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Autotronics Education – An Active Learning Approach

K. Bala Pratap[1], J. Harsha Vardhan[2], S. Venkata Ramana[3]
[1]*Assistant Professor, Department of Mechanical Engineering, Audisankara College of Engineering & Technology, Gudur, India*
[2,3]*UG Student, Department of Mechanical Engineering, Audisankara College of Engineering & Technology, Gudur, India*

***Abstract*: The industrial communication network field has experienced a great growth throughout the years due to the complexity achieved by the automation systems in several areas (industrial control, automotive, aircrafts, ships, home automation, etc.). An autotronics laboratory for learning automotive communication network CAN (Controller Area Network), automotive electronics and automotive control systems in the context of an industrial collaboration agreement is presented. Several workshops are described in order to illustrate the autotronics educational project based on active learning methods. Results are evaluated based on ABET criteria.**

***Keywords*: Autotronics Education, Active Learning**

1. Introduction

As part of its 2015's mission aiming to develop values, attitudes and abilities in its students, the Tecnológico de Monterrey has carried out a complete re-design of its educational system, dramatically challenging the traditional environment based on giving lectures. In this new model, the main role of the learning process is played by the student rather than the teacher. Collaborative learning is combined with individual work, so that the exploration of the student complements without replacement of the lectures. In addition, established teaching techniques - whose efficiency has been already demonstrated - are applied and incorporated into the didactic processes. On the other hand, the underlying educational model makes extensive use of information technology that offers, enriches and enhances the learning process. In short, the student occupies a main role, revolving around his/her self-learning, and following fundamental principles such as constructivism and experimentation. [1].

2. State of the art

Due to an exponential increase in the number of electronic systems, the introduction of field buses in automotive applications has become important; this results in a considerably reduction of wiring in a vehicle as well as its weight. In 1980, Robert Bosch developed the Controller Area Network (CAN), which was first integrated in Mercedes production cars in the early 1990s. Today, it has become the most widely used network in automotive systems, [2].

There are some advantages in the use of the bus- multiplexed structure of electronic systems inside a vehicle. The most important one is the reduction of size and length of wires that consequently reduces the electromagnetic interference. In addition, common sensor data is available in the system and more flexibility is introduced since new functions can be implemented by software. The former stated can only be done by networking, using a CAN bus. Furthermore, the need for the CAN network in embedded system has become more important, particularly in electric vehicle applications, where many applications need to share data with different requirements and objectives. For example: Networking controllers for engine timing, chassis, transmission and brakes, need a transmission rate of 200 kbit/s, while networking components such as lighting control, air conditioning transmit at 50 kbit/s. For that reason, a new developed unit based on CAN network, for data control and acquisition in different levels: conception, structure and links with other systems is shown in [3].

As stated before, the CAN was developed to accelerate the development of the computerization of vehicles and to use less lines to communicate data between mechatronic devices like test devices, microprocessors, sensors and actuators. Since the working conditions of a vehicle are variable, special requirements are needed which can be handled by CAN network, different devices must be supported at the same time and accessed according to predetermined priority; reliability must be guaranteed and it must be able to detect devices automatically in order to avoid failures resulting from devices affecting others. Additionally, the CAN bus is flexible, could be expanded and has the capacity of real time control, short latency time, ability to reject electromagnetic noise, error handling and fault recovery. Moreover, it is flexible and it could be expanded. Some of the advantages of CAN bus with respect to BITBUS are: In a BITBUS nodes cannot communicate with other nodes, so any malfunction in the master node will break down the network; the efficiency of BITBUS is low and BITBUS has low capacity to deal with errors, [4]-[7].

Motivated by the increasing use of CAN networks in the automotive industry, some efforts have been made to introduce

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it in the education, in order to prepare future automation engineers with a wide field of knowledge. For example, [5] developed the ALDS software using C++ and introduced it on a network consisting of 14 nodes, in which the first one was reserved for the gateway. They introduced two kinds of communications among the nodes in the application layer protocol in the CAN model: broadcasting and peer to peer; the main objective was to develop a distributive control system in real time linked by CAN. Furthermore, they took advantage of the gateway card to share the communication by the LAN using a database over a PC.

