Introducing embedded system concept through a multi thematic funny hexapod robot design project

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Abstract: In this paper, we first describe the pedagogical reform process in our school. Then, we point out the major human difficulties in reforming. The complexity of the relation between the new student generation and the teachers is briefly described. And some major changes in student's behaviour are given as example. The consequences on the teaching strategy are then indicated. At least, we show that theses evolutions require adaptation, efforts and changes in the way of teaching. And we finally present here, in our field of competence, a concrete and pedagogical robot design project (with technical details) we did, as an answer to the reform necessity.

Key words : Educational reform, "teaching efficiency ", Embedded system, Multi thematic robot project, Student's motivation.

1. Introduction

1.1 ENSEIRB learning overview

1.1.1 ENSEIRB Teaching reform

Since a few years, we observe in our electronic and informatics engineer school, a kind of increasing gap between the student's needs and what we gave to them. A global disaffection for all theoretical lessons appeared and our traditional pedagogical reached its limits.
These tendencies we noticed in our school are confirmed by French national statistics: there is a global demotivation for the scientific curriculum. Economical, commercial studies seem to be now more attractive for this new generation of students.

In front of this situation, a Quality program has then been engaged in our school inducing a deep pedagogical reform as well on the bottom as on the form. All the scientific, electronic, and other engineering fields of the ENSEIRB program will have to be reformatted. Each one of us had to suggest improvement, modification in each own field of competence.

1.1.2 Reformatting fields of teaching in our electronic department

Comparing the situation in 1990 with the one of nowadays, some major evolutions appears in our department:
In 1990, up to 90% of the courses were based on physics, mathematics and electronics. While 10% was dedicated to human and social sciences. The annual working time of students was around 900h.
In 2005, the working time of the students decreases till 770h with a complete different repartition of the scientific and non scientific thematic : Indeed, the evolution of industrial needs, European criterion, and engineer profiles required, obliged us to redefine the relative proportion of each field as follow :

-Scientific teaching around 70% of the whole program including the main following topics:
Physics and mathematics
Analogue Electronic
Digital Electronic (circuit and system)
Informatic languages and tools,
RF and Power Electronic
Integrated circuit technology and design…

-Non scientific field: 30% of the whole program including
Foreign language,
Human science training,
Management and business training…

In the scientific field of teaching, we observe that interest for analogue electronic is, year after year, reduced, while digital electronic (and embedded systems in particular) is more and more present.

1.1.3 The student's evolution

In parallel, we have attended for a few years, a change of 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:

- A global disinterest for theoretical sciences is observed [12], [13]: This phenomenon is confirmed by national [14] and local statistics. There is a global loss of motivation for scientific matters. The total number of French students carrying on studies at a university level is decreasing with an annual rate of 1,3%. And the national rate of students choosing sciences studies is less than 2%.

- The international origin [15], [19] 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.

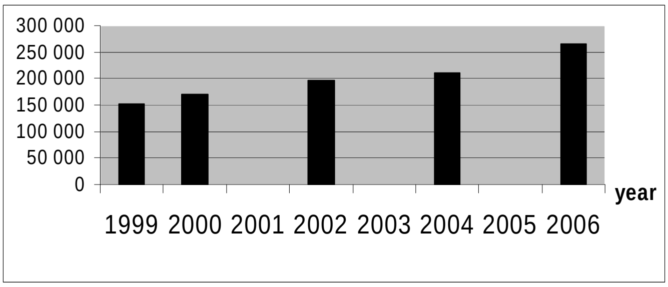

Figure 1a: number of foreign students in France [12]

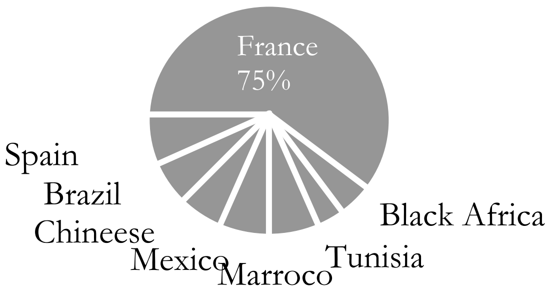

Figure 1b: international student's origin at Enseirb

- Reduction of the long cycle of attention (inherent in human being and normally about 45 min with 1 hour): on a traditional course of 1 hour, we observe a progressive unhooking of the audience faster than before.

