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DISTRIBUTED RESISTIVE SENSOR AND WEB DATA MANAGEMENT FOR SYSTEMATIC STUDIES OF TWO-PHASE GAS-LIQUID FLOWS

Gabriel de A. Torelli[1], torelli@alunos.utfpr.edu.br
Rafael Bressan Dias[1], rbressan@alunos.utfpr.edu.br
Natan S. Reginaldo[1], natan@alunos.utfpr.edu.br
Eduardo N. dos Santos[1], ensantos@utfpr.edu.br
Rigoberto E.M. Morales[2], rmorales@utfpr.edu.br
Dalton Bertoldi[2], daltonbertoldi@utfpr.edu.br
Marco J. da Silva[1], mdasilva@utfpr.edu.br
[1]Department of Electrical Engineering (CPGEI), Universidade Tecnológica Federal do Paraná
[2]Department of Mechanical Engineering, Universidade Tecnológica Federal do Paraná
Av. Sete de Setembro, 3165 - Rebouças 80230-901 - Curitiba - PR - Brasil

Abstract. *Two-phase gas-liquid flows are found in many industrial applications being of particular industrial interest when the flows are confined to pipes, for instance, in oil and gas extraction and processing. In the past, several studies have been performed to investigate two-phase flows under controlled conditions at small and medium scale test facilities. Such studies generate data and give support to the development of flow models and engineering correlations. In this paper we describe a data acquisition and management system in which 8 distributed sensors (expansible to up 50 sensors) are connected through a CAN bus. The supervisory and data management system is developed in a web platform and allows multiple connections simultaneously, providing a complete platform to acquire, store, visualize and share data. Each sensor is based on electrical conductivity measurement, to investigate two phase flows. The sensors are low cost, minimally invasive, and have high temporal resolution (2 kHz). CAN bus protocol was chosen to cover long distances, reducing wiring costs, due to its robustness. Emerging web development technologies, such as jQuery and HTML5 are used to assure a better user experience, responsive design and cross-browser compatibility for the application. All collected data are stored in a centralized database, allowing online visualization, report generation, and data access from external network. Initial results have shown the great potential of the proposed platform as flexible and reliable, system for two-phase flow investigation and the associated data management.*

Keywords*: two-phase flow, data acquisition, CAN bus, laravel framework, design thinking.*

1. INTRODUCTION

Flow monitoring in industrial scenarios where long distance and distributed sensors are required is always challenging. From sensor and instrumentation point of view, electromagnetic compatibility (EMC), noise, and the amount of data transmitted are critical issues when dealing with this particular environment. Controller Area Network (CAN) bus is a 2-wire bus serial data communication protocol developed by Bosch company in the early 1980s to solve the data exchange between control and test equipment in many modern cars (Junpeng and Weiyu, 2014). CAN bus has become a very popular protocol nowadays, thanks to your technical advantages, such as high-velocity (1 Mbit/s), multi-master communication, high safety against EMC problems, and fault mechanisms. All these advantages, plus low cost implementation and simple configuration made this protocol a good choice.

Two-phase flow running in pilot plants operating in controlled conditions is of great importance for a better understanding of physical phenomena, which in turn are employed for validation and improvement of flow models. Measuring parameters along the pipe is often required to observe the evolution of the flow. The data volume produced in such scenario (laboratory or industrial) needs a solution for data management in order to organize and make them available for field engineers and researchers. Some procedures are commonly used here such as external drives, spreadsheets, and LabVIEW® acquisition clients. Cross-platform web applications can turn this task more user-friendly, helping to store data using any device with a built-in browser and server access. Performed experiments are organized using a centralized fileserver and database, in a totally automated process, without user intervention. Important notes are attached to identify and describe the experiment. To fasten the web development, Laravel MVC Framework was implemented. Laravel was chosen because it has a number of helpful functions like Bundle, Eloquent ORM, Application Logic, Reverse Routing, Class Auto Loading, etc. (Alfat et al., 2015). The responsive web-user interface was developed using HTML5, CSS3 and jQuery.

In this paper, two components are introduced: a resistive sensor acquisition instrumentation based on previous works (Dias, 2015; Machado, 2013) using CAN bus protocol, and a web-based experiment management system. These solutions are designed to work together, composing a platform to be used on systematic studies of two-phase gas-liquid flows.

