IOT ENABLED HYDROPONIC FARM MONITORING USING ARDUINO & CLOUD

THESIS

CASE STUDY

by

Jason Alexander Tan *2440042310*

BINUS INTERNATIONAL
BINUS UNIVERSITY
JAKARTA
2024

IOT ENABLED HYDROPONIC FARM MONITORING USING ARDUINO & CLOUD

THESIS

Proposed as a requirement for obtaining
Sarjana degree at
Business Information Systems
Master Track (Macquarie) – Information Systems Management
Education Level Strata-1 (Sarjana/Bachelor)

by

Jason Alexander Tan *2440042310*

BINUS INTERNATIONAL
BINUS UNIVERSITY
JAKARTA
2024

IOT ENABLED HYDROPONIC FARM MONITORING USING ARDUINO & CLOUD

THESIS

Prepared by:

Jason Alexander Tan
2440042310

Approved by:

Supervisor

Samuel Mahatmaputra T, S.Kom., M.Info.Tech
Lecture Code : D2131

BINUS UNIVERSITY
Jakarta
2024

STATEMENT FROM THE BOARD OF EXAMINERS

We, the members of the Board of Examiners for the S-1 Thesis Defense,
Hereby declare that

JASON ALEXANDER TAN (2440042310)

Who presented an S-1 Thesis entitle

IOT ENABLED HYDROPONIC FARM MONITORING USING ARDUINO & CLOUD

People
Innovation
Excellence

Successfully passed the S-1 Thesis Defense Examination conducted on 19 December 2023

		Name	Signature
1.	Chair	Dr. Michael Baskara L. A. Siek,S.Si.,S.Kom.,M.Sc.	
2.	Member	Dr.-Ing Rein Suadamara, S.Kom, M.Si.	
3.	Supervisor	Samuel Mahatmaputra T, S.Kom., M.Info.Tech	

JWC Campus
Jl. Hang Lekir I No.6
Senayan, Jakarta 10270
Indonesia

t. +6221 720 2222, 720 3333
f. +6221 720 8569, 720 5555
e. inquiry-jwc@binus.edu

international.binus.ac.id

PERNYATAAN
STATEMENT

Dengan ini, saya/kami,

With this, I/We,

Nama (Name): JASON ALEXANDER TAN

NIM (Student ID): 2440042310

Judul Tesis (Thesis Title): IOT ENABLED HYDROPONIC FARM MONITORING USING ARDUINO & CLOUD

Memberikan kepada Universitas Bina Nusantara hak non-eksklusif untuk menyimpan, memperbanyak, dan menyebarluaskan tesis saya/kami, secara keseluruhan atau hanya sebagian atau hanya ringkasannya saja, dalam bentuk format tercetak atau elektronik.
Hereby grant to my/our school, Bina Nusantara University, the non-exclusive right to archive, reproduce, and distribute my/our thesis, in whole or in part, whether in the form of a printed or electronic format.

Menyatakan bahwa saya/kami, akan mempertahankan hak exclusive saya/kami, untuk menggunakan seluruh atau sebagian isi tesis saya/kami, guna pengembangkan karya di masa depan, misalnya dalam bentuk artikel, buku, perangkat lunak, ataupun sistem informasi.
I/We acknowledge that I/we retain exclusive rights of my/our thesis by using all or part of it in a future work or output, such as an article, a book, software, or information system.

Catatan: Pernyataan ini dibuat dalam 2 (dua) bahasa, Indonesia dan Inggris, dan apabila terdapat perbedaan penafsiran, maka yang berlaku adalah versi Bahasa Indonesia.
Note: This Statement is made in 2 (two) languages, Indonesian and English, and in the case of a different interpretation, the Indonesian version shall prevail.

Jakarta, 11/04/2023

Jason Alexander Tan
2440042310

BINUS INTERNATIONAL

BINUS UNIVERSITY

Business Information Systems

Master Track (Macquarie) – Information Systems Management

Sarjana Komputer Thesis

Odd Semester 2023

IOT ENABLED HYDROPONIC FARM MONITORING USING ARDUINO & CLOUD

Jason Alexander Tan 2440042310

Abstract

This case study focuses on the development of an Arduino and PHP based integrated hydroponic farm monitoring system by leveraging IoT and cloud technologies. The system's objective is to deliver relevant environmental parameter data, such as parts per million (PPM), pH levels, CO_2 levels, humidity, and temperature, to greatly optimize the routine hydroponic monitoring activity performed by JUST HYDROPONICS.

