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Easy Mobile Device Programming for Educational Purposes

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Abstract— **This paper presents the architecture and several applications of a system aimed at developing mobile device-based courses in an easy and graphical way, without requiring knowledge and programming skills. The proposed system is used to create a remote course about greenhouse climatic control, as well as the necessary steps to build the mobile-based application.**

I. INTRODUCTION

In the last decades our society has been itself coiled by the vertiginous advances undergone in the information and communication technologies (ICT), giving rise to innumerable changes in enterprise, cultural, social and educational fields. These advances have produced a creation of new techniques and methods opening a wide range of possibilities not only in the industrial area (remote control, remote management, flexible timetable, etc.), but also in the educational field (distance education, interactive tools, remote and virtual laboratories, etc.). The rapid development of the computers, Internet and the distributed computing facilitates the development of feasible and cost-effective solutions. The main advantages of the ICT are related with teleaccess, teleoperation and telecontrol [1], [2]. Thanks to the advances in Internet technologies, a new method for accessing the information has appeared, the *teleaccess*, providing a way to safely access to the information from any part of the world without temporal constraints. Both in the industrial and research/educational fields high costs are often related to the restricted use of systems with usage-time constraints or to the displacements required to control them. With *teleoperation* (extension of sensorial capabilities and human skill to the remote place) and *telecontrol* (specific part of teleoperation whose goal is to send commands to the actuators) technologies it is possible to control systems remotely through Internet, thus helping to diminish displacement costs and allowing to extend the use of time-limited resources or equipment [1].

In the educational field, new teaching methods have appeared allowing the teachers to find innovative techniques to enhance the students motivation and improve their education. All these methods are involved and/or described by new terms such as: *online learning*, *e-learning* and *distance learning* [3]. The development of a great number of projects and research works for improving the education in the Automatic Control field has been carried out during the last years [1], [4]. There are many works about interactivity [4], [5], [6] [7], web-based simulation, virtual and remote labs [8], [9], [10], [11], [12], [13], [14] and virtual and remote courses [15] that open a wide range of possibilities as support to the students' education.

All these works have been developed using a computer as device or link to the virtual and remote labs/courses. However, the vertiginous advance in the mobile device technology (phone mobile, PDAs, etc…) and its wide use by the people (most people have a mobile phone) can be used in order to open additional degrees of freedom within the virtual or remote teaching fields [16], [17], [18], [19]. Most students have a mobile phone, and then, if virtual and remote courses are available for these mobile devices, they can work from anywhere and without temporal constraints. Nowadays, the mobile device programming, and overall, the mobile phone programming, consists of developing *ad hoc* applications performed mainly in J2ME (Java 2 Micro Edition) [20]. In order to facilitate this work, this paper presents a full system to allow the development of mobile-based applications in an easy–graphical way and without writing any code line. Some works, such as remote labs [14] and virtual courses [15], are being used for teaching greenhouse climatic control in undergraduate and doctorate courses in the University of Almería. In order to complement the previous works and advance in this field, the proposed system has been used to create a remote course about greenhouse climatic control where the theoretical contents are presented in several mobile screens, and practical exercises using a remote lab [14].

This paper is organised as follows. Section 2 briefly describes the system architecture, while the main applications of the system (*Application descriptor* and *Application builder*) are explained in Section 3. Section 4

overviews a greenhouse climatic control course developed using the proposed system, as well as the necessary steps to build the mobile-based course. Some concluding remarks are drawn in Section 5.

II. SYSTEM ARQUITECTURE

The system is described as a well-known client-server architecture (Fig. 1). Hence, the system functionality is divided in two different parts, the *server side* and the *client side,* which are connected through internet. A description of each one is shown in the following.
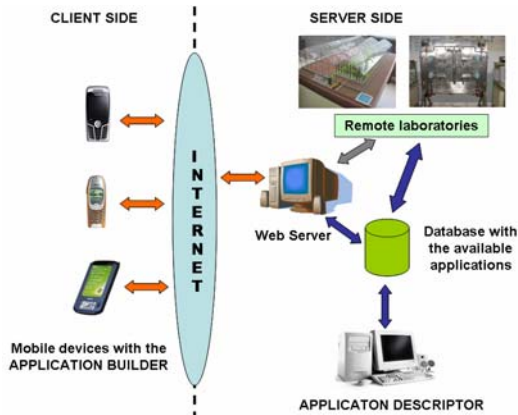

Fig 1. General system architecture

A. Server side

The elements of this system have as objective to allow mobile devices access the virtual courses, and control remote laboratory plants. As shown Fig. 1, in order to reach this purpose, several elements are necessary: web server, database manager, web site able to accept www request and connection with databases (e.g., "php", "asp", "jsp", etc.), and communication interface with the available remote plants. In this way, when a mobile device requests information about a certain course, the web server, through the dynamic web site, takes information about this course from the database, returning it to the client. When connecting to a remote laboratory, the request is analyzed in the web server in order to read sensor information and write control parameters.

