, so that we added a copper shield and we put the compass module as far as possible from the DC motor.

Figure 12b: model car fully finished

3.10 Validation test area

The square "car parking" (100m x 150m) (figure 13) of ENSEIRB School was chosen to check the movement of the equipped model car.

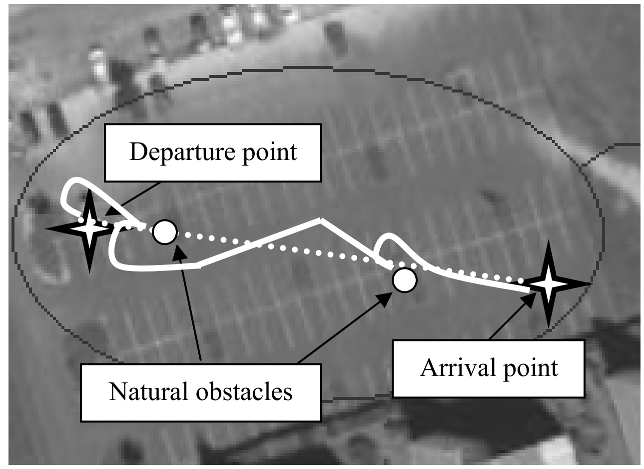


Figure 13: test area

Theoretical trajectory
Practical run of the car

When GPS is correctly locked, 5 minutes are approximately necessary to reach the arrival point after two obstacles avoidance and turn around.

4. Project flowchart

The project was first performed by two students during 2 full months of training period in ENSEIRB to check all the steps of the approach, and to solve any possible technical problems.
Then, this project can be now included in the traditional curses using the human tools we spoke about in a previous WSEAS publication [7]:

- Student group constitution: Initiation with the team work. During this first step, the individual Herman profile [3] of each student is done. Please understand that there no good or bad profiles but only different profiles.

A view of Hermann brain model is given in figure 14. A and B quadrant are left brain, C and D are right brain. The cerebral preferences of a human person are described following the two main horizontal and vertical axis. Quadrant A (blue) shows the preference of the individual for logic, modelling, (typical profile: mathematician, data processing specialist …). B (green) shows its aptitude for the practice and planning (real time production scheduler, administrative profile…). The quadrant D (yellow) shows the preference for the risk and projection in the future (typical profile : "start-up" manager, risk manager, artist…), and C (red) for the relational one, emotion (typical profile : social and commercial workers…).

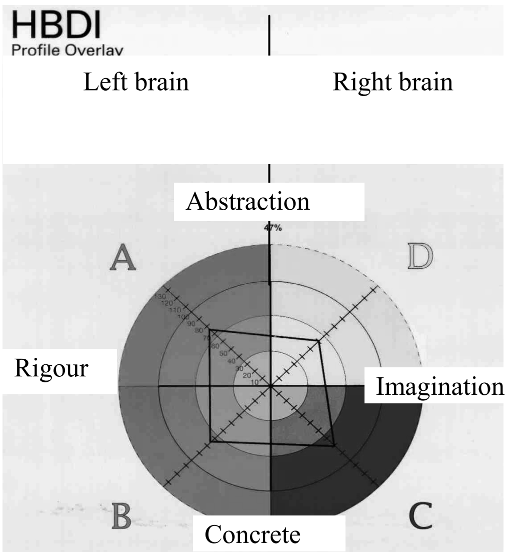


Figure 14 : Typical Hermann profile

-From complementary courses on human resources management [6], the team psychological profile [4] is then identified (open, close synchronous, random) (Cf figure 15).

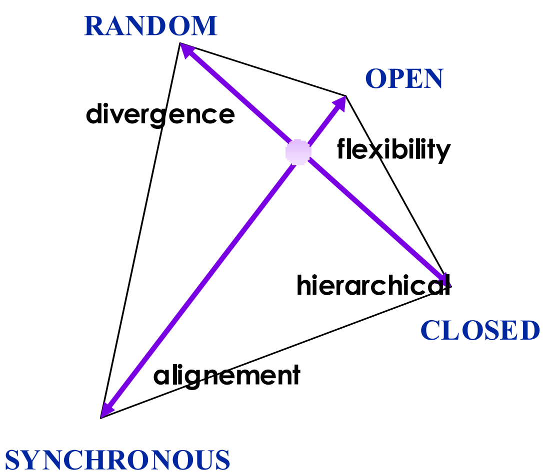


Figure 15 : the four types of team and characteristics

The main characteristics of each team profile are summarized hereafter. But there are deeply described by the communication teacher in front of the students. As for Herman profile there is no good or bad team but only different type of team.