- Multiplication of the short cycles of attention:
These one duration cycles from 6 to 7 minutes, are also inherent in the human being. They have appeared however more openly since a few years. They are concretised by successive unhooking and accosting during the course, phenomenon improperly qualified of "zapping" by some. These typical human behaviour are well known by neuro-linguistic programming specialists [1] but they are now more frequent.

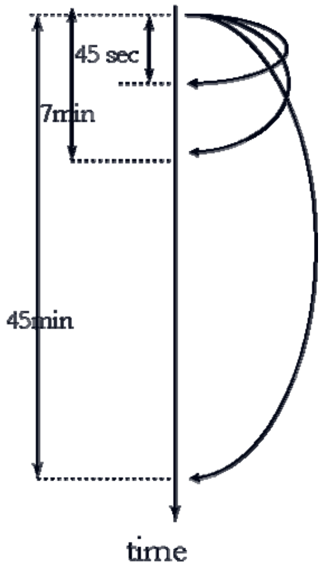

Figure 2 : human cycles of attention

- 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.

1.1.4 Adaptation to the new deals

The phenomenons we spoke about in the previous paragraph obliged the teachers to adapt their competencies and knowledge to this new situation. It is obviously not easy for many human and structural reasons as indicated in the next paragraph.

1.1.5 Classical resistances in reforming

We often practice what we call "mismatching" in Neuro Linguistic Programming words [1], in front of a new situation. We know all the small "killing" sentences: "Yes but…" "That will never go"... "It is a waste of time!" …. Or "it is not for us because we are not like the others!"… "Why change something since all is all right till now? This is often a manner to reject something without thinking about before. This is also the best way to lock a situation (like closing a door and forgetting to look behind).

The main classical locks which can obviously be transposed in any human life evolution processes are:

- Judgments : when judging a person or a situation, it is like putting a barrier or a limit,
- Individual or collective beliefs: often the consequence of different internal mental construction, ours beliefs forbid us to be creative. One of the best illustration is the famous sentence :

"not knowing that it was impossible, it did it"

- Initial education: Family conditioning and social rules format the human behaviour and reduce the power of creativity.
- Conscious or unconscious links with the past (it can be for example clothes, objects or concepts…) prevent from progressing and innovating.

Anyway, in this paper and as an example of this reform process, we describe here what some of us did to progressively move from analogue domain to embedded system field. Even if analogue electronic specialist can not become immediately a high level digital specialist, he can acquire enough new competences to manage some student's projects like this one we suggest in this paper. This experience can just be seen as a first teaching evolution step…

2. Learning embedded systems through a multi thematic funny project

2.1 Definition

An Embedded system can be defined as an electronic autonomous system dedicated to a precise task. It generally consists of a processor, a set of sensors with their analogue and digital conditioning circuits and actuators [4] [9].

2.1 Teaching strategy

As a practical complementary approach of embedded system theoretical courses given by the specialized colleagues, we suggest here the design and the programming of an hexapod robot.

If this concept of such project is obviously not new, its introduction in our scientific school is quite recent. The aim of this approach is to improve the motivation and to develop the curiosity of the students by a complementary practical approach.

Such approach allows a soft approach to difficult theoretical courses and trainings which are nowadays rejected by the students. It also makes the student more confident and responsible of his work and results.

An other collateral effect of a long term project is the opportunity for the student to develop his team work spirit and his management ability.

2.3 Practical application

The funny robot (figure 3) (from easyrobotics company) [7] has been chosen to experiment this learning concept. As this robot's use was initially suggested for teenager's hobbyists, some modifications have been done to make this robot appropriate to a engineer level teaching: the initial processing board has been replaced by a microcontroller PIC 16F873 board in order to program in assembler or C language instead of the BASIC language from Parallax.