Preliminary information collection is done qualitatively, which is used in the system's conception process. The Arduino is used as the sensor. The detailed specifications of the Arduino's software and hardware are discussed in detail, including the specific models of the components and subcomponents used in the creation of the Arduino prototype, which are specifically compatible with Arduino. The web application provides the users with an interface to visualize the collected data. The web API, which is built into the web application serves as a receiver for data from the Arduino. The design of the web application and API are also discussed in detail. The cloud platform provides application hosting, data storage, and remote access to the system.

Primary evaluation of the system's performance is done by studying the system's accuracy and reliability. A secondary evaluation is done qualitatively by directly interviewing JUST HYDROPONICS's owners & management about the system's impact and effectiveness.

The findings of this case study contribute to the progress of research on IoT and precision agriculture, which are highly important fields in addressing the sustainability and security of food in the world. The findings of this case study should be easily adaptable to a variety of hydroponic farm types.

Key Words

IOT, Hydroponic, Farm, Arduino, Cloud

Acknowledgements

This case study is dedicated to a few people, without whom I would have to endure unspeakable difficulties to get to where I am today. Words alone cannot express how grateful I am to have their unyielding support and company.

1. To my core family, especially my mother, to whom I owe everything.
2. To my extended family, which have been so kind and supportive as to allow me to use their business as the object of this case study and put up with my annoyingly large number of questions.
3. To my girlfriend, for her unwavering support, for her words of encouragement, and for her extraordinary ability to calm me down when times are difficult.
4. To my closest friends, for their invaluable friendship, their company, and the laughs we shared, which has opened many doors to me, be it physical, mental, or emotional.
5. To my thesis supervisor, Samuel Mahatmaputra T, S.Kom., M.Info.Tech., for providing me with invaluable guidance and inspiration during my thesis period and throughout the years since I started studying in Binus International, for being the lecturer who taught me the very lessons that are quintessential to my ability to perform this case study, for being the anchor of stability in my efforts of navigating Binus's bureaucratic nightmare for Master Track, all of which were crucial in enabling me to finish this case study.

Table of Contents

List of Tables

List of Figures

References

About Arduino. (2021, September 15). Arduino. https://www.arduino.cc/en/about

Ada, L. (2015). *Adafruit HUZZAH ESP8266 Breakout*. Adafruit. https://learn.adafruit.com/adafruit-huzzah-esp8266-breakout/overview

Amazon. (2023). *What is AWS?* Amazon AWS. https://aws.amazon.com/what-is-aws/

Amazon. (2023). *What is Amazon Relational Database Service (Amazon RDS)?* Amazon AWS. https://docs.aws.amazon.com/AmazonRDS/latest/UserGuide/Welcome.html

Amazon. (2023). *What is Amazon EC2?* Amazon AWS. https://docs.aws.amazon.com/AWSEC2/latest/UserGuide/concepts.html

Arduino. (2023, June 26). *SoftwareSerial Library*. Arduino Documentation. https://docs.arduino.cc/learn/built-in-libraries/software-serial

Barela, A. (2023). *ESP8266 Temperature / Humidity Webserver*. Adafruit. https://learn.adafruit.com/esp8266-temperature-slash-humidity-webserver/overview

Bhimsen. (2022, September 9). *ESP8266 AT Commands List and Working Explained.* Electronics Fun. https://electronics-fun.com/esp8266-at-commands/

Binance. (2023). *Turing Complete*. Binance Academy. https://academy.binance.com/en/glossary/turing-complete

Bootstrap – The most popular HTML, CSS, and JS library in the world. (n.d.). Bootstrap. Retrieved April 17, 2023, from https://getbootstrap.com/

Campbell, S. (2015, October 1). *How to Set Up the DHT11 Humidity Sensor on an Arduino*. Circuit Basics. https://www.circuitbasics.com/how-to-set-up-the-dht11-humidity-sensor-on-an-arduino/

Case Study Evaluation Approach. (n.d.). EvalCommunity. Retrieved September 26, 2023, from https://www.evalcommunity.com/career-center/case-study-evaluation-approach/

CimpleO, (2020, April 23). *Arduino pH-meter using PH-4502C*. CimpleO. https://cimpleo.com/blog/simple-arduino-ph-meter/

CSS Introduction. (n.d.). W3Schools. Retrieved April 17, 2023, from https://www.w3schools.com/css/css_intro.asp

