DESIGN OF REAL TIME ANALYSIS SIMULATION FOR TWO INTERACTING TANK MODEL SYSTEM USING PYTHON PROGRAMMING LANGUAGE

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By

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NURIN NAFISA

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LIST OF SYMBOLS

Symbol	Description	Unit
A_1	Area of tank 1	m^2
A_2	Area of tank 2	m^2
R_1	Resistance of tank 1	sec/m^2
R_2	Resistance of tank 2	sec/m^2
h_1	The height of the liquid level in tank 1	mm,m,cm
h_2	The height of the liquid level in tank 2	mm,m,cm
t	Time	sec
Q_{in}	Volumetric flow into tank 1	m^3/sec
$Q_{1,out}$	Volumetric flow rate from tank 1	m^3/sec
$Q_{2,out}$	Volumetric flow rate from tank 2	m^3/sec

LIST OF ABBREVIATION

Abbreviation	Description
AI	Artificial Intelligence
GUI	Graphical User Interface
ODE	Ordinary Differential Equation
PI	Proportional Integral
PID	Proportional Integral Derivatives
SPYDER	Specific Python Development Environment

ABSTRAK

Oleh kerana pandemik global yang disebabkan oleh COVID-19, institusi telah menerapkan pendekatan digital untuk pengajaran, meningkatkan integrasi dan penerapan teknologi dalam penyesuaian metodologi. Kajian ini adalah salah satu kaedah untuk menerapkan teknologi dalam mewujudkan perubahan baru dalam pendidikan kejuruteraan. Dalam kajian ini, komputer yang diprogramkan digunakan untuk mengembangkan sistem simulasi yang sesuai pada sistem tangki interaksi dengan menggunakan pemodelan matematik fizikal. Pemodelan matematik dua tangki digunakan untuk mengembangkan program dengan mempertimbangkan rintangan aliran adalah linear. Dari kod terprogram Python yang dikembangkan, pengguna dapat berinteraksi dengan model menggunakan antara muka pengguna grafik yang dikenali sebagai GUI. Dengan mempertimbangkan kemajuan teknologi, para penyelidik dalam bidang berkaitan telah membuat platform eksperimen maya. Keupayaan makmal maya mesti memenuhi syarat untuk hasil eksperimen teori. Gambarajah aliran simulasi yang dibina menggambarkan hubungan antara input data, model matematik, dan output. Pengaturcaraan Python yang digunakan merangkumi pelbagai modul untuk mensimulasikan pemodelan matematik. Pengesahan prestasi program yang dikembangkan Python telah dilakukan dengan membandingkan hasil output dengan Microsoft Excel dan kajian literatur. Parameter yang telah dimanipulasi dalam projek ini adalah kadar aliran cecair ke tangki 1 dan perbezaan pada rintangan kedua tangki. Hasil program membuktikan bagaimana parameter ini berinteraksi antara satu sama lain dan menunjukkan pemboleh ubah berinteraksi antara sistem dua tangki.

Kata Kunci: Simulasi, Python, Dua Tangki Berinteraksi, Pemodelan Matematik, Pembelajaran Maya

ABSTRACT

Due to the global pandemic caused by COVID-19, institutions have adopted a digital approach to teaching, boosting the integration and application of technology in methodological adaptation. This study is one of method to implement the technology in creating new changing in engineering education. In this study, the computer programmed was used to develop the suitable simulation system on interacting tank system by employing physical mathematical modelling. The mathematical modelling of two tank was used to develop the program by considering the resistance to flow is linear. From the developed Python programmed code, the user able to interact with the model using graphical user interface know as GUI. The discussion on the interaction between the parameter of the tank related to liquid level response were further discuss in this thesis. Considering technological advancements, researchers in linked fields have created a virtual experiment platform. The virtual lab's capability must meet the requirements for theoretical experiment results. The constructed simulation's flow diagram depicts the relationship between data input, mathematical model, and output. The Python programming used include several of module to simulate the mathematical modelling. The validation of the performance of the Python developed programme was done by comparing the output results with Microsoft Excel and literature studies. The parameter that have been manipulate in this project are liquid flow rate into the tank 1 and the different on the resistance of both tank. The output of the program proves how this parameter interact with each other and it shown the interacting variable between the two-tank system.

Keyword: Simulation, Python, Two Interacting Tank, Mathematical Modelling, Virtual Learning

CHAPTER 1

INTRODUCTION

Chapter 1 give brief introduction on how this project was conducted involving the background, problem statement and objectives. The problem statement and objective meets the requirement to run the real time experiment based on the develop programme.

1.1   Background of Study

Information technology, offering new resources across the spectrum of engineering disciplines, has had a major influence on engineering. The use of technologies to achieve educational goals is growing but somehow it is growing slower than expected. Thus, the main objective of this thesis is to develop the design using the software where it is comparable to the physical experiment results. (Botero et al., 2016) have proved that the web lab by assessing the design throughout the web lab simulation is comparable to the physical learning. It was intend to provide learners with critical training with a pedagogical and authentic experience and able to operate and share the experiments as a fully operating chemical engineering facility.

This thesis from the selected model was mainly focus on the implement working principle the tank into Python where it is applicable for develop the model of the two interacting tank system. Python consists of module such as NumPy, Matplotlib, Panda, Animation, SciPy and other useful model that would be helpful to solve the ODE and make sure the project run as desired model. When it comes to solving many different mathematical problems that occur in engineering, many different software

options exist for finding an exact or approximate solution. Based on (Jeffrey J. Heys, 2017) this software include many advantages such as

I.   It is freely available and runs on Windows, MacOS, and Linux, including most major computer platforms.

II. It has a large range of additional libraries that are free and incorporate machine mathematics capabilities as well. The Numpy library, for instance, provides Python with capabilities close to those of MATLAB.