2. PLATFORM SUMMARIZATION

First of all, a complete understanding of the user needs is necessary to minimize project risk of failure and deliver a valuable solution. There are several methods to identify requirements, choosing the right one can drastically reduce development time and increase satisfaction. A brief introduction to Design Thinking is presented, and how this methodology can help multidisciplinary projects such as one described here. Next, sensor node, CAN bus USB gateway, communication protocol, data acquisition and circuit details will be explained. A diagnostic routine for CAN bus was developed, informing user which sensor is working properly before experiment starts, along with correspondent address. Finally, front and back-ends technologies are described.

2.1 Design Thinking as Strategy for Development

Design thinking is a creative approach to solving various problem types and sizes that are not easily handled by critical and analytical thinking, being solution focused and not problem focused (Bailey et al., 2011). Design Thinking evaluates usability (human values), profitability (business), and feasibility (technology) of the idea from different points of view (group). Briefly, it is a way to create applications where user needs, not technological opportunities, drive the development (Fauquex et al., 2015).

In order, to solve complex problems, the know-how of a single discipline and the expertise of a single person is no longer sufficient. Diversity in design teams can approach different areas of interest, producing unusual and innovative results. Stanford d.school's five steps Design Thinking Framework was adopted as reference for platform requirements analysis (Platter, 2010). Design thinking meetings, brainstorming sessions and surveys were conducted with students and researchers who operate resistive sensor equipment at Research Center of Multiphase Flows (NUEM) at UTFPR, in order to gather the necessary hardware and software requirements for the system development, following the framework steps (empathy, define, ideate, prototype and test).

2.2 Sensor Node and CAN Bus USB Gateway

The sensor is capable to flow monitoring at distances of some tens of meters. Currently the target is forty meters which is the distance necessary for experiments of NUEM. The sensor node has a flanged low intrusive design and its working principle is based on electrical conductivity measurement for discriminating two phases within a flow. Other operating principle such capacitive of optical can be easily adapted. Sensor nodes are composed by two identical printed circuit board (PCB), stacked 5 cm from each other (Fig. 1) to measure indirect flow velocity.

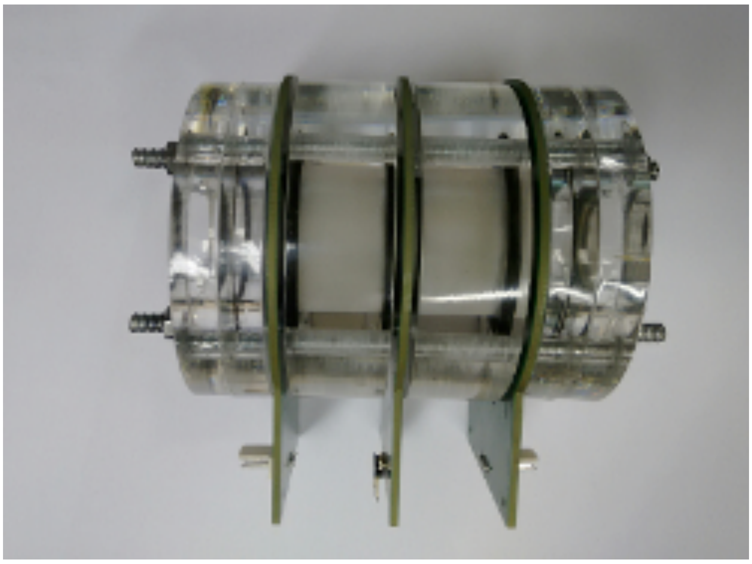
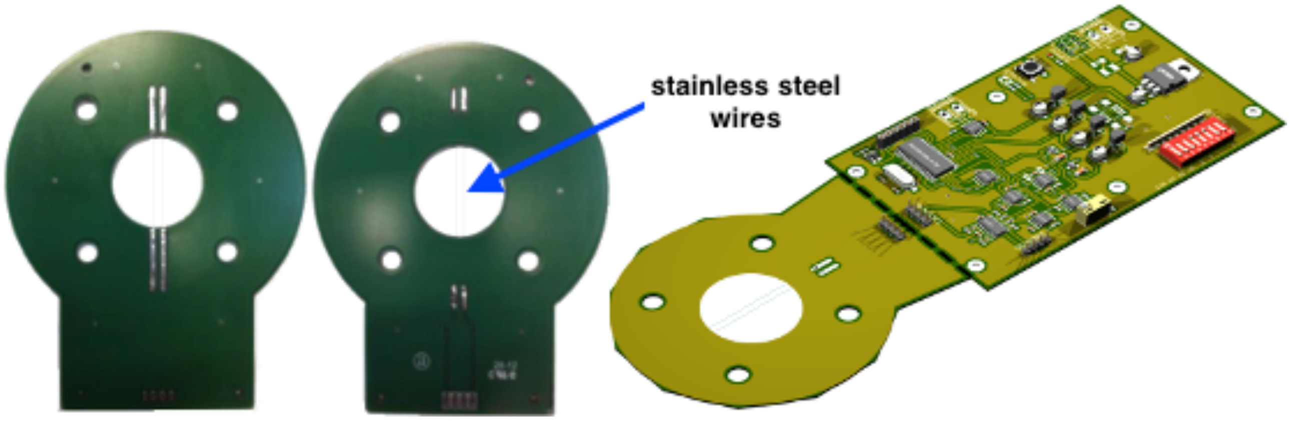