DFRobot. (n.d.). *SEN0244 Gravity Analog TDS Sensor Meter for Arduino*. DFRobot Open-Source Hardware Electronics and Kits. Retrieved April 16, 2023, from https://wiki.dfrobot.com/Gravity__Analog_TDS_Sensor___Meter_For_Arduino_SKU__SEN0244

DPV Technology. (2019, September 29). *Sending data to thingspeak website using esp8266 Arduino Tutorial* [Video]. YouTube. URL https://www.youtube.com/watch?v=nMWwqcn7ofw

Electronoobs. (2019, August 4). *ESP8266 + Arduino + database – Control Anything from Anywhere* [Video]. YouTube. URL https://www.youtube.com/watch?v=6hpIjx8d15s&t=491s

ESP8266 Pinout Reference: Which GPIO pins should you use? (2019, May 6). Random Nerd Tutorials. https://randomnerdtutorials.com/esp8266-pinout-reference-gpios/

Fahad, E. (2022, June 24). *MH-Z19B NDIR CO_2 Sensor with Arduino*. Electronic Clinic. https://www.electroniclinic.com/mh-z19b-ndir-co2-sensor-with-arduino-mhz19b/

Fernandez, E. (2014, February 20). Hydroponic Nutrients TDS, PPMs and EC Explained! [Video]. YouTube. https://www.youtube.com/watch?v=uI9D-ONNdHg

freeCodeCamp.org. (2021, June 8). Arduino Course for Beginners – Open-Source sElectronics Platform [Video]. YouTube. https://www.youtube.com/watch?v=zJ-LqeX_fLU

General Hydroponics. (2023). *How Often Should I Check My pH Level?* General Hydroponics FAQs. https://generalhydroponics.com/faqs/how-often-should-i-check-my-ph-level/

Google. (2023). *Google Cloud Documentation*. Google Cloud. https://cloud.google.com/docs

Hernandez, R. D. (2021, April 19). *The Model View Controller Pattern – MVC Architecture and Frameworks Explained*. freeCodeCamp. https://www.freecodecamp.org/news/the-model-view-controller-pattern-mvc-architecture-and-frameworks-explained/

HTML Introduction. (n.d.). W3Schools. Retrieved April 17, 2023, from https://www.w3schools.com/html/html_intro.asp

IoTSpace. (2021, September 17). *Arduino CO_2 Sensor – MH-Z19 Beispiel und Sketch*. IoTSpace. https://iotspace.dev/arduino-co2-sensor-mh-z19-beispiel-und-sketch/

Janes, L. (2019, July 30). *Top 15 Reasons Why You Should Grow Vegetables In A Hydroponic Garden*. VH Hydroponics. https://www.vhhydroponics.com/hydroponic-garden/

MariaDB. (2023). *MariaDB Server: The open-source relational database*. MariaDB. https://mariadb.org/

Maxim Integrated. (2019). *DS18B20 – Programmable Resolution 1-Wire Digital Thermometer*. Maxim Integrated. https://www.analog.com/media/en/technical-documentation/data-sheets/ds18b20.pdf

Mouser Electronics. (n.d.). *DHT11 Humidity & Temperature Sensor*. Mouser Electronics. Retrieved April 16, 2023, from https://www.mouser.com/datasheet/2/758/DHT11-Technical-Data-Sheet-Translated-Version-1143054.pdf

Mozilla. (2023, September 16). *What is JavaScript?* MDN Web Docs. https://developer.mozilla.org/en-US/docs/Learn/JavaScript/First_steps/What_is_JavaScript

MySQL. (n.d.). *MySQL 8.0 Reference Manual*. Dev MySQL. https://dev.mysql.com/doc/refman/8.0/en/what-is-mysql.html

NodeMCU ESP8266. (2020, April 22). Components 101. https://components101.com/development-boards/nodemcu-esp8266-pinout-features-and-datasheet

PHP. (2023). *History of PHP and Related Projects*. PHP. https://www.php.net/manual/en/history.php

pH Probe Architecture. (n.d.). Digital Analysis Corporation. Retrieved 4 September 2023, from https://www.digital-analysis.com/TArticles/pH_Probe.html

Prasanniya. (2023, March 28). *A Closer Look at the Latest Technologies in Hydroponics*. Hydroponic Way. https://hydroponicway.com/latest-technologies-in-hydroponics/

