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Multimedia System for the Teaching of Proximity Sensors*

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Throughout this article we will outline a new software tool aimed at explaining the major features of proximity sensors, as well as their different types, to engineering students and automation experts. We propose an interactive multimedia application that shows the basics of this type of sensor, their electrical, physical, mechanical and operating characteristics, the types of electrical outputs, operating modes and configurations. Through a large number of simulations, animations, industrial system videos, links to manufacturer Web pages, catalogues and data sheets we introduce a comprehensive view of inductive, capacitive, optoelectronic, ultrasonic and magnetic sensors, micro-switches and limit detectors intended to work as proximity sensors in an industrial environment.

Keywords: e-Learning; multimedia; proximity sensors.

INTRODUCTION

PROXIMITY SENSORS comprise a large set of devices intended to measure certain parameters of controllable processes. Like any other types of sensor, they represent the control system back-end of the industrial communication hierarchy, as they deliver electric signals with information on important variables in any control process. Proximity sensors not only detect the presence of objects or people but also detect some elements of certain materials in the work area.

As widely used field devices in manufacturing plants and automated systems, they require the deep knowledge and consideration of the future industrial engineers, especially those specialised in electricity, electronics or robotics, since their careers will demand the troubleshooting of automation equipment, maintaining or repairing failures that will undoubtedly arise. Thus, these sensors are essential background for engineers in the fields of automation, control and electronic instrumentation. It is therefore necessary to study proximity sensors from all angles that may be of potential interest to engineers. In this way, these devices have, over past years, been introduced in numerous undergraduate programs of different industrial engineering degrees.

Notwithstanding their interest for engineers, as well as for experts in industrial maintenance, it should be pointed out that training in proximity sensors might not be a straightforward task. Traditional educational methods can no longer provide the proper training that highly skilled future professionals require. The teaching methodology relying heavily on lectures and slides is no longer suitable for conveying every concept involved in sensor performance, let alone prompting students to learn. With these drawbacks, the laboratory sessions serve as a complement to the lectures, giving some practical cases to work through and, thus, the student can directly observe the operation of the devices. However, the situation most similar to a real system for students is a demo-board, with one or more sensors, which is designed to demonstrate their operation. Our Department is has planned an alternative approach to teaching support, and has developed an interactive multimedia tool to study proximity sensors. This is user-friendly software with a large number of animations, simulations, videos of real processes, links to manufacturer Web pages, etc. to support the graphical and textual presentation. It takes in the background of proximity sensors, as well as their electrical, mechanical and operating parameters, applications, tips for installation and many other interesting aspects, to give a comprehensive understanding of their operation and features.

This development responds to the need for software tools to aid learning, so that it can be included in the rising trend to provide on-line education through multimedia options (e-Learning). This approach allows one to overcome the barriers of physical distance or disabilities and supports knowledge development as one of the major goals to foster within the future European frame [12].

SENSORS IN THE INDUSTRIAL WORLD

Improvement in the production and logistic processes demands a better control of the subsystems involved to increase the response speed, coordinate related systems, enhance process quality, reduce faults and technical halts, to cut down

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costs and increase the overall quality. The best way of achieving this is, in most cases, process automation. This is applicable to any discipline that involves repetitive tasks or that follows a predefined behaviour. It can be successfully extended to a wide range of examples, such as the control of piece mechanization or dynamically generated software. The field of automation extends over many industrial sectors, always being aimed at saving time and effort, task minimization, quality control, feasibility and production enhancement. Standing out among these are those concerning plant production, internal logistic or maintenance and autonomous system regulation. It is here that the proximity sensors fit best as capture devices to provide information for the control system.

Industrial process control is feasible through the information obtained from sensor measurements. That is, from measurements in plant, we deduce the actual state of the system and so it becomes controllable. In this way, sensors are the primary inputs to the controlled system and the production management. They constitute the bottom layer of the industrial communication pyramid, provide the actual state information and allow one to find out the current state of every process. From the sensors measurements we are able to control the behaviour of an automated process as well as carry out information management (for instance, counting the number of people getting in and out of an area) or surveillance tasks.

Sensors provide field background information through control or reference variables included in the system under control. They lie at the bottom level of the industrial communication classical hierarchy, which includes the input/output devices [6, 7, 8] along with actuators. They allow both the interaction between the plant and the control system for overall correct performance. Sensors measure the values of a number of parameters, whereas actuators operate on the supervised process following the higher layer commands (Fig. 1).

Proximity sensors stand out from all other types of sensors for certain reasons. First, they comprise a wide range of devices with many different operating grounds and applications. For instance, this range includes the limit detectors (mechanical switches to detect physical contact) and optoelectronic sensors based on lasers (detection sensors with no physical contact). Both detect the proximity of objects or people in different environments. Second, proximity detection is one of the most widely ranged and versatile applications. It allows one to determine precisely the predefined state of a system (machine, production chain, transport system or any other device that uses these sensors), so that it works according to specifications. This feature can be used, for instance, to detect the presence of certain elements in a production chain, or display the position of a robot arm or the presence of people in restricted areas or discriminate objects by the label position. These are only a few examples of the large number of applications for these sensors.

The importance of reliable performance in industrial control processes requires the engineers and experts involved in their design, development, enhancement and maintenance to have a thorough knowledge of their components. Therefore, it is essential to train future engineers, especially those specialized in automation, electronics and electricity, in the most wide-ranging devices and, among them, proximity sensors. The aim is twofold: on the one hand give a theoretical background and on the other to introduce a practical knowledge that will be useful in their future career.

