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DEVELOPMENT OF A HYBRID LABORATORY BASED ON THE INTERNET OF THINGS

Marco Antonio Hernández-Vargas
Instituto Internacional de Aguascalientes
Tecnológico Nacional de Mexico Campus
Aguascalientes
Aguascalientes – Mexico
https://orcid.org/0000-0002-8146-9307

Héctor Jesús Macías-Figueroa
Instituto Internacional de Aguascalientes
Tecnológico Nacional de Mexico Campus
Aguascalientes
Aguascalientes – Mexico
https://orcid.org/0009-0001-3309-1899

César Dunay Acevedo-Arreola
Instituto Internacional de Aguascalientes
Tecnológico Nacional de Mexico Campus
Aguascalientes
Aguascalientes – Mexico
https://orcid.org/0009-0001-9370-2997

Ricardo Luna-Carlos
Instituto Internacional de Aguascalientes
Tecnológico Nacional de Mexico Campus
Aguascalientes
Aguascalientes – Mexico
https://orcid.org/0009-0004-9146-1415

Caritina Ávila López
Instituto Internacional de Aguascalientes
Tecnológico Nacional de Mexico Campus
Aguascalientes
Aguascalientes – Mexico
https://orcid.org/0009-0008-5538-4095

Gabriela Chávez-Salazar
Tecnológico Nacional de Mexico Campus Aguascalientes
Aguascalientes – Mexico
https://orcid.org/0009-0003-2560-2008

Lucrecia Guadalupe Valenzuela Segura
Tecnológico Nacional de Mexico
CDMX – Mexico
https://orcid.org/0009-0001-0267-2260

José Roberto Aguilera Fernández
Instituto Internacional de Aguascalientes
Tecnológico Nacional de Mexico Campus Aguascalientes
Aguascalientes – Mexico
https://orcid.org/0009-0008-0259-0119

María Magdalena Becerra López
Tecnológico Nacional de Mexico Campus Aguascalientes
Aguascalientes – Mexico
https://orcid.org/0009-0004-7203-5998

Adriana Pupo Ulloa
Tecnológico Nacional de Mexico Campus Aguascalientes
Aguascalientes – Mexico
https://orcid.org/0009-0007-5082-4103

Sonia Elizabeth Serna Ramírez
Colegio Cristóbal Colón
Estado de Mexico – Mexico
https://orcid.org/0009-0001-1215-7369

Miguel Ortiz Martínez
Tecnológico Nacional de Mexico Campus Aguascalientes
Aguascalientes – Mexico
https://orcid.org/0009-0004-5440-5182

Abstract: In technical and scientific disciplines, carrying out experiments with real equipment is essential to consolidate the concepts acquired in theoretical classes. However, due to different reasons, real laboratories are not always available or do not have the necessary equipment for this purpose, which imposes restrictions on student learning. In some higher level educational institutions and, in particular, public ones, there are subjects that are not taken to a practical level due to the lack of the respective equipment. The Hybrid Laboratory of Fluid Mechanics based on the Internet of Things (IoT) proposed in this research work, consists of a low-cost prototype composed of a bank of sensors that allows managing the main variables used in the calculation of the power of a pump in a context of negative suction, both in real and remote mode (remote mode), as well as in a simulated way (virtual mode); both cases managed by a mobile application. This proposal is focused at the level of public higher education and, in particular, towards students who are studying the Fluid Mechanics subject of the Mechanical Engineering educational program of the Technological Institute of Aguascalientes (ITA) belonging to the National Technological Institute of Mexico (TecNM).

Keywords: Virtual Laboratory, Remote Laboratory, Fluid Mechanics, Internet of Things.

INTRODUCTION

In technical and scientific disciplines, carrying out experiments with real equipment is essential to consolidate the concepts acquired in the classroom. However, due to different reasons, the real laboratories are not always available or the necessary equipment is not available to address some subjects of the subjects, which imposes restrictions on the student's learning. Fortunately, the development of new information and communication technologies has brought about numerous changes in society in recent years (Alexiou et al., 2005). Communication, using the Internet as support, has evolved to provide new, more complex and useful forms of distance interaction (Hassan et al., 2022). The application of these technologies reaches, to a greater or lesser extent, practically all the fields of knowledge, focusing this proposal on the area of education (Balamuralithara & Woods, 2009).

