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Control system for automation of a didactic testbench water canal

Sistema de control para automatización de un canal de agua para pruebas didáctico

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Abstract

Didactic testbench water canals are a great tool to teach students in several subjects, for example hydraulics and hydrostatic, with their help to explain phenomena such as waves, drag, erosion and water flow. Many of these systems are sold by manufactures, but they are defined in several versions such as basic and full equipment's, which basic model is used to teach basic practices during classes; whether a more complete system is required, the cost of these devises is considerably increased. For all that, many educational institutions have no possibilities to obtain full version test bench canals. An automation system design for a didactic canal is presented in this work, which allows to control slope preset by means of a gyroscope and a mobile application. In the same way, water flow can be known that has been running through the pipes of the equipment due to the flowmeter installed, which leads the students to validate their math calculations comparing it to the display reading in real time, at low cost and effectivity.

Canal application, Automation, Hydraulics

Resumen

Los canales de agua didácticos son una gran herramienta para instruir a los alumnos en materias como hidráulica e hidrostática, ayudando a explicar fenómenos como el oleaje, el arrastre, la erosión y gasto de agua. Muchos de estos sistemas se venden por diversos fabricantes, pero ya vienen definidos con una configuración básica de inicio para poder iniciar con prácticas durante la clase, se si quiere contar con un sistema de pruebas más completo o automatizado el costo de esos equipos se incrementa considerablemente, lo que deja a muchas instituciones educativas fuera de la posibilidad de contar en las versiones completas de estos sistemas. Este trabajo presenta un sistema de automatización diseñado para un canal didáctico, el cual permite darle una inclinación predeterminada por medio de un giroscopio y de una aplicación móvil. De igual forma, se puede conocer la cantidad de agua que se ha estado desplazando por el canal gracias a un medidor de flujo instalado en las tuberías del canal, lo que permite al alumno corroborar sus cálculos manuales con la lectura obtenida por el equipo del medidor de gasto y la aplicación en tiempo real, aun bajo costo y con efectividad en la medición de las variables.

Aplicación para canal, Automatización, Hidráulica

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Introduction

In Civil Ingeneering, the Hydraulic subject is important in order to observe the phenomena such as sediment drag, canal water flow and waves, among others. In addition, a didactic hydraulic testbench water canals come to be a really helpful tool to study these topics, because waves, water flow and sediment drag can be controlled and measured with these equipements so students can analyze theory and compare it with the practice.

Clearly, there are several testbench water canal manufactures, which produce different versions of canals for different topics, never the less, users usually buy the basic configuration didactic canals because of the system price. Since these systems come separately from the rest of accessories in the case a user desires to perform more practices. The more accessories a user ask for, the bigger budget is required. For that reason, it is common that in some universities a basic equipment is bought because of education budget they have.

In this propose, a system for automation a commercial didactic equipment is presented, which can result in a good alternative to update old or basic equipements for an automated one. There have been other similar works in other publications, The Corning canal is one of the test canals proposed by the American Society of Civil Engineers (ASCE). This canal as explained in Horvath *et al*, 2014 and is shown in figure 1.

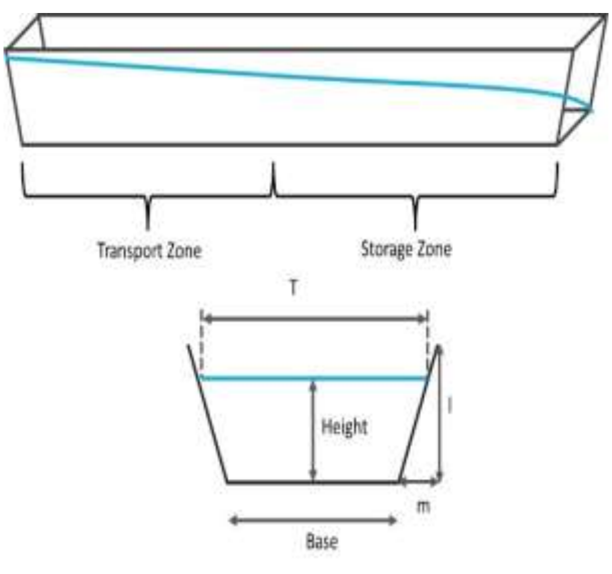

Figure 1 Model of a water canal

In order to be able to work with this canal, several mathematical models are used, for example, Muskingum, Hayami, the integrator delay and the integrator delay zero model. Some comparison can be accomplished such as time and frequency domain or state space models. For these tests the canals can be adjusted with certain slope in order to measure water flow, sediment drag and waves.