Figure 1. Sensor mounted on acrylic pipe.

Two parallel stainless steel wires (excitation and receiver electrodes) with 100 μm thickness are stretched over pipe cross section (Fig. 2). The excitation electrode is connected to a square wave voltage source of 1.75 kHz. The receiver electrode is connected to the measuring circuit. The signal obtained varies depending the amount of liquid level in the pipe cross section. This signal is sent to the A/D converter of a microcontroller (PIC18F26K80), achieving 12-bit resolution at 10kHz sample rate (maximum).



(a) (b)

Figure 2. (a) Two-wire resistive sensor; (b) sensor with detachable PCB.

CAN bus gateway (Fig. 3) is based on Microchip MCP2515 CAN controller with the MCP2551 CAN transceiver, using CAN 2.0B specification and communication speed can reach up to 1 Mbit/s (Ran et al., 2010). CAN connection between sensors is via a standard 9-way sub-D port. A diagnostic routine was implemented using broadcasted ID messages, indicating if sensor is working, allowing its use or not through the acquisition software. This message can be configured using a dip-switch located on the sensor's PCB.

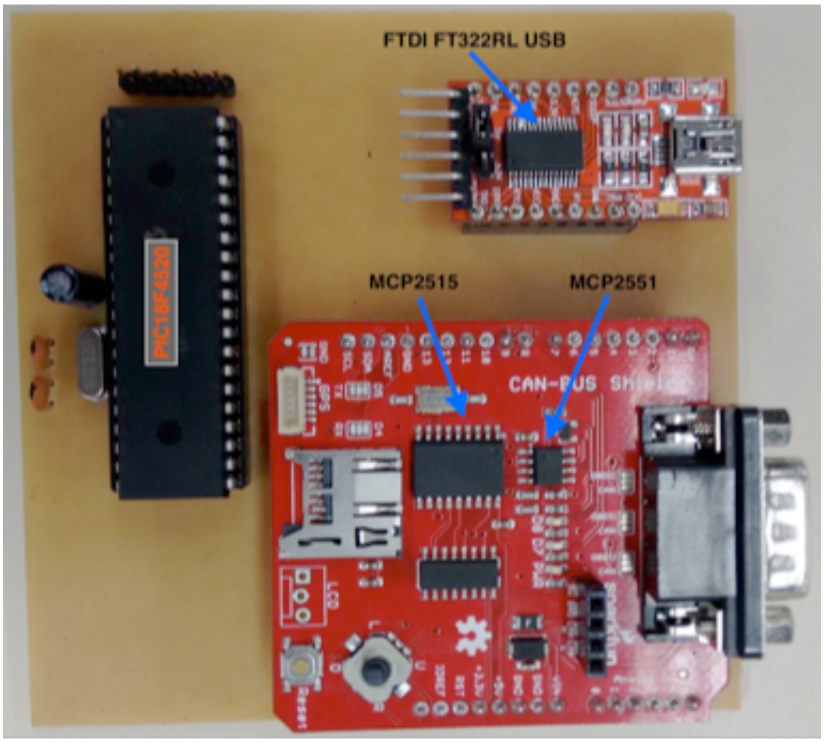
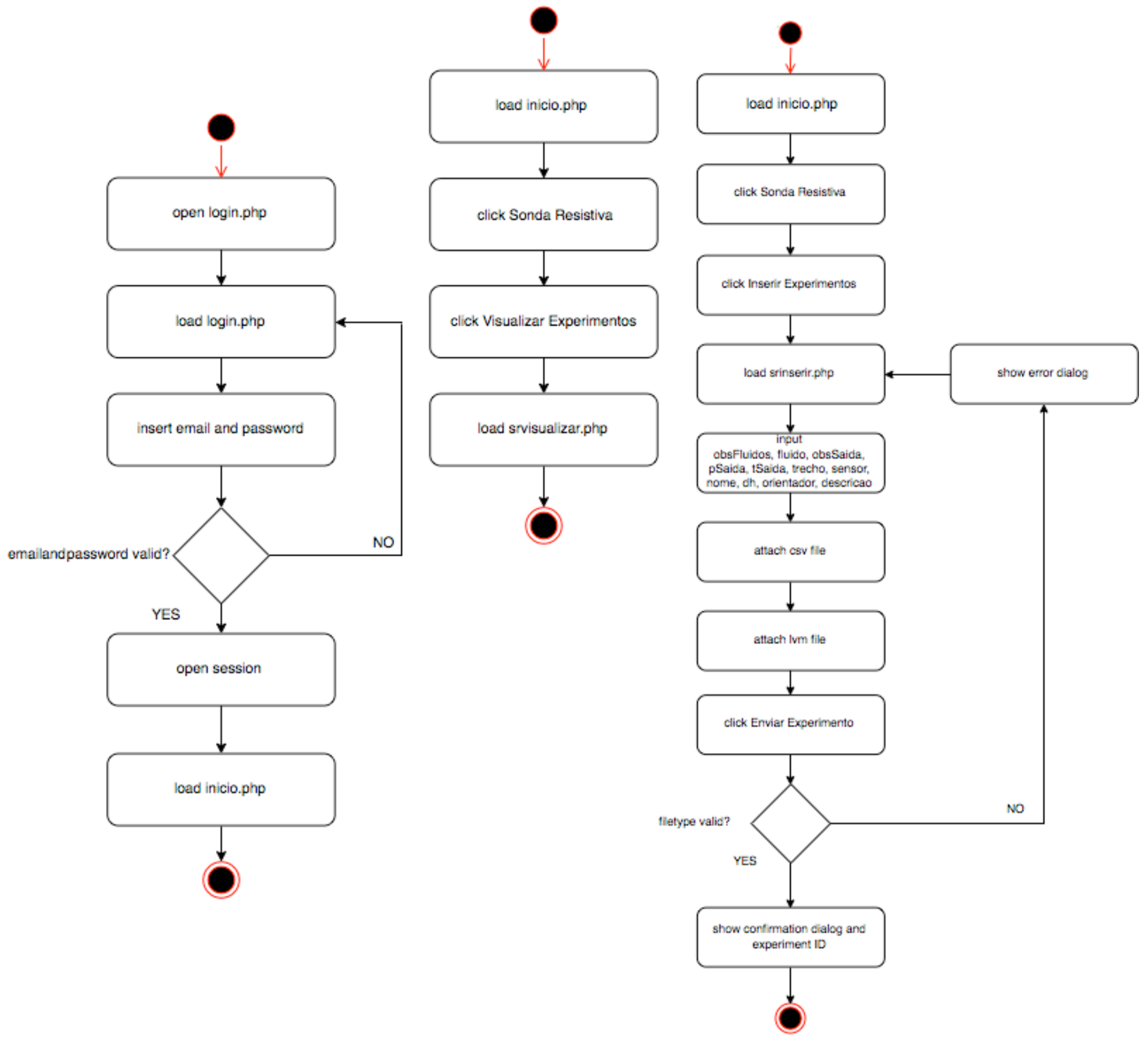


Figure 3. CAN bus USB gateway.

2.3 Front and Back-Ends Technologies

A web-based application is a client-server software that uses a website as the interface (front-end). Users can access the application from any computer connected to the Internet using a browser, instead of using an application that has been installed on their local computer. Some of their principal advantages are cost effective development, platform-independent model, accessible anywhere, improved interoperability, security, easy installation and maintenance, and flexible technologies. The experiment management was built using concepts like clean interface and responsive design, offering a professional user experience.

The back-end of a website consists of a HTTP server, an application, and a database. Laravel was the framework chosen for back-end application development. It embraces a philosophy that sets a high priority on creating maintainable code, obeying several proven web development patterns and best practices. Laravel allows to focus on the functionality in way to develop powerful web applications quickly.