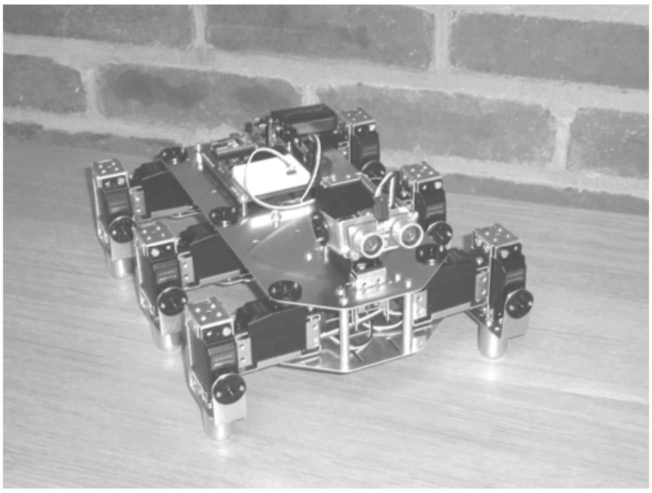

Figure 3 : assembled robot

With the use of this robot, the old full classroom course concept is now replaced by a global and practical approach : It allows a cross connection between different fields of science in one project: the "sensor world" of course, the embedded software for sensor management, the actuator control, the feed back theory, and power management. This approach covers exactly the same main fields than the old course but the human approach and the motivation process are completely different.

In that way, an hexapod "competition" could be organized at the end of the project, to improve a little more the motivation of the students.

3. Description of the robot

3.1 General description

This mini robot consists mainly of:

- Mechanical parts
- A set of sensors,
- 12 servo motors and 6 legs
- A rotating turret with 2 servo motors
- A Basic stamp processing board
- A servo controller board
- A battery cells 6,8V 2400mAh

It is 15 cm high and 30cm length.

3.2 The set of sensors

Some sensors can be used to help the robot moving. In our case, a set of quite simple or sophisticated sensors is available. The most popular are shortly listed below.

3.2.1 Ultrasonic sensor

The ultrasonic module (figure 4a) [6] can be mounted on the mobile turret (figure 4b) in order to look for obstacle close to the robot.

Figure 4a : ultrasonic module

It works as a classical couple of 40 kHz emitter and receiver, measuring the flight time of the ultrasonic wave in burst mode (figure 4c). From this measurement, it is then possible to guess the distance to the obstacle. The primary echo is sorted in order to detect the nearest obstacle.

By rotating the turret and scanning the immediate right and left environment, the sensor can find an open free space to escape when the robot is stopped by a frontal obstacle for example.

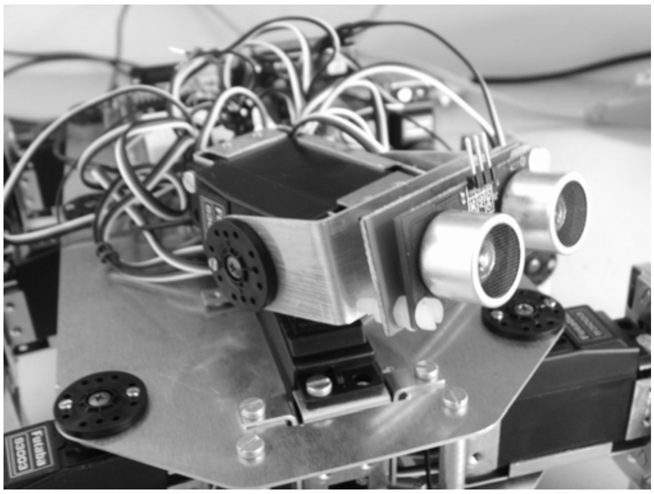

Figure 4b : ultrasonic sensors

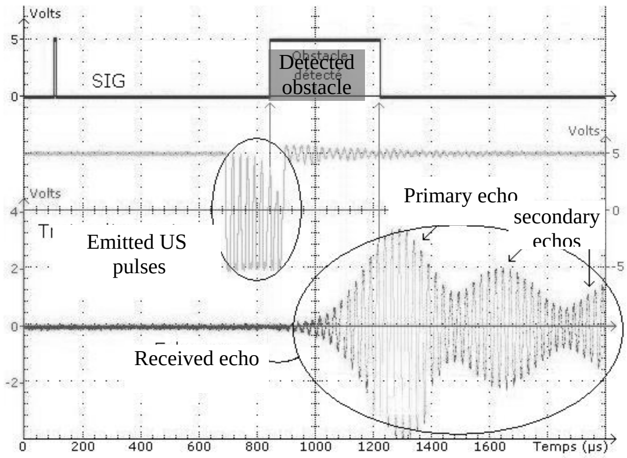

Figure 4c : ultrasonic sensors response

In figure 5, the robot stands in front of a wall and decide to turn right after a panoramic situation observation with ultrasonic sensor.