III. It is possible to import many libraries of previously compiled algorithms into Python, which enables very quick and efficient calculations.

The report of the web lab approach in chemical engineering has been discuss more by (Selmer et al., 2007). The researchers aim to implement the different ways of using web labs as well as study the effectiveness of the new approach. There are several advantages reported by the users involving the benefits of unlimited access toward the experiment and conducting the experiment without being observe by an assistant. This study proves that, virtual learning can be implement in chemical engineering studies.

Following the technology advancement, researcher in the related fields has built the platform of virtual experiment. The capability of the virtual lab need to meet the requirement of theoretical experiment results. The simulation strategy of the process include the fundamental topics and complex operations. The flows of developed simulation shows the relation of data input, mathematical model and the output.
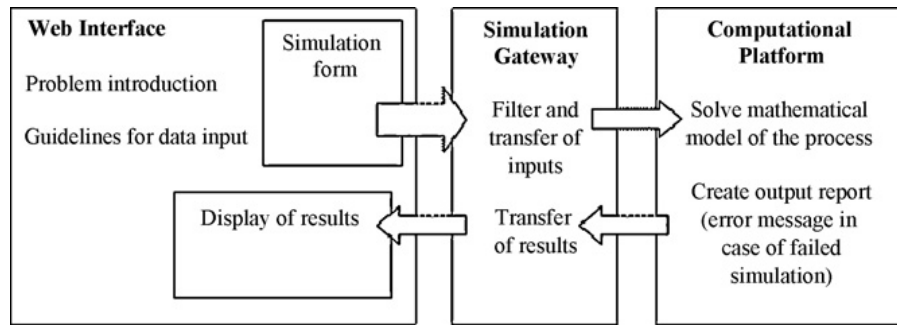
Figure 1.1 *Flow Chart of Simulation Component (Rasteiro et al., 2009)*

The control of the liquid level in two interacting tank system has drawn the attention of many researchers around the world. The objective of this project is to be able to create the simulation where it can simulate the liquid level in two interacting tank system. The properties is identical and observing its response we come to know its appropriate measurement in an interacting tank system the two tanks are connected in series, the output of first tank is connected to the input of the second tank (Swarada et al., 2017).

The development of the liquid level algorithm for the system of two water tanks is complex and more complicated because the dynamics of the coupled tank system are nonlinear, exhibiting non-minimum step behaviour (Kebede, 2019). The model used include the nonlinear ODE as well as the derivatives of the equations. However, in this modelling, the flow is consider as linear flow. The basic of the two tank currently run by using water as the liquid. The basic experimental system principle of the two tank is when the two holdup tanks, which are coupled by an orifice. The input is deliver by a variable speed pump, which fills the first tank with water. This orifice enables the water to flow into and from the second tank to the reservoir. The basic control issue is to regulate the amount of fluid in one of the tanks by adjusting the pump speed as resistance of the pipe (Shingare & Joshi, 2007). From this project,

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the users should be get the results of the tank level related to the input variables of the tank.

1.2 Problem Statement

This report focusing on implementing the concept of modelling simulation to helps the users to access the experiment without considering the time limitations. This is because engineering courses normally conducted in traditional ways such as face-to-face and hand on laboratory practices. In order to conduct the lab simulation to replace the physical lab, the evaluation of the proposed simulation should be comparable to experimental results. Another problem encounter from physical laboratory system are requiring equipment, space and maintenance. Some equipment need to be run while considering high safety requirement, which is dangerous. Thus, this concept of simulation helps to minimize the encounter problem and help in providing additional benefits where it is supporting distance learning, improving lab accessibility by can changing the control parameters, run experiments and obtained the results regardless the time and locations.

Thus, for this project the simulation for two-tank model system was develop based on the real time practices. In process industries such as petroleum refineries, chemical, paper industries, water treatment industries, liquid level control in tank systems and flow between tanks is a major problem. Manipulating the input variables of the tank can physically done, however in order to meet the development of engineering technology, it can be implement in simulation as it can be accessed from anywhere and anytime. This project identify the liquid level from the mathematical modelling and implement in Python programme language. Since the Python was use

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in this project, the performance of the developed design need to be comparable with published article data and validation through Microsoft Excel.

1.3 Research Objectives

The objectives of the study are as follows:

1) To develop the suitable simulation system on interacting tank system by employing physical mathematical modelling by using PYTHON programme techniques.

2) To evaluate performance of the developed design and validate the results of the simulation with the real time data obtained with published results from literature.

3) To manipulate the input variables to achieve desired tank level throughout the process.

4) Produce the GUI of the simulation where constant input value can be manipulate throughout the process.

1.4 Thesis Outline

Chapter 1 consist of brief introduction of the works including the objectives of the thesis. Following the introduction, Chapter 2 mainly on the literature review of the topics involve. The chapter give the literature review of the main topic such as concepts of virtual learning, background of the tank system and the mathematical modelling. Next, Chapter 3 highlights the technical processes of tool creation, including preliminary work, implementation, quality assurance, and data gathering. Subsequently, Chapter 4 explains the simulate results, real time analysis response as well as the validation of the system results. Finally, in Chapter 5, the thesis concludes with a discussion and conclusion, as well as a prediction for future work recommendation.

CHAPTER 2

LITERATURE REVIEW

This section presents the literature review and research available from credible scientific records and references that are relatable to this final year project topic. This chapter covers the overview of the concepts of virtual learning, background of two-tank system, mathematical modelling and factor that affecting the output variations. This chapter gives more information on understanding the purpose of relating the virtual learning towards process control simulation and the mathematical model of the system.