COURSEWARE

The classical methods of teaching and training are no longer adequate to explain technical concepts concerning change of physical parameters, application fields and their implications. It is often essential to draw attention to secondary issues for a more illustrative, practical and clear vision of the concepts involved in improving students' levels of knowledge. The current trend is to set up teaching support items to help the understanding of a concept through graphics and visual projections. However, it seems necessary to

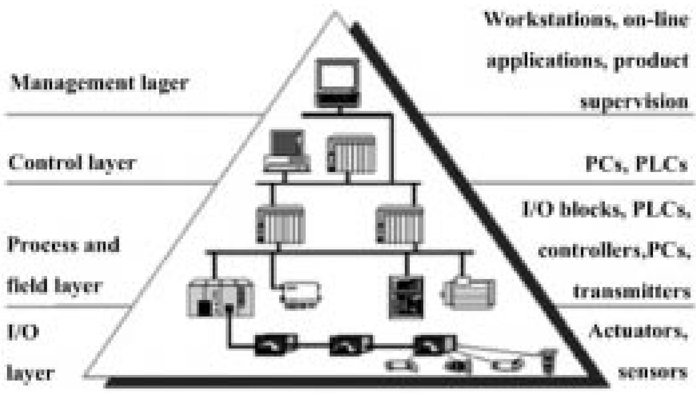

Fig. 1. Proximity sensors lie at the input/output level.

take a step beyond this. We not only need tools to draw the attention of students and provide visual explanations, but also to allow interaction and intuitive handling. In other words, from our point of view education needs auxiliary means to enhance student knowledge, taking into account issues like student involvement, use of simulation software and an overview of actual applications.

With these goals in mind, in the Electronic Technology Department of the University of Vigo, we have developed, through some final degree projects, a group of software didactic tools aimed at education. Electronics, as part of engineering, is a discipline where these tools are of particular interest as an aid to achieving greater knowledge. Within this technical discipline, simulations are crucial to the understanding of the operation of a device in the application environment, the variation of physical properties, the element interaction, the system evolution and the analysis of electric signals or any other physical parameter.

A new educational line has emerged to overcome previously insuperable barriers, such as distance or disability. The implication of new communication technologies in education has been coined as e-Learning [12], a trend of increasing interest, whose financial support (public funds) and acknowledgement (awards) guarantee successful development in the coming years. The EU has its own development plan in this area for the near future, which is based on a few initiatives with four major goals (digital literacy, virtual campus, collaboration between centres/faculty education and transversal actions for promoting e-Learning), chosen for their key relevance to the upgrade of European educational and training programmes. Our tool also pursues the objectives established by the new development plan for education.

EDITING AND PROGRAMMING SOFTWARE

The starting point in choosing editing and programming software to design the tool is to determine the features of the final application. That is, once the targets are set, the application model is outlined with the required properties that justify its development. As has been stated, the application is aimed at teaching and training engineers and experts who are to develop their careers in environments where proximity sensors play an important role.

Those properties require the new software to be interactive, integrable in Web pages, easily executable on any platform and aimed at graphics (including features such as scalability, animation, etc.) and simulations.

Once requirements had been assessed and priority set to interactivity, friendly execution, publishing options and dynamic features, we chose the application Flash MX as the editing and programming software that would best meet the original goals. Thus, the application was developed within the editing environment Flash MX and formatted as a SWF (flash film) or HTML file. Flash allows one to edit an application with heavy vectorial behaviour (for easy display on any screen without resolution loss), is executable on any navigator (no owner software is required), has dynamic and interactive user-targeted features, modularity and is publishable in HTML format.

In addition to choosing Flash as the developing tool, we used other applications, such as Dreamweaver MX and Fireworks MX, to tackle specific problems:

- Flash MX: an application-developing tool for movie editing and programming, animations and simulations to be published in HTML or SWF format.
- Dreamweaver: an HTML code editor to design and manage sites and Web pages.
- Fireworks: a tool for designing and presenting graphics on the Web, editing and animating Web graphics, as well as add interactivity and optimize images.

DEVELOPED TOOL

We have developed a tool called 'Multimedia System for the Teaching of Proximity Sensors' following the above-mentioned goals. This is an interactive programme to help understanding of the background principles, the electric, physical, mechanical and operating features, the electric output types, the operating modes, configurations, standards and any other interesting aspect of different types of proximity sensors, i.e., an interactive, dynamic and friendly software, easily integrable in Web pages, aimed at teaching the object detection basics, proximity sensors features and parameters involved in industrial automation with these devices.

Each section is devoted to a different type of proximity sensor and follows a similar structure based on the analysis of major technical aspects, like physical background of the object detection, sensor operating modes and performance, technical features, electrical parameters, standards, protection types, graphical support, manufacturer data sheets and so forth. They are all conveyed through text, graphics, images, animations, and interactive simulations where the user is involved and videos showing sensors operating in industrial environments. Furthermore, catalogues, data sheets and links to manufacturer Web pages allow one to access updated information on actual products that are currently available.

The evaluation block makes a qualitative assessment of the knowledge acquired so far. To this end, the student is prompted to answer the questions accompanying each chapter and, depending on their success, the program sets the difficulty level for the next group of questions. Thus, the user dynamically determines his/her knowledge level with a number of questions ranging from 9 to 15.

The application provides ancillary items to improve navigation, that is, easy access to key pages, bibliographic references of interest and help applets.

