



Mobile Phone Application for Measuring Air Parameters in Getting Discomfort Index and
Amount of Air Pollutants with the Use of a Microcontroller-based System

A Thesis
Presented to the Faculty of the
Department of Electronics and Communications Engineering
Gokongwei College of Engineering
De La Salle University

In Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Computer Engineering

by

CHEONG, Junlae
NIHALANI, Rohit P.
PAULINO, Noel B.
PO, Ryback Tyrone G.

June, 2016



De La Salle University

ORAL DEFENSE RECOMMENDATION SHEET

This thesis, entitled **Mobile Phone Application for Measuring Air Parameters in Getting Discomfort Index and Amount of Air Pollutants with the Use of a Microcontroller-based System**, prepared and submitted by thesis group, ESG-04, composed of:

CHEONG, Junlae
NIHALANI, Rohit P.
PAULINO, Noel B.
PO, Ryback Tyrone G.

in partial fulfillment of the requirements for the degree of **Bachelor of Science in Computer Engineering (BS-CPE)** has been examined and is recommended for acceptance and approval for **ORAL DEFENSE**.

Engr. Donabel D. Abuan
Adviser

June 12, 2016



De La Salle University

THESIS APPROVAL SHEET

This thesis entitled **Mobile Phone Application for Measuring Air Parameters in Getting Discomfort Index and Amount of Air Pollutants with the Use of a Microcontroller-based System**, prepared and submitted by:

CHEONG, Junlae
NIHALANI, Rohit P.
PAULINO, Noel B.
PO, Ryback Tyrone G.

with group number ESG-04 in partial fulfillment of the requirements for the degree of **Bachelor of Science in Computer Engineering (BS-CPE)** has been examined and is recommended for acceptance and approval.

PANEL OF EXAMINERS

Engr. Julius P. Bancud
Chair

Engr. Blanca I. Bucao
Member

Dr. Rionel B. Caldo
Member

Engr. Donabel D. Abuan
Adviser

Date: June 12, 2016



De La Salle University

60
61
62
63

2016

All Rights Reserved. No part of this publication may be reproduced, stored in an information retrieval system, or transmitted, in any form or by any means, electronic, mechanical, by photocopying, scanning, recording, or otherwise, except under the terms of the applicable law.



De La Salle University

64

ACKNOWLEDGMENT

65

66

Write this prior to hard binding if you have submitted all requirements and are told by your adviser that you have passed.



67

ABSTRACT

68

Keep your abstract short by giving the gist/nutshell of your thesis.

69

Index Terms—alloy system, characterization, InP, InGaAs.



70

TABLE OF CONTENTS

71

Oral Defense Recommendation Sheet	ii
-----------------------------------	----

72

Thesis Approval Sheet	iii
-----------------------	-----

73

Acknowledgment	v
----------------	---

74

Abstract	vi
----------	----

75

Table of Contents	vii
-------------------	-----

76

List of Figures	x
-----------------	---

77

List of Tables	xi
----------------	----

78

Abbreviations	xii
---------------	-----

79

Notation	xiii
----------	------

80

Glossary	xiv
----------	-----

81

Listings	xv
----------	----

82

Chapter 1 INTRODUCTION	1
------------------------	---

83

1.1 Background of the Study	2
---------------------------------------	---

84

1.2 Prior Studies	3
-----------------------------	---

85

1.3 Problem Statement	4
---------------------------------	---

86

1.4 Objectives	5
--------------------------	---

87

1.4.1 General Objective(s)	5
--------------------------------------	---

88

1.4.2 Specific Objectives	5
-------------------------------------	---

89

1.5 Significance of the Study	5
---	---

90

1.6 Assumptions, Scope and Delimitations	6
--	---

91

1.7 Description and Methodology	6
---	---

92

1.8 Overview	7
------------------------	---

93

Chapter 2 LITERATURE REVIEW	9
-----------------------------	---

94

2.1 Temperature Monitoring System	10
---	----

95

2.2 Humidity Monitoring System	11
--	----



96	2.3	PM ₁₀ Temporal Monitoring	13
97	2.4	Wireless Air Quality Monitoring System	13
98	2.5	Discomfort Index Monitoring System	14
99	2.6	Air Quality Standards	15
100	Chapter 3	THEORETICAL CONSIDERATIONS	16
101	3.1	Summary	18
102	Chapter 4	DESIGN CONSIDERATIONS	20
103	4.1	Summary	22
104	Chapter 5	METHODOLOGY	23
105	5.1	Implementation	24
106	5.2	Evaluation	26
107	5.3	Summary	28
108	Chapter 6	RESULTS AND DISCUSSION	29
109	6.1	Summary	31
110	Chapter 7	CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIREC-	
111		TIVES	32
112	7.1	Concluding Remarks	33
113	7.2	Contributions	33
114	7.3	Recommendations	33
115	7.4	Future Prospects	35
116	References		36
117	Appendix A	ANSWERS TO QUESTIONS TO THIS THESIS	37
118	A1	How important is the problem to practice?	38
119	A2	How will you know if the solution/s that you will achieve would be better	
120		than existing ones?	38
121	A2.1	How will you measure the improvement/s?	38
122	A2.1.1	What is/are your basis/bases for the improvement/s? . .	39
123	A2.1.2	Why did you choose that/those basis/bases?	39
124	A2.1.3	How significant are your measure/s of the improvement/s? .	39
125	A3	What is the difference of the solution/s from existing ones?	40
126	A3.1	How is it different from previous and existing ones?	40
127	A4	What are the assumptions made (that are behind for your proposed solution	
128		to work)?	40
129	A4.1	Will your proposed solution/s be sensitive to these assumptions? .	41