2.1   Concepts of Virtual Learning

Online education has been widely gaining over the past two decades. Engineering education and profession increasing rapidly an the potential developments are speculate based on rational analyses and reasoned arguments (Rosen, 2009). The approach gives opportunities to enhance the existing technology, build the new area in engineering as well as adaptation into new methods.

Over the 100 years, major shift in engineering evolved according to the technology era. The change in engineering education affecting the future growth. The major shift focusing on the influence of information, communication and computational technology of engineering education. Based on the feedback on online learning, (B.Rawat & Bajracharya, 2015) the adaptation of engineering learning gives benefits to both instructor and students.

Other than complete online study, blended learning method also widely used in engineering education. The need of currents situation, pushes the technology to have the blending learning system of engineering degree (Rahman, 2017). However, there are few of misconception regarding this method, where the method of online education is a solitary, non-instructor-led, self-paced activity. Some of the research believe that online education may offer no significant difference in term of achievement (Bourne et al., 2005). This mode of study could also assist students working in-person remote assembly for laboratory sessions and provide a good way to operate the laboratory equipment. This mode of laboratory implemented in conducting three tank system laboratory by (Duro et al., 2008) where it states that the simulation requires skills in advanced graphical programming to create the interactive GUI on the virtual laboratory and software has proved to be a very useful solution for control engineering. Since the technology is changing around the world, (Rasteiro et al., 2009) the author reported that the initiative on making the laboratory available remotely by introducing the portal on the simulation consist of chemical engineering processes.

Laboratory work in engineering education, usually performed in face-to-face practice are no longer in normal hand-on interaction. This is because through virtual learning, the students would be able to attend the class or laboratory by only accessing to the computer. The solution is to create an online laboratory, whether it is a remote laboratory, a virtual laboratory or a pure simulation. The 'begin from the end of mind' approach is to obtain from any user a virtual laboratory with complete engagement in manipulation. People assume that the laboratory should physically operated, but some research shows that in order to save cost and time and monitor the equipment that is not physically accessible in the laboratory, the virtual laboratory should offer more

advantages (Bourne et al., 2005). The development of a useful virtual laboratory is a highly complex process involving the implementation of numerous components, from digital interface and visualisation to pedagogy (Seifan et al., 2020). The virtual lab conducting various fermentation experiments and comparing the resulting data without concern about time, laboratory resources and health and safety problems through a more pleasant learning environment, students are significantly helpful in understanding the fundamentals of biotechnological processes.
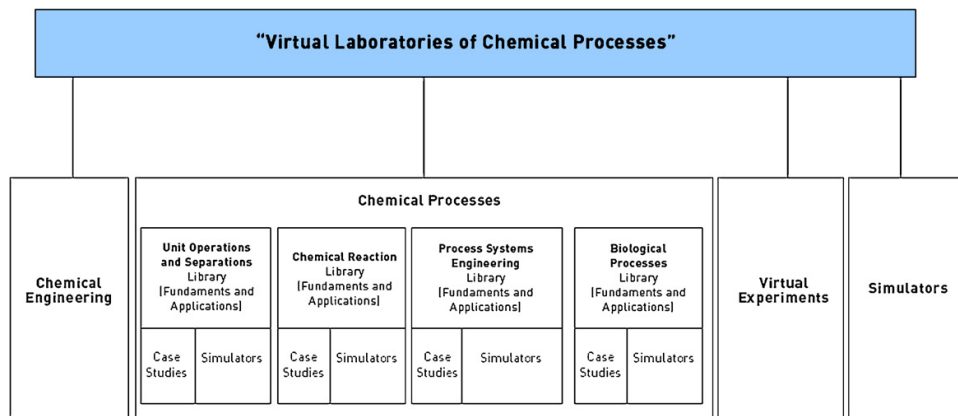
Figure 2.1 Significant of virtual lab in chemical engineering (Rasteiro et al., 2009).

2.2 Definition of Simulation

The word simulation can be define in both a noun and verb. As a noun, it refers to when something is an imitation of reality. Simulation in engineering is the use of computer modelling to examine relationships between physical phenomena and the system being studied without building a full-scale model or implementation. This is done because it is expensive, time-consuming, too big, inaccessible, or dangerous to build a full-scale model for some type of system. In the simulation, there are several problem can be encounter. The problem is known as a 'rating problem' when the

process inputs are known and the output variables must be determined. The model equations can be solved directly to solve the problem (Vázquez et al., 2010).

The phrase "simulation" can refer to an actual system, an abstract system, an electronically generated environment, or a process in general. (Shaw, 2017) defines simulation as a depiction of real-world systems that focuses on a certain component of reality. Simulations, games, and role play exercises, according to (Matthew Krain, 2006) are active learning activities aimed at developing students' theoretical grasp of a given topic, collecting interactions, or employing student engagement to simulate a socio-political process. They provide a virtual or actual environment in which to illustrate a condition or scenario. Computer-based simulations are used in a variety of applications. Computer-based simulations are used in research, design, analysis, training, teaching, and entertainment. Simulation is used to assess a system's performance and forecast the impact of modifications to current systems. It's a great tool for system design and simulation. If one wants to analyse the effect of randomness on a genuine system, a simulation can be stochastic, as previously stated. Randomness can be used to model unpredictably random system properties and components.

2.3 Simulation Based Learning Environment

Simulation generally like theory and experimentation, can be regarded a third technique of gaining knowledge, has become ubiquitous in engineering education. Simulation has the benefit of being an active learning method that can be combine with intelligent tutoring tools. Simulations can include real-world factors like measurement mistakes (Froyd et al., 2012). However, (Goodwin et al., 2011) states

that actual laboratories waste university space and students' time. In addition, hands-on laboratories, on the other hand, it argue that student engineers should be expose to real-world situations. Simulation is one of these strong and fascinating computer-assisted instructional methods. In its most basic form, simulation is simply the "representation of reality or any known process/phenomenon." Although the exact details of how to integrate simulation-based tools into the entire undergraduate curriculum are still being worked out, simulations have been swiftly integrated into the engineering curriculum (Akkoyun, 2017).

