A Tool for the Automatic Selection of Mechatronics Remote Laboratories based on their Actual Effective Costs

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***Abstract*— This Research to Practice Work in Progress presents a solution for managing distance learning laboratories. Remote Access Laboratories are software and hardware tools that allow students to remotely operate real equipment located in physical facilities such as universities laboratories. This work presents the development of an Automatic Selection System for Remote Access of Mechatronic Laboratories. The system checks the current laboratory activities in real time, verifying if it is active, inactive, occupied or free, according to a student's experiment. After analyzing those characteristics, the system examines the number of students and the state of the internet connection to determine the most appropriate laboratory. Finally, experiments using the selection functions and the proposed architecture are presented to investigate the system's efficiency.**

Keywords— Mechatronic Laboratories, Remote Laboratories, Distant Learning Experiments, On-Line Students.

I. INTRODUCTION

The characteristics of distance education, especially the flexibility of time and the use of new tools such as software systems and modern users' interfaces, helps both students and teachers to develop teaching and learning together [1, 2, 3]. Those facts were motivators for the development of this work. The flexibility of time happens because distance education approaches allow the students to manage their own pace of learning from anywhere with Internet access. This flexibilization allied with modern technologies has leveraged several teaching strategies to improve the quality and speed of learning of the student [4, 5]. It was observed that the use of flexible time to explore the maximum potential of the interactivities that involve the theory applied to practice is an important educational strategy, especially in engineering courses [6, 7, 8]. This kind of approach is one challenge in many different application scenarios [9, 10, 11].

Therefore, one automatic selection system for mechatronics remote access laboratories was developed to look for Didactic Modular Production Systems (MPS) environments available for the student to use when practicing their experiments. The MPS is a very robust didactic plant, from Festo Didactic, aiming the learning of industrial automation topics. It is relatively expensive, and there are not a lot of them available all over Brazil. The selection happens based on the conditions of each mechatronics laboratory. It considers if it is active or inactive, occupied or free and if the didactic plant is the same as the student's experiment. After analyzing these conditions, the number of enrolled students, and the state of internet connection, the system can choose the best laboratory site for the student at that moment. This selection process resulted in the creation of a method for finding the effective laboratory cost.

The paper is organized as follows: section II presents the problem solved by the system. section III shows the components developed and implemented in the system. In section IV experiments performed to test the laboratory selection method are described, and in section V the conclusions obtained about the work are shown.

II. PROBLEM DESCRIPTION

Remote Access Laboratories (RALs) are software and hardware tools that allow students to remotely access a real experiment that is connected to the Internet [12, 13, 14], where Remote Access Laboratories, or online Lab, can be of physical type, virtual type, or simulated type according to Avila, Amaral, and Tarouco [15]. Thus, with RALs, it is possible to share didactic plants between educational institutions. To access one of these labs the student only needs to have access to the internet [16, 17, 18, 19, 20]. In the operationalization of RALs, there is a problem associated with simultaneous access by more than one student to the same laboratory. Consider a situation in which three students wish to access a network composed of three mechatronics laboratories. The first student is quickly connected to the first laboratory. The second student tries to connect to the first lab, but it is busy now, then gets the connection to the second lab, and the third student tries to connect to the first two labs to then get the connection with the third one. The search time for the second and third students to find the appropriate laboratories to receive their connections is the problem to be solved in this work. In this context, the problem addressed by this work can be formalized as how to select the best available laboratory automatically for online use by the students?

In this scenario, this work proposes a method to solve the management of remote access laboratories, specifically for mechatronics laboratories. This method automatically indicates to the student which laboratory should be used, thus optimizing the waiting time.

III. PROPOSED SYSTEM

The proposed system consists of the following elements: the remote access laboratory, the student platform, and the manager element. Fig. 1 shows the overview of the system. In this figure, laptops represent students logged in the learning system, in fact, they should use their personal

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computers from anywhere with Internet access to connect to the remote laboratories. The access to the desired laboratory occurs through the authorization of the management element.