(a) (b) (c)

Figure 4. Web Activity Diagram. (a) Login; (b) Display uploaded experiments; (c) Upload.

Figure 4 shows three web activities diagrams that have been chosen to understand some operations performed by the experiment manager. First diagram (Figure 4a) is the login activity, where the user enters a valid email address and password. If the combination is valid, the start page will be loaded, otherwise, the user is redirected back to login page and an error message is displayed. Figure 4b shows the visualization activity, in which the user can see all experiments uploaded and its details. Finally, the Figure 4c shows the upload activity. Users can attach files and put all relevant information about the experiment. The attached files are validated at server side, if the file size was exceeded, or the extension was wrong, the user is redirected back to upload page and an error message is displayed. More details about platform utilization are discussed at the following section.

3. RESULTS AND DISCUSSION

The main objective behind the platform is to simplify the acquisition process and organize data. Design methodologies previously discussed on section 2.1 were used to create applications that not only do the task, but provide the best and comfortable way to accomplish that. Data acquisition and management interface are presented below, along with some comparisons with the previously used methods. Three comparison parameters were adopted: usability, time-spent and flexibility.

3.1 Data Acquisition

Acquisition system is composed by sensors and the CAN gateway connected via USB to a PC. Using a C# application developed for this specific purpose, it is possible to calibrate sensors, acquire and save data, eliminating the use of other applications, such as LabVIEW® (conventional method), ensuring more agility to the acquisition process, portability (no installation needed) and a smaller file size. C# was chosen because the vast majority of computers used by students and researchers have Windows® installed. The output file is stored in a tabular plain text format, using coma-separated values (.csv) for an easy SQL Databases, Microsoft Excel® and MATLAB® integration.

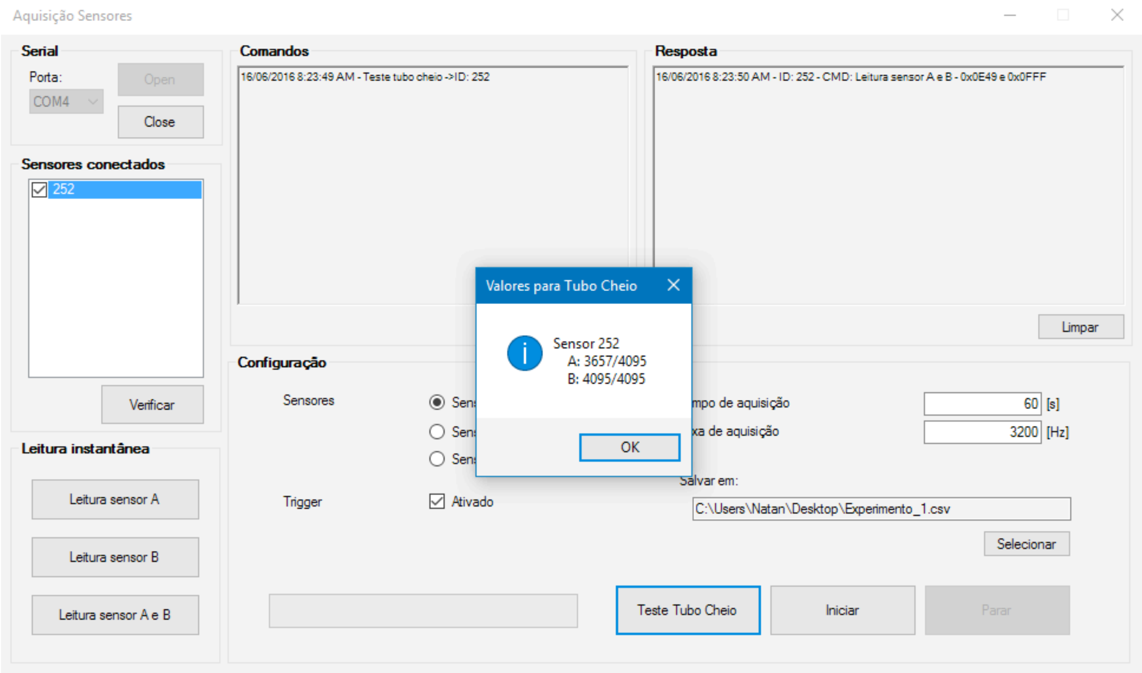


Figure 5. Acquisition screen.