2.4   Two Tank System Background

The two interacting tank system has two tanks that are connected through a cross-section connecting valve to each other, and these valves introduce nonlinearity within the system (Sneha, 2020). Mainly, the two tank system consist of pump, control valve, process tank, supply tank, rotameter, main power, supply switch and pump switch. The two tanks are connected in series to the interacting tank system, and the first tank output is connected to the second tank input. The height of the tank depends on the control valve that is linked between the two tanks in the middle. The flow of the liquid level depends on the control valve change and its flow rate in tank 2 (Swarada et al., 2017). In the chemical petroleum, paper chemical, mixing treatment industries, pharmaceutical and food processing industries, the most industrial application of liquid level control is harmful (Changela & Kumar, 2013).

The industrial relevance of the tank required maintaining a constant level and the others are required to follow a time varying reference signals. Liquid must be pumped and stored in tanks before being transferred to another tank in the process industries.

The tanks are frequently so close together that the levels interact (Medewar et al., 2017). The example of industry use of tank system are when high-strength slurries were fed into an airtight reactor in a wastewater treatment facility, where the organic fraction is converted by anaerobic digestion into biogas. Biogas is convert into heat and electricity and used as a source of renewable energy. The residual sludge is nutrient-rich and might be use in agriculture (Roy & Krishna Roy, 2016). This process mainly involve in controlling the liquid level in the tanks. Research by (Ramos & Dos Santos, 2007) focus on the modelling, detection, and control design problems typically faced by an engineer when dealing with practical control-oriented applications. The results given here can serve as a reference for many real world applications in mathematical modelling, device recognition, and controller design.

The basic experimental setup is made up of two holdup tanks connected by an aperture. The variable speed pump that feeds water to the first tank provides the input. This water can then flow into the second tank and out to the reservoir through the aperture. The primary control problem is to adjust the speed of the valve to regulate the level of fluid in one of the tanks (Shingare & Joshi, 2007). The study conducted by (Manikandan & Geetha, 2014) with certain parameter gives the output of the tank level as in Figure 2.2.

Description	Values
Area of the tanks ($A1, A2$)	0.0154 m^2
Acceleration due to gravity	9.81 m/sec^2
Maximum permissible height of water levels (H_{max})	0.63 m
Cross section of the connecting pipes (a)	0.005 m^2
Coefficient of the connecting pipes (s)	0.45
Nominal operating conditions	Nominal inflow rate
$H_1 = 0.4$ m	$F_{in1} = 0.00315$ m^3/sec
$H_2 = 0.3$ m	$F_{in2} = 0.00231$ m^3/sec
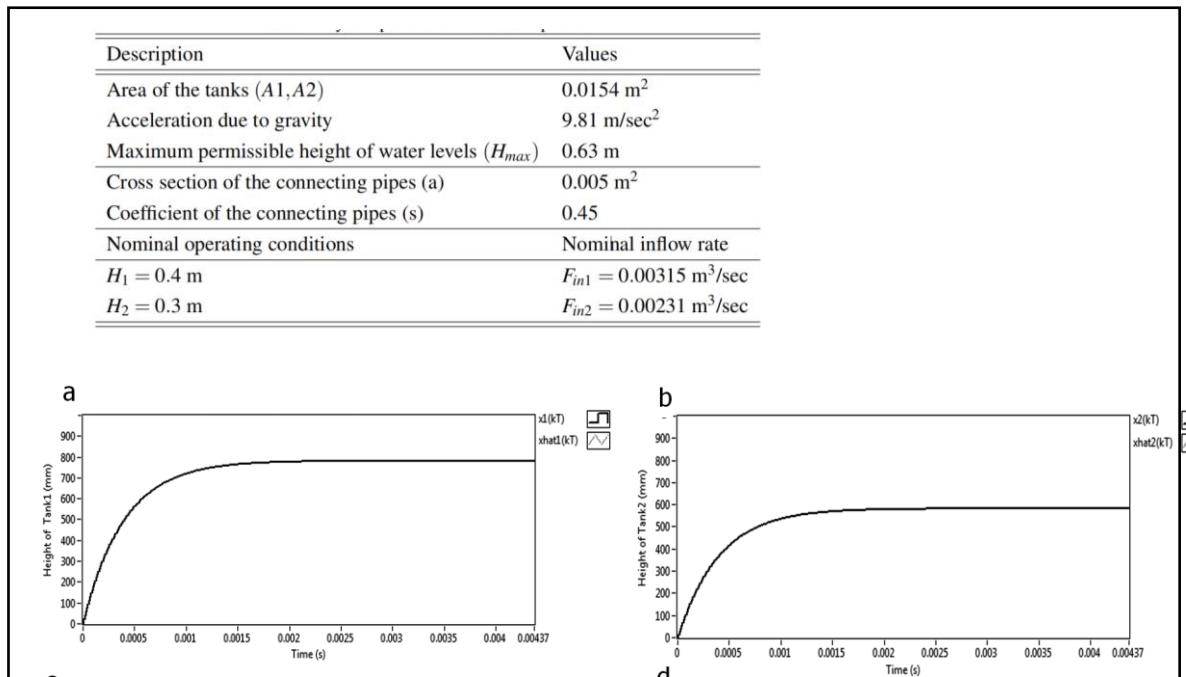
Figure 2.2 Tank Level and Parameter of the System (Manikandan & Geetha, 2014)
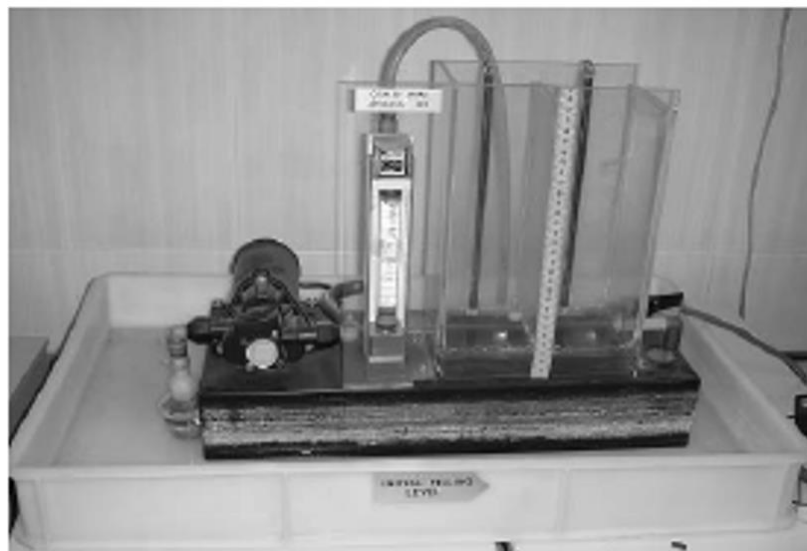
Figure 2.3 Coupled of two interacting tank used in lab scale (Shingare & Joshi, 2007)