It could be noticed that, in the open literature it exists a lack of research works focused on Autotronics, most of the papers present only the technology used for education but not necessary by using a specific learning- teaching technique, [1]. An Autotronics Laboratory for the learning of the CAN protocol, Automotive Electronics and Automotive Control in the context of an educational environment based on active teaching-learning technique is presented.

The main objective of this paper is to explore the efficiency of the implemented educational strategies in generating new knowledge, as well as provoking abstractive, creative, reflexive, and synthesizing mental processes. This paper proceeds as follows: first, the Autotronics Laboratory is laid out; second, methodologies and learning strategies are outlined and thoroughly discussed; next, a specific learning workshop here used are explained. Finally, conclusion remarks are shown.

3. Autotronics laboratory

The Autotronics Laboratory is equipped with a pedagogic scale model of an automobile's electronic system using a full CAN network. Twelve modules compose this scale model: Built – In System Interface (BSI), Built – In Supply Module (BSM), air conditioning, passenger door, driver door, front lights, back lights, dashboard, radio, AFIL (Lane Departure Warning System for the abbreviation in French), tow module and alarm, Figure 1.

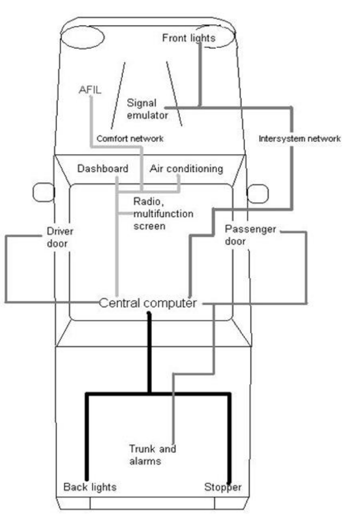

Fig. 1. Network architecture

The BSI is the multiplex brain. It is in this part in which the user connects the necessary interface to analyze the CAN protocol in a computer. This interface is constituted by a USB – MUX – 4C2L box from EXXOTEST. The lab is equipped with 4 of these boxes and two USB – MUX – DIAG also from EXXOTEST. The latter mentioned can also be used as a CAN interface device but it only allows 1 CANHS (CAN high speed) connection. On the other hand, the BSM constitutes the main power supply and also emulates the engine's functioning. The other modules listed before compose the respective automobile part as its name implies.

These subsystems illustrated in Figure 1 are the intersystem network, the comfort network, the chassis network 1 and the chassis network 2. The intersystem network has the ABS system, the motor status, and the steering wheel sensor; due to its requirements, it is a high speed network. The comfort network controls the devices which give additional comfort to the passengers such as the air conditioning, radio and multifunction screen. The chassis network 1 supports the devices for warning and lighting located at the back of the car such as the back lights and the stoppers. The chassis network

2 manages the signals to get into the car: doors, windows, trunk and alarms.

The software used to monitor, analyze and manipulate a CAN network is the MUXTRACE from EXXOTEST, [6]. The lab has 6 CD's with this software as well as the necessary libraries to create an application based in C\C++.

4. Teaching-learning techniques

Students acquire knowledge and skills through practice and reflection instead of watching and listening. Active learning promotes long-term retention of information, comprehension, problem-solving skills, motivation to learn and subsequent interest in the subject. Besides, active learning methods make workshops much more enjoyable for both students and instructors. Once a workshop starts on a problem, the workshop becomes a place for: discussions, arguments, tests, etc. Concerning collaborative learning, Representatives of industry say that teamwork is one of the most important topics at their wish list for new engineering students, most engineering is done collaboratively, where interpersonal and communication skills are more important than technical skills in order to get successful results. Collaborative learning is an instructional approach in which students work in teams over a learning task structured to have the following features:

1. *Independence.* Every team member must have a specific job in order to meet the team goal. There are assigned task for each member. Also, each member is responsible for sharing their contributions.
2. *Interaction.* Problems demand team member's interaction during the designing/construction of the control system. Some problems are impossible to be solved by one person.

3. *Interpersonal and teamwork skills.* Leadership, communication, conflict resolution, and time management skills are needed for a successful teamwork.
4. *Instant feedback.* After every design/implementation student can see the results. They could learn themselves from the failure and success.