1° "Closed Team":

Coordination = hierarchical (traditional authority)
Regulation = negative feed back
Priorities = stability, continuity
Decision = « top-down »

2° "Random team":

Coordination = Initiative, independence
Regulation = positive feed back loop; (amplified)
Priorities = variety, individual, creativity [16]
Decision = non formal, « bottom-up »,

3° "Open team":

Coordination = adaptative and collaborative process
Regulation = positive and negative feed back loop; reactivity, flexible
Priorities = stability & change, group & individual
Decision = negotiation, consensus, by processes

4° "Synchronous team":

Coordination = harmony
Regulation = structured, shared, uniformity
Priorities = harmony, coordination without effort
Decision = predefined; by a common and global vision.

Then, the methodology, and the human organisation, (task management, leadership…) are described as consequences of the individual and team profile, for a first student sensitizing to team management

According to the individual profiles of each student [3], the student teams are then made up.

After this preliminary phase, the teaching process goes on:

- Practical demonstration: Existing finished small model car is shown to the students. They are invited to experiment it and to think about
- Specifications definitions: The specifications are defined all together to give some freedom to the students (but inside a frame given by the teacher)
- Project management initiation: Once the specification and block diagram are defined, the job of each member of the team is defined. By a short

seminar on project management, we help the students to make task repartition, team manager designation.
- Bibliography: Showing the necessity of collecting information before starting the design, we encourage the student to find documents, books, and articles. Despite the internet facilities, we suggest to the students to find them rather in our internal books and periodic library. This process is often more efficient and more economic in term of paper reprint.
- Electronic design: a few lessons are dedicated to the design.
- At this period of the process, the students may consult different available teachers depending on their needs. Then, the whole electrical schematic diagram is then established by the team manager.
- Electronic design report: At the end of the design step, a written report is generated by the students. The technical and financial choices as well as the micro controller program are explained and justified.
- Manufacturing: electronic board are wired and mechanical elements are assembled by the students
- Manufacturing report: in this structured report, the students must clearly describe the soldering, wiring and assembly process, to make their prototype reproducible (like in private companies).
- Sub module and global test: When the whole system is manufactured, each part is tested individually. Finally, the global performances are validated.
- Test report: The students must indicate the results and performances they obtain, in comparison with the nominal specifications.
- Final report: All the intermediate reports are collected to make the final report.
- Oral report: each group must orally expose the subject during the last meeting, in thirty minutes.

5. Positive Consequences of "learning by project"

5.1 Technical aspects

- The funny aspect of the project is a source of motivation. It is also an opportunity to teach some difficult fields of electronic as simply as possible.
- Our « system » approach allows mixing different fields of electronic (analogue, digital, sensors, micro programming, and power electronic). It ensures a better comprehension, a better cross connection between them, and causes a global interest for the technical and theoretical lessons.

5.2 Human aspects

- Despite a frame worked project, some freedom into the design gives the impression to the students to be actor and creator. It acts like a "creativity" amplifier.
- The complexity of the design is better received by the students through a practical approach.
- This project is the opportunity of a self encouragement to the student to deepen himself his knowledge (by necessity and not obligation).
- The project is also a time for a human experience, a pleasant team work. Each student can discover his own preferences, profile, and personal interest.
- At least, a positive emulation inter group is developed, in a good environment of work.

5.3 Collateral effects

This kind of project is an opportunity for our students, to become aware of the complexity of the electronic systems, time of design and to learn humility. It is also, restoring in their mind a "scale of value" too much devalued by the very low prices of high added value consumer's electronics such as GPS mobile phone and so on.

6. Comparison with other experiences or approaches

Comparing to other experiences [1], [2], [3], [9], [12] [15], [16] done in different French and foreign engineer schools, we see first that many colleagues are now using this approach. The same evolution in term of motivation is observed, even if it will never possible to obtained 100% of satisfaction rate.

7. Pedagogical results

Even if it is always difficult to quantify the efficiency of a pedagogical strategy, we can quote first a strong implication of the two students initiating the project. After that, we asked to our electronic department to make an annual opinion poll and report among the students in order to get some feed back about this strategy: around

60% of the students answered to this questioner and the result shows a global satisfaction rate rising from 50% up to 65% for this field of teaching.
However, we must be careful, because "learning by project approach" has also its own limits in term efficiency and quantity of information given to the student by unit of time. Despite our efforts, we have had also some chess with students who prefer a perfect scholar guided framework.

8. Conclusion

We showed in this paper alternative approach to the traditional teaching methods. Indeed, classical courses do not match anymore with the actual pedagogical needs for environmental, individual, and society evolution reasons. As we can not change the students, we only thing we can do, is to adapt our pedagogical approach to them: "Learning by project" seems to be a good way (among others) to improve the efficiency and the quality of our teaching. Through a serious, complex but funny design project, we showed that it was possible to improve the behaviour, the motivation and the curiosity, of our students. Permanent adjustments and adaptation between student's needs and teaching strategy is probably the best way to make our scientific curriculum more attractive in the future.

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