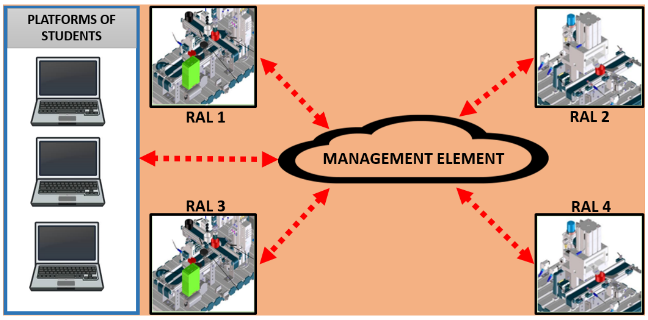

Fig. 1. Overview of the proposed system.

A. Remote Access Laboratory – RAL

The RAL component is a location consisting of a computer, a didactic plant or experiment, a controller, and a camera. RALs are hosted in educational institutions (schools, colleges, and universities) that wish to share their equipment with this system.

In this work, the implementation of the RALs was carried out in the dependencies of the Federal University of Amazonas (UFAM) and the National Service of Industrial Learning of Amazonas (SENAI), both located in Manaus – AM - Brazil. Figure 2 shows the actual components that were chosen for the proposed system implementation at both sites. These components are the RAL computer, the didactic plant MPS platform, the controller plant (a PLC), and an IP camera for feedback purposes.

Fig. 2. RAL of UFAM.

The implementation of each RAL component will be described in the next paragraphs.

1) RAL computer: its main role is to work as a server for student remote access. On the RAL computer, the following items were installed: Windows operating system with profiles for student simulation and execution, PLC programming software (codesys V2.3), and the cost and server modules that support the management element. The programming/simulation profile is used by students who want to develop or simulate their programs, so this profile has been configured with some access locks that did not disturb the profile with runnable functions. The RAL computer is also embedded with two applications, one is the cost module and one server module. These two modules are responsible for managing the laboratories.

- *Cost Module:*

The developed module has two main functions: the first is that this program informs if the laboratory is active for the database of the management element, and the second, and most important for the system, is that this module calculates the cost of the RAL in which it is running. Fig. 3 shows the diagram of the operation of the cost module.

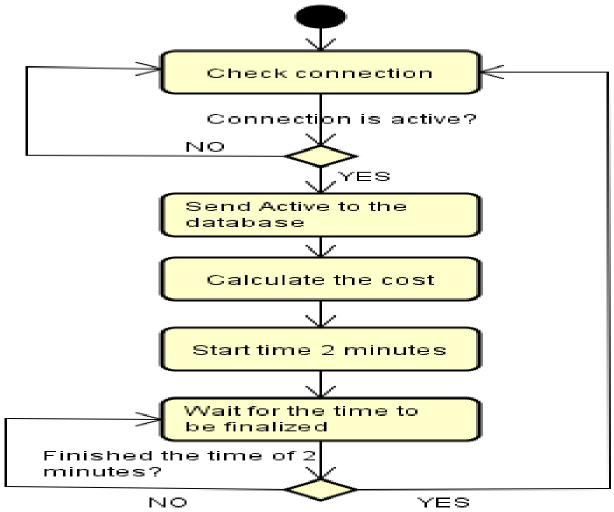

Fig. 3. Activity diagram of the cost module.

This cost is calculated as follows:

$$C = N + TT \qquad (1)$$

In Eq. (1), C means the cost of the laboratory, N means the number of students and TT means the data transfer time. The arithmetic average between the upload and download time of a standard text file (1 Kb) was used to generate TT.

- *Server Module:*

This module was installed on the RAL computer to manage the student files, manage the connected profiles and usage time in the execution profile. This program is initialized from the Windows login in either one of the profiles. The executable file is in the operating system's boot folder. As soon as the student get access to the system, the server module informs the management element that it is occupied by the profile currently used and it increases the total number of students in the laboratory in which the application is running. Fig. 4 shows the graphical interface of the server module. After increasing the number of students, the server module is waiting to activate the accessible buttons to the student.