Collaborative learning is one the most effective approach for teaching "how to do teamwork" and promoting critical thinking and problem-solving skills, interpersonal and communication skills

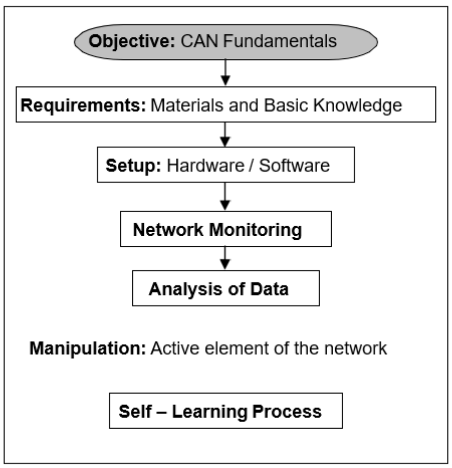

Fig. 2. Workshop structure

Figure 2 presents a general workshop structure proposed for Autotronics Education. In the following this model is illustrated by some examples of possible practices to be performed in this laboratory.

5. Workshop

The objective of this lab is to improve skills and competences in electronics, communications and automobile control, as well as to develop investigation projects and technological developments aimed to this important field.

EXXOTEST 1134 (Fig. 3) was recently acquired, which has de following specifications.

Fig. 3. EXXOtesi 1134

The DE/DI-1134 card represents the car computer (which is named BSI) and the real sensors operation, that are being used in the present.

The system also includes:

1. A CAN HS network with signals emitted from the central computer to the computer that controls the core of DE/DI-1110 (1320) card.
2. A CAN Comfort network with signals emitted from the central computer to the multiplexed combined (0004).
3. A CAN LS / VAN with signals emitted from the central computer to the DE/DI-1120 (9056) light station card.
4. A system with detection of fused lamps related with back lights.
5. Real Components:
   Multiplexed combined (407 series)
   Lighting system combined (Mux8006 series)
   Exterior luminosity receiver.
   System of ignition with key
   Back lights (tow lights)
6. Simulated sensors:
   Fuel levels
   Hand-break interrupter.
   Blinkers interrupter
   Sonorous warning.
7. Exterior environments simulation:
   Exterior luminosity level

Fig. 4. POL structure

6. Project oriented learning (POL)

EXXOTEST 1134 module has permitted the development of advanced workshops, based on Project Oriented Learning (POL) technique, one way of learning that responds to the demand of learning through doing it.

POL is a multidisciplinary methodology which allows students to acquire knowledge through the project practice.

The structure of each workshop based in POL goes through the following elements for the project development, Figure 4.

It has been contemplated, in the workshop development, the student growth with automobile electronic knowledge, CAN networks for car control and the student growth as an integral part of a collaborative team therefore, it is needed to propose projects which represent a challenge for the team to get the project done.

Basic workshops had been developed in the laboratory where the students know the tools and CAN network concepts. In these practices, we have created specific problems focused on the main issue, in order to give the students, the tools as well as the main elements that are integrated in automobile networks.

In advanced workshops, students propose the issue based on requirements and defined objectives for the project. Each team is responsible of the definition of the steps, in order to follow a schedule in time and form. Here is where the student plan, analyze and propose solutions to different problems, which they will face during the project development. It is important to mention that the students, who develop the advanced workshops, have knowledge of CAN networks and the development tools, Figure 5.

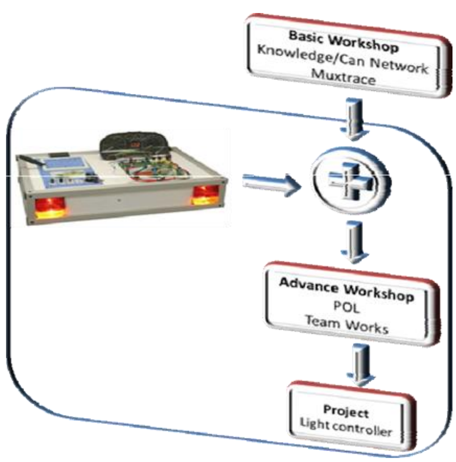

Fig. 5. Workshop structure 1

7. Fundamental concepts of exotest 1134 module

In this workshop, the students will know the fundaments of EXXOTEST 1134 module operation (Basic, ECU Electronic Central Unit, from an automobile). The general objective is to know the ECU operation, as well as the identification of communicating interfaces

The particular objectives are:

To develop a module that represents the front lights of a vehicle, which would have the following objective:

- Communication toward the vehicle using networks, and CAN protocol
- ON-OFF lights control
- Power interface that isolate the electric and the programming tools needed to do the basic modification of activation, in the main program of 1134 module control.