The tool features determine the choice of development environment. In this way, the first approach was a conceptual outline to meet the initial requirements and to carry out efficiently the task that it was designed for. Apart from being interactive, intuitive, user-friendly, integrable into Web pages, dynamic, etc. it should be graphically scalable and extendable to future upgrades. A major design aspect, both visual and functional, was an attractive appearance to encourage teachers and students to use the application.

The outcome is a comprehensive tool for carrying out a full study of the proximity sensors, aided by numerous items to improve understanding, as well as self-assessment of acquired knowledge and a quick search for specific concepts.

APPLICATION COMPONENTS

Following the ideas above, the application thoroughly analyses the different types of proximity sensors. The arrangement comprises the following sections: Introduction, Capacitive Sensors, Inductive Sensors, Optoelectronic Sensors, Ultrasonic Sensors, Magnetic Sensors, Micro-Switches, Limit Detectors, Security Sensors and Evaluation. Each one is an independent input, although they share similar items and approaches.

The sections are briefly commented on below.

Introduction

The introduction analyses the basic features of a measurement system, classifies sensors by different standards, sets up the electrical, mechanical and

Fig. 2. Application main window.

Fig. 3. Animations, simulations and videos.

Fig. 4. Main window and simulations.

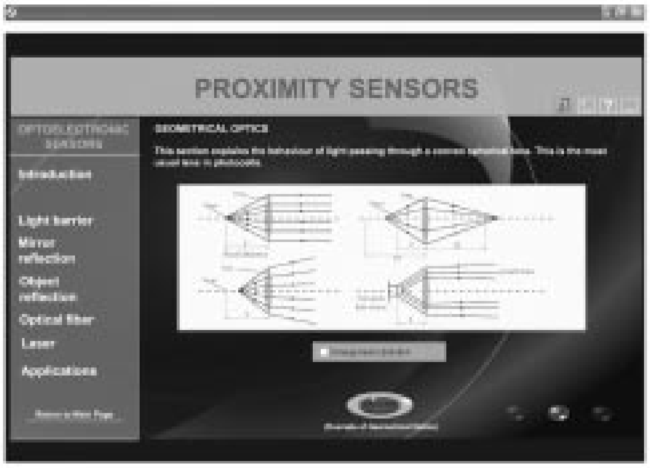

Fig. 5. Graphical descriptions.

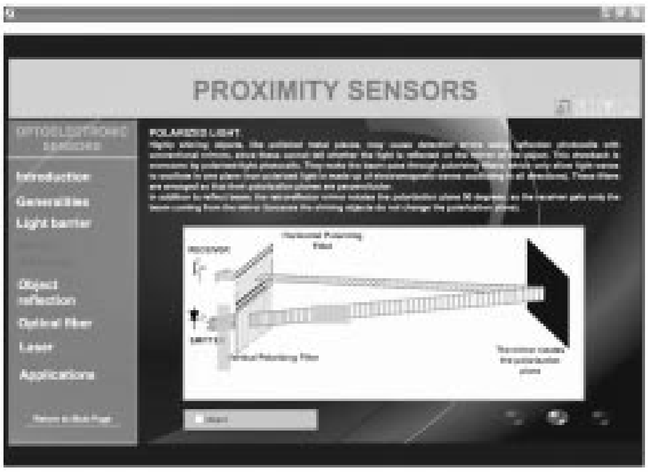

Fig. 6. Supporting text and graphics.

operating characteristics common to all of them and justifies the relevance of proximity sensors in the industrial automation field. The goal is to introduce the measurement concepts to non-skilled users.

Capacitive sensors

This section analyses them and introduces the concept of detection for capacity change (due to permittivity changes in the environment surrounding the sensor) from a physical standpoint.

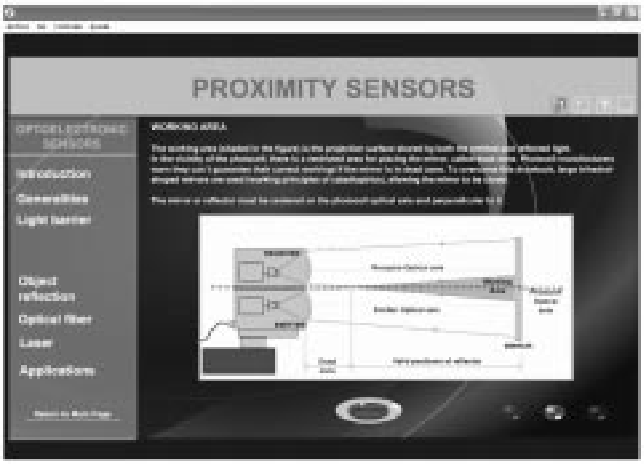

Fig. 7. Interactive graphics for concept description.

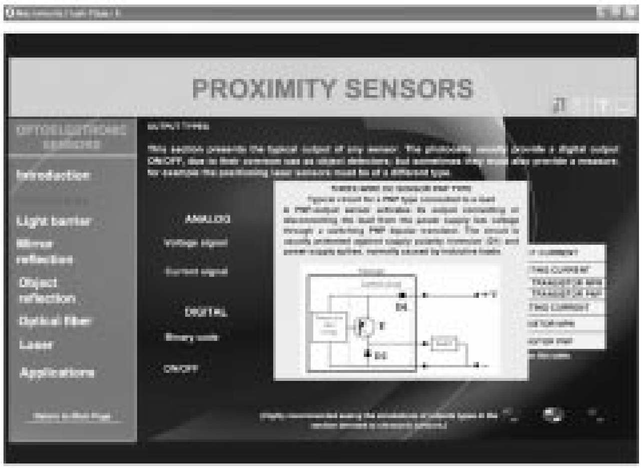

Fig. 8. Supporting animated labels for concept comprehension.

