IMPLEMENTATION OF AN ECONOMICAL IoT-BASED LIQUID TANK CONTROL SYSTEM TO SUPPORT ONLINE PROCESS CONTROL PRACTICUM

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ABSTRACT

Due to the pandemic era, many courses in higher education were conducted online to minimize the risk of disease transmission. For several engineering courses that contain practical material, an appropriate method is required to deliver practicum learning materials online to maintain the quality of these courses. Therefore, in this paper, the implementation of an economical IoT-based (Internet of Things) liquid tank control system was introduced to support the online practicum class. The tank system design has a height of 120 cm and a diameter of 50 cm. The tank features a valve, flowmeter, and an 18 LPM water pump. The control systems, consisting of Arduino Uno, an ultrasonic sensor, and a stepper motor, was run on the MATLAB Simulink application. IoT systems can be deployed using the TeamViewer app. After running the simulation, it was found that the lower setpoint change did not make significant changes in the process and produced the same curve shape as the steady state. The curves at steady state and during processing are not much different for the disturbance change. The error can be calculated using IAE and ITAE. The performances of the control system with IAE and ITAE values are 1.460 and 915.122 for setpoint change, respectively. For disturbance change, the IAE and ITAE values are 0.877 and 490.446, respectively. This system can help students better understand the industry 4.0 concept and allow them do practical work effectively from home at a low cost.

Keywords: *liquid tank control system, online practicum, internet of things, engineering education.*

INTRODUCTION

During this COVID-19 pandemic, almost all community activities have been turned into virtual activities to minimize direct contact with one another to reduce the spread of the virus. Activities that should be done face-to-face such as learning, work, etc. are limited so that forcing people to adapt online. For college students, this significant change makes them have difficulty understanding during the lesson. While several courses in the engineering field contain practical material, practical learning will be difficult to deliver to students through online classes. An appropriate method is required to deliver practicum learning materials online to maintain the quality of these courses. Fortunately, information technology was developed so fast such as IoT which can be applicable in many areas, including education aspect. The Internet of Things (IoT) is a concept where objects can transfer data over the internet without requiring human-to-human or human-to-computer interaction. IoT allows us to create an online practicum system.

In a recent study, Yumurtaci et al. has developed a liquid-level control based on Matlab Simulink with PID system, the result is possible to control the liquid level [1]. Besides, Dey et al. and Azmi et al. were studied the design and implementation liquid-level control system with fuzzy control. According to that, liquid levels were reached accurately and matched the set point with some error detected [2, 3]. Meanwhile, Jayakar et al. has a different implementation of the industrial tank level control process by connecting it with the cloud. The process of liquid-level control can be managed by using clout using the Internet of Things. Using the Arduino UNO board and the Blynk web service, the device can be able to control and monitor set point at anytime and anywhere [4]. However, these studies only consider about the design and performance of the control systems. According to current research, the study about the design and implementation of control system using Internet of Things (IoT) which considers the performance and economical aspect is not yet to be discussed.

Therefore, in this paper, the implementation of an economical IoT-based (Internet of Things) liquid tank control system was introduced to support online practicum classes. The performance of the control system was also calculated based on IAE and ITAE. The total expenses for the equipment were described in this paper as well.

EXPERIMENTAL

General Scheme of Methodology

In this study, the methodology is prepared to describe in detail the steps that need to be carried out in the making of a liquid-level control system.

To control the system in Simulink, the transfer function is needed. In the control loop system, there are two system blocks, namely the setpoint change and disturbance change where in the control of this system, both will be used. For the setpoint change, the transfer function equation is:

$$\frac{H'}{L'} = \frac{-4.33747}{s + 1.07052} \tag{1}$$

while the transfer function equation for the disturbance change is:

$$\frac{H'}{Q'} = \frac{5.09295}{s} \tag{2}$$

where H' is for liquid level in centimeters, L' is for valve opening and Q' is for inlet stream in LPM.

The transfer function parameters have to be tuned to find the most fitting parameters for the overall system. In this study, the IMC Method is used. After finding the fitting parameters for the system, the liquid-level control tank system can be tested. The testing is done by leaving the tank in a steady state and looping 3 times to ensure that the system is really in a steady state. It is done by letting the set point height be constant and the input flow rate also constant.