As commented above, the information of the courses is stored in the database. The creation of each course, its structure, and contents are performed in an easy way using the developed tool called *Application Descriptor.* This tool allows to create mobile-based courses without having any knowledge about mobile programming and without writing any code line. Thus, it is only necessary to define the course in terms of visual elements to appear in the mobile application: buttons, windows, text to be displayed, images, actions, etc., being possible to save the course descriptions as templates for future courses. This application will be described in detail in the next section.

B. Client Side

Once the server side is operative, the mobile devices can be used in order to request access to the courses, being possible to use typical mobile devices such as mobile phones or Palm PCs. Nowadays, if one desires to dispose of an application in the mobile device, the application must be usually downloaded and then executed. The typical Java applications (calculator, games, etc.) need high memory size, and the download process can take long time and high economic cost. These problems are avoided in the proposed system.

The only requirement of the mobile device is to have a small application installed. This application, called *Application Builder,* will allow the connection with the server side in order to request information about the available courses. Once the connection is established, the server sends the list of available courses to the client. Then, the client selects the desired course and request its description to the server, which as seen above is composed of text, containing the information about the application elements. The information received in the mobile device is interpreted and the course application is dynamically generated, being then available for its use. When the user finishes the course, the application is closed and the course information disappears. However, the course description can be stored in the mobile device in order to load it at anytime without connecting with the server. With this philosophy, the problems about storage size and time connection are considerably reduced.

Some courses need to exchange information with the server side, mainly when it is necessary to connect with a remote laboratory. In order to perform this information exchange the mobile device will make www request to the web server in the server side. The www technology has been used for the information exchange, because it easiness and widespread use.

III. APPLICATION DESCRIPTOR AND APPLICATION BUILDER

A. Application descriptor

The selected philosophy is based on EJS (Easy Java Simulations) [21], which is a tool to develop graphical Java applications based on computer without writing almost any code line. Hence, before creating an application using the *Application descriptor,* it will be necessary to know the required graphic elements and the actions to perform with the mobile device. The *Application descriptor* is a Java tool which has the aspect shown in Fig. 2, where as it can be seen, the elements of the course are set in a graphical way. The different elements which can be used are the following:
1) *Screens*. The different windows which can be used in the mobile device. There are three kinds:
   - *Text boxes*. In order to show long text information.

- *List*. It contains text option items or image based option items.
- *Forms.* The mobile device windows which contain text fields, images, buttons, etc.

These are the main elements in one application and contain the other element groups.
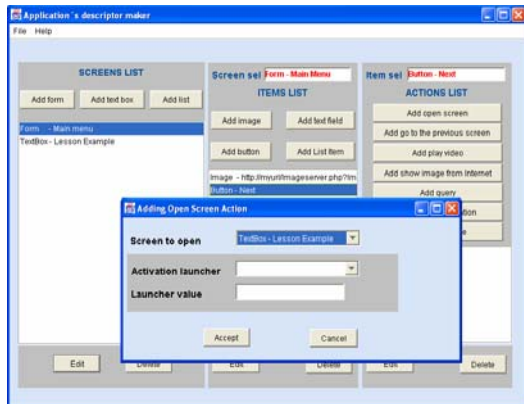

Fig 2 . Screenshot of the Application descriptor tool.

2) *Item lists*. The different elements that the Screen components contain:
- *Text field*. It shows or allows writing short text information.
- *Buttons.* It can be added in order to give functionality to the application.
- *Image.* It can be loaded from a web site or from the mobile device.
- *Option item.* It is an element of the Screen *List*.

3) *Actions*. Some components such as button and option items can launch actions: open a screen, come back to the previous screen, show an image from internet, play video from internet, show alerts, exit the application, and also to perform queries to a certain web server, launching other actions depending on the server replies.

All these elements have several configurable parameters to offer a flexible behaviour depending on the application objective. Mixing these features, it is possible to create different kind of mobile applications and of course, to allow having several degrees of freedom to develop educational courses. So, in order to create an application, first the different Screens are defined. After that and for each Screen element, the Item list components are added, and finally, the desired actions for each button or option item are described. Once the application is created, it is stored in the database, being available to a request from a mobile device.

