Platform for teaching of location technologies based on Zigbee Wireless Sensor Networks by learning-through-play theory

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Abstract—**In this paper an experimental Wireless Sensor Network (WSN) platform is introduced as an aid in teaching location techniques based on RSSI (Received Signal Strength Indicator) in the frame of a an radiolocation course at graduate level. The platform is implemented using low-cost commercial modules and one easy-to-use software program. The teaching methodology tries to develop the *learning by doing* theory and it is completed with a final practice that implements the *learning-through-play theory*. Both techniques have resulted in positive learning outcomes by enhancing the student role in the learning process.**

Keywords- learning through play, learning by doing

I. INTRODUCTION

The development of innovative material as well as new methodological approaches will be a demand in the new study plans that incorporate the European Higher Education Area (EHEA) requirements for the imminent future of European universities.

The introduction of new teaching-learning methodologies in classical areas as engineering has found large reticence mainly due to some risks supposed to innovative methodologies, such as loss of contents, incorrect timing dimensioning, not enough number of resources (labs, material …) These and other lacks have discourage instructors.

The use of active learning methodologies results largely suitable for the teaching of technical disciplines since they facilitate that students learn both engineering processes and content knowledge. Simple experimental tests can facilitate the acquisition of most important concepts that students will need to use and apply as professional engineers after the graduation.

In this paper we present an educational platform for approaching the teaching of wireless technologies. For our case, the 2.4GHz band was selected, due to its unlicensed feature and the interest of actual applications developed in this frequency, especially the wireless sensor networks and the use of them for location and tracking applications.

Similar experimental systems have been previously developed regarding WSNs [1, 2], but they can be also found in the field of electromagnetism teaching as [2-8]. In [2, 6] we can read the importance of the instrumentation in the radio courses curriculum and how the RF instruments and experimentation can help to emphasize signal and system theory concepts to students. In [7, 8] cost-effective solutions are implemented to design educational modules used in wireless communication courses showing a good performance.

In our case, a commercial kit has been used to deploy a WSN. The system was completed by programs developed in MATLAB software. This allows planning different experiments focused on the main concepts related to location estimation based on RSSI technique, as well as routing in a Zigbee network.

One initial practice will introduce students in the deployment of a Zigbee WSN, the location estimation according to the RSSI measurement and triangulation principle. The experiment has as goal to achieve the full operation of the WSN and the real-time estimation of the user nodes, tracking their positions by using the specific software tool.

After this a challenge is developed as a practical implementation of the *learning-through-play* theory: the TUs are randomly activated and distributed all over one indoor scenario, and the student teams have to determine which one of them are active and their corresponding positions.

The first application of the system here introduced was for the development of two Master Thesis that finally achieved one conference publication [9]. In the present paper we introduce the first year of the experience, a pilot version carried out with a small group of twelve students offered as volunteers from the total of students registered in the course.

In section II we introduce the theoretical background of the teaching experience. The developed teaching methodology is explained in section III, including the implementation. Finally, in section IV, we present the evaluation method followed to infer the progress and success of the experience. In the last section, we offer the conclusions to this research work and indicate some ideas for future work.

This research work was supported in part by the Xunta de Galicia under Grant CO-199-07.

II. ACTIVE LEARNING IN THE CLASSROOM

Traditional lectures are the more extended teaching method that can be found in the colleges and universities. But in the last two decades this traditional methodology has suffered a clear evolution toward other forms of understanding the knowledge acquisition [10-15].

The development of material that incorporates active learning experiences is a challenge for the instructors that are not usually encouraged to face this step. Among other reasons, the EHEA process has determined the university and studies structures but not the training methodologies that should consider the use of active methodologies to improve the student learning process [16-19].

In this section we analyze two main methodologies that try to incorporate active learning teaching: learning by doing and learning by play. We have selected them among other ones due to the suitability to our goals and contents.

A. Learning by doing

The learning based on the experience, experiential, factual, "learning by doing" or "hands-on learning" is generally framed in the active learning methodologies. This supposes to encourage people to discover by themselves the principles of operation of the systems, processes, etc. through the experimentation and the exploration [20-24].