The Hybrid Fluid Mechanics Laboratory based on the Internet of Things will consist of a prototype made up of various sensors that will allow the management of the main variables used in calculating the power of a pump in a negative suction scenario, both manually real and remote using the Internet as a connectivity platform (remote mode), as well as in a simulated way (virtual mode).

Likewise, the Hybrid Fluid Mechanics Laboratory may be managed by a mobile application for the virtual mode, where the corresponding variables will be entered so that the necessary operations are carried out to calculate the power of the pump in a negative suction scenario. ; all this in a simulated way and without the variables of the real environment.

This Hybrid Laboratory proposal will be focused on the educational environment and in particular on students who are studying the Fluid Mechanics subject of the Mechanical Engineering higher education program belonging to the Tecnológico Nacional de Mexico Campus Aguascalientes. The calculations that the student performs within this course are completely theoretical and the learning objective is not achieved. Therefore, what is intended with this laboratory is to systematize the procedure for calculating the power of the pump, allowing the student to understand this process in a dynamic and interactive way.

Due to the fact that the Mechanical Engineering Laboratory of the Technological Institute of Aguascalientes does not currently have the necessary equipment to carry out practices related to Fluid Mechanics (in this case, negative suction), a way to design and implement a prototype was found. in this sense based on the new information and communication technologies (Potkonjak et al., 2016).

MATERIALS AND METHODS

The hybrid laboratory prototype model was designed using the symbols proposed in the flowcharts by ISO (ISO 9001 Processes, s. f.). Figure 1 shows the two operating modes of the prototype.

For "VIRTUAL" access to the hybrid laboratory, there is a simulation software layer that will be the intermediary for the management of fluid mechanics formulas, for the monitoring and control of the negative suction pumping system.

For "REMOTE" access to the hybrid laboratory, there is direct monitoring and control of its different variables (temperature, pressure, viscosity, etc.) through a bank of sensors installed in the prototype and which will be processed under the paradigm of cloud computing (for statistical data storage) and fog computing.

On the other hand, Figure 2 shows the important elements that make up the architecture of the hybrid laboratory: cloud computing, fog computing, IoT and the mobile application.

Cloud computing has been used for the storage and processing of hybrid laboratory variables in real time using FireBase technology (Firebase Realtime Database | Stores and synchronizes data in real time, n.d.); variables such as temperature, pressure, velocity, fluid density and viscosity, and fluid levels in storage tanks. For the acquisition

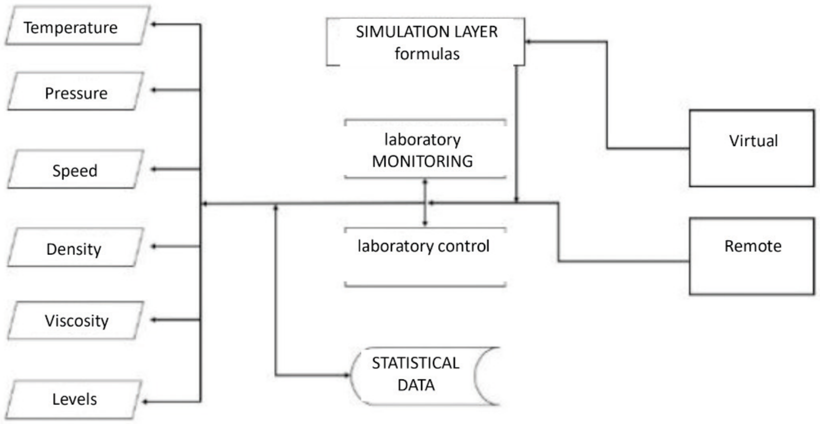

Figure 1. Model of the hybrid virtual laboratory based on ISO.