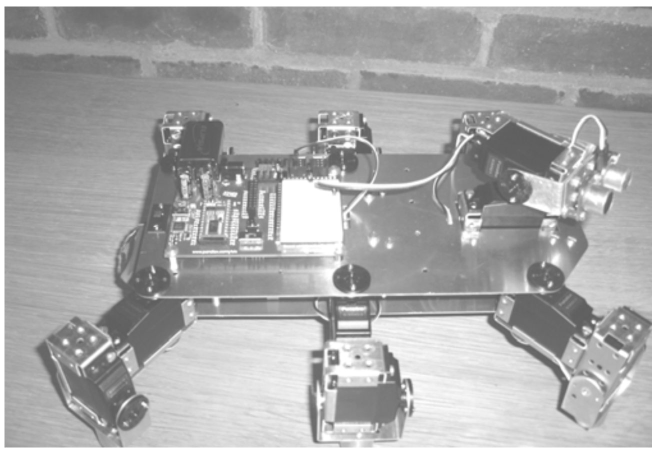

Figure 5 : wall obstacle avoidance

3.2.2 Other sensors

Some other sensors are available for testing various robot's behaviours: whiskers, PIR (pyroelectric) sensors and so on.

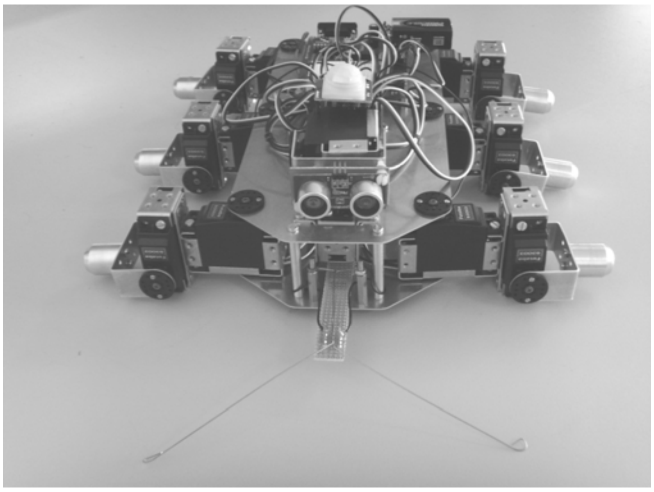

Figure 6 : Front whiskers and Top Passive Infra Red sensor (PIR) (white ball on the top)

3.3 Motion motors

We use here classical 200° angle servo motor for robot walking (Figure 7a) with two servomotors per leg.

Figure7a : servomotor

An internal feed back loop allows the servo to be driven by a PWM signal as shown on figure 7b.

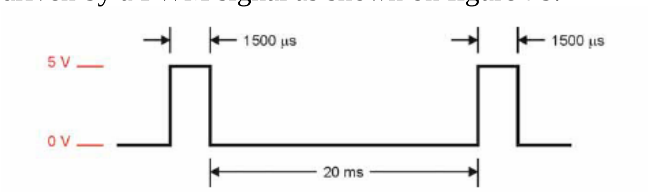

Figure 7b: Typical PWM servo command signal

The angle position is proportional to the pulse width (between 1000us to 2000us for angle varying from 0° to 180°) (Figure 8a and 8b)

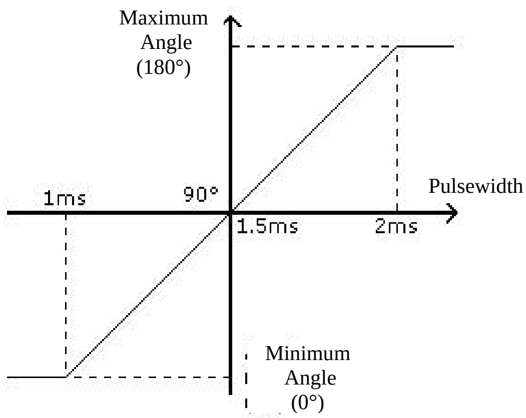

Figure 8a : rotation angle (°) vs pulse width (ms)

The rotation velocity of the servo motor is not an important characteristic to move the hexapod. So, we did not give it here.