This kind of methodology promotes the construction of deep cognition and increases the comprehensive as well as the effectiveness and efficiency to put in practice the learned skills [21] according to a succession of stages as indicated in Figure 1. This feature is largely interesting to give the students a practical view for their imminent professional future.

B. Learning through play

Students must learn the fundamental concepts and the necessary skills to apply them effectively in a game-based experience. This methodology has been widely applied in computational and engineering teaching field [26-28] showing a large level of satisfaction, and becoming also largely effective at the cognitive level.

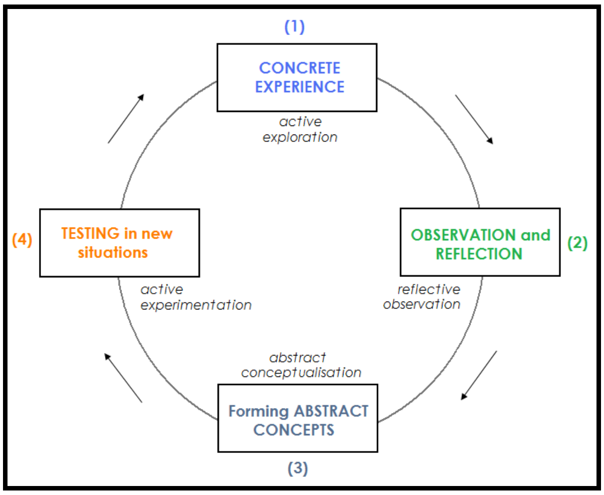


Figure 1. Stages in learning by doing (experiential) method [21].

III. TEACHING METHODOLOGY

The experience described in this paper tries to approach the teaching of one primary location technique that can be widely found in radio wireless applications. It is inscribed in the framework of the graduate-level course *"Radio determination"* offered in the last year at the Electrical and Computer Engineering degree at the University of Vigo, Spain.

This course is optional, so students decide to select it according to a criterion of the curriculum/profile that they desire to develop. Usually, students with specialization in radio select this course, but it is common also to find students from the networking or electronics branches. Among the criteria that students hold to select an optional course, the attractive offered by the course and the grade of update showed are factors playing an important role.

The contents of the course include radionavigation and radiolocation systems used in aeronautics and aerospace, as landing aid systems (ILS, VOR), or navigation aid (GPS, Galileo, GLONASS). The theoretical contents are given following traditional lecture classes, and lab practices have been designed according a learning-by-doing methodology.

In the last years, the radio location techniques are spreading the field of use and they are commonly found in many dairy applications. Some of the radio locations have become very popular thanks to the emerging wireless communications in unlicensed bands, especially the Wireless Sensor Networks (WSN) case have awaken a large interest due to the attractive features. The incorporation of Zigbee protocol offers additional value and facilities to these networks.

In an attempt to update, the course has incorporated the teaching of radio location techniques in the frame of WSN as a third block in the contents of the course, with theoretical classes and practical experiences.

But this technique can be hardly understood if only theoretical explanations are provided, and even if simulations are employed. On the other side, one objective of the active learning is to attract the attention of the students and keeping their motivation. A combination of learning-by-doing and learning-through play has considered the optimal solution to join both teaching and learning milestones.

In the following sections we present the resources that have been used and developed in this experience, and some details of the practical implementation.

A. Resources

Learning by doing experiences based in field experiences imply the use of material that sometimes is not covered by the general purpose instrumentation. The acquisition of specific educational material is large-cost and not usually affordable.

But many solutions exist in form of development kits available for the industry and perfectly valid for academic purposes. It has been our case, and we proceeded to acquire a Zigbee WSN commercial kit with the feature of estimating the power of the received signal. The core chip used by this kit incorporates the transceiver front-end as well as an 8051 core to program the user applications.

In order to implement a radio location system to estimate the position of a mobile user, three elements are mainly necessary:

(1) Reference units (RU) at known positions transmitting a predefined value of power. They act also as routing elements of the information transmitted from the mobile users.