130	A4.2	Can your proposed solution/s be applied to more general cases	
131		when some of the assumptions are eliminated? If so, how?	41
132	A5	What is the necessity of your approach / proposed solution/s?	41
133	A5.1	What will be the limits of applicability of your proposed solution/s?	42
134	A5.2	What will be the message of the proposed solution to technical	
135		people? How about to non-technical managers and business men?	42
136	A6	How will you know if your proposed solution/s is/are correct?	42
137	A6.1	Will your results warrant the level of mathematics used (i.e., will	
138		the end justify the means)?	43
139	A7	Is/are there an/_ alternative way/s to get to the same solution/s?	43
140	A7.1	Can you come up with illustrating examples, or even better, counter	
141		examples to your proposed solution/s?	43
142	A7.2	Is there an approximation that can arrive at the essentially the same	
143		proposed solution/s more easily?	44
144	A8	If you were the examiner of your proposal, how would you present the	
145		proposal in another way?	44
146	A8.1	What are the weaknesses of your proposal?	44
147	Appendix B	USAGE EXAMPLES	46
148	B1	Equations	47
149	B2	Notations	49
150	B3	Abbreviation	55
151	B4	Glossary	57
152	B5	Figure	58
153	B6	Table	64
154	B7	Algorithm or Pseudocode Listing	68
155	B8	Program/Code Listing	70
156	B9	Referencing	72
157	B9.1	A subsection	73
158	B9.1.1	A sub-subsection	74
159	B10	Index	75
160	B11	Adding Relevant PDF Pages (e.g. Standards, Datasheets, Specification	
161		Sheets, Application Notes, etc.)	76
162	Appendix C	PUBLICATION LIST AND AWARD	80
163	Appendix D	VITA	82
164	Index		84



165

LIST OF FIGURES

166

3.1 A quadrilateral image example. 19

167

B.1 A quadrilateral image example. 58

168

B.2 Figures on top of each other. See List. B.6 for the corresponding \LaTeX code. 60

169

B.3 Four figures in each corner. See List. B.7 for the corresponding \LaTeX code. . 62



170

LIST OF TABLES

171

B.1 Feasible triples for highly variable grid 64

172

B.2 Calculation of $y = x^n$ 68



173

ABBREVIATIONS

174	AC	Alternating Current.....	55
175	CSS	Cascading Style Sheet	55
176	HTML	Hyper-text Markup Language	55
177	XML	eXtensible Markup Language	55



NOTATION

179	$ \mathcal{S} $	the number of elements in the set \mathcal{S}	57
180	\emptyset	the set with no elements	57
181	$h(t)$	impulse response	47
182	\mathcal{S}	a collection of distinct objects	57
183	\mathcal{U}	the set containing everything	57
184	$x(t)$	input signal represented in the time domain	47
185	$y(t)$	output signal represented in the time domain	47

186 Throughout this thesis, mathematical notations conform to ISO 80000-2 standard, e.g.
187 variable names are printed in italics, the only exception being acronyms like e.g. SNR,
188 which are printed in regular font. Constants are also set in regular font like j . Functions are
189 also set in regular font, e.g. in $\sin(\cdot)$. Commonly used notations are t , f , $j = \sqrt{-1}$, n and
190 $\exp(\cdot)$, which refer to the time variable, frequency variable, imaginary unit, n th variable,
191 and exponential function, respectively.



192

GLOSSARY

193

matrix a concise and useful way of uniquely representing and working with linear transformations; a rectangular table of elements.....57



194

LISTINGS

195	B.1 Sample \LaTeX code for equations and notations usage	48
196	B.2 Sample \LaTeX code for notations usage	52
197	B.3 Sample \LaTeX code for abbreviations usage	56
198	B.4 Sample \LaTeX code for glossary and notations usage	57
199	B.5 Sample \LaTeX code for a single figure	59
200	B.6 Sample \LaTeX code for three figures on top of each other	61
201	B.7 Sample \LaTeX code for the four figures	63
202	B.8 Sample \LaTeX code for making typical table environment	66
203	B.9 Sample \LaTeX code for algorithm or pseudocode listing usage	69
204	B.10 Computing Fibonacci numbers	70
205	B.11 Sample \LaTeX code for program listing	71
206	B.12 Sample \LaTeX code for referencing sections	72
207	B.13 Sample \LaTeX code for referencing subsections	73
208	B.14 Sample \LaTeX code for referencing sub-subsections	74
209	B.15 Sample \LaTeX code for Index usage	75
210	B.16 Sample \LaTeX code for including PDF pages	76



211

Chapter 1

212

INTRODUCTION

213

Contents

214

215

216

217

218

219

220

221

222

223

224

225

1.1	Background of the Study	2
1.2	Prior Studies	3
1.3	Problem Statement	4
1.4	Objectives	5
1.4.1	General Objective(s)	5
1.4.2	Specific Objectives	5
1.5	Significance of the Study	5
1.6	Assumptions, Scope and Delimitations	6
1.7	Description and Methodology	6
1.8	Overview	7



1.1 Background of the Study

There has been many reasons why one tries to avoid any outdoor activity but one of these is how the air feels whether it is too hot or too polluted or even both. One undeniable fact is that heat and humidity all play roles in making the weather hot. Both of these weather parameters are involved in the calculation of the heat index and the discomfort index.