The model of the tank reported in various research. The real time of an interacting fabricated system is use for collecting the input and output data. The mathematical model of the tank system can be derived using mass balance equation and Bernoulli's law. (Kebede, 2019) conduct the research by using MATLAB ODE solver and the MATLAB Simulink to model the differential equation in terms of water level heights

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and state space formed in the system. (Swarada et al., 2017) proves that the complex model of the interacting tank be solved by using computer-based software. The mathematical model and the transfer function found and tested using the step response considering various factors such as height of tank, area, resistance, and capacitance of liquid and flow rate. The level of liquid in each tank depends on difference between inflow and outflow rate and tank cross section. (Shingare & Joshi, 2007) find the step response where it is ideal for the model. The zero in the transfer function is ignored in the study. The level of the tank and the dynamic data details is further reported by (Bhuvaneswari et al., 2012). (Fellani & Gabaj, 2015) reported that liquid level design system is mathematically oriented by nature, and most design challenges become tiresome and lengthy without the use of computer aid.

Controller design in the tank system widely introduce by different approach. Since two tank system is develop through the mathematical modelling, thus the approach in term of simulation is highly used in implementation of virtual simulation laboratory. (Behbahani et al., 2019) used the simulation to study the controller design of the interacting two tank system. Techniques for controlling for the two-tank system reported in many researches. There are several approach regarding controlling the model of the liquid level in the tank system, which is neural network, fuzzy control, PI controller and other techniques. (Majstorović et al., 2008) states that neural network control proves that it is can applied in a wider spectrum of working regimes without any further tuning. The neural network controlling study were conducted by using MATLAB and Simulink. Fuzzy controller often used in the controlling process. (Haneema Varghese & Rose, 2015)use the fuzzy controller for the interacting two-tank model where the controller resulted in no overshoot. The system with PID controller gives relatively slow response with peak overshoot for unit step input

(Changela & Kumar, 2013). The approach of PID and Fuzzy logic controller states that the fuzzy logic controller allows the system to reach the steady state faster with no overshoots, while the conventional controller gives a large overshoot response (Sneha, 2020). Model controlling system is to maintain the liquid level in certain height for efficient performance of the system. The phase variable canonical form of the system use as feedback controller design (Sabah Abd Elmonem Ahmed, 2014). The state feedback controller is the line vector that should be connect to the feedback line of plant system.

2.5   Background of Mathematical Modelling and Machine Learning

The language of mathematics is used to describe the phenomena of the real world, test theories and make predictions about the real world. The first step in system development involves mathematical process modelling (Sneha, 2020). The theory of conservation of mass is the physical law governing the behaviour of the liquid level system as defined here (Ramos & Dos Santos, 2007). Process control systems are concerned need simple description of how process reacts to various inputs and this is what mathematical model can provide to control designer (Parvat Deo, and Kaduc, 2015).

Mathematical model is use when engineers evaluate a scheme to be regulated or optimised. In research, as a hypothesis of how the system will operate, engineers may construct a descriptive model of the system, or try to estimate how an unforeseeable event could affect the system. Similarly, engineers pursue various control techniques in simulations to control a device. The problem of teaching online science and engineering laboratory experiments includes the quest for an optimal

solution that meets all 13 goals defined by ABET, although goal 5 of science laboratory experiments do not have to be achieved (Badjou & Dahmani, 2013).

Since, mathematical model involve in solving algebraic, differential equations and numerical integration, (Kebede, 2019) argue that MATLAB is widely used because it is a high-level language and interactive environment used by millions of engineers and scientists around the world. However, it allows us to explore and visualize concepts while also allowing us to collaborate across disciplines.