3.2 Experiments Manager

With data collected, the next step is to associate it with the experiment information. Users can access the web-interface from any device using a browser. This is an important feature for research groups, because it makes the experiment available to other users from anywhere after uploading, decreasing the time to receive this data. At the login screen, authorized users can access the system using a registered email and password. After successful login, the user is redirected to timeline page, where the last ten submitted experiments are listed and can be retrieved via download.

By clicking on "Sonda resistiva > Inserir Experimento" leads to upload interface (Fig. 6). This interface was created from design thinking sketches and continues to evolve as requisites are identified. Pipe segments and sensors can be added using "+" button and removed dynamically using jQuery.

Information collected from interface:

- Fluids information: water, air, other(specify), observations;
- Flow output: pressure, temperature, observations;
- Pipe segment: diameter, length, inclination;
- Sensors: distance from input, distance between PCB's, acquisition rate;
- Others: student/researcher name, date and time, advisor, experiment description, csv and lvm file input for pipeline data.

As output data, csv files are generated by acquisition software, and lvm files are from pressure transducers installed in the pipeline (another system) and it is necessary to generate valid experiment data. When user submit an experiment, a unique ID is created, all information is sanitized and saved in server's database. Files are organized by moving them to a new directory where directory's name is the ID created, finally, they are renamed with "sr2f" prefix, file type (csv or lvm) and ID. This directory can be accessed easily via Windows/macOS clients using SAMBA network share, or file transfer protocol (FTP). After that, the user receives a confirmation message in a green box with experiment ID.

Another feature is to visualize all uploaded experiments. This can be done by clicking in "Sonda Resistiva > Visualizar Experimentos" (Fig. 7). On this screen, users can access a quick summary, download csv or lvm files, and delete experiments (available only for system administrators).