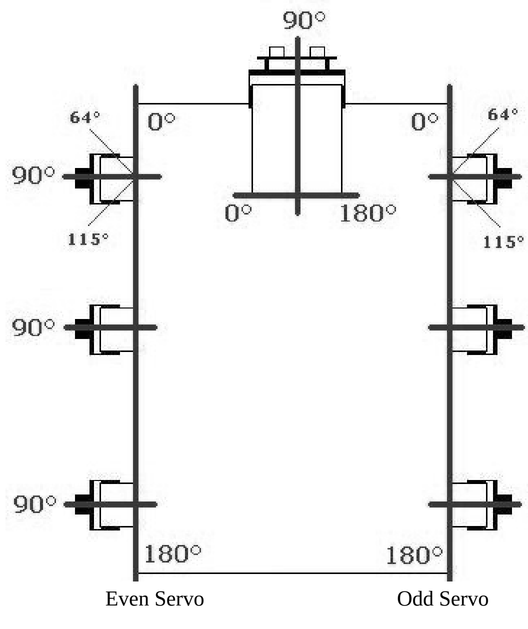

Figure 8b : servomotors and reference angles

As all the servomotors must be driven simultaneously, we use the controller board shown on figure 9. It is located on the back of hexapod. It acts as an interface between the processing board and the servo motors. This board also manages directly the servomotors power supply.

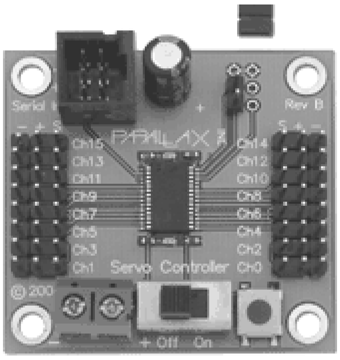
Figure 9 : Parallax Servo controller board (16 channels)

3.5 Power management aspects

The quiescent current per servomotor is around 10mA. When “powering on” the robot, the minimum consumption is 140mA (10mA*14). When walking, 12 among the 14 servomotors are working simultaneously, (figure 10) so that the total average supply current is close to 1.8 A. So, well sized NimH battery cells of 6,8V, 2400mAh has been chosen to power the robot. Instantaneous robot consumption is given on figure 10.

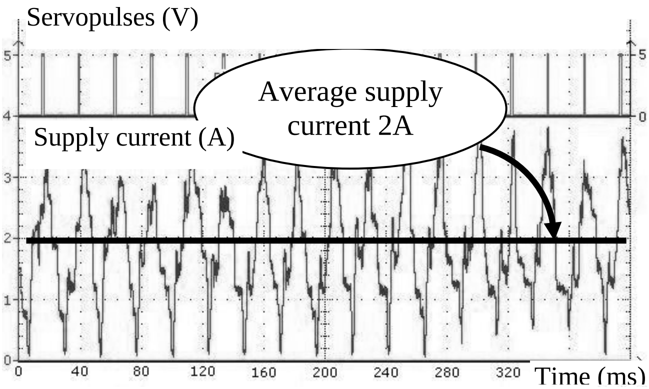

Figure 10 : instantaneous current consumption

3.5 Walking strategy

Walking with an hexapod is not so easy than it could appears! We have to program and to synchronize the movements of the 6 legs and feet. For example, the figure 11a shows the 6 elementary movements sequenced to move forward. (Clear point: leg “up”; dark point: leg “down”). In a same way, we can define the other basic movements: backward, turning left and right. These movements are the four indispensable programmed movements.

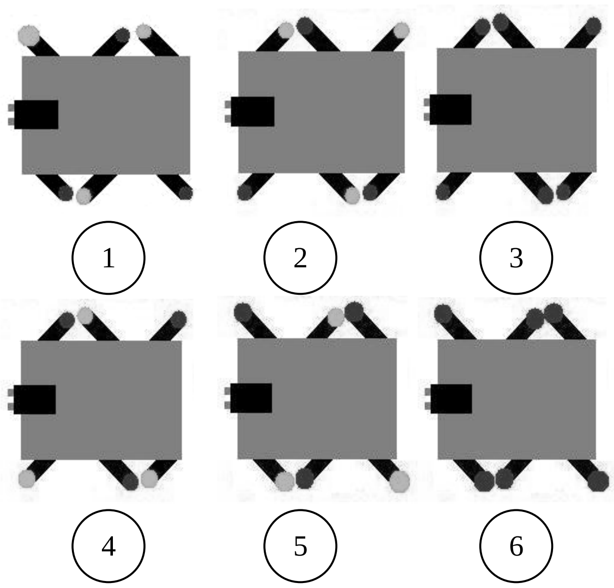

Figure 11a: walking forward sequence

A optional movement is given in figure 9b: in case of touching an unknown front obstacle, the hexapod stops, sits down and puts his two front legs in a defence position.