Heat index and discomfort index have their similarities because the factors that affect these two are the temperature and the relative humidity. The heat index is the perceived temperature by people when the rising temperature and the relative humidity is combined.

The unit used here is a unit of temperature and the mathematical formula for computing the heat index shows a rather direct square proportionality with the temperature and the humidity. But when it comes to a more human readable scale, reaching 34 degrees Celsius is already a discomfort to some. Reaching at least 46 degrees Celsius is already dangerous to all as this can cause heat stroke and even imminent death to some people. The discomfort index is similar to the heat index but instead, its mathematical formula only indicates a direct proportionality with the temperature and the relative humidity. The scaling is rather similar to that in the heat index. When the discomfort index reaches at least 21 degrees Celsius, it is already a discomfort for some people. Reaching 29 degrees Celsius is already dangerous to all that when it even gets higher, a state of emergency can be declared.

The human body is capable of regulating body temperature because of its abilities as a warm-blooded organism. When the human body detects extreme temperatures, it drastically adjusts the body just to get the internal temperature back to a normal 37 degrees Celsius. When your body detects a lot of heat, it tries to cool itself down by increasing your heart rate and sweating. However, one can sweat too much, he feels drained by the lack of fluids



249 in his body causing discomfort, weakness, loss of stamina, and even muscle pains, leading
250 to a heat stroke.

251 Other than high temperatures and humidity, the pollutants in the air can be harmful to the
252 respiratory system. Dust is a particle suspended in the air and it usually comes from the soil
253 or the pollution. This can cause irritation in the respiratory system because dust entering
254 the lungs can cause serious complications. This is already bad for those with respiratory
255 problems such as asthma or emphysema. Carbon monoxide, however, is a colorless and
256 odorless gas and it usually comes from smoke. When this is inhaled, it can cause serious
257 complications in the body since this inhibits the delivery of oxygen from the blood to the
258 other organs in the body which can cause death. Not only do all of this increase the risk of
259 getting sickness but these also affect the visibility of an area.

260 This study will focus on a mobile application that enables people to have a foresight on
261 how the outside air feels like. A microcontroller-based system will be used in detecting the
262 parameters stated above while the mobile application will take note of the visibility with
263 the use of the phone's camera.

264 1.2 Prior Studies

265 Put here a summary of your literature review. Preferably, a table showing the summary
266 would be helpful. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis
267 facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante.
268 Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim
269 nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit.
270 Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit.



271 Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam
272 rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit
273 blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris
274 lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

275 **1.3 Problem Statement**

276 Though there have been mobile applications that display the weather in real time, none
277 have been able to show the discomfort index given the data. Also, there are no applications
278 that tell the amount of dust or carbon monoxide in the air considering that these are some
279 important factors when people choose to commute by an ordinary jeepney or do any outdoor
280 activity in urban areas.

281 The aim of this study is to develop a new mobile application that is able to report the
282 condition of the air such as weather parameters and the amount of pollutants present. The
283 system will make use of a microcontroller along with different sensors that will measure
284 the said parameters. Also, the mobile application will make use of computer vision to
285 measure the visibility in an area.

286 Can a mobile application be developed to report real time conditions of the air and the
287 amount of pollutants present with the used of a sensor-based microcontroller system?



1.4 Objectives

1.4.1 General Objective(s)

To design and develop an indoor/outdoor system for getting the discomfort index of the air...;

1.4.2 Specific Objectives

1. To make use of the temperature, humidity, amount of dust, amount of carbon monoxide, and visibility in calculating discomfort index and measuring pollutants...;
2. To utilize different sensors for temperature, humidity, dust, and carbon monoxide measurement...;
3. To make use of computer vision with the use of a cellphone camera to measure visibility...;
4. To achieve a social impact on the conditions and quality of the air for the people in urban areas where smoke is present and abundant...;

1.5 Significance of the Study

The significance of this topic is to be able to design and produce a device of checking the air quality and discomfort index for the public health awareness. There are millions of commuters in the Philippines riding jeepneys or light rail transit system. The problem of this way of commuting is the air because there are a lot of old vehicles producing smoke and most people just breathe in either direct or indirect way. It is very important for the people



307 to know the status of the air to secure their respiratory health. Together with this, the group
308 aim to the user friendly device that anyone can easily understand how to use the device
309 through an android application. Since a lot of people uses android mobile phones, making
310 an application for free will be very helpful. The application will display the required data
311 in graphics so that it is easy to understand for the public and to make the aware of the effect
312 of the environment to their health. This study will surely help a lot of people who still dont
313 know about why it is important to know the air we are breathing outside.