After testing the overall system, it is necessary to determine the error. The errors can help to determine which parameters fit the system best. There are four popular integral error criteria, namely Integral of the absolute value of the error (IAE), Integral of the squared error (ISE), Integral of the time-weighted absolute error (ITAE), Integral of the error (IE). In this liquid-level control system, IAE and ITAE are used. The value of IAE can be determined using the [7]:

$$IAE = \int_0^\infty |e(t)|dt \tag{3}$$

whereas the value of ITAE can be determined using:

$$ITAE = \int_0^\infty t|e(t)|dt \tag{4}$$

The *e(t)* in the equations above stands for error that shows the difference between the height calculated by the system and the height seen from the sensor. After the system testing is done and the parameters for the system are determined, the system then can be integrated with IoT. For this study, the program that is used as a Remote Computer is TeamViewer.

Schematic Diagram of the Physical and Electronic Apparatus

The control system consisted of 2 types of apparatus, physical and electronic. The physical apparatus is the tank system equipped with flowmeters, valves, and water pumps. The schematic diagram for the physical apparatus can be seen in Fig. 1.

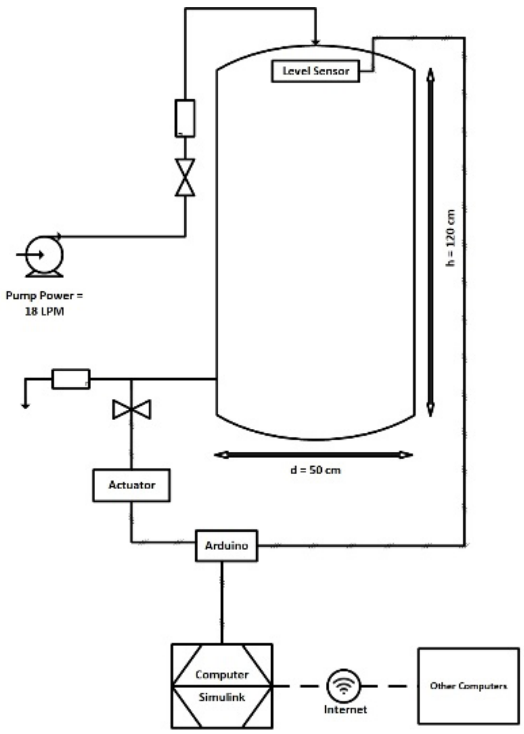
Some things should be considered in designing the tank and control system.

1. The liquid level in the tank is affected by the inflow rate and the outflow rate.
2. The liquid level is measured using an ultrasonic level sensor.
3. The inflow rate is set manually (constant assumption).
4. Outflow rate is controlled by an actuator.
5. Arduino receives a signal from the sensor and sends a signal to the actuator.

6. Simulink on the main computer is connected to Arduino to process data from the sensor and determine the signal to be sent to the actuator.
7. Remote computer can control the main computer by IoT (remote computer).

In the application of the liquid level control system in the tank, it is necessary to have a supporting electronic device. The electronic chart of the tank level control system is illustrated on Fig. 2.

The IoT system for this control system will be



Tank Specification	Dimension	Unit
Height	120	cm
Diameter	50	cm
Pump power	18	LPM

Streams	Description
⟶	Liquid Stream
——	Electrical Stream
- - - - →	Internet Network

Fig. 1. Schematic Diagram of the Physical Apparatus and its Dimension.

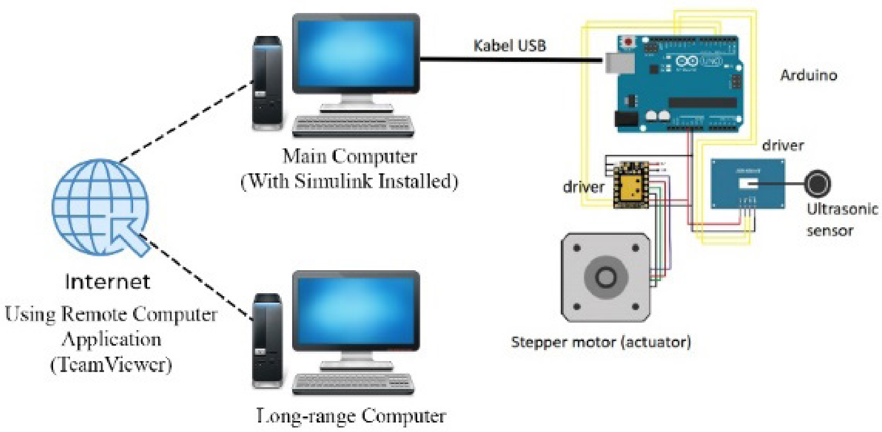


Fig. 2. Schematic Diagram of the Electronics Control System.

implemented using the Remote Computer platform, more precisely TeamViewer [8]. The main computer that contains Simulink can be accessed and controlled by others using TeamViewer.