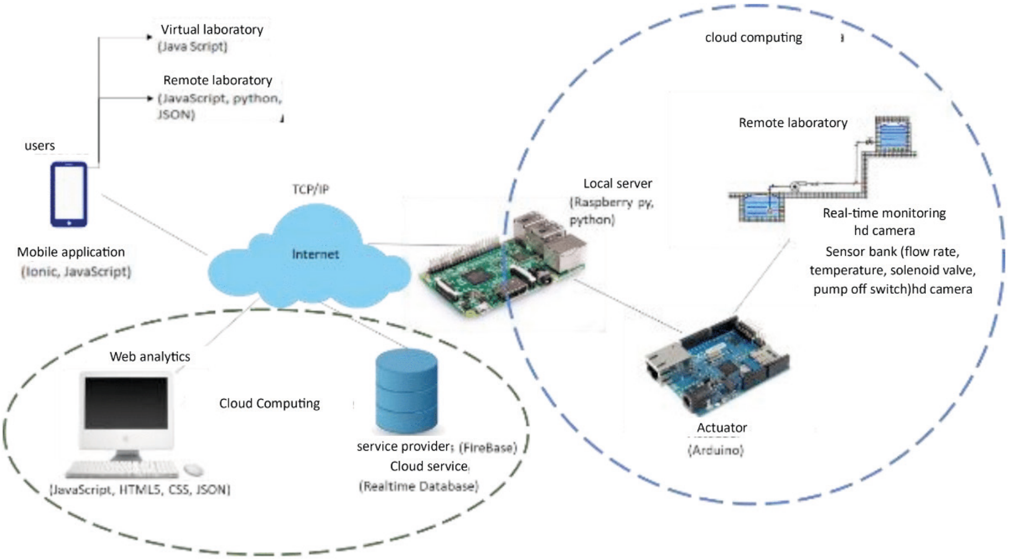

Figure 2. Architecture of the Hybrid Laboratory based on IoT.

A vessel			B vessel		
Temperature (ºC)	**Date**	**Hour (24 h)**	**Temperature(ºC)**	**Date**	**Hour (24 h)**
28.12	05/18/2022	09:12:17	29.88	18/05/2022	09:11:35
27.81	05/18/2022	09:40:48	29.5	18/05/2022	10:42:40
27.75	0518/2022	10:42:53	29.51	18/05/2022	10:42:46
30.88	05/18/2022	16:02:05	29.5	18/05/2022	10:42:53
22.69	05/20/2022	07:45:39	30.12	20/05/2022	07:45:39
26.75	05/20/2022	09:39:58	30.12	20/05/2022	07:45:53
26.5	05/20/2022	10:43:25	21.62	20/05/2022	09:39:58
26.62	05/20/2022	10:50:51	21.56	20/05/2022	09:40:11
25	05/30/2022	09:22:22	26.69	30/05/2022	09:22:22
25	05/30/2022	09:22:56	26.69	30/05/2022	09:22:56
33.25	05/30/2022	10:23:55	27.15	30/05/2022	10:23:55
30.06	05/30/2022	10:29:22	27.38	30/05/2022	10:25:09

Table 1. Fluid temperature in vessels A and B.

and sending of data to the cloud, a bank of sensors and microcontrollers such as the Raspberry B+ (Ltd, s. f.) and the Arduino UNO (Arduino Uno Rev3, s. f.) have been used. In the case of local decision-making (automatic determination of maximum and minimum levels of fluids in storage tanks), fog computing and Internet of Things technology (What is the Internet of Things) have been used? things (IoT)?, s.f.). Finally, the management of the Hybrid Laboratory in its two modes of operation (Virtual and Remote) will be through the mobile application. For the development of the mobile application, technologies such as JavaScript, JSON, Python and Ionic have been used.

Below is the procedure used to calculate the power of the pump in a Negative Suction Fluid Mechanics scenario ("Power of a hydraulic pump", 2023).

POWER OF A CENTRIFUGAL PUMP

Equation 1 has been used to calculate the theoretical power (P) as a function of the specific weight (***y*** in *N/m³*), the flow (***Q*** in *m³/s*) and the total dynamic head of pumping (***H*** in *m*):

$$P = y\,Q\,H \qquad (1)$$

ACTUAL POWER

Equation 2 has been used to calculate the real power of a pump expressed in Watts:

$$Pr = \frac{\gamma QHM}{\eta} \quad Pr = \left(\frac{m^3}{s}\right)\left(\frac{\frac{Kg \cdot m}{s^2}}{m^3}\right)(m)\ Watts \qquad (2)$$

Where:

η = is the efficiency of the pump (always less than unity).