Also, simulations can be used for teaching, when there is no form to have a testbench water canal, as described in Olabanji 2020 and Shubin 2015, in order to measure water flow, sediment drag and waves. However, there have been other works focused on setting complete labs to teach different subjets such as Świder 2006, but againd the idea is to improve what there already exists. On another idea, there is a work to simulate Hydrolic vibrations using a sutiching device, employing a complex mathematical mothel but without performing prectices for students, Nizhegorodov 2016. In Dinca 2010, Dorchies 2015 and Dobrokhodov 2019, complex systems are reported, but they are examples for systems which can be built for teaching as well. Altererrnatives for introducing students to hydraulics and hydrostatic subjets are presented by Mantecón 2012 and Zahorodny 2022, where some practices are perfomed with the equipment presented by them.

Furthermore, equipmnets with a complete systems to monitor and control their functioning, are reported in Coello 2022, Valendia 2022 and Uribe 2022, which is the an idea for this work as well. However, other alternatives proposed by Mayo 2022 and Palango 2022, include the idea of electroneumatic systems.

Operation of a commercial equipment

In fact, Commercial systems are formed by a water tank, the canal, a lifting shaft, water deposit, and a frame to support the canal, as observed in figure 2. In these equipements, some parameters most be calculated, for example: the water velocity, the cross-section area of the canal, the water flow and the slope.

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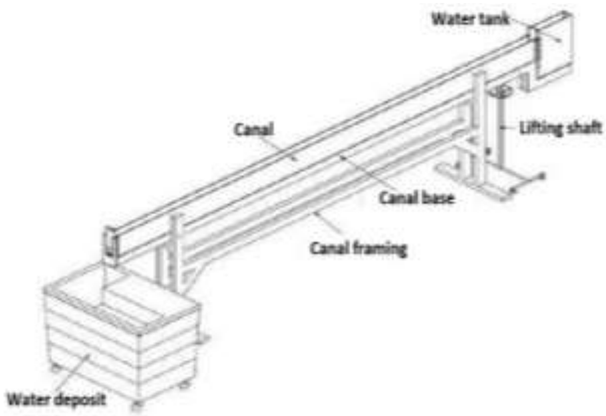

Figure 2 Configuration of a didactic basic canal

The water flow measurement is performed by knowing the cross-sectional area of the channel and the level of the water and the mean value of the velocity of the water, according to equation (1). Water velocity is basically commanded by two ways; the first one, increasing the slope of the canal or increasing the water pump velocity in order to have more water inside the tank and let the water overflow.

$$Q = \frac{V}{t} \quad (1)$$

Where:

Q = Water flow in m^2/s

V = Volume of the water in m/s

t = Time (s)

As mentioned before, whether the slope needs to be adjusted, the lifting shaft most be manually turned manually, as observed in figure 3. And for increasing the water pump velocity another speed needs to be selected, the system pump is shown in figure 4.

Figure 3 Manual mechanism for slope adjustment

In both cases, the process is not automated, so professor or students must adjust either one or the other by hand. Beside the water flow calculation.

Figure 4 Water pump with multiple speed

Canal system operation

In order to perform practices such as sediment drag, students need to turn around the lifting ball screw to elevate the water tank in the rear part of the equipment, it has a slope percentage indicator, which indicates the slope required for that practice. The algorithm implemented in the main board is presented in figure 5. Both actions, water flow measurement and data saving, and slope control is accomplished by the board