The following functions are implemented:

A) Email/Password: when the student wants to download or upload their program it is necessary to insert the registered email and password.

B) Insert Program: when the student is in the simulation/programming profile and finishes the development, the path location of the student's program must be inserted in this area.

C) Upload the Program: when the file path is inserted, this button must be clicked to start the file upload, so the program is stored in the file server of the manager element until the moment it is executed.

D) Download the Program: when the student wants to run one program, it is necessary to click this button to download the file.

E) Exit the Program: when the student decides not to perform any of the activities, simply click on this button to leave the profile used, then it is decremented minus a student in the laboratory.

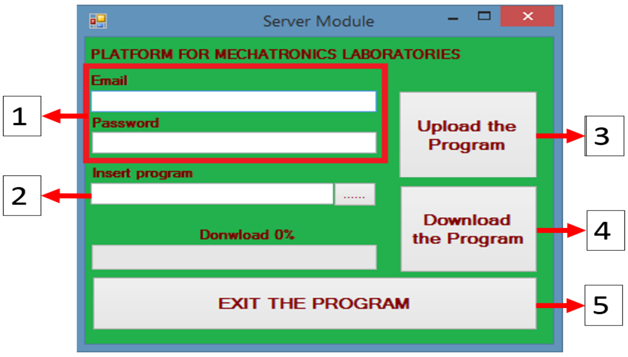

Fig. 4. Graphical server module interface.

2) The didactic plants of mechatronics area: These plants are teaching tools aimed at students' practice involving pneumatic, electrical, and mechanical systems. The didactic plants that were chosen to compose this system are the platforms of the MPS line from Festo Didactic, for the validation of this work the plant that has the didactic task of punching was used. In this process, coins are pierced and inserted into pots that pass through one mat. At the time of using the RALs, the student can choose which process will be used. In a previous step, the educational institution must register the didactic plant in the management element.

3) Plant controller: the controller chosen for this implementation was the Programmable Logic Controller (PLC) because it is robust and widely used in industrial processes. PLCs work interconnected to the didactic plant receiving and sending control signals. For this work, the controller of the family CEC-CPX of the company Festo was used. In the CEC-CPX controller, the TCP / IP / Modbus Ethernet communication port is used to load the students program into the PLC; there are also available two controller cards one digital input and one digital output.

4) Camera: a mobile camera was used as IP webcam in the implementation of the RAL. This camera only takes action from a student platform request and if the student is using the execution profile. The image is an important feedback tool to visualize process sensors and actuators, as well as, the pots walking along on the treadmill when the student program runs.

B. Student Plattform

In the main screen of the platform (Fig. 5), the student can activate the button to send one task, then a new screen is presented, which allows the sending of the student's file to the FTP server. Later, at the moment the student wants to execute one program, the platform is already available considering the student's login profile. The buttons Programming and Test Application of the student's interface work in similar ways, the difference is that when the Programming button is activated the student module directs this student to a simulation profile within the chosen laboratory, and the Test Application button directs the student to the execution profile within the chosen laboratory.

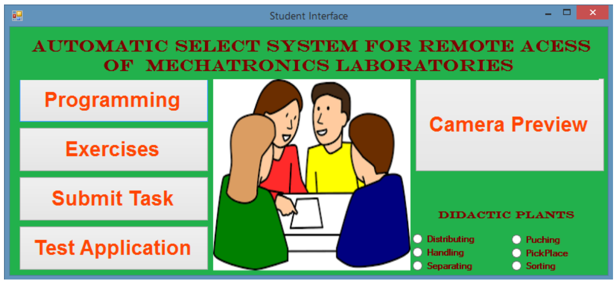

Fig. 5. Students' interface.