(2) Mobile terminal units (TU) with unknown positions that estimate the power received from the RUs (Received Strength Signal Indicator, RSSI) and feedback this value to the master node (MN) using the network of RUs.

(3) Master node: in our case, this node is the responsible of estimating the TU position by triangulating the power received from it at the RUs. The triangulation implies the assumption of one radio mobile channel, one important concept of this experience besides the own triangulation technique. The MN is connected to a computer via RS-232.

In Figure 2 we show the three elements above described, and it can be shown that they share the same chip board. A brassboard has been designed for the TUs, containing one led-push button, reset button and one inclinometer. Sensors can be easily incorporated for future use.

Additional software elements have been designed to complete the material of this experience. The tools developed will facilitate to the students the development of the experience helping them to focus on the targeted concepts:

(1) Compiled C Code for RUs: it includes the functionalities of network routing and power message transmission.

(2) Compiled C Code for TUs: it includes the functionalities of network routing and power messages reception. Automatically selects the frequency channel of operation, and it recognizes the

(3) Compiled C Code for MN: it includes the functionalities of network routing and the serial communications with the computer.

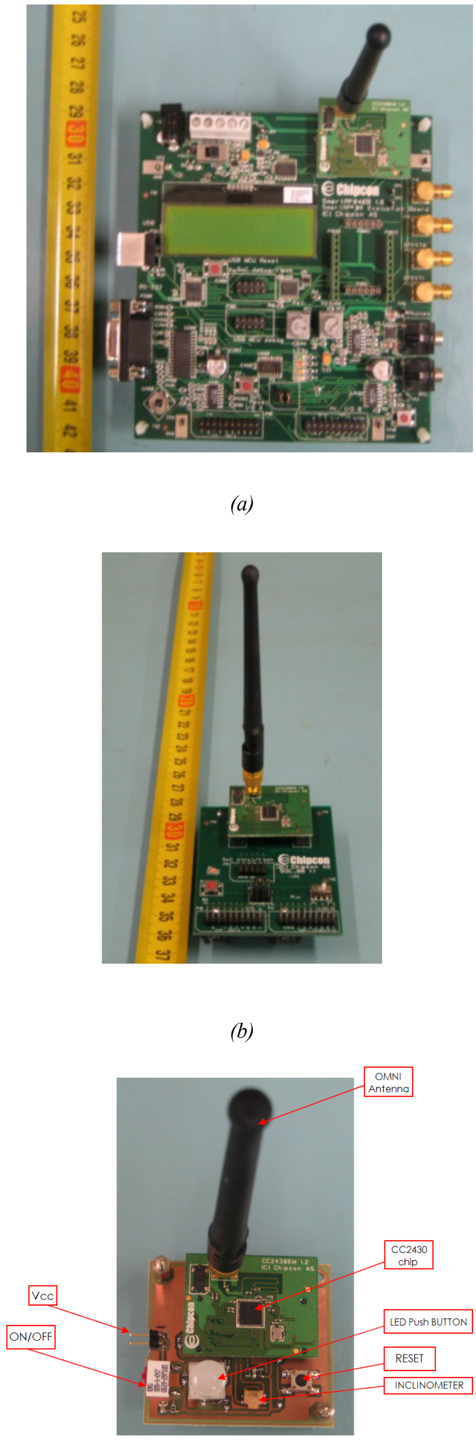
(4) Student program: implemented in Matlab, it receives the data needed for the triangulation according to the propagation model.

The code corresponding to RU, TU and MN has to be uploaded to the core chip via JTAG programming tool as indicated in Figure 3.

The student program has become fundamental for the development of the experience. It provides functionalities to dimension the network, to assign a role to a board chip (TU, RU, MN), to fit the propagation model and to perform correctly the triangulation. In Figure 4 it is shown the main screen of this tool.

B. *Implementation of the experience*

A learning-by-doing methodology has been estimated as an optimal solution to present the *modus operandis* of real time positioning systems based on the estimation of the received signal strength. Firstly, a set of four short practices introduce the different objective concepts. One session of two hours has been assigned to each practice. Students elaborate one four-page report after the completion of the four practices.