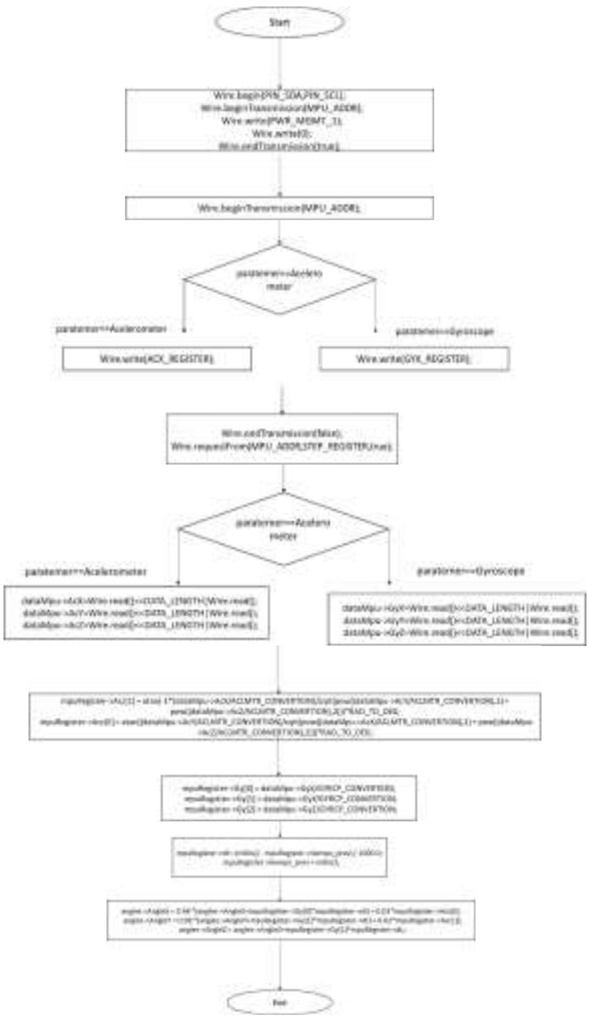

Figure 5 Block diagram for the slope calculation and water flow measurement

Stages of the automating system

First, the update for the basic water canal is integrated with a 90 Volts DC motor, which is connected to a DC motor driver board (MMT-2300R), but board output is connected to a set of 4 relays in two modules (it is a LOW Level 5V 2-channel relay interface board), where two are used to commute and change the motor shaft direction and a third one is used to indicate or disactivate the DC motor. Then, the control signals for these relays come from the ESP32 module (specifically GPIO D18 and D5) Each system part is shown on figure 6, with their interconnection. For water measuring the devise used is a 30L/min Water Brass Hall Turbine Flow Sensor Meter Water Liquid Rate (3/4 DN20). In order to sense the slope of the canal, an accelerometer and Gyroscope Sensor model MPU-6050 is used.

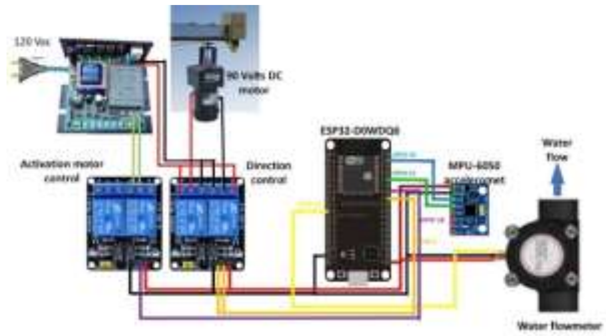

Figure 6 System stages

The control system is controlled by an app, which cab be installed on a mobile devises, which works with Android operative system. This interface is presents in figure 7.

Figure 7 App for mobile devises with Android operative system

Finally, the complete equipment is presented on figure 8, where system parts described previously are mounted on an aluminum mechanical structure. It was form with aluminum bosch framing. Frame to support the optical fiber filament is set on top of the structure.

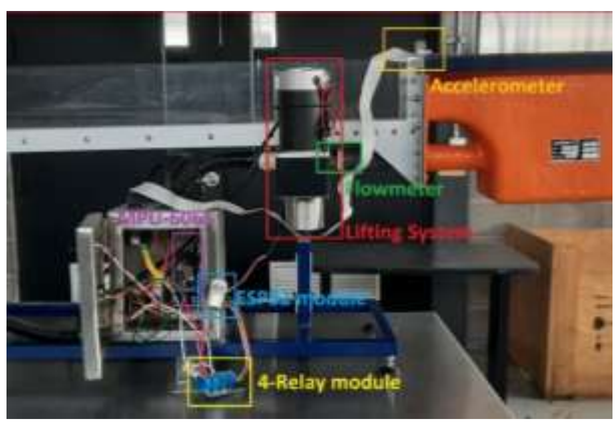

Figure 8 Water canal upadated with new components

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Results

The slope position control has an accuracy of 98% compared to the plastic scale glued on the metallic structure. The water flow measurement helps to corroborate the water flow estimated by students with a high precision sensor, so students compare they estimation. The water flow can be saved even per weeks on a cloud data base.

Conclusions

The proposed modifications present a good alternative to update and automate a basic configuration testbench canal at a low cost. The slope can easily be selected and the water flow can be measured as well, besides the amount of water passing through the canal in liters is saved in real time in a cloud data base. The main board can be replaced for a bigger one according to necessities, due to the modularity of the system. A future work on the system update is to control the water pump to move more water into the tank and increase water speed.

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References

A.I. Nizhegorodov, A.N. Gavrilin, B.B. Moyzes, "Hydraulic Power of Vibration Test Stand with Vibration Generator Based on Switching Device", Key Engineering Materials, 2016, Vol. 685, pp: 320-324, doi:10.4028/www.scientific.net/KEM.685.320.