By activating these buttons, a group of functions belonging to the management element, called the student module, will choose the best available laboratory. This choice will be explained from here onwards the following steps:

- *1st step:* from the RALs registered in the management element, the student module verifies which laboratories are active.
- *2nd step:* among the active RALs, those that are free are checked.
- *3rd step:* among the free RALs, those that are with the same didactic plant of the student are verified.
- *4th step:* among the RALs with the same teaching plant, it is verified the one that has the lowest cost.

Thus, the laboratory that goes through all these steps will be chosen as the best laboratory to perform the student activity. A diagram is shown in Fig. 6 to illustrate this selection process, where green color and random costs representing the flow of choice were assigned to demonstrate the choices. It is noted in Fig. 6 that Laboratory 3 was chosen because all the steps were evaluated as true and it had the lowest cost, at that moment, when compared to Laboratory 1.

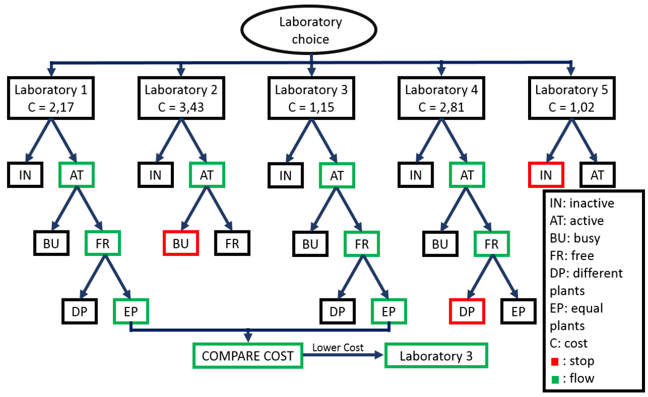

Fig. 6 Flow of process choice.

The implementation of this module was done following the greedy algorithm that always searches for the best path [21]. Based on this algorithm and the decisions made, an objective function was developed to select the chosen laboratory to optimize the selection of laboratories. This equation is given as:

$$S_i = (N_i + TT_i)*ST_i*SI_i*P_i \quad (2)$$

$$S_i = C_i*ST_i*SI_i*P_i \quad (3)$$

Where $\boldsymbol{i}$ = (1, 2, ..., n) being $\boldsymbol{n}$ the total number of laboratories available in the system. $\boldsymbol{S_i}$ is the selected laboratory. $\boldsymbol{C_i}$ is the laboratory associated costs, resulting from Eq. 1. $\boldsymbol{ST_i}$ is the laboratory status, that can be 1 if is active or 0 if it is inactive. $\boldsymbol{SI_i}$ is the situation of the laboratory, that can be 1 if it is free or 0 if it is occupied, according to the profile chosen by the student. Finally, $\boldsymbol{P_i}$ is the didactic plant itself that can be 1 if the plant is equal to the one desired by the student or 0 if it is different. The objective function (Eq. 3) is calculated for each registered laboratory, and the minimum obtained value (not equal to null) is the optimal environment choice. With the choice of the laboratory performed the student is directed to the chosen laboratory through the RDP protocol, where an interface screen was created to show the remote section with the student's connection to the RAL.

To finish the implementation of the platform, clicking on the camera preview button will bring up a new screen, where the users have the start and stop buttons to view the feedback video. When the student requests this image, the student module requests the IP camera of the chosen RAL, and through an HTTP protocol link, the image is generated and can be viewed on the student's screen.

C. Management Element

The management element was implemented using a website hosting service. Within this service one FTP server was used to store students' programming files, a MySQL database server was also used to store data regarding the students, institutions, and processes used within this system. Therefore, the implementation of the job manager element is divided into two parts: the system site and the database.

1) System Site: The site was implemented using the Yii framework in the PHP language, which greatly facilitated the structural part of the site. The homepage of the site offers two buttons, one for registering the institutions' laboratories and another for registering students. With these registrations, students can access the RALs registered by the institutions.