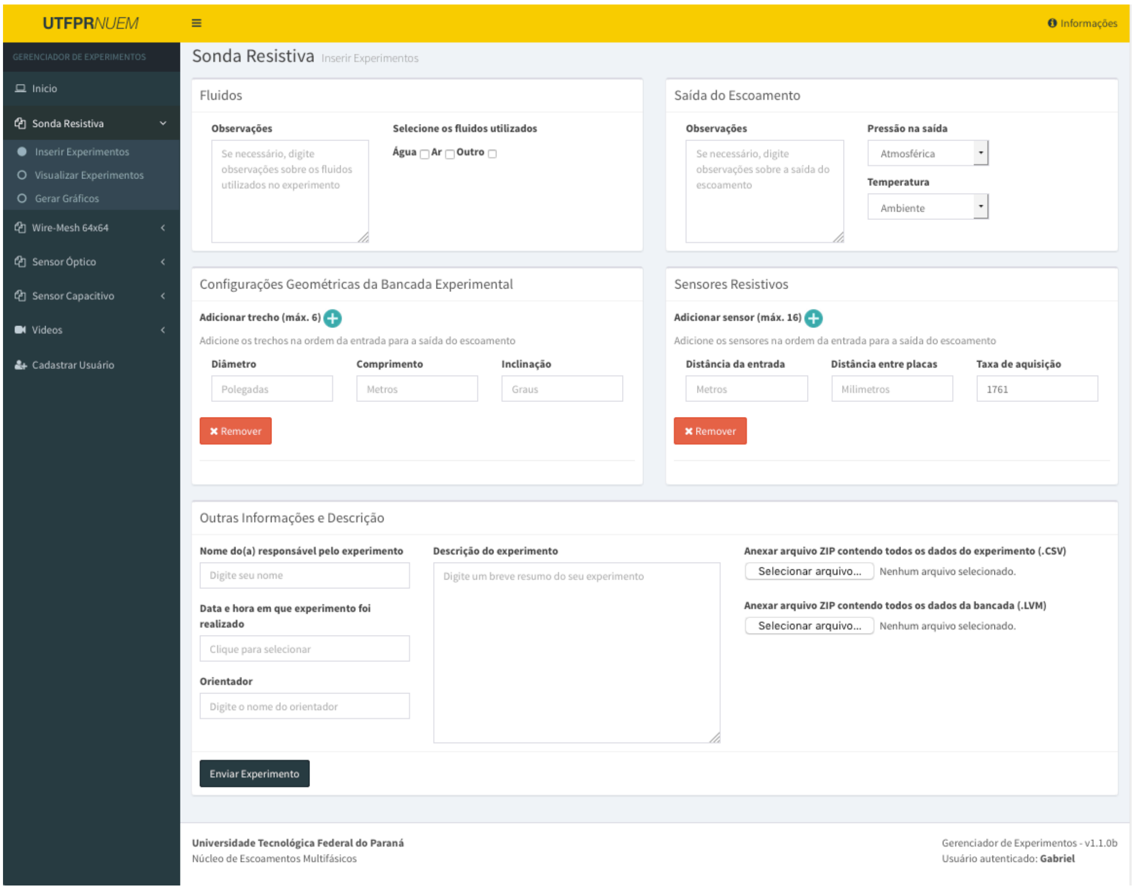


Figure 6. Resistive sensor experiment upload interface.

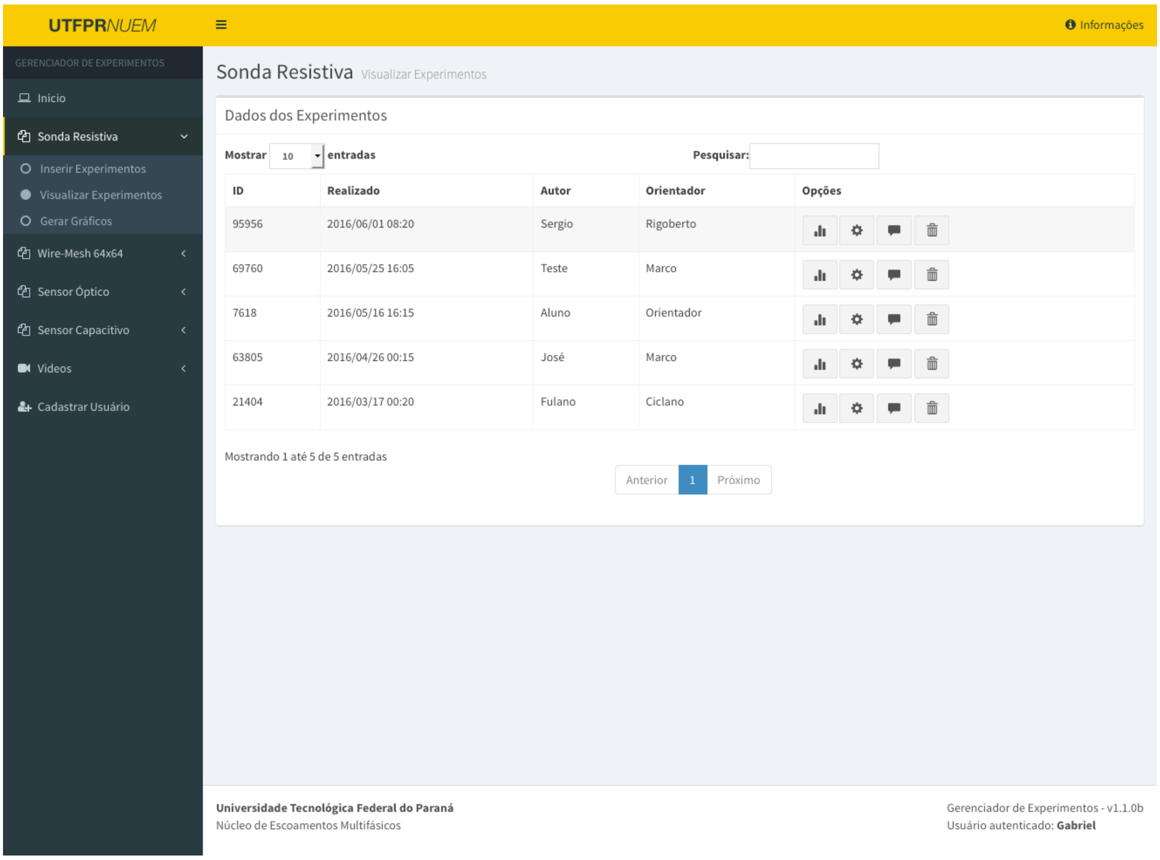


Figure 7. Experiment download interface.

Experiments are listed from newer to older, and can be located by ID, author, advisor, or date using the search field. If user prefer, they can be classified using column`s names. New features will be added, such as the search by specific operational conditions, for instance given liquid and/or gas flow rates.