(a)

(b)

(c)

Figure 2. (a) Master node (b) Reference node (c) Terminal user

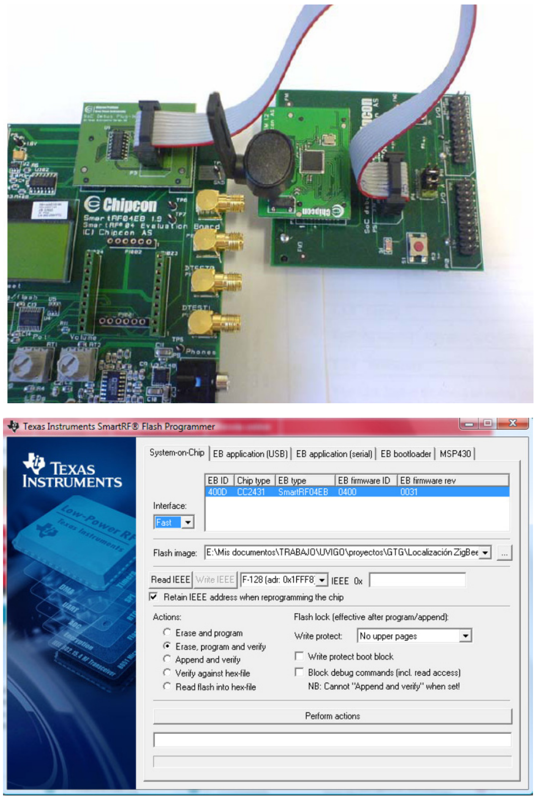


Figure 3. Programming facilities.

Following we briefly describe the main milestones of the initial four short practices:

(1) Dimension the network and assignation of one role to the chip boards. Some parameters of the RUs and TUs as ID, and position (X, Y, Z) have to be predefined. In Figure 5 the node setup menu is shown. In Figure 6 it can be observed an example output of this practice.

(2) Test of communication: the different elements are activated and the network deployed in an actual indoor scenario. Test messages are routed among the nodes. A mesh topology is followed.

(3) Fit the propagation model: one main parameter of the propagation model has to be set: *N*. It approximates the power decay curve for the signal transmitted from one RU and received by one TU. This propagation model is commonly used in indoor scenarios, and as is called log-distance model. The accuracy in the estimation of *N* is deeply related to more accurate position estimation. In Figure 7 it can be observed the model fit menu.

(4) Triangulation: students have to implement the algorithm for position estimation based on the equilateral triangulation technique of received RSSIs.

The methodology is completed with one final practice that summarizes all the learned concepts and is valid to put in practice the skills learned and developed by the students. It is presented in form of through-play.

As an outcome of the initial practices, the students are in position of estimating the location of any TU, as well as the ID of the available RUs, in the deployed network always that the learning process has been successfully completed. So, in the next step they have to determine under blind conditions, which RU nodes of the network are working, how many TUs are active and also they have to determine the TUs location.

If the software tools have been correctly fitted, and a comprehensive cognition has taken place, the students will pass this challenge with less effort that if it is planned as a single practice.

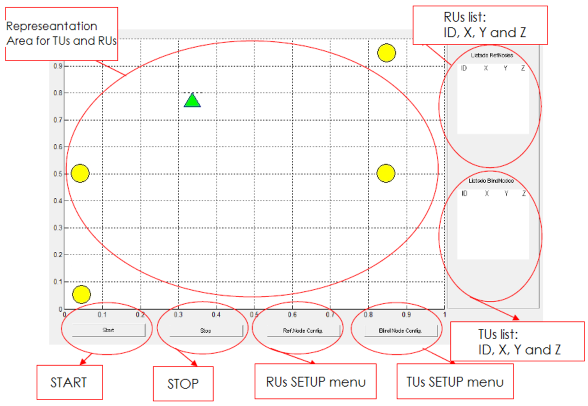


Figure 4. MATLAB student's interface program.