Programming Electronics Academy. (2021, April 11). *DIY Hydroponic Garden w/Arduinoand IoT* [Video]. URL https://www.youtube.com/watch?v=Ng7qDDH9Yqk

Santos, R. (2016, August 24). *Guide for DS18B20 Temperature Sensor with Arduino*. Random Nerd Tutorials. https://randomnerdtutorials.com/guide-for-ds18b20-temperature-sensor-with-arduino/

Shinde, S. (2023, January 25). *What are the Key Pros and Cons of the Arduino Programming Language?* Emeritus. https://emeritus.org/blog/coding-arduino-programming-language/

Winsen. (2016). *Intelligent Infrared CO_2 Module (Model: MH-Z19B)*. Zhengzhou Winsen Electronics Technology Co., Ltd. https://www.winsen-sensor.com/d/files/infrared-gas-sensor/mh-z19b-co2-ver1_0.pdf

XAMPP Team. (2023). *Windows Frequently Asked Questions*. Apache Friends. https://www.apachefriends.org/faq_windows.html

Appendices

Appendix 1: UI Design Suggestions

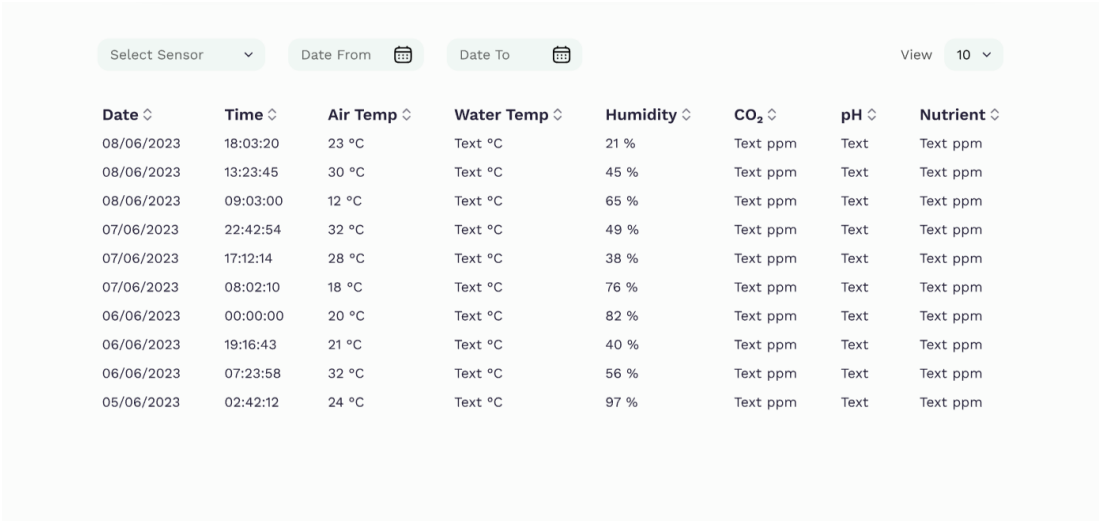

Figure A1.1 – UI Suggestion 1

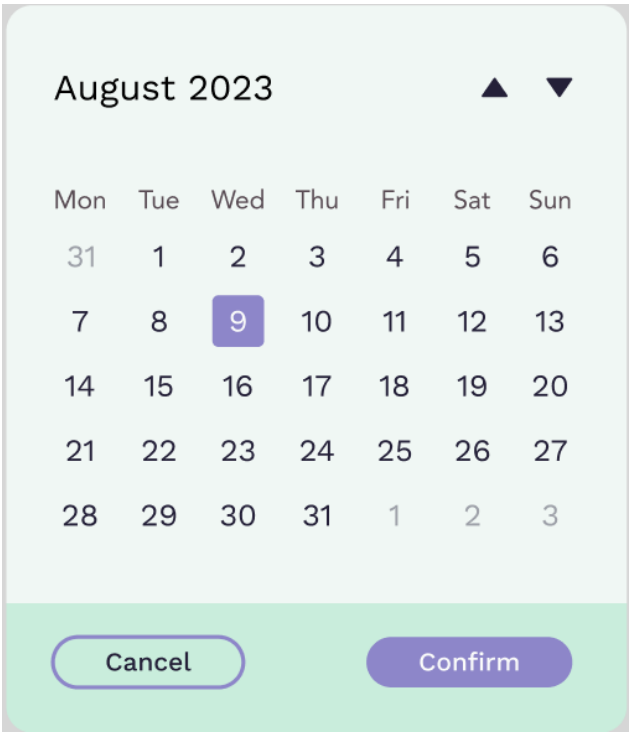

Figure A1.2 – UI Suggestion 2

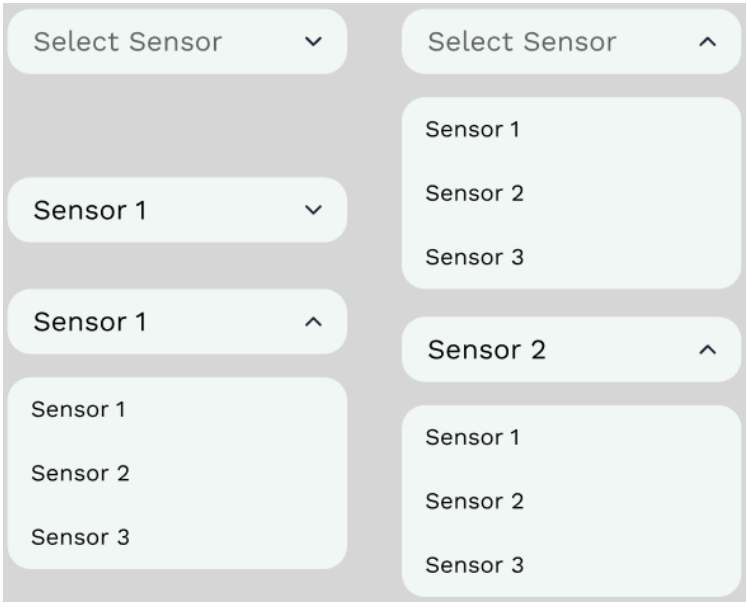

Figure A1.3 – UI Suggestion 3

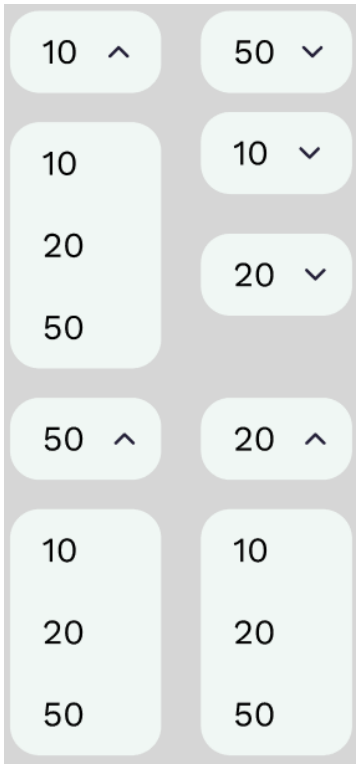

Figure A1.4 – UI Suggestion 4

Appendix 2: Results of Interview with Just Hydroponics

(Interview Results)

Date : Sunday, 1st of January 2023.

Time : ~11:00 AM

Location : Just Hydroponics, Outskirts of Bogor City
Jl. Pasir Bogor, Cipelang, Cijeruk, Bogor, Jawa Barat 16740

Interviewee : Anton & Ina (Owners of Just Hydroponics)