3.3 Two-Phase Flow (Gas-Liquid) Results

In order to check the system, two-phase measurements were performed by using 1 sensor (1 sensor = 2 PCB's). The acquisition was set to 1.75 kHz measuring a total of 30000 frames (17 seconds). Figure 8 shows an exemplary screenshot from the system with the data loaded on it. On the screen, the user is able to load csv files acquired from sensors and choose which data will be visualized, where "S11 S12" means "Sensor1 - PCB1 (A)" and "Sensor1 - PCB2 (B)", respectively. File contents is displayed below chart.

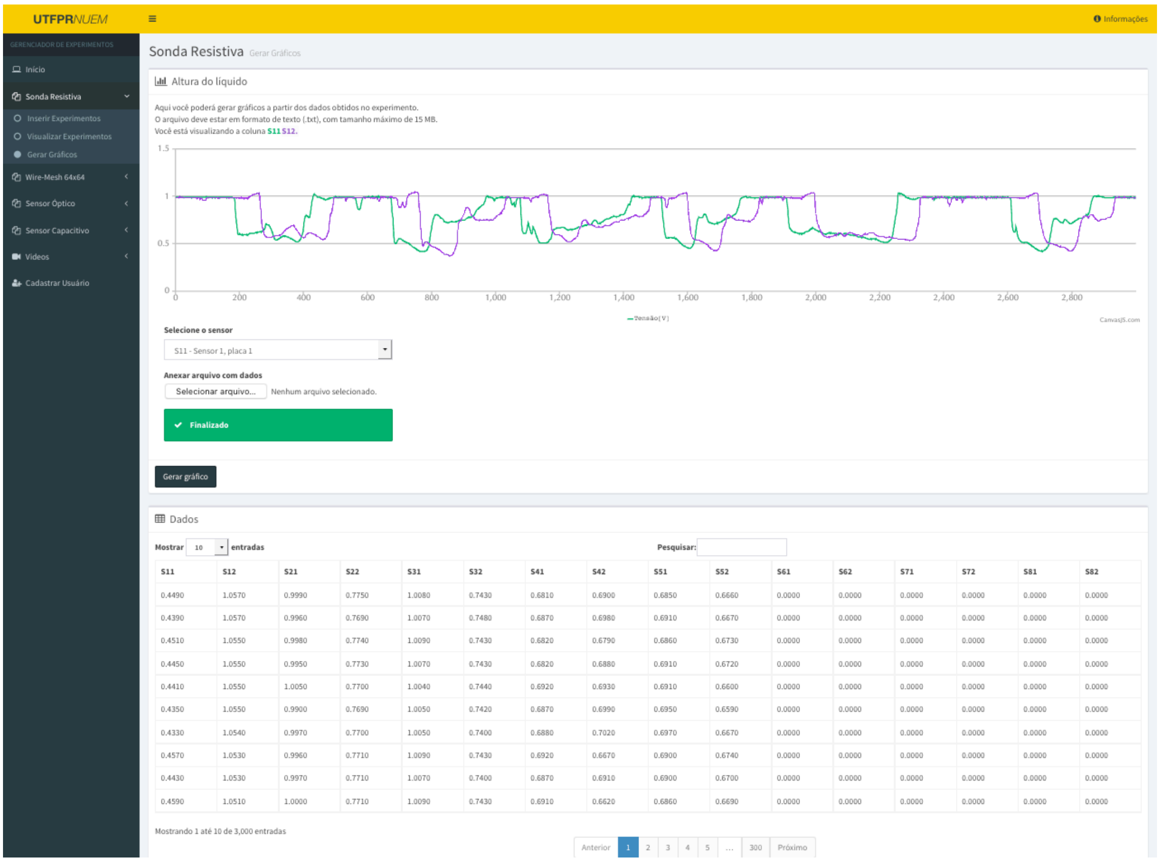


Figure 8. Sensors signal visualization using web-interface.

4. FINAL REMARKS

The objective of this current paper was to show a complete platform capable to cover all stages of experiment, such as acquisition, storage, management, retrieving and sharing information with students and researchers located inside and outside of the UTFPR campus. Modern and open technologies was used to assure fast development and possibility to add new features in future, including other equipment, such as capacitive and optical probes. There was a concern not only meet the requirements, but make the web interface a productivity tool, when compared to the conventional methods.

The use of an industrial grade CAN/PCI-Express interface is expected to replace the previously presented gateway. It is necessary to ensure system operation in environments with severe conditions.

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6. RESPONSIBILITY NOTICE

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