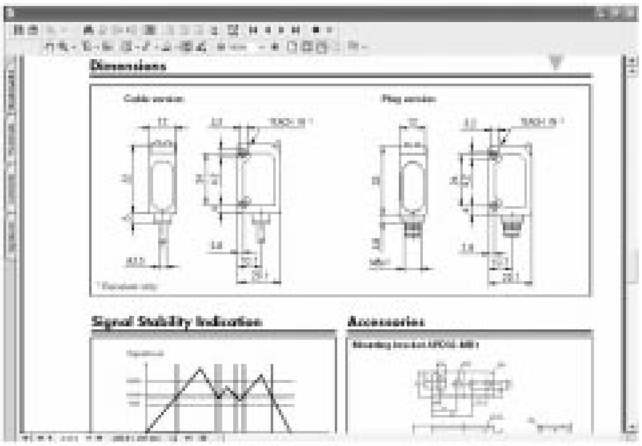

Fig. 9. Access to catalogues and data sheets.

Inductive sensors

They are among the most popular in industry, especially to detect metallic objects.

Optoelectronic sensors

Their functioning relies on the transmission and reception of light in different configurations and comprises a highly heterogeneous group.

Ultrasonic sensors

Their importance is growing over time for their good performance and ability to work in harsh environments.

Fig. 10. Access to manufacturer web pages.

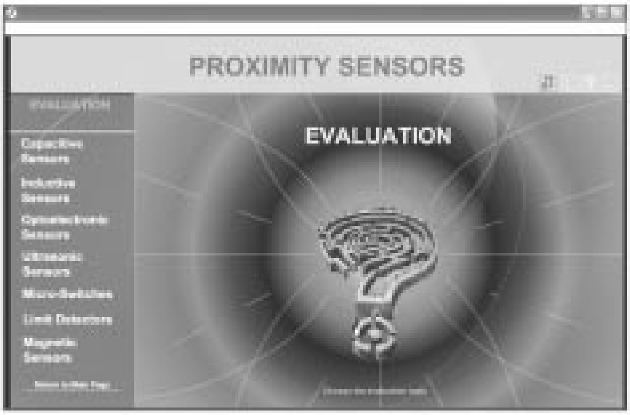

Fig. 11. Evaluation block main page.

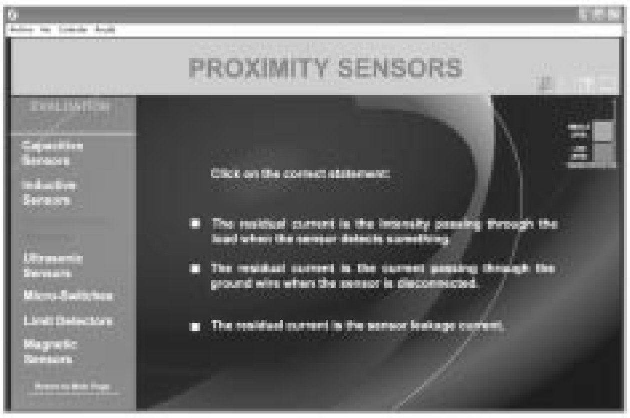

Fig. 12. An aspect of evaluation questions.

Magnetic sensors

This category comprises several types, all sharing the use of magnetic features to sense presence or proximity.

Micro-switches

These handle low current, so are aimed at low-power applications. Their major features derive from being contact sensors and they have a wide range of applications.

Limit detectors

These handle larger currents than micro-switches and are suitable for systems that require the determination of the final position of a mobile object.

Security sensors

The basics are the same, but these are aimed at security and surveillance applications, which require higher performance and reliability.

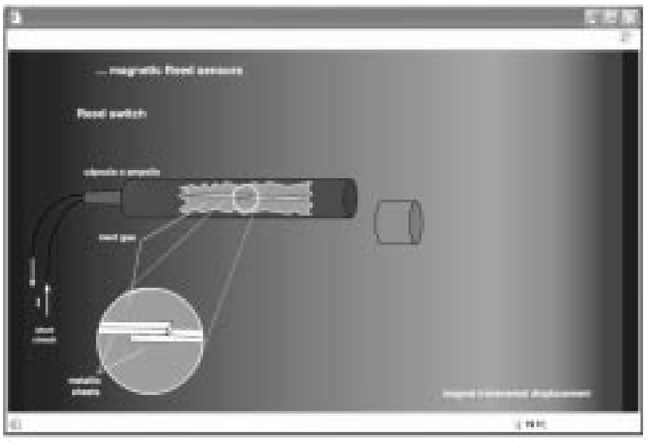

Fig. 13. Animation of a Reed type sensor performance.