**Note: This interview is not a 100% accurate & direct reference to what was said during the interview. For the sake of readability, the written transcript has been modified, rewritten, translated to English, and had some unnecessary dialogue which covers some banter, finances, other people's comments and the business's customer base removed.*

[Begin Interview]

Jason : Hi Auntie Ina, so I have this case upcoming case study thesis that I will need to start writing soon. I've been looking for ideas and your hydroponic farm seems like it would be a great object of study for my thesis. Do you mind if I use it and ask you some questions?

Ina : Hi Jason! Sure, of course. We've actually had someone else, I forgot who it was, who asked us the very same thing. He also wanted to use my farm for their thesis.

Jason : Do you mind giving me a tour of the place?

Ina : Yes sure! Everyone else can also come! We're planning to give you all a tour anyways, and at the end you can get your pick at some of our cancelled orders, on the house!

[*Tour* – Aunt Ina showed me (and quite a number of people from my extended family) her hydroponic farm, accompanied by her husband, Uncle Anton.]

Jason : Oh, so these whiteboards are where you write down the information about the [hydroponic] trays?

Ina : Yes, we measure the "PPM" of the hydroponic waters and write them down here for reference.

Jason : How do you measure the PPM levels?

Ina : Ah, I don't know too much about that, Uncle Anton usually handles this. <Calls uncle Anton over.>

Anton : Ah yes, we use handheld test kits, think I have them somewhere over here… Here it is. So you just dip this end into the water and… <explains how the tool works>.