Andrey G. Shubin; Boris M. Loginov; Vadim R. Khramshin; Sergey A. E, "System of Automated Control of Hydraulic Screw-down Mechanisms of Plate Mill Stand", International Conference on Mechanical Engineering, Automation and Control Systems (MEACS) 2015, DOI: 10.1109/MEACS.2015.7414858

Chuqui Palango, K. J. (2022). "Automatización de un sistema electroneumático para la clasificación de materiales en un sistema de producción". http://dspace.istvidanueva.edu.ec/xmlui/handle/123456789/211

Coello Coello, D. A., & Rosales Vásquez, J. J. (2022). "Diseño e implementación de prototipo de un sistema de control de temperatura e ingreso mediante tecnología RFID con integración a base de datos para la Unidad Educativa "Ciudad de Babahoyo", (Doctoral dissertation, Universidad de Guayaquil. Facultad de Ciencias Matemáticas y Físicas. Carrera de Ingeniería en Networking y Telecomunicaciones).

Cruz-Mayo, P., & Aguilar, A. (2022). Evaluación de la operación de un tramo del canal principal de riego con un enfoque económico. Tecnología Y Ciencias Del Agua, 13(1), 89-143. https://doi.org/10.24850/j-tyca-2022-01-03

D. Dorchies & P.-O. Malaterre, "Automatic Tuning of PI Controllers for Water Level Regulation of a Multi-pool Open-Channel Hydraulic System", Operations Research/Computer Science Interfaces Series book series 2015 (ORCS,volume 58), DOI: 10.1007/978-3-319-16133-4_9
DOI: https://doi.org/10.31908/19098367.2686

Engineers. DOI: 10.1061/(ASCE)EI.1943-5541.0000110
http://repositorio.ug.edu.ec/handle/redug/59883

https://www.researchgate.net/publication/342260865_Physical_Modelling_Simulation_and_Experimental_Analysis_for_Synchronizing_Multiple_Hydraulic_Actuators

J. Świder, P. Michalski, G. Wszołek, "Laboratory support for the didactic process of engineering processes automation at the Faculty of Mechanical Engineering" , Journal of Achievements in materials and manufacturing Engineering, 2006, Vol. 15, Issue 1-2

Juan A. Mantecón; Manuel Gómez; José Rodellar, "Introducing Dynamics and Control to Civil Engineers through an Experimental Flume", 2012 American Society of Civil

K. Dobrokhodov, A. Petrov1, “Methodology of dynamic pumps testing on high-viscosity liquids”, Series: Materials Science and Engineering 492 (2019) 012016, doi:10.1088/1757-899X/492/1/012016

Klaudia Horváth; Eduard Galvis; José Rodellar; Manuel Gómez Valentín, “Experimental comparison of canal models for control purposes using simulation and laboratory experiments”, Journal of Hydroinformatics (2014), Vol.16 Issue (6), pp: 1390–1408, https://doi.org/10.2166/hydro.2014.110

Liviu Dinca, Mihai Lascu-Cotofana, Mihai Ivan, Iosif Budau, Dumitru Sarbu , “Hydraulic Bench for Electro-Hydraulic Servo-Actuators and Servo-Valves Testing”, Annals of the University of Craiova, Electrical Engineering series 2010, No. 34, ISSN 1842-4805.

Olarte Uribe, J. S., & Bermúdez Mejía, G. (2022). “Sistema de germinación bajo ambientes controlados de cultivos de hortalizas”. https://repositorio.unbosque.edu.co/bitstream/handle/20.500.12495/7918/Proyecto_Olarte_Bermudez.pdf?sequence=1

Olayinka Mohammed Olabanji, Khumbulani Mpofu, “Physical Modelling, Simulation and Experimental Analysis for Synchronizing Multiple Hydraulic Actuators”, International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS 2020, Vol:19 No: 4

Sarah Meidl Zahorodny, Dennis Webb, Marcia R. Silva, “Evaluation of a Water System Model for Educational Research”, Creative Education, 2022, Vol. 13, pp: 637-657. ISSN Online: 2151-4771, ISSN Print: 2151-4755 DOI: 10.4236/ce.2022.132040

Velandia, J. E. G., López, K. C. P., Velandia, L. N. G., & Mateus, J. J. R. (2022). “Análisis del diseño de interfaces gráficas de usuario para el control y monitorización de sistemas optoelectrónicos aplicados a telecomunicaciones e instrumentación electrónica”. Entre Ciencia e Ingeniería, Vol. 16 (31), pp. 33-42.