314 **1.6 Assumptions, Scope and Delimitations**

- 315 1. The given data will only be determined by the air quality index and the discomfort
316 index.
- 317 2. The application will be used only for displaying the data gathered in the device.
- 318 3. People should be able to know the importance of their respiratory system in the body.
- 319 4. Users must aware the connection between air pollution and lung cancer.
- 320 5. The device will only deal with the common factors for discomfort such as temperature,
321 humidity, and the amount of dust in the air.

322 **1.7 Description and Methodology**

323 A device for checking air quality and discomfort index can be functional through the use of
324 the electronic sensors attached in the circuit and sensors for dust, humidity, and temperature
325 will provide the data for air quality index and discomfort index. The device will be user



friendly so that anyone can easily control and use it for the given purpose. The goal for this project is to come up with a device and android application for air quality and discomfort index which will provide data related to the health of the public. Challenges to this project would be the design of the circuit with indicated sensors and the accuracy of the data gathered by the device. The size of the device matters because it has to be user friendly and this will be designed for the typical citizens like commuters. The prototype test would determine if it has accurate data and user friendly in general. Android application will be supporting the device as a method of health awareness. the application will be able to show the data gathered in the device and show the effect of air quality index and discomfort index for respiratory health. The information is also one of the important part because people must know why it is important to know the air quality and their discomfort level.

1.8 Overview

In the first chapter, it will be helpful for readers to understand what is the purpose of making the device and android application and why it is important for the society. It also shows how the project will be implemented in the real world from the hypothesis. For the second part of the paper, there will be a lot of helpful literature related to the air quality, discomfort index, respiratory health, prevention of lung cancer, effect of dust to the human body, circuit design for humidity, dust, and temperature sensors. These literature will guide the group what is the right way to develop a project and make it functional in order to fulfill the standard of the public. Theoretical considerations will be the key part to determine the data gathered from the device because there are theoretical standards in other research to know what are the air quality and discomfort index. Considering the design, it will be



348 fully electronic design because the implementation in the hardware will be using electronic
349 circuits. methodology will introduce how the data is gathered in the device and represented
350 to the users. result and discussion will be providing the user feedback and the actual data
351 given by the device in real situation. The value of this project will be determined in the
352 conclusion based on all the provided data and actual simulation. It is the most important
353 part to prove how this project fulfilled its purpose for the public health awareness.



354

Chapter 2

355

LITERATURE REVIEW

356

Contents

357

358

2.1 Temperature Monitoring System 10

359

2.2 Humidity Monitoring System 11

360

2.3 PM₁₀ Temporal Monitoring 13

361

2.4 Wireless Air Quality Monitoring System 13

362

2.5 Discomfort Index Monitoring System 14

363

2.6 Air Quality Standards 15

364



There are several existing studies or researches about different kinds of applications of air parameters. Most of the studies found relating to these parameters are temperature, humidity, temporal, wireless air quality and discomfort index monitoring systems and air quality standards.

2.1 Temperature Monitoring System

An important parameter, not only in the air but also in everything, is the temperature. It is very important to monitor temperature of objects because most objects are sensitive to changes in the temperature such as products and some machines. Some existing researches of temperature monitoring system are found in the field of agriculture. Recent studies [?] shows how important data-acquisition systems in the agriculture through environmental monitoring. Environmental monitoring refers to the gathering of data of some parameters in the environment that may affect the products. Automated measurements are beneficial because gathering of data and measurements are made several times. Chavan and Karande have developed a system for wireless monitoring of soil moisture, temperature and humidity in the field of agriculture. The system uses a temperature sensor, humidity sensor and soil moisture sensor that are connected to an AVR microcontroller. It also uses GSM-Zigbee based remote monitoring and control system. The application of Zigbee to the monitoring system in the agriculture reduces human power and enables to evaluate some accurate changes that will happen.

Aside from the agricultural implementation of temperature monitoring, there are also existing studies that involves its application to automated systems for electronic devices or appliances. [?] designed a smart home automated control system. The system uses



a microcontroller for sensors and android application for the transmission of data and the receiving of data. One of the four major fields of the smart home system or SHS is the environmental monitoring, which includes the monitoring of the humidity and the temperature. The main components used in the system are microcontroller, adruino board, android and a bluetooth module. Wireless internet services are also used for several monitoring and controlling processes. The passive infrared sensors are capable off detecing movements of a human being through sensing the changes in the temperature over the scene. The SHS also uses LM35 temperature sensor for the Temperature sensing system for Air Conditioner. The system can transfer data from the sensors to the android phone. On the same way, it can transmit data or commands from the android to the appliances. The wireless monitoring of temperature allows the user to control electronic devices or appliances from anywhere in the world.

2.2 Humidity Monitoring System

Humidity is always associated with temperature. It plays an important role to human due to the skin being sensitive to the changes in humidity. This is also the reason why humans sweat. Not only humans are affected by the changes in the humidity in the air but also applies to the things related to the field of agriculture.