The Arduino system circuit is equipped with a driver, ultrasonic sensor, and stepper motor (actuator). The signal is then sent to Simulink and helps in determining the liquid level in real time.

Process Control System Program

To control the tank system, one of the platforms that can be used to create system block diagrams for designing a control system is Simulink. To be able to control the liquid level in the tank, it is necessary to build a control system on Simulink which is connected to Arduino, ultrasonic sensors, and stepper motors. The Block Diagram for the control system is shown in Fig. 3.

To run this system, the computer first has to be connected to the electronic control system circuit on the tank with a USB cable. Once connected, the system can then be run.

Internet of Things (IoT) Scheme

After testing the liquid level control in the tank on the Simulink application, the system can then be integrated with IoT. This can be done using the Remote Computer Application. One of the easy-to-use Remote Computer Applications is Team Viewer. By using TeamViewer, remote control can be done with just a code and password input.

To be able to control from a long distance with TeamViewer, some steps must be taken as follows:

- Each computer that wants to connect with TeamViewer must have the TeamViewer app on its device.
- To be able to control other computers, the partner ID has to be entered in the Remote Computer Control section.
- Meanwhile, so that other people can control our computer, the computer ID and password listed has to be provided in the Allow Remote Control section.

RESULTS AND DISCUSSION

From the scheme and design of the tank and control system that has been made, the realization of the prototype of the liquid level control system can be built as illustrated in Fig. 4,

The variable used to determine the response result is divided into 2, the setpoint change variable and the disturbance variable. For the setpoint change variable, (1) liquid level from 50 cm to 45 cm, (2) liquid level 50 cm to 60 cm, (3) liquid level 50 cm to 70 cm. And as for the disturbance variable, (1) inlet flowrate changes from 8 LPM to 3 LPM, (2) inlet flowrate changes from 5 LPM to 8 LPM, and (3) inlet flowrate changes from 3 LPM to 10 LPM.

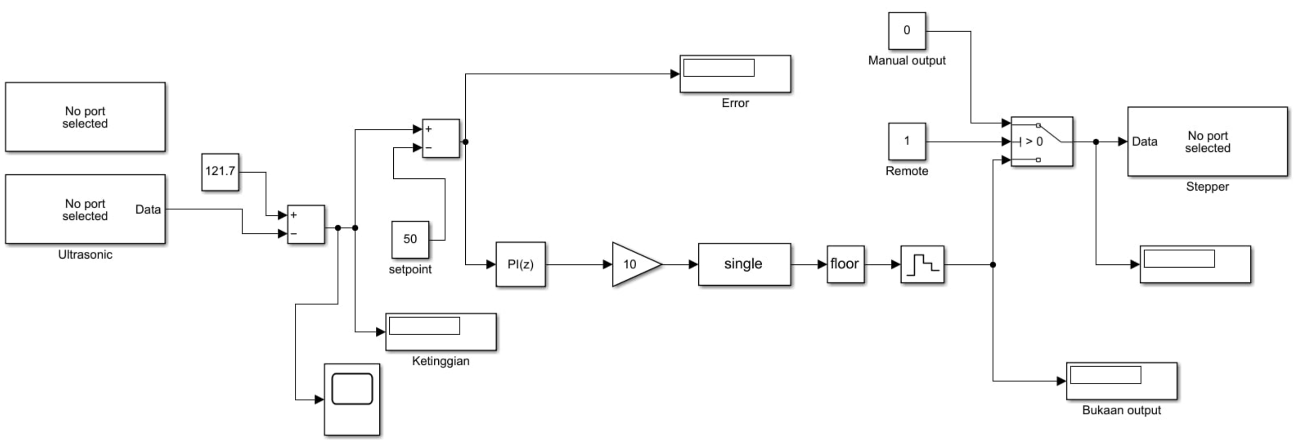


Fig. 3. Apparatus Block Diagram on Simulink in Real Time.