A last movement strategy example is given in figure 9c : in the event of an over flight by a “predator”, the hexapod stops and looks like a “dead body”.

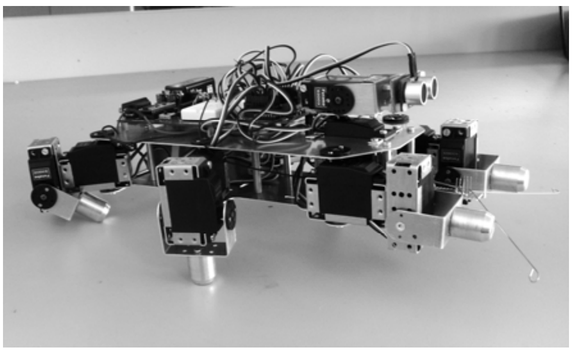
Figure 11b : Defence position

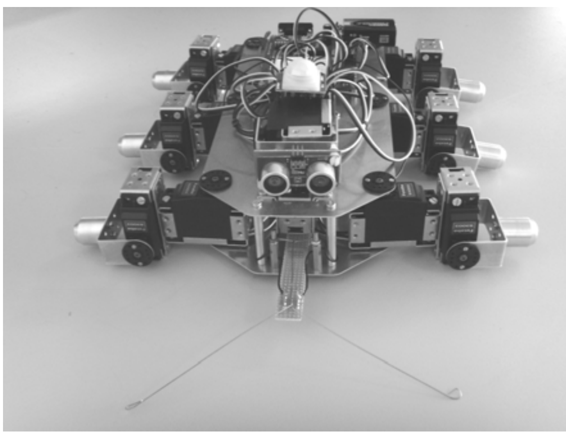
Figure 11c : dead position

3.6 Processing board [5]

Depending of the time schedule, we can use the Basic Stamp BS2 Parallax board (with a BASIC interpreter on board), (figure 12) or design our own microcontroller board.
In this case, a micro chip PIC 16F873 is often used.
And a sensor C language management program can be written. Effects and advantages of “Real time programming” can be then compared to interpreted language programming.

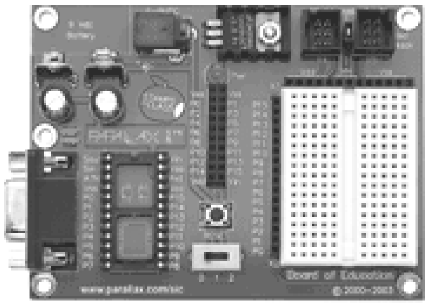

Figure 12 : Basic stamp 2 processing board (from Parallax inc)

3.7 Programming example

A motion algorithm is given as example of possible software implementation. This program contains around 400 lines of PBASIC code.
The Hexapod robot moves first forward. If a front obstacle is detected, the robot stops, and looks right and left with turret ultrasonic sensor. The robot will turns in direction of free space. If there is no free space around the robot, it will execute a full half turn and move backward. In case of detection of a « suspect » movement above it with the PIR sensor, it will stops and stay in dead position during a short time.

4. Pedagogical flowchart

The project proceeds by group of 2 or 4 students (in second year from GEII University Technological Institute for students doing their final training period at ENSEIRB). It is distributed over a locked period of two months. Because of the multi competence aspects of our approach, the project is managed by two or three teachers. This allows sharing the knowledge and a better cross connection between the different fields. The miles stones of the project are:

- Student group definition: Initiation with the team work. This allows a first student sensitizing to team management,
From complementary courses on human resources management, the team profile is then identified (open, close synchronous, random) (cf figure 13). The main human characteristics of each team type are explained by the teachers. Then, the methodology, and the human organisation, (task management, leadership…) are described as consequences of the team profile, for a first student sensitizing to team management
According to the individual profiles of each students, the student teams are then made up.