A mathematical model is a set of variables and equations that generate relationships between the variables that define a system. Variables can have any value, including real or integer numbers, Boolean values, texts, and so on (HAKIMI, 2010).
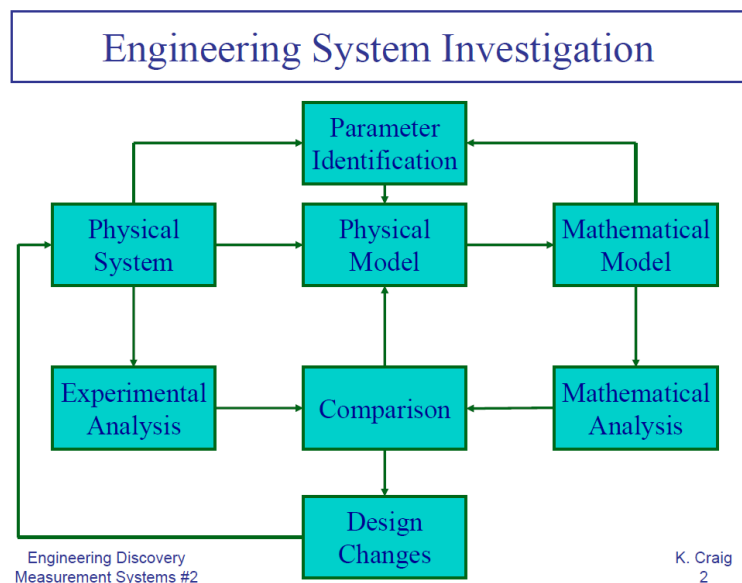
Figure 2.4 Steps involved in engineering design (Badjou & Dahmani, 2013)

Researcher are conducting promising experiments on the type called deep education, program patterned after the actual construction of the mind. Intense education programmes comprise layers of algorithm stacked each other. The information from one structure is then transmit into the future, with each subsequent

structure further processing these inputs. With this function, deep learning can easily recognise pattern and indulge in highly high-level process. As for this project, Python is used as it offers more advantages to its users. Based on (Jeffrey J. Heys, 2017) this Python software include many advantages such as :

I.   It is freely available and runs on Windows, MacOS, and Linux, including most major computer platforms.

II.   It has a large range of additional libraries that are free and incorporate machine mathematics capabilities as well. The Numpy library, for instance, provides Python with capabilities close to those of MATLAB.

III.   It is possible to import many libraries of previously compiled algorithms into Python, which enables very quick and efficient calculations.

CHAPTER 3

METHODOLOGY

Chapter 3 contains of few sections where project development is briefly explain from the start of the process until the final report. This project was done by simulation of Python where the firm model is decided based on the title. The expected results included in this section, as the simulation need to produce with high performance.

3.1   Research Methodology

Figure 3.1 shows the flow chart of the project development. First, the basic knowledge of two tank mathematical modelling system is study as there is the fundamental knowledge of this project. Then, the simulation of the level tank and

flow rate is investigate. Knowledge in using Python programming software is a prerequisite for my project also. After acquiring the basic knowledge of Python programming software, project can be start by creating the code for the model. The model should be able to run the real time related variables. Next, the graph simulate and the faults can be identify through this simulation graph. As results obtained, the troubleshooting and some improvement were make if the desired results are not required as expected results. After all these are completed, the results were analysed and compare theoretically and with experimental results reported with published articles.
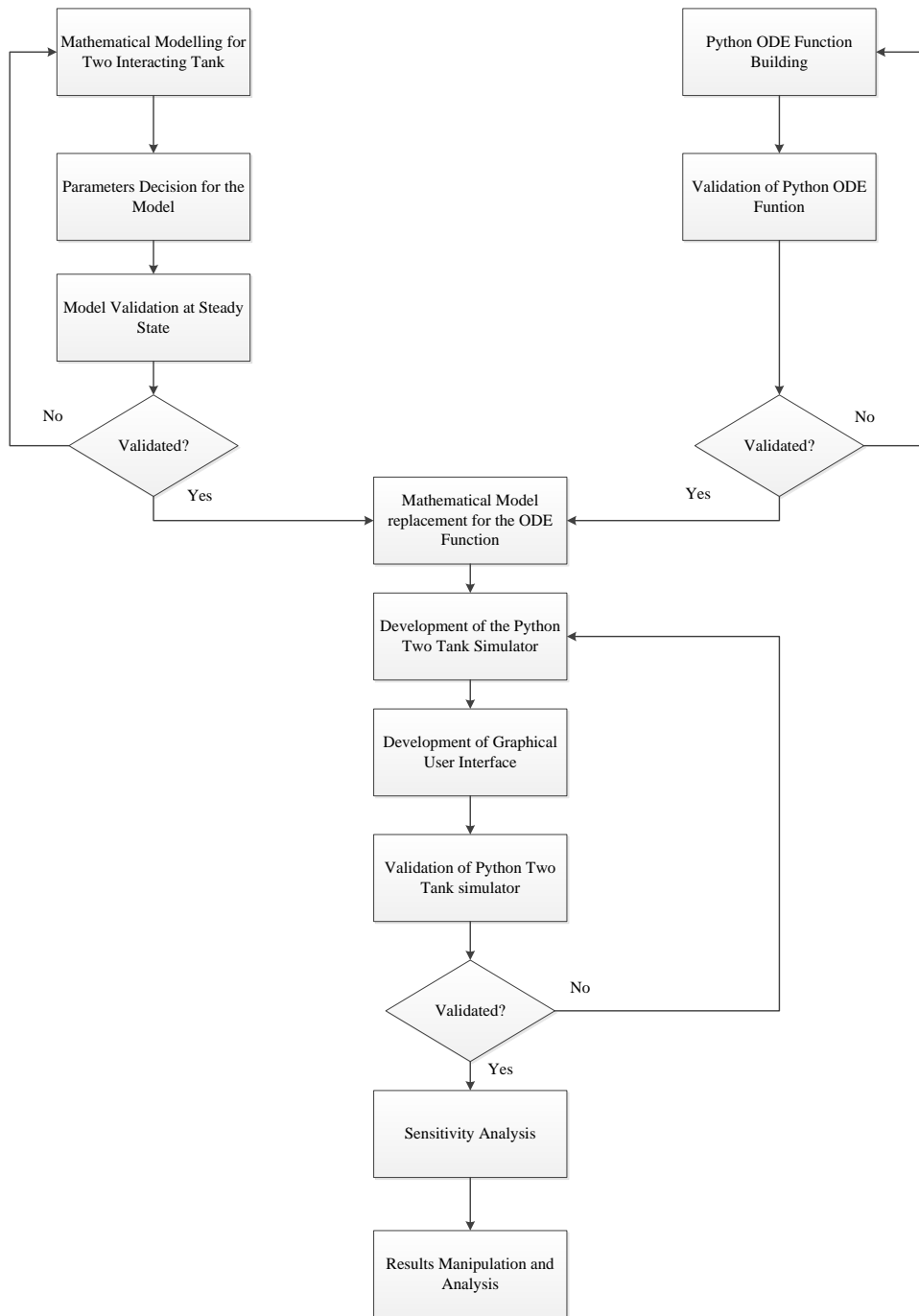
```
┌─────────────────────┐                              ┌─────────────────────┐
│ Mathematical Modelling│                             │ Python ODE Function │
│  for Two Interacting  │                             │      Building       │
│         Tank          │                             │                     │
└─────────────────────┘                              └─────────────────────┘
           │                                                     │
           ▼                                                     ▼
┌─────────────────────┐                              ┌─────────────────────┐
│ Parameters Decision  │                             │  Validation of Python│
│     for the Model    │                             │     ODE Funtion      │
└─────────────────────┘                              └─────────────────────┘
           │                                                     │
           ▼                                                     ▼
┌─────────────────────┐                              ┌─────────────────────┐
│ Model Validation at  │                             │                     │
│    Steady State      │                             │                     │
└─────────────────────┘                              └─────────────────────┘
           │                                                     │
           ▼                                                     ▼
  No     ◇ Validated? ◇                          No        ◇ Validated? ◇
         Yes                                               Yes

        ┌──────────────────────────┐
        │  Mathematical Model       │
        │  replacement for the ODE  │
        │        Function           │
        └──────────────────────────┘
                     │
                     ▼
        ┌──────────────────────────┐
        │ Development of the Python │
        │    Two Tank Simulator     │
        └──────────────────────────┘
                     │
                     ▼
        ┌──────────────────────────┐
        │ Development of Graphical  │
        │     User Interface        │
        └──────────────────────────┘
                     │
                     ▼
        ┌──────────────────────────┐
        │  Validation of Python Two │
        │      Tank simulator       │
        └──────────────────────────┘
                     │
                     ▼
               ◇ Validated? ◇        No
                    Yes
        ┌──────────────────────────┐
        │   Sensitivity Analysis    │
        └──────────────────────────┘
                     │
                     ▼
        ┌──────────────────────────┐
        │ Results Manipulation and  │
        │        Analysis           │
        └──────────────────────────┘
```