A group of researchers [?] designed a green house monitoring and controlling system using an android mobile application. The system can control the humidity inside a green house, based on the readings of the humidity sensor through the microcontroller which is connected to the central server and can be accessed through Wi-Fi connection. The system is consists of humidity sensor, Arduino UNO microcontroller, serial communication,



wireless connection and a computer. The data from the sensor will be transmitted to the microcontroller and transferred to the computer through serial communication. The computer will transmit the data to the android phone via wireless connection and the android phone can now control the system depending on the commands that will be selected. The android can receive data from the humidity sensor, send data for water sprayer to turn on, send data for stepper motor to work and other commands that the system is capable of doing. This system ensures the condition of the green house environment to be in good condition.

Other than agricultural applications, studies also shows how air quality such as temperature and humidity affects the health of a human being. Indoor air quality or IAQ is an important factor that may affect the level of comfort and the health of the people. This may increase the discomfort index of a human being which may result to difficulties in concentration or even headaches. [?] develop a wireless battery-powered system for online ambient monitoring. The system has the ability to monitor temperature, humidity, carbon dioxide level, absolute pressure and intensity of light in the indoor spaces. The data gathered can be sent through a computer for visualization and can send SMS for alarms. The system has sensors such as ambient, temperature, humidity and many more sensors to evaluate the indoor air quality. Wi-Fi connection is used as a data transmission, from the sensors to the computer, due to the fact that Wi-Fi can be found in almost every home. The study of indoor air quality will help prevent or solve issues that may affect the health and the performance of the people.



2.3 PM₁₀ Temporal Monitoring

PM₁₀ or particulate matter that have a diameter of 10 micrometers wide which are classified under fine particles. One study [?] used an internet protocol camera to observe real time changes in the amount of particles found in the air. The camera points to a reference location and the still images were divided into the RGB bands.

They developed an algorithm which makes use of the atmospheric reflectance and the concentration of the PM₁₀ using regression. The amount of reflectance is measured using a spectroradiometer and the concentration of the particles are determined by the different RGB bands of the camera. The PM₁₀ and the atmospheric reflectance are found to be linearly related through using the skylight parameter model, which utilizes the sun's radiation. The results produced were compared to a DustTrak meter and provide a high correlation coefficient of .78.

2.4 Wireless Air Quality Monitoring System

A study [?] monitored the amount of different air pollutants using Arduino. The pollutants that are measured are carbon monoxide, PM_{2.5}, and ozone which make use of the MQ-7 sensor, MQ-131 sensor, and Sharp dust sensor respectively. The sensors are mounted onto a redboard as well as GSM shield to send data wirelessly. The sensors are calibrated using a co-located ADEQ (Air Quality Division) sensor and were validated. The device is placed around the metro area and the data collected will be compared to a monitoring station. Data was collected for a period of time and a trend was found in CO and ozone levels. However, the use of the Sharp dust sensor was not very effective but could find slight differences at high pollution times with low pollution times.



Another similar study [?] of an air monitoring device is implemented using a micro-controller where several sensors are placed and data is sent through GSM wirelessly. The design tests the amount of CO₂ levels indoors. It also measures the temperature and humidity of the atmosphere locally. Calibration of the sensors is done by concentrating known amount of a certain gas into a test chamber and determine its offset from the results obtained. The design was tested in a seminar hall and the results obtained showed that the start and end of each class attributed to the increase in CO₂ emission. The design also shows the data through an online GUI.

One similar design, called HazeWatch, is done using several sensors and cloud computing [?]. The design is made compact and portable and can be mounted onto a car or bike. Data is harvested using a mobile phone and records the location in real time. Data is then sent wirelessly to cloud-based servers and is interpolated (Inverse Weighing and Ordinary Kriging interpolation) to generate estimates. The data can then be view visually using contour maps of the pollution or gas concentration levels in the area. The results obtained are compared to similar products (*Node* and *SensorDrone*)

2.5 Discomfort Index Monitoring System

A research was made about the importance of monitoring and controlling of atmospheric conditions to the efficiency of the performance of the human beings [?] . They designed a wireless sensor module that uses a Zigbee communication and sensor module, which consists of temperature, humidity, CO₂ and atmospheric pressure sensor, that maintains a comfortable environment for human beings or to prevent discomfort. The sensor module is the transmitter which delivers the sensor data to the receiver and the receiver will transmit



the filtered or recovered sensor data to a microcontroller board in monitoring the room environment. The room monitoring system is able to provide a comfortable environment for human beings through the wireless sensor network or WSN for monitoring the room environment.

2.6 Air Quality Standards

This review shows the different indoor air quality standards set by different countries across the world. The data is collected from documents from different health and environmental organization. This paper can be set as a tool for evaluating acceptable concentrations of different pollutants within an area. The pollutants included in this study are "carbon dioxide (CO₂), carbon monoxide (CO), formaldehyde (HCHO), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), total volatile organic compounds (TVOCs) and particulate matter (PM_{2.5} and PM₁₀).” The amount allowable depends on how bad the amount of a certain pollutant exists indoors. The paper also explains different harmful health effects each pollutant has on the human body.