TOTAL DYNAMIC PUMPING HEAD OR HEAD

The total dynamic pumping head or head (Hb in m) can be solved with Equation 3, Bernoulli's equation (What is Bernoulli's equation?, n.d.). As a function of pressure (P in KPa), fluid velocity (V in m/s), height (Z in m), gravity (g in m/s²), and friction losses (Hf in m):

$$Hb = \overbrace{\left(\frac{P_2 - P_1}{\gamma}\right)}^{EF} + \overbrace{\left(\frac{V_2^2 - V_1^2}{2g}\right)}^{EC} + \overbrace{(Z_2 - Z_1)}^{EP} + Hf \qquad (3)$$

The use of equation 4 will allow developing problems to calculate the dynamic head of pumping in a more detailed way.:

$$Hb = (h_d + h_s) + hfs + hfd + \frac{V^2}{2g} + (hrs - hrd) \qquad (4)$$

Where:

hg = (*hd* + *hs*) = Geometric height between the lower and upper level of the liquid.

$\sum \boldsymbol{hf} = (\boldsymbol{hfs} + \boldsymbol{hfd})$ = The sum of all losses (both in straight pipe and accessories) suffered by the fluid between the suction level and the discharge level.

V²/2g = Dynamic or kinetic energy.

Hr = (*hrs* – *hrd*) = It is the residual pressure that the pump must overcome when the fluid reaches its destination.

RESULTS AND DISCUSSION

Figure 3 shows the implementation of the Hybrid Laboratory prototype; using water as fluid. The important variables that have been managed are the temperature of the fluid with the DS18B20 sensor (Tutorial digital temperature sensor DS18B20, s. f.), the level of the fluid with the ultrasonic sensor HC-SR04 (Arduino Tutorial and ultrasonic sensor HC-SR04, s. f.) and the fluid flow with the YF-S201 sensor (Water flow sensor Tutorial, s. f.).

Figure 3. Hybrid Laboratory prototype based on IoT.

The temperature data was used to determine the density of the fluid and, in turn, its viscosity. Table 1 shows the data that the temperature sensor has recorded in the database on Firebase.

With the help of the ultrasonic sensor and the formula for calculating the volume of a cylinder, the volume of containers A and B can be calculated in real time (Volume and surface area of a cylinder (video) | Khan Academy, n.d.).

Another variable considered was the flow and that determines the amount of fluid that circulates through a section of the pipeline for a unit of time. Table 2 shows the values obtained. The last physical element considered was the bomb. Through the use of relays type SRD-5VDC (Relay 5VDC SRD-05VDC-SL-C, s. f.) and an Arduino UNO, digital values have been sent via mobile application to the pump to turn it on and off.

On the other hand, a mobile application was designed and developed offering a friendly and intuitive interface for the user. Through the options of the interface of the mobile application, it will be possible to manipulate the two operating modes of the Hybrid Laboratory, virtual and remote. Figures 4, 5 and 6 show some screens of the mobile application. Finally, Figure 7 shows the pump on and off button within the mobile application.

Flow L/m	Date	24 hours
0.27	5/18/2022	14:26:06
0.135	5/18/2022	14:31:54
11	5/18/2022	09:12:17
14	5/18/2022	09:40:48
0.27	5/20/2022	10:28:18
0.135	5/20/2022	10:29:32
11	5/20/2022	10:32:21
14	5/20/2022	10:36:14
15.67	5/30/2022	09:22:22
16.02	5/30/2022	09:22:56
21	5/30/2022	10:29:22

Table 2. Suction flow rate recorded values.

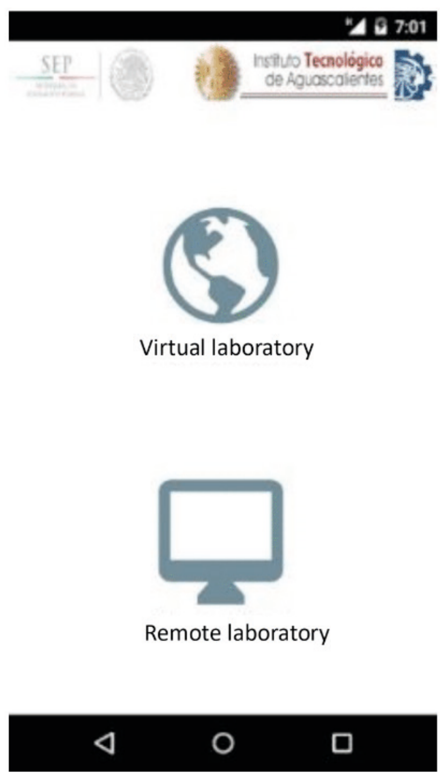

Figure 4. View in virtual mode of the application.