2) Database: This database was implemented in three tables. User table, with information about the users of the system site; Register table, where the students' data is stored; and Laboratory table with information about the characteristics of the laboratories. In the database are all the information necessary for the decision making of the automatic selection method.

IV. Experiment Procedures

The scenario created addressed the choice between two laboratories of different educational institutions, based in distinct locations and with the same infrastructure. In Table I, the following variables were considered: ST-status, SI-situation, and P- didactic plant. They were modified through the database, to test the selection of the best laboratory. The implemented test environment included the laboratories of Ufam and of Senai, both of which worked with the MPS line punching plant and the same PLC. In table I only one student who will use the system in the execution profile was considered for these tests, the number students (NS) connected is equal to zero and the time of choice was captured on the student response screen. The time count is started with the click on the test application button and finished at the moment in which the laboratory was chosen. The additional acronyms are C - cost, and TT - data transfer time.

TABLE I. Test of elementary conditions for the selection equation.

Test Entry Data								Results	
N	Description	Lab	St	Si	P	C	TT (s)	Selected Lab.	Choice Time(s)
1	Varying the status of Senai to inactive	Senai	0	1	1	0.7875	0.7875	Senai	10.218
		Ufam	1	1	1	1.1540	1.1540		
2	Varying the status of Ufam to inactive	Senai	1	1	1	0.7650	0.7650	Ufam	7.187
		Ufam	0	1	1	1.1545	1.1545		
3	Varying the situation of Senai to busy	Senai	1	0	1	0.7800	0.7800	Senai	6.484
		Ufam	1	1	1	1.1465	1.1465		
4	Varying the situation of Ufam to busy	Senai	1	1	1	0.7880	0.7880	Ufam	7.734
		Ufam	1	0	1	1.1620	1.1620		
5	Varying the didactic plant to a plant different from that used in Senai	Senai	1	1	0	0.7875	0.7875	Senai	5.64
		Ufam	1	1	1	1.1470	1.1470		
6	Varying the didactic plant for a plant different from that used in Ufam	Senai	1	1	1	0.7955	0.7955	Ufam	5.547
		Ufam	1	1	0	1.1385	1.1385		

Table I shows the input data of the tests at the time of choosing the laboratory for the student. The results of the tests are displayed in the last columns of Table 1, confirming the efficiency of the selection algorithm in the tested cases. These results showed that even with the variations of the conditions of the selection equation, our method reduces the student's waiting time in the choice of the laboratory. This is because when one of the elementary variables is equal to zero, this laboratory is already discarded according to the selection equation so that the times of choices were not greater than ten seconds, so it is possible to optimize the use of the laboratories using reduced times when selecting the RALs. Table II shows the choice of the laboratory with the elementary variables in 1, so the choice depends directly on the lowest cost between the connected laboratories.

TABLE II. Test of variation of the number of students in laboratories.

Test Entry Data									Results	
N	Description	Lab	St	Si	P	C	TT (s)	NS	Selected Lab.	Choice Time(s)
1	A student is already connected to SENAI	Senai	1	1	1	1,7955	0,7955	1	Ufam	28,265
		Ufam	1	1	1	1,17	1,1700	0		
2	A student is already connected to UFAM	Senai	1	1	1	0,78	0,7800	0	Senai	31,656
		Ufam	1	1	1	2,6755	1,6755	1		

V. Conclusions

The objective of selecting the RAL was reached because the proposed method solved the problem of the manual search performed by the student and provided the best choice of laboratories. The proposed equation verifies the characteristics of each mechatronics laboratory available and helps on the automatic selection.

In fact, this selection equation was the main contribution of this paper as it offers a choice based on the calculation of the current costs of the connected laboratories. As a result, the students do not need to worry on which lab is available or even which is the best one for a specific task. This reduction of overhead time may be used on the learning process itself and may improve the efficiency of the experiments practiced by the students in addition to providing practical activities in highly efficient laboratories for the field of mechatronics.

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