488

Chapter 3

489

THEORETICAL CONSIDERATIONS

490

Contents

491

492

493

3.1	Summary	18
-----	-------------------	----



494 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 495 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 496 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 497 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 498 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 499 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 500 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 501 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 502 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

503 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 504 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 505 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 506 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 507 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 508 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 509 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 510 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 511 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

512 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 513 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 514 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 515 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 516 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 517 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue



518 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 519 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 520 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

521 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 522 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 523 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 524 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 525 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 526 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 527 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 528 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 529 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

530 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 531 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 532 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 533 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 534 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 535 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 536 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 537 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 538 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

539 3.1 Summary

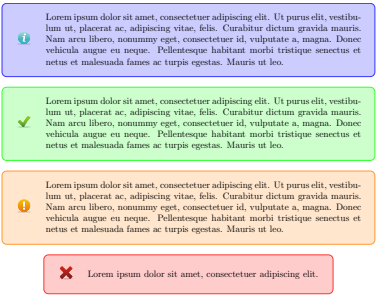


Fig. 3.1 A quadrilateral image example.



540

Chapter 4

541

DESIGN CONSIDERATIONS

542

Contents

543

544

545

4.1 Summary	22
-----------------------	----



546 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 547 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 548 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 549 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 550 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 551 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 552 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 553 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 554 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

555 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 556 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 557 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 558 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 559 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 560 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 561 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 562 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 563 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

564 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 565 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 566 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 567 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 568 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 569 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue



570 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 571 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 572 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

573 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 574 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 575 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 576 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 577 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 578 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 579 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 580 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 581 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

582 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 583 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 584 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 585 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 586 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 587 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 588 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 589 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 590 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

591 4.1 Summary



592

Chapter 5

593

METHODOLOGY

594

Contents

595

596

597

598

599

5.1	Implementation	24
5.2	Evaluation	26
5.3	Summary	28



600 5.1 Implementation

601 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 602 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 603 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 604 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 605 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 606 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 607 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 608 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 609 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

610 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 611 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 612 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 613 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 614 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 615 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 616 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 617 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 618 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

619 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 620 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 621 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 622 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.



623 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 624 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 625 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 626 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 627 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

628 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 629 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 630 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 631 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 632 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 633 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 634 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 635 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 636 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

637 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 638 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 639 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 640 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 641 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 642 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 643 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 644 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 645 amet ipsum. Nunc quis urna dictum turpis accumsan semper.



646 5.2 Evaluation

647 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 648 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 649 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 650 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 651 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 652 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 653 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 654 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 655 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

656 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 657 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 658 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 659 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 660 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 661 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 662 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 663 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 664 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

665 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 666 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 667 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 668 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.



669 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 670 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 671 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 672 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 673 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

674 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 675 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 676 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 677 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 678 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 679 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 680 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 681 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 682 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

683 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 684 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 685 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 686 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 687 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 688 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 689 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 690 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 691 amet ipsum. Nunc quis urna dictum turpis accumsan semper.



692

5.3 Summary



693

Chapter 6

694

RESULTS AND DISCUSSION

695

Contents

696

697

698

6.1 Summary	31
-----------------------	----



699 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 700 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 701 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 702 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 703 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 704 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 705 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 706 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 707 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

708 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 709 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 710 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 711 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 712 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 713 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 714 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 715 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 716 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

717 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 718 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 719 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 720 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 721 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 722 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue



723 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 724 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 725 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

726 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 727 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 728 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 729 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 730 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 731 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 732 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 733 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 734 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

735 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 736 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 737 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 738 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 739 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 740 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 741 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 742 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 743 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

744 6.1 Summary



Chapter 7

CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIRECTIVES

Contents

7.1	Concluding Remarks	33
7.2	Contributions	33
7.3	Recommendations	33
7.4	Future Prospects	35



7.1 Concluding Remarks

In this Thesis, . . .

7.2 Contributions

The interrelated contributions and supplements that have been developed in this Thesis are listed as follows.

- the ;

- the ;

- the ;

7.3 Recommendations

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.



773 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 774 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 775 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 776 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 777 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 778 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 779 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 780 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 781 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

782 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 783 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 784 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 785 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 786 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 787 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 788 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 789 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 790 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

791 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 792 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 793 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 794 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 795 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 796 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue



797 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 798 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 799 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

800 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 801 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 802 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 803 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 804 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 805 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 806 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 807 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 808 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

809 7.4 Future Prospects

810 There are several prospect related in this research that may be extended for further studies.
 811 ... So the suggested topics are listed in the following.