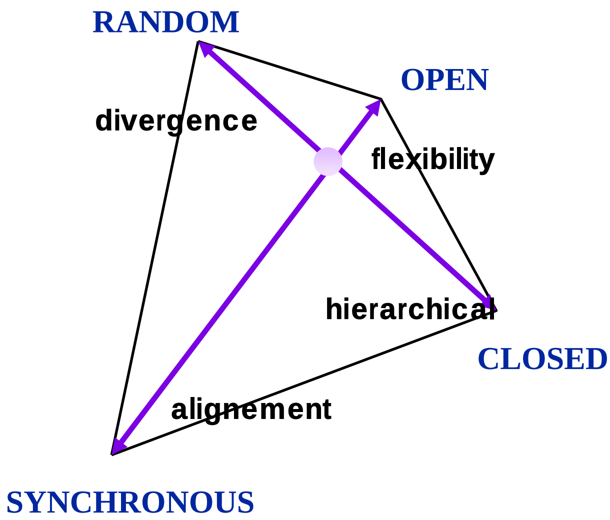

Figure 13 : the four types of team and characteristics

- Practical demonstration: an existing hexapod in action is shown to the students. They are invited to “to play” with it in order to improve their interest and to develop their curiosity.
- Specifications definitions: The technical specifications are defined all together in order to give some freedom to the students: choice among the set of available sensors, power supply constraint, definition of the motion strategy and reaction in case of obstacle detection…
- Project management initiation: Once the specifications are defined, the job of each member of the team must be defined. By a short seminar on project management, we help the students to make their task repartition, project manager designation and role attribution.
- Thematic bibliography: Showing the necessity of collecting information before starting working, we encourage the student to find documents, books, and articles in our technical library rather than on internet. This process is often more efficient.
- Sensors implementation: At this step of the teaching process, the students became conscious by their own, that they have to understand the physical principles and detailed description of the sensors before going further: In short lessons given by the “sensor” teacher,

the main sensor physical effects are explained. Some training about conditioning circuits, calibration, is done before going back to the project. Each sensor used by the students, is individually characterized. So our students become not only “simple users” but furthermore “intelligent users”…
The following example shows the characterisation of the PIR sensor.

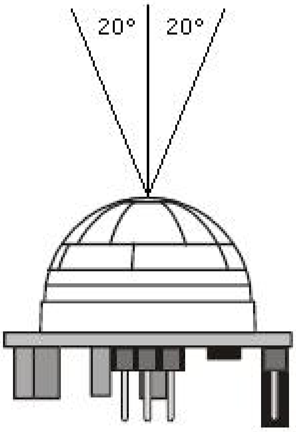

Figure 11a: PIR sensor angle response

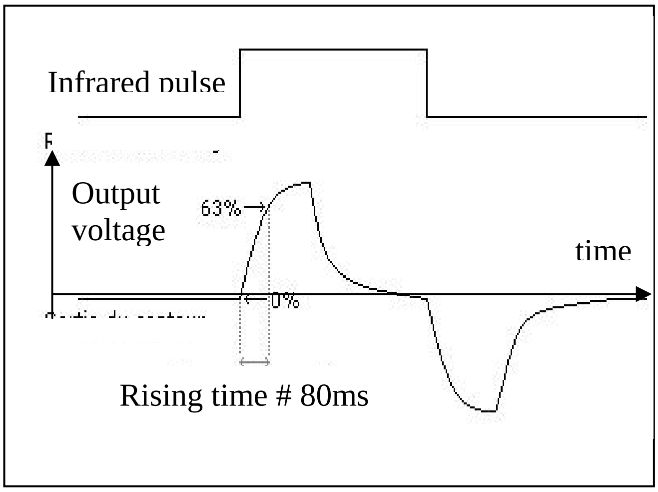

Figure 12 : PIR measured time reponse

The figure 11 shows a sensor view angle of 20° and figure 12 shows the time response of the sensor when submitted to an Infrared pulse.

- Motion: a few lessons given by the electro technical teacher are dedicated to DC motors, electronic drivers sizing, feed back theory, position and speed control. Each servomotor used by the students, is characterized (i.e, PWM signal, speed vs control signal, response time …) (cf. example in figure 13).

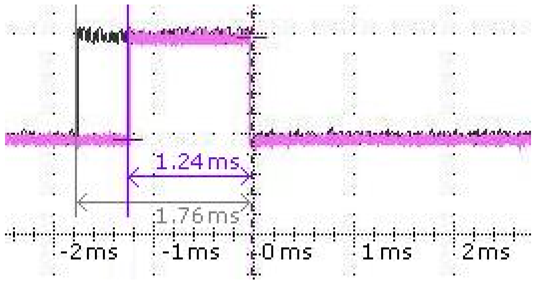

Figure 13 : PWM servomotor control signal
Vertical scale 5V/div, Horizontal scale 1ms/div