Fig. 2 shows an example where a small application is developed. The application contains two Screen elements: one initial form composed by a button (Next) and a welcome image, where the action for the button is to open the next screen element; and a Text Box which shows a small text and also contains a button (Exit) in order to exit the application. The resulting application in the mobile device will be shown in the next subsection.

B. The Application builder.

The information about the courses or mobile-based applications is stored in the server side. Hence, a tool is necessary for the mobile device allowing to perform this connection. This tool is the *Application builder*, which must be installed in the mobile device from Internet (as a typical mobile-based application), using Bluetooth, USB, or other mechanism. As has been pointed out, the *Application builder* is a tool developed with J2ME [20], which allows to connect with the server side, to obtain the list of the available courses or applications, to download the description of the desired application, and after that, to create the application dynamically.
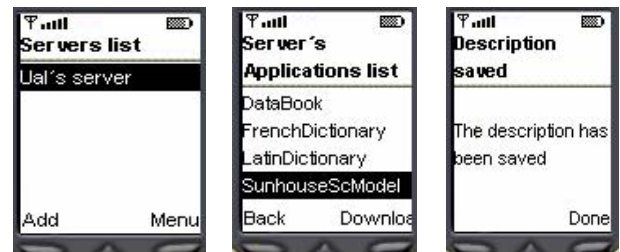

(a) Server connection   (b) Application list   (c) Application load
Fig. 3. Server connection, list of applications, and loading application

So, in order to connect with a server, the server address must be added to the *Application Builder* configuration, and then the next steps have to be performed (the example used in previous subsection is explained):

1) Show the list of servers and connect to the desired server (Fig. 3(a)).
2) The list of the available applications is received in the mobile device. Then, select the desired one and press the *Download* button, as shown Fig. 3(b).
3) Once the application is downloaded, the message "The description has been saved" is shown, as it can be seen in Fig. 3(c). In order to create the application dynamically, press *Done*.
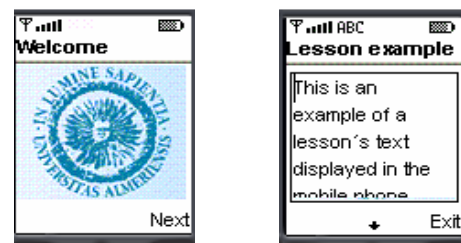
(a) Initial form   (b) Text box example
Fig. 4. Example in the mobile device

4) The application is created as shown in Fig. 4, where the initial form contains a welcome image. If the *Next* button is pressed, the application changes to the Text box shown in Fig. 4(b). The application can be finished pressing the *Exit* button.

IV. MOBILE-BASED COURSE ABOUT CLIMATE CONTROL IN GREENHOUSES

Agriculture is one of the main economic sectors in Almería (Southeast Spain), and thus, the University of Almería has several degrees related with this field. Professional associations and engineers of many companies have also shown a great interest in having a continuous training in the field of greenhouse automation, as this has been recently included in the academic degrees in Universities. So, it is quite important to allow engineers and technicians both from the academic and industrial fields to have the opportunity to achieve greenhouse control practice and to have the possibility to perform quasi-real tests without temporal and spatial restrictions. With this idea in mind and in order to show the functionality of the proposed system, a mobile-based course about climate control in greenhouses has been developed. The course consists of several theoretical lessons and some practical exercises. The theoretical part will be tackled through several Screens in the mobile device, and in order to perform the practical part, the mobile will be connected to a Remote laboratory of a Greenhouse Scale model [14].

A. Web server and database

As shown in the second section, the server side is composed of several applications which must be installed in order the system to be available. The *Apache Server* has been selected as web server [22], *PHP* as dynamic programming language [23], and *Mysql* as database server [24]. All these tools can be installed and configured in an easy way using the freeware package *EasyPhp* [25].

Once these tools are available, the dynamic web pages are programmed in order to access the database. So, PHP pages will receive the mobile device request and will perform the necessary transactions with the database to return the information required. The web pages developed support the next functionalities: listing the course or application descriptions available to be downloaded, send data to the database, read data from the database, check the login information, read images, and read the video images. This configuration for the server side can be changed easily with any other kind of technology, using always http requests as interface.

B. Remote Laboratory of a Greenhouse scale model

A Greenhouse scale model is installed at the *Automatic Control, Robotics and Artificial Vision Laboratory* of the University of Almería (see Fig. 5). It was developed under the framework of the DAMOCIA project (ESPRIT-Special Action P7510 PACE) [26], and it has several sensors installed to measure the main variables to be controlled: inside air temperature and humidity and inside PAR radiation. An external meteorological station has been also placed to allow measuring outside temperature, global and PAR radiation, humidity, wind speed and wind direction.