Fig. 6. Interconnection - PC and module 1

In this workshop the student will create a CAN network between the computer and 1134 module, Figure 6.

USB-MUX-4C2L interface will be used as a connection element between both devices and MUXTRACE software, as a basic element of development.

The skills that are reinforced with this Workshop are:

The use of specialized tools for the project development.

To motivate the student to identify, plan and solve an engineering real problem.

8. Central controller – front lights module

The next workshop is developed to make the learning and knowledge easier to the students, in the electronic and communication systems that are being used in automobiles, particularly, in the ones that use CAN protocol, as a main element of communication network.

It is required to know about C++ programming, and EXXOTEST 1134 module, as well as analog electronic and the basic principles of data acquisition.

The particular objectives are:

1. To know the basic elements of an ECU – To describe the general way of the operating system of a car, as well as the elements that integrates itself.
2. To examine the EXXOTEST 1134 module – To describe each of the elements that it compose it, encompasses the interfaces and the programming tools.

Based in 1134 module, to develop a computer interface using a CAN network that allows us to identify the signals in the light modules.

In the following, we describe the elements of hardware than we need for the project development.

Front lights module - It has 3 principal elements:

1. Lamps

It has 4 lights in the right side and 4 lamps in the left side. The four lamps in each side are:

- Head Lamp
- High Beam
- Driving Light
- Turning Light

2. Power interface

Individual circuits that connects a simple lamp to the system and it has the following specifications:

ON-OFF light – It receives a digital signal from the controller which turns On or Off the lamp.

Lamp status – The circuit is designed to send a digital output signal that shows the lamp status. This output signal is high (more than 3 V) when the lamp is in good conditions and low

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(less than
0.5 V) when the lamp is fused or there is no lamp connected.
3. Controller
System based in the Freescale HS08 microcontroller. Its main function is to establish the communication with the central controller through the CAN protocol and to do the acting activities and surveillance toward the power interface.

Central controller - We use a PC as a central controller and the National Instruments LabView/CVI 8 program as a development tool.

The main functions to do are:

A. Communication with EXXOtest 1134 module

It communicates with the 1134 module trough the
CAN2 bus of the USB-MUX-4C2L and it is used only as input to the central controller, where lies the directions taken for turning on or off the lights.

B. Communication with front lights module

It communicates with front lights module through the CAN1 of the USB-MUX-4C2L and its functions is to control the on and off of the lights, as well as doing the surveillance process for failure detection of the lamps and to report the status of itself.

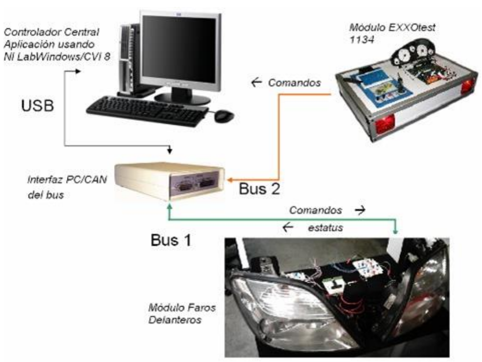

Fig. 7. Connection diagram 1

C. User interaction

The central controller must display a friendly screen showing to the user the system activity.

- The user sets the communication with the CAN bus, verifying the communication is established among the two modules.
- It must be graphically displayed in the interface, the activity and status of the lights in the process of turning on and off.
- Based on the identification of each of the lamps ID, it is needed to develop the messenger that permits the failure detection as well as the display of itself in the central controller.

Besides, we use EXXOTEST 1134 Module as command generator (on/off signals) and status indicator of front- lights. In this Workshop the student proposes a problem and define the activities to do based in the mission and requirements specified in the document. Due to the complexity of the project, it is advised, to work with teams no greater than four people.

The abilities that are encouraged in this workshop are:

- The multidisciplinary team work, the goal is that the students can come out with meetings of professional work, where they share valuable information, to foment the responsibility with the making process of the tasks assigned and delivering time, in such way it allows them to live a real situation of work.
- During the development of the project, they will face an engineering process, which they have to identify and work out.
- Students will know the new tools from the ones already known, so they will come with the project in an integral and professional way.