- Manufacturing: The robot is then wired and mechanical elements are assembled by the students. (cf. figure 14)

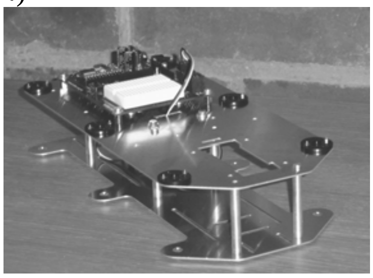

Figure 14 : hexapod partial mechanical assembly

In parallel, software is implemented into the processing board according to paragraph 3.7
- Manufacturing report: in this report (based on an industrial model), the students must clearly describe the wiring and assembly process as in the industrial life.
- Semi global and global test: once the whole system is correctly manufactured, the behaviour of the sensors is individually tested. The motor behaviour is also checked. Finally, a “under true conditions test” is performed by verifying the global motion strategy. A video clip can be optionally done to illustrate the oral report.
- Final report: In this report, we request the students to reformulate what they understood during the project. This enables us to be sure that the sensors, actuators and embedded system bases were assimilated.
- Oral report: the group must orally expose the covered subject at the end of the project with slides and video tools during 20 minutes. Some technical questions are asked to the students to check the knowledge appropriation.

5. Advantages of “learning by multi thematic project”

- The funny aspects of the project are a source of interest. It is thus an opportunity to teach some unpleasing fields of electronic as simply as possible.
- Some freedom into the design gives the impression to the students to be actor and creator. It acts like a motivation amplifier.
- While in a classical approach, the students often complain about the ”bulk-heading” or the absence of connection between the courses, here, our « system » approach allows connecting different fields of electronic (Analogue, digital, sensors, embedded systems, micro programming, motor driving). It ensures a better comprehension, and causes a global interest for the lessons.
- Embedded systems concept is well received with such concrete and funny application.
- The physical and mathematical complexity of the sensors world is better received by the students through a practical approach.
- At least, this multi thematic project is the opportunity of a self encouragement to the student to deepen himself his knowledge by necessity and not obligation. It is also a time for a human experience, a pleasant team work, and management: Each student can discover his own preferences, and personal interest in his work.

6. Results

6.1 Internal Statistics

Even if it is always difficult to “measure” the impact of a teaching strategy, this one seems to be more attractive than before.

Each year, an opinion poll is performed (through anonymous WEB formulary) in our electronic department to get feed back from the students on the whole fields of studies. For our subject, 70% of the students answered to the poll. The last result shows that the global satisfaction rate raised from 45% up to 65%. (The satisfaction index includes technical, pedagogical and human’s aspects). Of course, we are far from the perfection but what is important is that the satisfaction rate increases.

6.2 Feed back from the students

In this report, the students point out the funny aspect of the project, and also the system approach which allows mixing their different acquired technical knowledge. Some of them (the most motivated for embedded electronic) found the project too easy. However, if the technical level of this project is not very high, the most important for us was to improve the motivation, the interest, physical and mental presence of the students.

6.3 Impact on teacher’s evolution

Through this multi thematic approach, it allows to the teachers to enlarge their knowledge and to move softly from their previous teaching field to newest one’s like this very important “embedded systems” domain. Of course, this experience is not enough for the teachers to become immediately specialists in embedded systems practice, but we are able to help and to support the main teachers in this field of electronic.

6.4 Comparison with other experiences

Comparing to other experiences [2], [3], [8], [10], [17], [18] done in different European Engineer schools, we see first that many colleagues are now testing this kind of approach in different fields of electronics. The same evolution in term of motivation is observed, even if it will never possible to obtained 100% of satisfaction rate. However, we must be careful, because “learning by project approach” has also its own limits in term efficiency and quantity of information given top the student by unit of time.

7. Conclusion

We first discussed in this paper the necessity of reforming our teaching approach: we had to adapt ourselves to the new emergent fields of electronic. We showed, as an example, a possible conversion from analogue to embedded field of teaching through the management of a multi thematic robot design project. We showed also that it was possible for non specialist teacher to carry a complementary, integrated pedagogical offer to the students. Moreover, replacing some classical unpleasing lectures by “Learning by project” approach seems to be a good way to improve the efficiency of our teaching and also the behaviour, the motivation and the curiosity of the students. We are obviously conscious that pedagogy requires permanent adjustments to fit as well as possible to the student’s needs and scientific evolution.

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