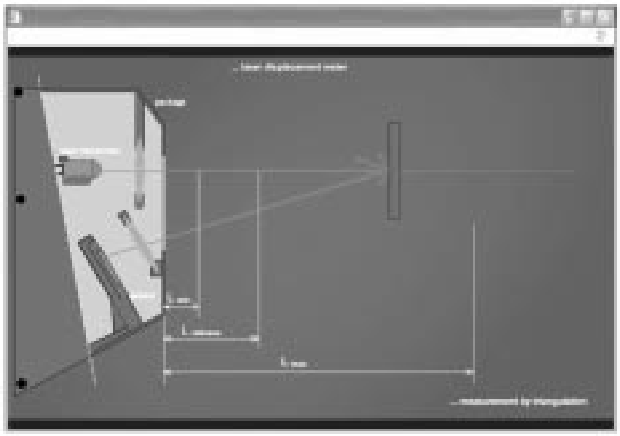

Fig. 14. Simulation of a laser sensor performance.

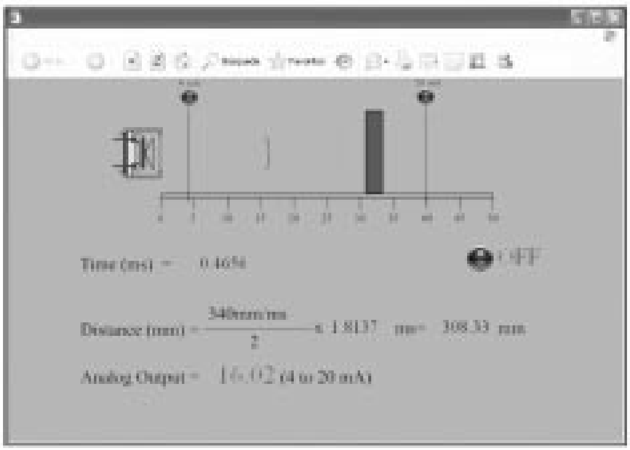

Fig. 15. Simulation of an ultrasonic sensor performance.

Evaluation

Finally, the application includes a self-evaluation system to measure the quality of knowledge the students have acquired. The system comprises three different levels the user reaches automatically when they successfully complete a series of proposed questions of increasing complexity.

The evaluation format relies on technical questions with different levels of difficulty (three levels have been established), which are successively proposed. The student must choose one out of three answers to each question and the tool reports whether the answer is correct. In this way, the next difficulty level is dynamically determined. The evaluation is then interactive as the application sets while executing the difficulty level

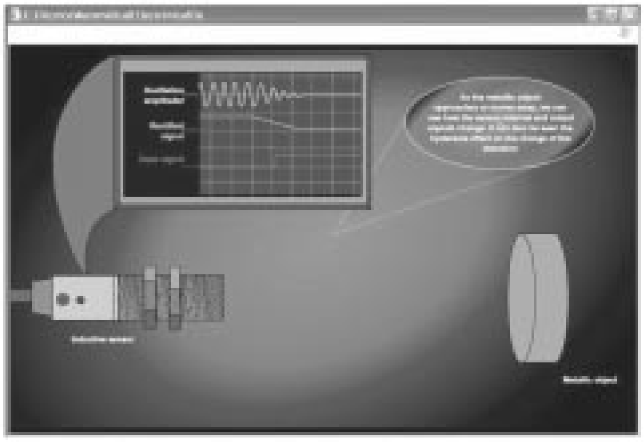

Fig. 16. Simulation of an inductive sensor performance.

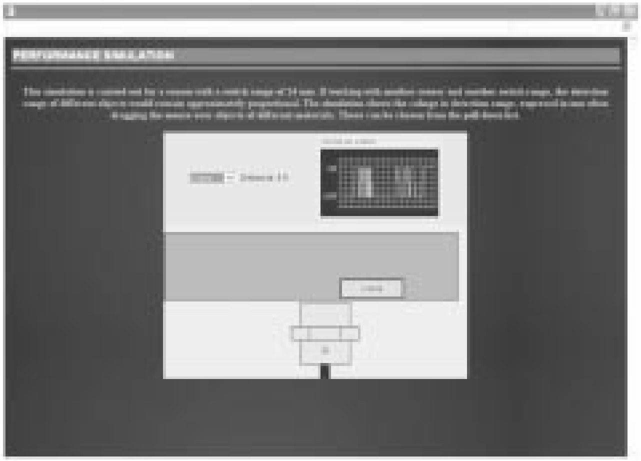

Fig. 17. Operating mode simulation for a capacitive sensor.

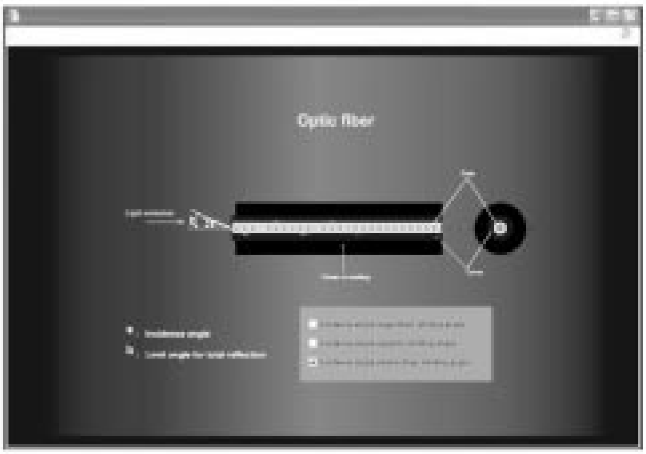

Fig. 18. Animation of light propagation in an optical fibre.

to the knowledge acquired in previous sessions. Lastly, after a number of questions (between 9 and 15), the student is scored according to his/her knowledge.

The same scheme applies separately to each type of sensor within the application.