Figure 3.1 Flow diagram of research project development of simulating two tank

system

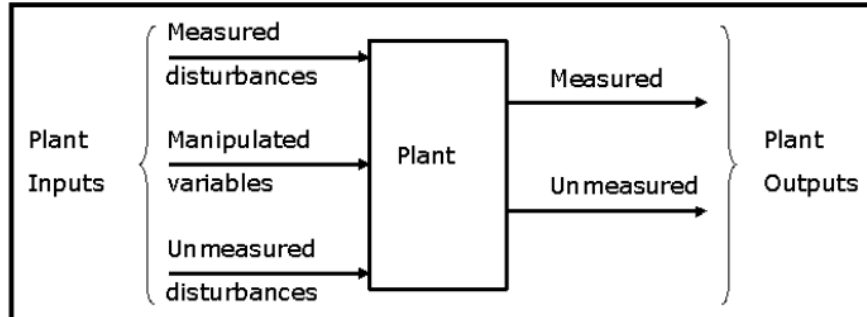## 3.2 Modelling of Two Interacting Tank

Tank System Model

Figure 3.2 Plant model flow diagram

Various factors are consider to determine the liquid level, such as tank height, tank area, liquid level resistance, liquid level capacitance, liquid flow rate, etc. Firstly, we need to measure individual parameters so that the transfer function can easily accessible.
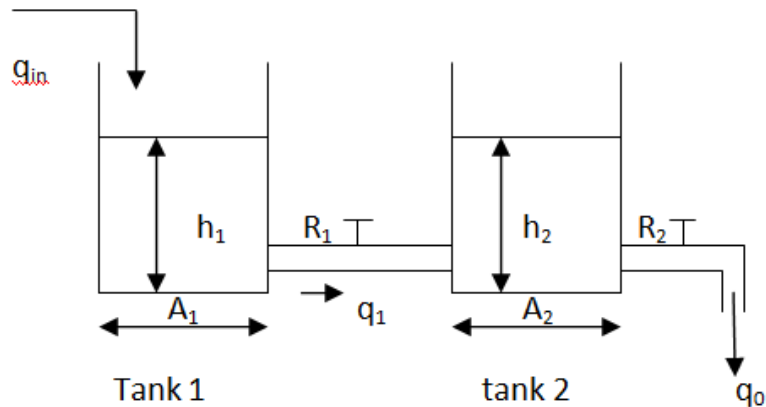

Figure 3.3 Two Interacting Tank Model (Changela & Kumar, 2013).