The solar radiation variations are simulated by using a focus of 500 W placed onto the greenhouse scale model. Wind speed is also simulated using a DC ventilator controlled by the serial port. There exists also the possibility of reading data from files obtained from the experiences in real greenhouses. From the control point of view, the scale model is provided with a natural ventilation system (with two DC motors for zenital and lateral vents aperture), a forced ventilation system (with a DC ventilator), a simulated irrigation and fertilization system (with leds), a simulated distributed pipes heating system (with leds), a heating system using heaters and a shade screen (with one DC motor). The actuators are activated using a set of relays by the serial port. Two RS232 control modules have also been used for acquiring the data.

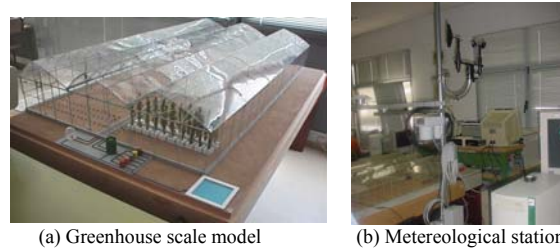(a) Greenhouse scale model   (b) Metereological station
Fig. 5. Greenhouse scale model and meteorological station

An important aspect in a remote laboratory is to allow the students feeling that they are controlling a real system. One way to do this is to use visual feedback. For this reason, a video server (AXIS 2400) and two CCD cameras have been used, allowing to view the scale model remotely. In [14] an application was developed using LabVIEW in order to perform the climatic control of the Greenhouse Scale Model [27]. From this application the sensors values and the control parameters are accessible trough the database, so that this way will be used in the mobile-based course in order to access to the Greenhouse Scale model.

C. Mobile-Based Climate Control Course

As commented before, the course consists of two parts, a theoretical part and a practical part. The theoretical part will be composed of five lessons with the following information:

1) *Introduction.* The importance of the agricultural field in the Southeast of Spain (specially the greenhouse) is described, as well as the necessity of academic degrees in the University and formation courses.

2) *Climatic control problem.* The different variables which influence in the plant growth under greenhouse are treated. Then, the different control problems such as temperature control problem, humidity control problem, radiation control problem, and irrigation control problem, are described.

3) *Temperature control problem.* Instead of creating a course with all control problems, a course based only in the temperature control problem has been developed for simplicity reasons.

4) *Modelling greenhouse temperature.* A brief introduction about modelling concepts is performed.

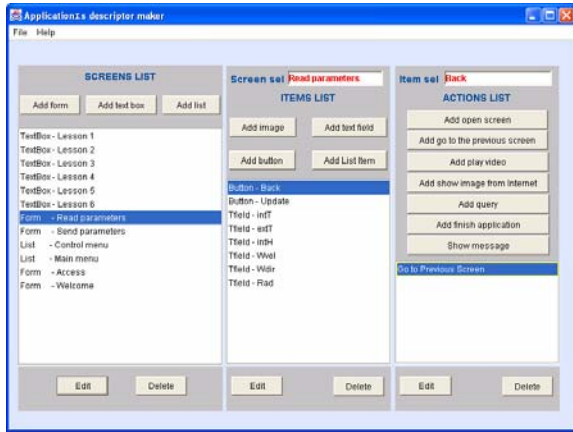*5)* *Control algorithms.* The different temperature control algorithms are studied.

Fig. 6. Greenhouse Climatic Control Course

On the other hand, the practical part of the course consists in controlling the temperature of the greenhouse scale model using the theoretical concepts seen in the first part. Once the information about the course is defined, the next step consists of developing the mobile-based course using the *Application descriptor*. So, it is necessary to select the graphical elements for the application (Fig. 6).

First, five Text boxes are created in order to store the information about the theoretical part of the course. In each Text box a button with the action *come back to the previous screen* is added. Fig. 7(a) shows an example for the first lesson. Once all lessons have been created, the forms to connect with the greenhouse scale model are developed. In order to read values from the sensors one form with so much text fields as sensors is created. This form (Fig. 7(b)) has two buttons, one of them to update the sensor values form the server (Fig. 7(b) shows the inner temperature, *XTINV_sim*, and the wind speed, *VV_ext*), and the other to come back to the previous window. The form to send the control parameters to the server is performed in the same way. Now, the form contains text fields with the set-points and controller parameters, and two buttons, one for sending the values and other to come back to the previous windows. This form is shown in Fig. 7(c) where the temperature set-points for the day (*Setp_tday*) and night (Setp_night) can be observed.