Information display features

All the blocks above, accounting for a type of proximity sensor, display a similar structure based on the analysis of physical principles for object detection, sensor operating and working modes, electrical, mechanical and operating

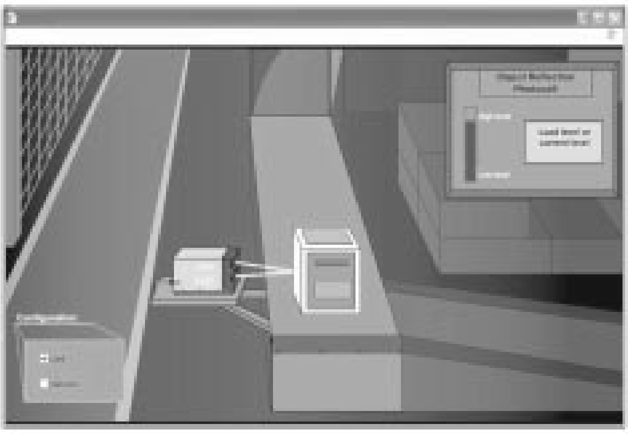

Fig. 19. Simulation of the operating mode.

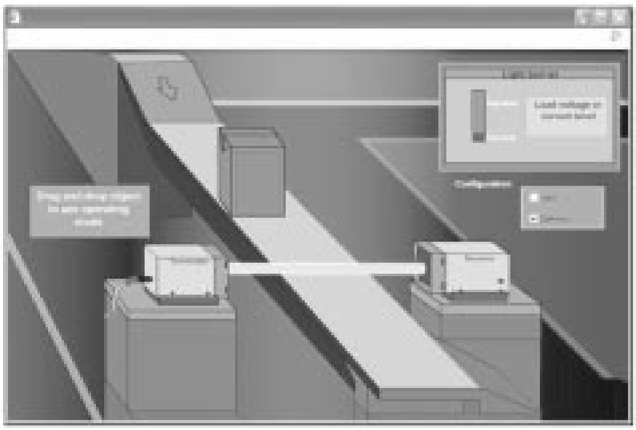

Fig. 20. Simulation of the operating mode.

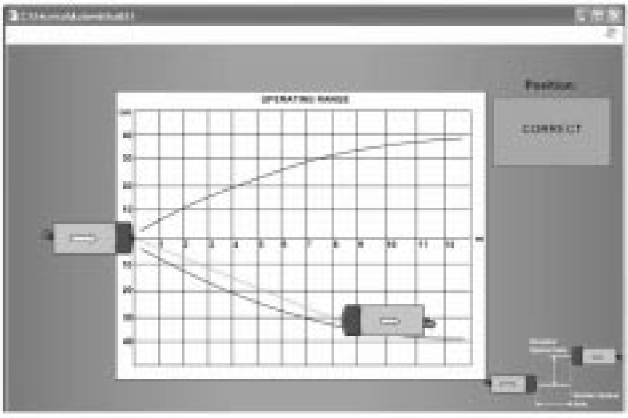

Fig. 21. Simulation of the working area.

features, typical applications, types of electrical outputs, standards and regulation, protection classes, manufacturer data sheets and any other aspects of interest. The remaining blocks, Introduction and Evaluation, are more formally structured to accomplish their intended goal.

Animation of physical phenomena and simulation of operating modes

One of the best methods of introducing the ongoing concepts is through *simulations* and *animations*, which will contribute to understanding the working modes or the change of sensor features. Simulations are graphical applications intended to display changing processes of didactic interest. Thus, their main goal is to provide a conceptual understanding of sensor performance in potential environments, as well as variations in their physical properties or their interaction with real systems in plant.

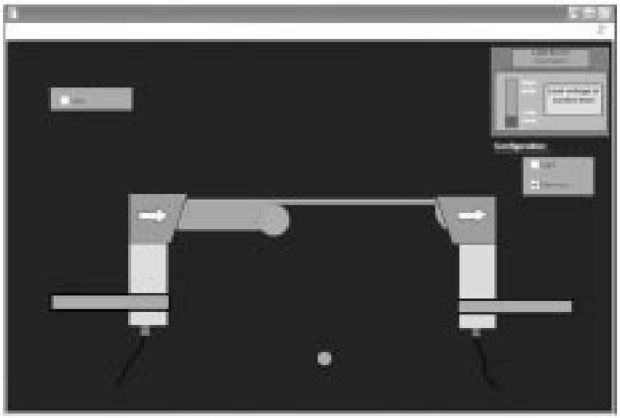

Fig. 22. Simulation of the operating mode.

Fig. 23. Videos of applications.

Fig. 24. Videos of industrial applications.

This approach adds conceptual clearness, easy extrapolation of concepts and interactive behaviour to the program, so that the user may change the operating conditions to assess their effect on performance.

Videos on real industrial applications

In addition to simulations and animations of physical phenomena, which are very useful from a conceptual standpoint, the tool includes videos on real industrial applications using these devices, which allow one to observe processes in industrial plants, test sensor operating modes under different conditions and work within educational demoboards developed in our Department.