The parameters and variables that were used in the modelling equations:

q_{in} :   Volumetric flow into tank 1

q_1 :   Volumetric flow rate from tank 1

q_0 :   Volumetric flow rate from tank 2

A_1 :   Area of tank 1

A_2 :   Area of tank 2

h_1 :   The height of the liquid level in tank 1

h_2 :   The height of the liquid level in tank 2

R_1 :   Resistance tank 1

R_2 :   Resistance tank 2

3.3 Mass Balance of Two Interacting Tanks System

The model setup should consider the mass and energy balances across the tanks. From these mass balances, we were able to develop relationships for the volumetric flow rate and final height of the liquid level of the tanks. The outflow flow from tank 1 flows straight into tank 2. Furthermore, the flow of liquid through valve R1 is influenced by h1 and h2. The transient reaction in tank 1 is modified by the fluctuation in h2 in tank 2. The general equation for a mass balance in any system is as follows (Changela and Kumar, 2013; Thillairani et al., 2014; Swarada *et al.*, 2017):

Mass Balance of the Tank

$$Rate\ of\ Accumulation \tag{1}$$
$$= Flow\ Rate\ in - Flow\ Rate\ Out\ +\ Rate\ Generation$$

For tank 1,

The rate of accumulation is,

$$Rate\ of\ Accumulation\ = A_1 \frac{dh_1}{dt} \tag{2}$$

$$Flow\ Rate\ In - Flow\ Rate\ Out\ = q_{in} - q_1 \tag{3}$$

No rate generation, thus rate generation = 0

Assume linear resistance to flow,

$$q_1 = \frac{h_1 - h_2}{R_1}$$

The mass balance equation for tank 1 are:

$$A_1 \frac{dh_1}{dt} = q_{in} - \left(\frac{h_1 - h_2}{R_1}\right) \qquad (4)$$

$$A_1 R_1 \frac{dh_1}{dt} = R_1 q_{in} - h_1 + h_2 \qquad (5)$$

For tank 2,

The rate of accumulation is,

$$Rate\ of\ Accumulation\ = A_2 \frac{dh_2}{dt} \qquad (6)$$

$$Flow\ Rate\ In - Flow\ Rate\ Out\ = q_1 - q_0 \qquad (7)$$

No rate generation, thus rate generation = 0

Assume linear resistance to flow,

$$q_0 = \frac{h_2}{R_2}$$

The mass balance equation for two interacting tank are:

$$A_2 \frac{dh_2}{dt} = \frac{h_1 - h_2}{R_1} - \frac{h_2}{R_2} \qquad (8)$$

$$R_2 A_1 R_1 \frac{dh_2}{dt} = (h_1 - h_2)R_2 - h_2 R_1 \qquad (9)$$

3.4   Development of Simulator

The main goal of this project is to create a tool that can replicate the level of the two tanks. This is done based on in section 3.4 on mathematical modelling of system states By implementing real-time based events, the tool simulates the model's behaviour. From a technical standpoint, this chapter explains the software engineering process. Section 3.5.2 begins by outlining the activities that must be completed prior to implementation, such as requirement formulation and software design. Section 3.5.3 describes the most essential software features as well as the methods used to implement them. Before beginning software development, it is critical to define the product's primary needs, specify the technological framework, and begin with an appropriate software design.
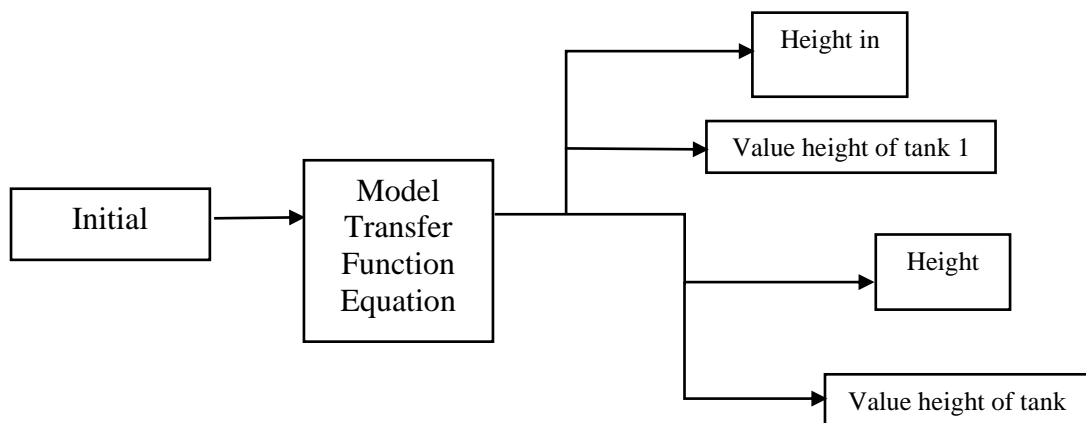
3.4.1   Simulate the Tank Model

Figure 3.4 System Flow of Two Tank Simulation

A discrete event simulation model is a model that represents a real-world system. It entails directing items through a logic structure in order to get and observe desired behaviour. It is possible to find a set of features that are similar to all simulation models by following Law's methodology (Law, A. M., Kelton, 2000). Special-

purpose programming languages for discrete event simulation become popular in the recent decade. The main reason for this is that creating a simulation model is quite simple, and the simulation program handles elements like time simulation management and random number generation. The scope of this thesis involves the Python Programming language. Python code was develop based on the mathematical model of the system. The simulation step required the understanding on how the Python works in compiling the model equation. This project is software-based project. The expectation from this project is would be able to simulate the graph of the level of liquid in the tank. The simulation should be able to allow the users to interact with the system and see changes due to the model interaction. The interaction of the two tank need to done by using graphical user interface. Solving the ODE of the two-tank model required specific module from the Python such as Numpy, Scipy, Matplotlib and others (Jeffrey J. Heys, 2017). The Python simulation need integrated development environment (IDE) used to facilitate the writing of Python source code. The Python need the user to define the problem to solve by defining the function (Finlayson, 2017). To develop the simulation, the firm model of interacting tank is chosen. Learning the Python is must before able to develop the model into the coding. The model consist of few variables to be investigate along the process development. The model involve the ODE of the interacting tank is connected in series. The time constant equation was further derive from the equation. Then, the tank constant derived is used to get the level of the tank in the results.