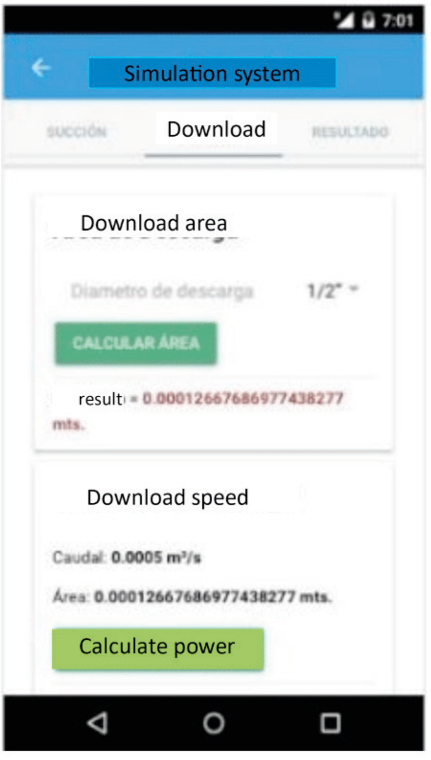

Figure 5. View in virtual mode of the application.

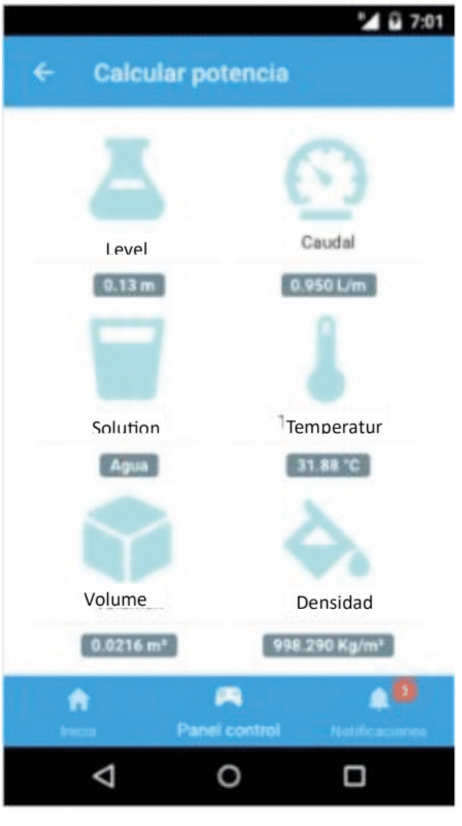

Figure 6. Remote view of the application.

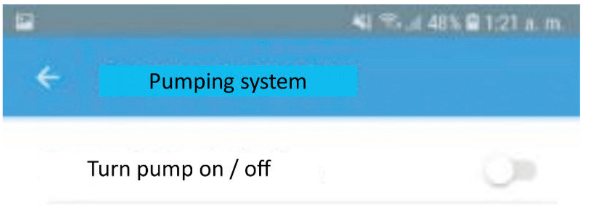

Figure 7. Pump on/off button with a current state of off.

CONCLUSIONS

With the development of new information and communication technologies, it has led to numerous changes in society in recent years. Data communication using Internet connectivity technology has evolved to provide new, more complex and useful forms of remote interaction. The application of these technologies comes, to a greater or lesser extent, in the field of education.

Due to the above, the Hybrid Laboratory based on the Internet of Things, managed both locally and remotely through a mobile application, will provide the student who is studying the Fluid Mechanics subject of the Mechanical Engineering program, a real scenario for the management of the main variables involved in calculating the power of the pump in a more automated way and from anywhere at any time. This is how it is intended to strengthen the teaching-learning process in the public educational environment at a higher level in institutions that do not have the necessary equipment to carry out this type of laboratory practice.

As future work, the integration of this laboratory in the classrooms of the Fluid Mechanics subject is visualized to determine the level of acceptance of the students. Likewise, Artificial Intelligence will be integrated in the laboratory to perform a finer adjustment of the variables that intervene in the negative suction scenario.

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