Other ancillary tools range from links to manufacturer web pages, to the possibility of accessing catalogues with examples of proximity sensors and inputs to references considered important, to

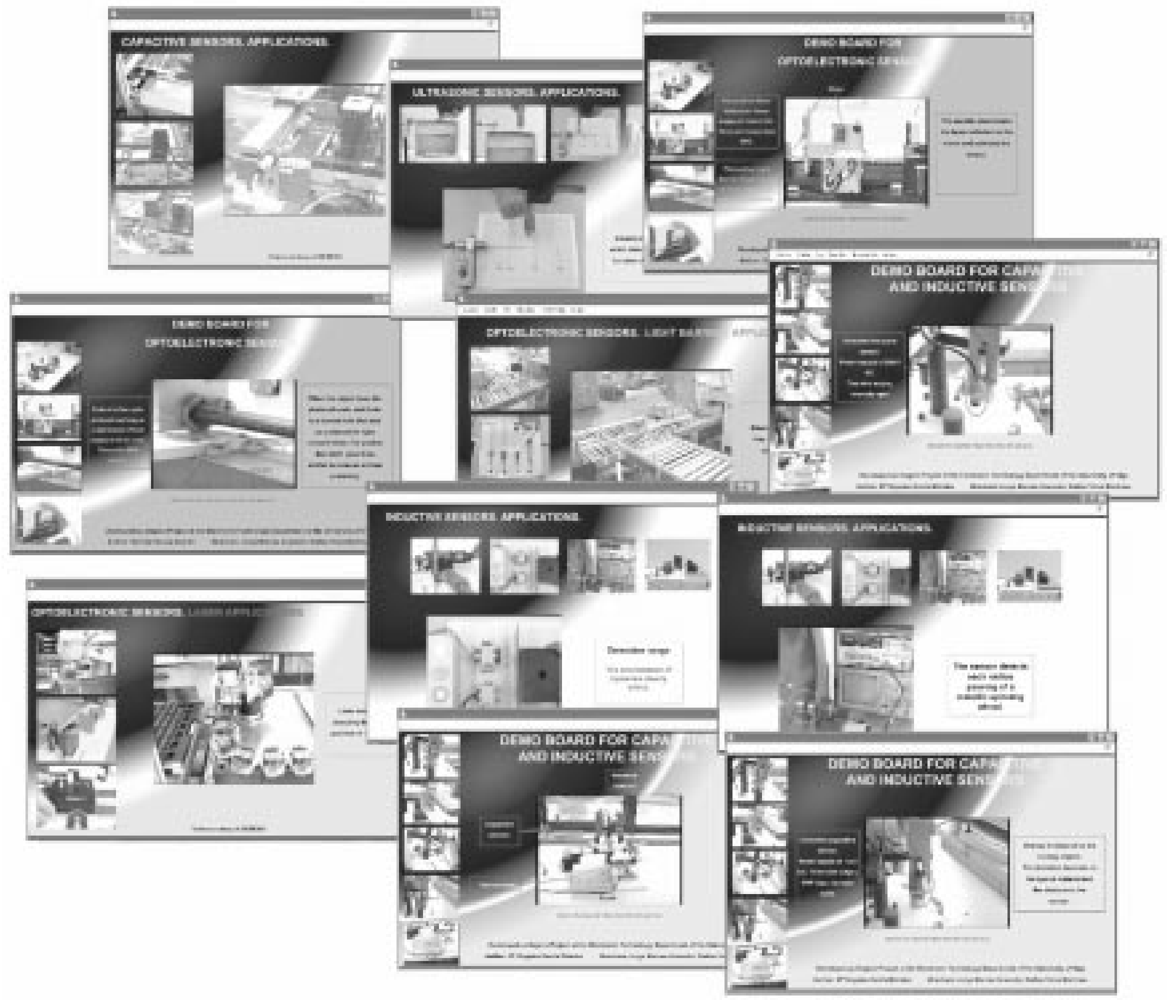

Fig. 25. Multiple open windows showing videos of proximity sensors applications.

provide the student with more information on a specific topic.

ACHIEVEMENTS

Following our objective to improve the educational work through multimedia applications, we started using the developed tool to teach proximity sensors in the discipline of Industrial Electronics (5th year of Industrial Engineering degree, speciality of Electrical Engineering). We currently intend to extend the experience to other disciplines that our Department teaches.

The supposed success of the tool should be externally reviewed in order to check the achievement of initial goals and the acceptance rate amongst users. Thus, as part of the educational software development process, the evaluation is carried out by students of different electronic disciplines whose programs include sensors. The first results show good acceptance of this type of tool and a general feeling of approval has been noticed. The major drawback to assessing the evaluation process objectively is the choice of appropriate standards. In the last decades, many proposals have been elaborated on standard criteria to select and evaluate educational software, sometimes individually, at other times institutionally. Even though they vary somewhat in content and style, all share the common goal of helping the student choose and assess an appropriate program. The aim is then to evaluate the software quality according to the objectives established beforehand, that is, to truly determine the usefulness of the program developed, and its possible drawbacks and shortcomings.

The evaluation questionnaires, according to the most accepted standards [13–19], should include close and open questions and checking boxes, allowing the interviewee to report troublesome or specific aspects not taken into account during the form's design. The wording and vocabulary have been carefully selected to avoid confusion. The questionnaire is broad enough to consider all aspects involved in any educational software. Furthermore, it includes some items on making the tool a singular program that meets the above-mentioned requirements. A comprehensive survey has been carried out to allow one to extract data to assess the tool and the evaluation process itself, which is fairly advanced for this type of tools. It is made up of three clearly different parts: an analysis of contents display (visual aspect), a functional analysis of the program (how it works, ease of use), and a technical study of contents (educational quality, resources available and contents). All three are approached from two perspectives: the first part is free-answer questions, of a qualitative nature, and the second (quantitative) with numerical scoring of various aspects. Finally, we asked for a global assessment for the tool as well as the most and least successful items and the flaws found (Table 1).