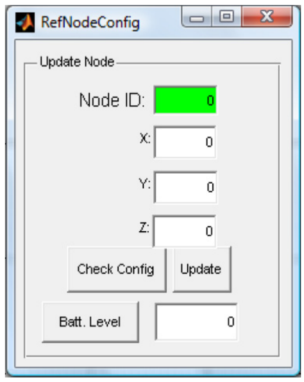


Figure 5. Node setup menu.

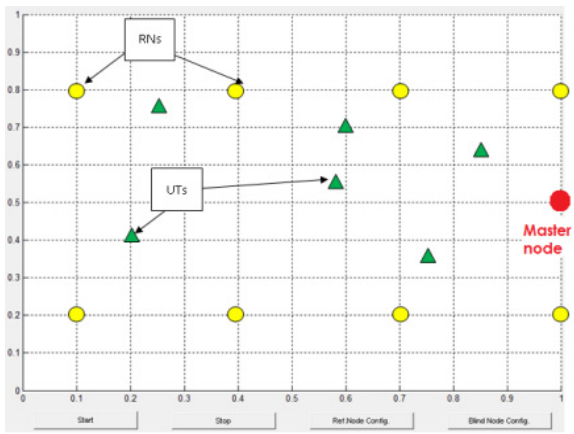


Figure 6. Geometrical disposition of elements in the Zigbee mesh network.

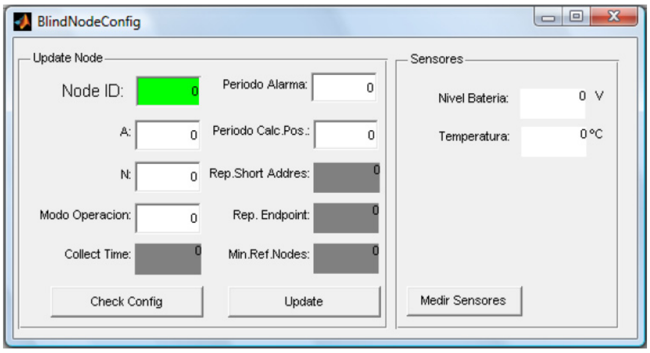


Figure 7. Propagation model fit menu.

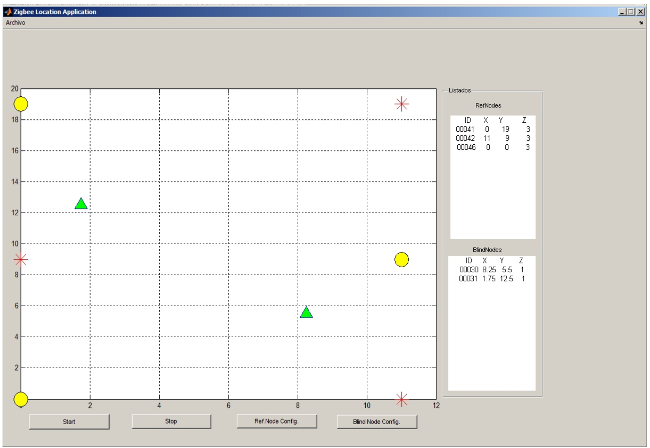


Figure 8. Example of final challenge scenario.

It will result useful in a double sense: firstly, it summarizes the concepts and skills object of this block of the course content; secondly, it allows the student a general scope of the technique here presented that can help to clarify some remaining doubts. In itself this challenge constitutes an auto-evaluation of the previously learned concepts. In Figure 8 it can be observed one example of scenario for this challenge.

IV. Evaluation of Results

Another not less important aspect to consider along the development of this kind of learning is the way of evaluating the acquisition of knowledge [29]. It is essential to collect information in the cognitive and in the affective dimension. This information has to be analyzed to evaluate a classical trade-off: the satisfaction level and the effective cognitive learning.

The evaluation of the subject was divided in two parts. The evaluation of the theoretical contents follows an innovative method based on online surveys provided via a web educational platform that uses the open source eLearning and eWorking platform *Claroline* [30, 31]. The surveys include ten short questions regarding the theoretical part. In Figure 9 we can see the home page of the website dedicated to the eLearning platform.