The Performance of Apparatus

After determining the experimental variables, running the system starts using Simulink. After running the system with different setpoint change variables, the best results of the variable setpoint responses from the Simulink graph as seen in Fig. 5.

It can be seen from the graph in Fig. 5, that as soon as the setpoint is changed, there is a big fluctuation in the graph. But after a few loops, the fluctuation is decreasing.

The best results among the three variable disturbance change responses from the Simulink graph can be seen in Fig. 6.

In Fig. 6, it can be seen that the difference in fluctuations before and after the change in the incoming flowrate is visible. Although it's not obvious, the effect of oscillation is quite large, causing the system to take a long time to reach a steady state. Therefore, changes occurring in the input stream should be avoided.

From those 6 experiments, all the variables could control the liquid level. But, as for process control, efficiency must also be considered. So, it is necessary to find the error using IAE and ITAE methods. The error for the setpoint changes variable is shown in Table 1, while the error for disturbance variables is shown in Table 2.

a) b) c)

Fig. 4. A physical prototype of the tank and control system, liquid level tank (a), electronics apparatus (b), stepper motor (c).

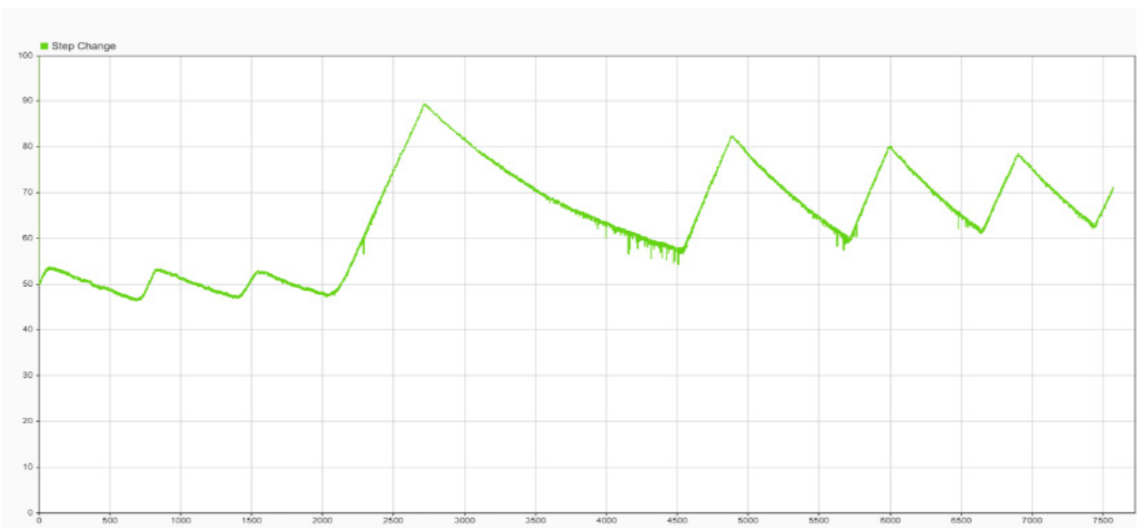


Fig. 5. Simulink Response from Setpoint 50 cm to 70 cm.