9. Abet criteria

One of the biggest concerns of the Tecnológico de Monterrey Campus Monterrey is the ability to evaluate the quality of its

Table 1
The course evaluation results of 100 students

Course evaluation	Average	ABET
1. Technical skills developed through this project.		
a) You feel you developed additional technical skills (not included in your resume or last courses taken)	4.3	K
b) You feel you developed abilities for solving problems	4.1	E
c) You apply theoretical tools like mathematics and physics to solve your problems	3.2	A
d) You used state of the art of technological tools like computational software or Electronics, etc.	4.3	K
2. Advantages and differences with respect to classical capstone projects.		
The development of the project was interesting for you. It is a practical and real life case of engineering design. An industry is involved.	4.1 4.4	H H F
c) Reports are being made in order to file all the documentation about the project.	4.3	
d) You feel motivated because this project is done for a very important automotive company.	5	I
e) You got the required feedback from your professor.	4.1	G
3. Team and collaborative work skills.		
a) Team work was required for the correct development of the project or workshops.	4.2	D
b) There was a good relationship between all the team members.	4.3	G
c) You found some problems deciding where to meet and work.	2.9	D
4. Future work and lessons learned		
a) Developing this course gives your resume an extra value.	4.2	I
b) You were motivated through the entire semester with your course.	4.8	I
c) You know how to use all the necessary tools to work on the workshop and practical works.	3.1	K

academic programs and to have the certainty that they fulfill the requirements that are made in comparison with other programs in the world. In this context, we consider fundamental to have as reference the "Engineering Criteria 2006-2007" by the Accreditation Board for Engineering and Technology (ABET) [9] and the equivalent in our country by the Accreditation Council of Engineering Instruction (CACEI), [10]. In this educational project, we hope to comply with the ABET accreditation objectives.

Notice than the results are satisfactory vis-à- vis the ABET criteria described in Table 2. The methodology followed to answer this evaluation was grading the statement using the following scale: 1) completely disagree; 2) disagree; 3) undefined; 4) agree; 5) totally agree.

Table 2
ABET criteria

ABET Criteria	
A	An ability to apply knowledge of mathematics, science, and engineering.
B	An ability to design and conduct experiments, as well as to analyze and interpret data.
C	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
D	An ability to function on multi-disciplinary teams.
E	An ability to identify, formulate, and solve engineering problems.
F	An understanding responsibility of professional and ethical
G	An ability to communicate effectively.
H	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
I	A recognition of the need for, and an ability to engage in life-long learning.
J	A knowledge of contemporary issues
K	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Notice than the results are satisfactory vis-à- vis the ABET criteria described in Table 2. The methodology followed to answer this evaluation was grading the statement using the following scale: 1) completely disagree; 2) disagree; 3) undefined; 4) agree; 5) totally agree.

10. Conclusion

The Autotronics Laboratory was described as a part of this educational technology at Tecnológico de Monterrey and responds to the mechatronics spirit to the integration of the technologies of mechanics, electronics and information technology to provide enhanced products, processes and systems in particular in the automotive field.

Combining active learning into workshops and collaborative learning and problem-based learning for the experimental sessions, we have been promoting several skills and getting better comprehension about autotronics systems in general, but mainly in the knowledge of automotive communication network, understanding of the CAN controller messaging logic and the identification of the elements of a CAN network.

The autotronics laboratory provides a great opportunity to experience up- and downsides of the student work, normally not available in traditional courses. The students recognize that the enterprise involvement is relevant and must be remarked in this educational project. In addition, this laboratory demonstrate to comply with the ABET accreditation objectives. The students were highly motivated and displayed the ability of managing industrial communication network. They also showed good resources and creativity in developing solutions complying with the project objectives. The results reported in Table 1 demonstrate compliance with the ABET accreditation objectives reported in Table 2. The students were highly motivated and displayed the ability of managing industrial communication network. They also showed good resources and creativity in developing solutions complying with the project objectives.

In this context, the University-Industry collaboration brings many benefits for both students and Company. The students are very motivated because they are working with the state of the art electronic and automotive communication networks. Thus, students can acquire a practical knowledge about the different fieldbus protocols existing in the market. Moreover, students learn specific knowledge and its application in real industrial equipment.

Future work will consist on incorporating some workshops related to Steering by Wire Systems and Networked Control Systems (NCS). It consists in the analysis of the effects of time delay in the communications between sensors and actuators in feedback systems.

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