From these results, we carried out an analysis of the conclusions and the survey process quality itself through external evaluation standards based on available studies of educational software quality, which can be found in the references cited above.

The most relevant features extracted from the collected survey data can be summarized as follows:

1. The tool developed had great acceptance by all surveyed. The average score was 7.81 out of 10.
2. The tool exceeds (scored more than 5 out of 10) the average for all proposed standards.
3. The highest valued items were the simulations and videos, whereas the lowest were the lengthiness (excessive information), the evaluation difficulty and the theory part.
4. All students surveyed reported that their knowledge had improved to a greater or less extent thanks to the tool.
5. Most of them liked the arrangement, found the navigation friendly, the application neat and comprehensive, and did not consider more items to include. There is a clear discrepancy over whether the program should include more information on how to use it or should be left mostly to the user's intuition.
6. The aspects to be improved usually referred to background colour preferences, letter size or the shape of navigation buttons.
7. The evaluation form should be upgraded to include the option 'Don't know'/'No answer', because occasionally some questions are left blank.
8. After studying the most common evaluation standards in this field, the conclusion was made that the form should include a few questions more related to application flexibility.

The results of the quality study summarized here confirm the utility and acceptance of this approach to creating multimedia software tools to support the teaching of electronics and related fields. The application is aimed at university students, more specifically to the education of future industrial engineers, but it can be extended to experts in electronics, instrumentation or automation. Thus, the starting point is an accepted and validated model, that is able to face future developments with improved features, such as interaction capacity, dynamism and display aspects.

PERSPECTIVE

The development of this multimedia tool is part of an educational software design process focused on improving the teaching of different topics to future electrical engineers. From this starting point, our purpose is to broaden the development frame to other types of electronic sensors and even to the field of power electronics. In these future developments, some currently ongoing, we will

Table 1. Summary of some evaluated items

Result summary
Data summary: Application global score: 7.81 Video score: 8.15 Evaluation score: 7.6 General aspect score: 7.75 Learning level score: 6.77 Simulation score: 8.15 Minimum score average: 5.8 in degree of difficulty in evaluation Maximum score average: 8.2 in display format Average qualification (for all the items): Fair
Opinion summary: 83.3% do not know what e-Learning is, and the remaining 16.67% vaguely know but aren't sure.
Presentation summary: In general, the exposition sequence has fair acceptance, as well as the colour composition and appearance. There are some critiques, like those referring to letter size, shape of forward/backward/index buttons or background colour. Functional analysis summary: The structure is highly valued; a vast majority consider it easy, neat and complete, and no more items seem to be necessary. Yet there is no consensus on whether the program should be more intuitive or explain a bit more. Improvements in buttons and dynamic texts are suggested as well
Technical analysis summary: The tool is mostly seen as complete, with no need for any other help items or deeper explanations. All consider it applicable to other disciplines and of great utility, after reporting their knowledge had improved to a greater or less extent. The most enjoyable, by far, is the inclusion of simulations and videos. The least satisfying is the large extension, the evaluation and the theory.

Table 2. Example of evaluation standards, according to [16]

Standards for educational software evaluation
1. Ease of use and installation
2. Versatility (adaptability to different contexts)
Programmable
Open
Evaluation and tracking system
Continue the homework/tasks
3. Quality of audiovisual environment
Clear and friendly design of windows System
Technical and aesthetic quality of items
Appropriate integration of averages
4. Quality of contents (databases)
Correct and updated information
Correct spelling
No discriminations
Presentation and documentation
5. Navigation and interaction
Site map
Navigation system
Keyboard use
Answer analysis
Question, answer and action management
Program execution
6. Originality and use of cutting-edge technology
7. Capacity for motivation
8. Adaptability to user work pace
Contents
Activities
Communication environment
9. Potential of educational resources
10. Encourage for self-learning and initiative
11. Current educational focus
12. Documentation
Summary file
User manual
Didactic guide
13. Learning effort

gather the most valued features of the application and introduce improvements to the less friendly aspects. The ultimate goal of this developing line focuses on a base program of sensors, from which to access specific tools for each type of sensor.

In addition to these enhancements, our intention is to embed the tool into a web page, which will require links to other educational pages, either from the subjects themselves or from any other e-Learning environments. This will allow dynamic features to be added that have not as yet been included because the application was not intended for mass distribution. Therefore, the evaluation data will be dynamically recorded; even the application quality survey can be included, in order to obtain an automated and updated analysis of features, so that the amount of time devoted to data assessment will not increase.

CONCLUSIONS

Improving teaching requires introducing new learning approaches, upgrading the means to ease the comprehension of new concepts and prompting the student to be interested in the topics about which he or she is about to learn. This is applicable to technical teaching, common to the different specialities within engineering and especially suitable for electronics. Thus, the Electronic Technology Department of the University of Vigo has launched a design process of educational software [1–5] useful for teaching tasks, one of whose first outcomes is the application 'Multimedia System for the Teaching of Proximity Sensors'. This approach to new help tools for learning provides certain important features: reduction in lecture time, inherent clarity of visual descriptions (almost intuitive), interaction between users and tools, real application samples through links to catalogues and videos of actual industrial systems, links to manufacturer Web pages, etc. All this contributes to improving the knowledge of proximity sensors, so that their use, selection and installation in plant will be familiar to the automation engineer. The ultimate goal is to broaden the application to other fields related to electronics and to continuous improvement based upon the objective evaluation with external standards.

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