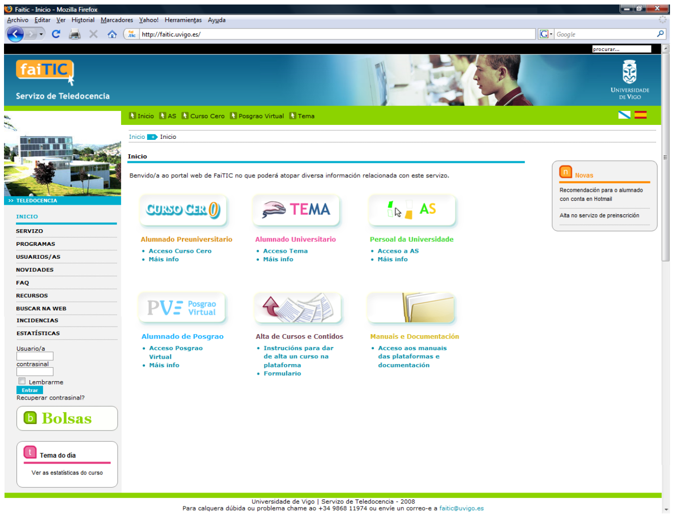


Figure 9. Screen shot of *faitic.uvigo.es* web.

The number of students attending the subject last year was 70. For the lab practices, they were divided in groups of two, and later assigned to one turn controlled by a different teacher. Three blocks of practices were designed, and the experimental experience regards block #3.

Volunteers were solicited to develop this pilot experience and a total of 12 students attended the call. A different task was assigned to the students that did not participate in the pilot group, consisting in a documentation work to be exposed at the classroom. These works were evaluated by the rest of groups.

For the evaluation of the other practical contents a traditional method usually extended in engineering was used, consisting in the elaboration of reports regarding the lab practices.

In order to evaluate the cognitive level, for each practice a set of questions are included in the memory to be solved and answer by the group. So, individual scores cannot be evaluated separately. This can result in an unfair score for students and does not reflect the individual effort.

A statistical analysis based on boxplot results a powerful tool to analyze the deviation of the individual, group and turn scores with respect to their respective medians. This simple analysis offers a good graphical inspection tool of influence factors as important as: teacher in charge of the turn, difficulty level of the practices. Students requiring reinforce can be identified.

Generally, for practical block 3, groups achieved larger scores in the pilot experience than for the documentation work. Among the reasons to explain this fact, we can remark that usually the level of effort is less in this kind of tasks and also the level of motivation. We have detected also that some of the works were identical to the last year. In general, the level of deepening in the topic assigned is not large and the students tend to minimizes effort and time. The result is that a 10% of the students fail this practice with scores under 5.

The success of the experimental practice can be explained also by the large level of control that the experience provides for its development. All the steps are predefined and the objectives are presented in a piecewise mode, from simple to complex levels, so it results in a straightforward progress for the student.

The satisfaction level was inferred from the surveys that our institution passes each semester to every subject. The surveys demonstrated a good performance in the affective dimension. This can be inferred also form the results of pilot experience scores.

V. CONCLUSIONS

After In this paper we have analyzed one pilot experience developed at the graduate level of an engineering degree. We can state that education has evolved from a teaching to a learning focus and the incorporation of active learning is the way for this transformation. Active learning based methodologies have demonstrated to be more effective than passive learning. We analyzed that the use of active learning methodologies results largely suitable for the teaching of technical disciplines such as engineering.

We conclude that simple experimental tests can facilitate the acquisition of most important concepts that students will need to use and apply as professional engineers after the graduation.

We presented the methodology developed and the material needed to carry out this practice. The pilot experience showed a large level of enthusiasm and satisfactory feeling among students.

In the evaluation method, it results necessary to implement a form of differentiating the individual and the group scores in the lab practices. The design of individual surveys may be a solution and it is of easy implementation thanks to the available eLearning platforms.

The good results achieved encouraged the teachers to repeat the experience next year trying to introduce some novelties thanks to the developed and tested methodology and the available material, as well as the experience acquired by the teachers.

ACKNOWLEDGMENT

This work has been supported by People Program of 7th FrameWork Programme (2008 Marie Curie IOF Action).

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