Jason : So you only measure the "PPM"?

Anton : Yes, it's the "nutrient density". I don't really understand how the science behind it works, but I follow guides.

Jason : How about other things like CO_2 and temperature?

Anton : That's why we built this greenhouse around it. I don't know exactly how much CO_2 there is and is needed, but this greenhouse works wonders.

Jason : And you store the nutrient density notes on these whiteboards? What if they get wet, or accidentally wiped?

Anton : Well of course we will try not to let that happen, but what's the worst that could happen if it does get wiped? It's not like the crops are just going to die, it's still going to grow normally, it's just that we won't know exactly what's going on, until we measure it again that is, which is pretty simple. Plus, these greenhouses don't allow rainwater in, so the whiteboards won't get wet.

Jason : But what if I can come up with a way to store these notes like on a database or something?

Anton : It would be interesting, but I'm getting old, might be too much for me to learn.

Jason : Shouldn't be a problem, I should be able to make it very simple to use. You do have Wi-Fi here right?

Anton : Yes, but it's rather slow, and can be unreliable at times.

Jason : Hmm, its good that there is Wi-Fi, but the unreliability could be a problem…

[*Tour* – We moved to the far end of the farm complex, to the undeveloped lands around it.]

Ina : Well, our lands are quite big as you can see.

Jason : Wow, that's quite large, I wonder how much all of this costs.

Ina : Well, it's remote, with difficult access to almost everything really, so it's not too expensive. This whole entire land costs around IDR 2 bio.

Jason : Wow, that's really cheap for a land this massive, especially compared to Jakarta.

Anton : Yeah, that's the point, we plan to expand because demand is on the rise.

Jason : Wouldn't it get more and more tedious to individually monitor and care for all these greenhouses the more you expand?

Anton : Well yes, but that's why we have staff tending to the crops. Of course, it will eventually get difficult, but that's still far in the future, might even be a decade ahead, so we'll think about that when it comes to it.

Jason : I might be able to do something about that with my case study.

Ina : Really? We'll it'll be interesting to see what you can come up with, maybe we'll even pay you hahaha.

Jason : Yeah…, maybe…, haha…

Anton : Well, do you have any other questions?

Jason : No, I think that's it for now… thanks a lot for all of this. I know I must be bothering you.

Ina : Oh no not at all…, <proceeded to shift the conversation to about my university life.>

[End Interview]

Appendix 3: Additional Attachments

I have included the following attachments onto the final submission of this thesis:

- Arduino High-Level Architecture Diagram
- Web Application High-Level Architecture Diagram
- Class Diagram
- Empathy Map
- Process Cycle Diagram
- Use Case Diagram
- Value Proposition Canvas
- Arduino “Final” Schematic
- Schematic of ESP-01 in Bypass Mode
- Schematic of ESP-01 in SoftwareSerial Mode
- Schematic of the MH-Z19B in Analog Mode
- Schematic of the PH-4502C

Any tables, figures, or diagrams not attached in this appendix should be available directly in this report in high-resolution. Please zoom-in to view.

Appendix 4: Database Seed File

I will also be attaching the **.SQL** *seed* file, which was generated via *mysqldump* from my own local test database.

Appendix 5: Web Application Code, PHP Project Folder

I am attaching the web application’s source code in the form of the PHP project folder as an appendix for inspection.

Appendix 6: Hydroponic Sensor Code, Arduino Project Folder

I am also attaching the Hydroponic Sensor device’s source code in the form of the Arduino project folder.

Curriculum Vitae

Name	:	Jason Alexander Tan
Place, Day of Birth	:	Jakarta, 5 November 2001
Sex	:	Male
Address	:	Jl. Tajuk Rencana H-117 Cipinang Muara, Jatinegara, Jakarta Timur 13420
Telephone	:	(+62) 858 8888 9900
Education and Training	:	

Binus University International **July 2020 - Present**
Undergraduate, Business Information Systems Jakarta, Indonesia

SMAK 1 BPK Penabur Jakarta **July 2017 – Jun 2020**
High School Diploma, School of Science Jakarta, Indonesia

Work History :

PT. Bank DBS Indonesia **February 2023 - Present**
Business Platform Management (Internship) Jakarta, Indonesia

NHS England **February 2022 – September 2022**
Project Management (Internship, Remote) Jakarta, Indonesia