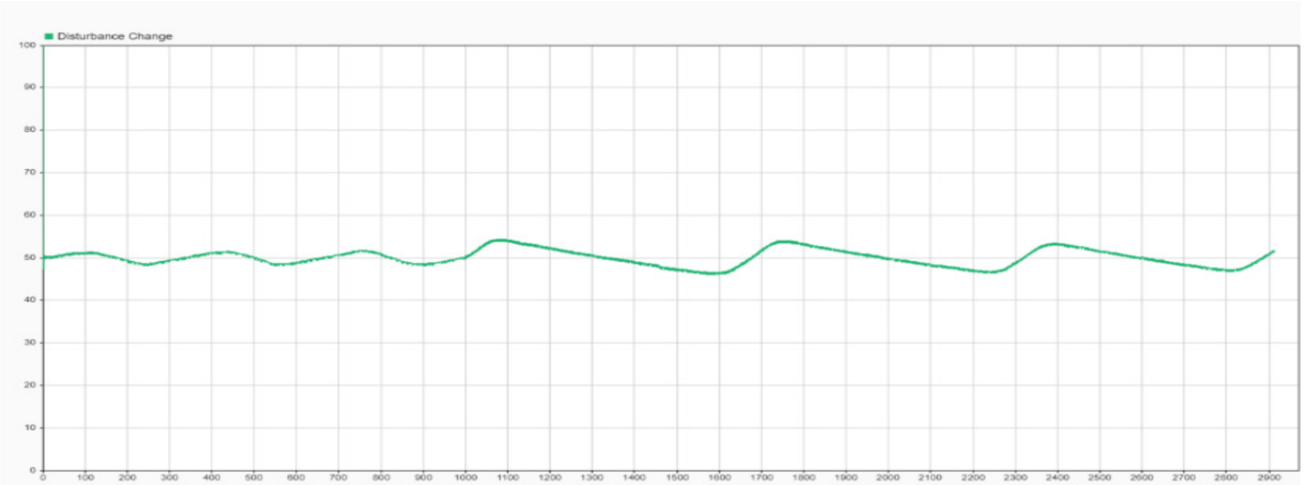


Fig. 6. Simulink Response Flowrate Input 8 LPM to 3 LPM.

Table 1. Calculation of error values for setpoint changes method.

No	Transformation (cm)	IAE		ITAE	
		Steady	Process	Steady	Process
1	50 → 45	1.978	1.460	1236.328	915.122
2	50 → 60	1.250	4.812	599.474	4989.084
3	50 → 70	1.893	8.729	1952.389	39419.39

Table 2. Calculation of error values for disturbance changes method.

No	Transformation (LPM)	IAE		ITAE	
		Steady	Process	Steady	Process
1	8 → 3	1.620	1.610	910.237	591.324
2	5 → 8	1.041	0.877	544.359	490.447
3	3 → 10	0.860	1.756	468.008	623.222

Therefore, from the result and discussion that has been explained, we can conclude that the system is good enough for use in practicum learning. Also, it can be proven that this liquid-level system is functioning properly.

IoT Advantage to the Practicum Learning

By integrating the liquid level control system with IoT, there will be a lot of benefits for practicum learning. TeamViewer as the Remote Computer program helps students to access the control the liquid tank system in Simulink from the main computer and allows them to control the system from their computer at home. This will help students to understand better about control system theory applications even though they weren't able to do the practicum with the actual apparatuses on the field. Integrating the control system with IoT also helps students to have more understanding related to the concept of industry 4.0 which will be applied by many industries in the future.

Table 3. Physical and Electronics Apparatus of the Prototype's Prices [9, 10].

No.	Apparatus	Prices ($)
	Physical	
1.	Cylindrical Tank	55.68
2.	Valve	3.48
3.	Water Pump (18 LPM)	33.06
4.	Pipes	0.45
	Electronics	
1.	Arduino Uno Board	22.17
2.	Driver	10.99
3.	Ultrasonic Sensor	16.99
4.	Stepper Motor	13.99
	Total	156.81

Economic Analysis

From Fig. 4 it can be seen that the prototype of the liquid tank control system consists of several physical and electronic apparatus. Table 3 outlines all the apparatuses that are used and the costs of the apparatus to construct the prototype.

From Table 3, it can be concluded that the total cost of the apparatus to build the prototype is quite affordable so it can be constructed by any teacher for their students all over the world.

CONCLUSIONS

In this paper, the implementation of an economical IoT-based (Internet of Things) liquid tank control system was introduced to support online practicum classes. Based on the results of the experiment, the performances of the control system give quite a good result with IAE and ITAE values of 1.460 and 915.122 for setpoint change, respectively. Meanwhile, for disturbance change, the IAE and ITAE values are 0.877 and 490.446, respectively. Meanwhile, from the economic analysis, the total costs to construct the prototype are $156.81 which is quite affordable. By applying this method in the process control course, students can do practical work by online controlling the apparatus on campus from home. In line with learning outcomes from the process control course, with this method, students are also introduced to the application of process control theory to the physical equipment. Moreover, students have more understanding related to the concept of industry 4.0 which will be applied by many industries in the future.

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