812 1. the

813 2. the

814 3. the



REFERENCES

- [Aji Hanggoro and Sari, 2013] Aji Hanggoro, Mahesa Adhitya Putra, R. R. and Sari, R. F. (2013). Green house monitoring and controlling using android mobile application. *Quality in Research* 2013.
- [Chavan and V.Karande, 2014] Chavan, P. C. H. and V.Karande, M. (2014). Wireless monitoring of soil moisture, temperature & humidity using zigbee in agriculture. *International Journal of Engineering Trends and Technology (IJETT)*.
- [Folea and Mois, 2015] Folea, S. C. and Mois, G. (2015). A low-power wireless sensor for online ambient monitoring. *IEEE SENSORS JOURNAL*.
- [Hebbar et al., 2014] Hebbar, S., V, K., K, K. G., Kumar, A., Kumari, A. S. A., Yasasvi, R., Gupta, A. K., Mishra, V., Amrutur, B., and Bhat, N. (2014). System engineering and deployment of envirobat an urban air pollution monitoring device. In *Electronics, Computing and Communication Technologies (IEEE CONECCT), 2014 IEEE International Conference on*, pages 1–6.
- [Hu et al., 2016] Hu, K., Sivaraman, V., Luxan, B. G., and Rahman, A. (2016). Design and evaluation of a metropolitan air pollution sensing system. *IEEE Sensors Journal*, 16(5):1448–1459.
- [ISO, 2009] ISO (2009). 80000-2. *Quantities and units–Part 2: Mathematical signs and symbols to be used in the natural sciences and technology*.
- [Mohamed Abd El-Latif Mowad, 2014] Mohamed Abd El-Latif Mowad, Ahmed Fathy, A. H. (2014). Smart home automated control system using android application and microcontroller. *International Journal of Scientific & Engineering Research*.
- [Noh et al., 2013] Noh, S.-K., Kim, K.-S., and Ji, Y.-K. (2013). Design of a room monitoring system for wireless sensor networks. *International Journal of Distributed Sensor Networks*.
- [Oetiker et al., 2014] Oetiker, T., Partl, H., Hyna, I., and Schlegl, E. (2014). *The Not So Short Introduction to L^AT_EX 2_ε Or L^AT_EX 2_ε in 157 minutes*. n.a.
- [Reilly et al., 2015] Reilly, K. M., Birner, M. T., and Johnson, N. G. (2015). Measuring air quality using wireless self-powered devices. In *Global Humanitarian Technology Conference (GHTC), 2015 IEEE*, pages 267–272.
- [Wong et al., 2007] Wong, C. J., MatJafri, M. Z., Abdullah, K., Lim, H. S., and Low, K. L. (2007). Temporal air quality monitoring using surveillance camera. In *2007 IEEE International Geoscience and Remote Sensing Symposium*, pages 2864–2868.



Appendix A ANSWERS TO QUESTIONS TO THIS THESIS

Contents

A1	How important is the problem to practice?	38
A2	How will you know if the solution/s that you will achieve would be better than existing ones?	38
A2.1	How will you measure the improvement/s?	38
A2.1.1	What is/are your basis/bases for the improvement/s? . .	39
A2.1.2	Why did you choose that/those basis/bases?	39
A2.1.3	How significant are your measure/s of the improvement/s? .	39
A3	What is the difference of the solution/s from existing ones?	40
A3.1	How is it different from previous and existing ones?	40
A4	What are the assumptions made (that are behind for your proposed solution to work)?	40
A4.1	Will your proposed solution/s be sensitive to these assumptions? .	41
A4.2	Can your proposed solution/s be applied to more general cases when some of the assumptions are eliminated? If so, how?	41
A5	What is the necessity of your approach / proposed solution/s?	41
A5.1	What will be the limits of applicability of your proposed solution/s? .	42
A5.2	What will be the message of the proposed solution to technical people? How about to non-technical managers and business men? .	42
A6	How will you know if your proposed solution/s is/are correct?	42
A6.1	Will your results warrant the level of mathematics used (i.e., will the end justify the means)?	43
A7	Is/are there an/_ alternative way/s to get to the same solution/s?	43
A7.1	Can you come up with illustrating examples, or even better, counter examples to your proposed solution/s?	43
A7.2	Is there an approximation that can arrive at the essentially the same proposed solution/s more easily?	44
A8	If you were the examiner of your proposal, how would you present the proposal in another way?	44
A8.1	What are the weaknesses of your proposal?	44



882 **A1 How important is the problem to practice?**

883 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 884 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 885 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 886 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 887 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 888 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 889 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 890 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 891 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

892 **A2 How will you know if the solution/s that you will** 893 **achieve would be better than existing ones?**

894 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 895 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 896 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 897 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 898 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 899 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 900 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 901 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 902 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

903 **A2.1 How will you measure the improvement/s?**

904 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 905 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 906 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 907 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 908 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 909 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 910 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 911 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 912 amet ipsum. Nunc quis urna dictum turpis accumsan semper.



913 **A2.1.1 What is/are your basis/bases for the improvement/s?**

914 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 915 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 916 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 917 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 918 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 919 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 920 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 921 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 922 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

923 **A2.1.2 Why did you choose that/those basis/bases?**

924 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 925 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 926 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 927 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 928 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 929 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 930 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 931 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 932 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

933 **A2.1.3 How significant are your measure/s of the improvement/s?**

934 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 935 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 936 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 937 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 938 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 939 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 940 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 941 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 942 amet ipsum. Nunc quis urna dictum turpis accumsan semper.



943

944

A3 What is the difference of the solution/s from existing ones?

945

946

947

948

949

950

951

952

953

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

954

A3.1 How is it different from previous and existing ones?

955

956

957

958

959

960

961

962

963

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

964

965

A4 What are the assumptions made (that are behind for your proposed solution to work)?

966

967

968

969

970

971

972

973

974

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.



975 **A4.1 Will your proposed solution/s be sensitive to these as-**
 976 **sumptions?**

977 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 978 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 979 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 980 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 981 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 982 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 983 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 984 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 985 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

986 **A4.2 Can your proposed solution/s be applied to more general**
 987 **cases when some of the assumptions are eliminated? If**
 988 **so, how?**

989 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 990 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 991 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 992 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 993 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 994 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 995 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 996 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 997 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

998 **A5 What is the necessity of your approach / pro-**
 999 **posed solution/s?**

1000 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 1001 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 1002 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 1003 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 1004 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 1005 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 1006 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.