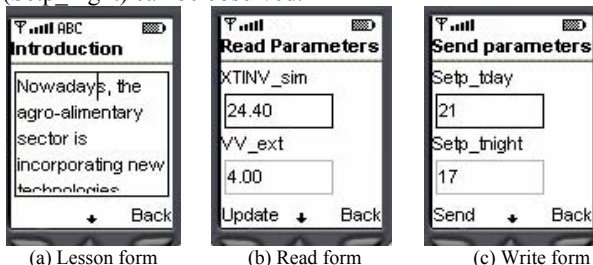(a) Lesson form   (b) Read form   (c) Write form
Fig. 7. Lesson form, read and write forms

In order to give access to the reading and writing forms, one Item list is created with the remote control options. This window is shown in Fig. 8(a), where three options can be seen, the first two corresponding with the sending and writing forms, and the last one, *Play video*, is created in order to open a remote image of the greenhouse scale model (Fig. 8(b)). Also, a button to come back to the previous screen is added.

(a) ControlMenu form   (b) Play video form   (c) Main menu form
Fig. 8. Remote control forms, and main menu form

The next step consists of creating the main menu form, which allows accessing to the different lessons. This form is shown in Fig. 8(c) and its options are the names of the lessons: Introduction, Climatic control problem, Temperature control problem, modelling greenhouse temperature, Control algorithms, and remote control. This last option gives access to the Control menu form (Fig. 8 (a)). Now, a form for user access control is developed (Fig. 9(a)). This form contains two text fields, the Name field (login) and the password field. Also, it contains two buttons, one of them for sending the information to the server in order to check the data, and other to come back to the previous screen. Once the mobile device receives the server response, if the access data are correct the Main menu form will appear, and in other case a Login Error message will be shown (see Fig. 9(b)).
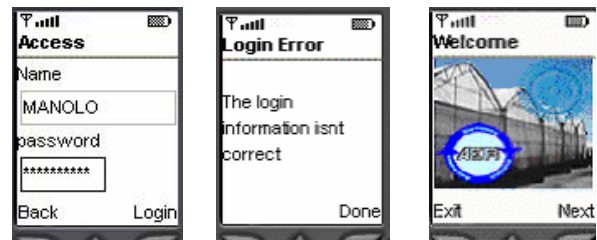
(a) Access form   (b) Login error form   (c) Welcome form
Fig. 9. Access forms and welcome form.

Finally, the welcome screen is created. This form contains an image of presentation, and two buttons as Fig. 9(c) shows. One button is to exit of the course, and the other one to open the Access form.

V. CONCLUSIONS AND FUTURE WORKS

A. Conclusions

A system allowing the development of mobile-based applications in an easy way has been developed and explained in this paper. Applications for mobile devices

can be developed without having knowledge about mobile device programming, and without writing any code line. The applications are defined in graphical way using the *Application descriptor*, and after that the application is created transparently in the mobile device through the *Application builder*. Using this system it is possible to develop a remote course for educational purposes providing the students access from anywhere and without time constraints. As an illustrative example, a greenhouse climatic control course has been presented.

Some tests have been done in order to test the courses, where mobile simulators and real mobile phones have been used. During this year a pilot-experience has been performed with the students of the *Control and Robotics in Agriculture* subject in the University Campus of Almería obtaining satisfactory response from them. However, in order to develop a course with the proposed system, some considerations must be taken into account: the course contents must be condensed since the mobile phone memory is limited, and the equation must be written as text or images. Instead of these characteristics, the system has also several advantages: the programming is performed in a graphical way, the course is available from any place (beach, mountain, etc...), and the size and transmission time of the course are smaller than the typical applications with a reduction of 90 % as shown in Table 1.

In the future, other courses related with multivariable control and manipulation robotics will be developed, where a four-tanks scale model and a robotics cell (both of them available in the the *Automatic Control Laboratory* of the University of Almería) will be used.

TABLE I

Used tool	Size application (kB)	Transmission time (s)
Typical application	45,7	16,3
Proposed system	5,8	2,1

Comparison for the development of a greenhouse climatic control course with a transfer speed of 2,8 Kb/s [19]

B. Future works

As future works the following items are proposed:
1) The *Application builder* tool can be improved in order to decrease the time spent during the construction of the applications.
2) Improve the transmission of the images, and to study the possibility of introducing real sounds.

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