1007 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1008 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1009 **A5.1 What will be the limits of applicability of your proposed so-**
1010 **lution/s?**

1011 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
1012 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
1013 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
1014 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
1015 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
1016 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1017 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1018 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1019 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1020 **A5.2 What will be the message of the proposed solution to**
1021 **technical people? How about to non-technical managers**
1022 **and business men?**

1023 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
1024 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
1025 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
1026 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
1027 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
1028 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1029 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1030 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1031 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1032 **A6 How will you know if your proposed solution/s**
1033 **is/are correct?**

1034 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
1035 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
1036 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
1037 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
1038 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla



1039 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1040 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1041 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1042 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1043 **A6.1 Will your results warrant the level of mathematics used**
1044 **(i.e., will the end justify the means)?**

1045 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
1046 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
1047 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
1048 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
1049 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
1050 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1051 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1052 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1053 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1054 **A7 Is/are there an/_ alternative way/s to get to the**
1055 **same solution/s?**

1056 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
1057 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
1058 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
1059 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
1060 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
1061 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1062 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1063 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1064 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1065 **A7.1 Can you come up with illustrating examples, or even bet-**
1066 **ter, counter examples to your proposed solution/s?**

1067 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
1068 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
1069 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
1070 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.



1071 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
1072 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1073 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1074 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1075 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1076 **A7.2 Is there an approximation that can arrive at the essen-** 1077 **tially the same proposed solution/s more easily?**

1078 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
1079 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
1080 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
1081 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
1082 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
1083 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1084 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1085 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1086 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1087 **A8 If you were the examiner of your proposal, how** 1088 **would you present the proposal in another way?**

1089 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
1090 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
1091 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
1092 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
1093 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
1094 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1095 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1096 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1097 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1098 **A8.1 What are the weaknesses of your proposal?**

1099 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
1100 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
1101 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
1102 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.



De La Salle University

1103 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
1104 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
1105 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
1106 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
1107 amet ipsum. Nunc quis urna dictum turpis accumsan semper.



De La Salle University

1108

Appendix B

1109

USAGE EXAMPLES



The user is expected to have a working knowledge of \LaTeX . A good introduction is in [Oetiker et al., 2014]. Its latest version can be accessed at <http://www.ctan.org/tex-archive/info/lshort>.

B1 Equations

The following examples show how to typeset equations in \LaTeX . This section also shows examples of the use of `\gls{ }` commands in conjunction with the items that are in the `notation.tex` file. **Please make sure that the entries in `notation.tex` are those that are referenced in the \LaTeX document files used by this Thesis. Please comment out unused notations and be careful with the commas and brackets in `notation.tex`.**

In (B.1), the output signal $y(t)$ is the result of the convolution of the input signal $x(t)$ and the impulse response $h(t)$.

$$y(t) = h(t) * x(t) = \int_{-\infty}^{+\infty} h(t - \tau) x(\tau) d\tau \quad (\text{B.1})$$

Other example equations are as follows.

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix} \quad (\text{B.2})$$

$$\frac{1}{2} < \left[\text{mod} \left(\left\lfloor \frac{y}{17} \right\rfloor 2^{-17\lfloor x \rfloor - \text{mod}(\lfloor y \rfloor, 17)}, 2 \right) \right], \quad (\text{B.3})$$

$$|\zeta(x)^3 \zeta(x + iy)^4 \zeta(x + 2iy)| = \exp \sum_{n,p} \frac{3 + 4 \cos(ny \log p) + \cos(2ny \log p)}{np^{nx}} \geq 1 \quad (\text{B.4})$$



1123

The verbatim L^AT_EX code of Sec. B1 is in List. B.1.

Listing B.1: Sample L^AT_EX code for equations and notations usage

```

1 The following examples show how to typeset equations in \LaTeX.
2
3 In~\eqref{eq:conv}, the output signal \gls{not:output_sigt} is the
  result of the convolution of the input signal \gls{not:input_sigt}
  and the impulse response \gls{not:ir}.
4
5 \begin{eqnarray}
6   y\left( t \right) = h\left( t \right) * x\left( t \right)=\int_{-\infty}^{+\infty}h\left( t-\tau \right)x\left( \tau \right) \mathrm{d}\tau
7   \label{eq:conv}
8 \end{eqnarray}
9
10 Other example equations are as follows.
11
12 \begin{eqnarray}
13   \left[ \dfrac{V_{1}}{I_{1}} \right] =
14   \begin{bmatrix}
15     A & B \\
16     C & D
17   \end{bmatrix}
18   \left[ \dfrac{V_{2}}{I_{2}} \right]
19   \label{eq:ABCD}
20 \end{eqnarray}
21
22 \begin{eqnarray}
23   {1\over 2} < \left\lfloor \mathrm{mod}\right\left(\left\lfloor {y \over 17} \right\rfloor 2^{-17} \lfloor x \rfloor - \mathrm{mod}(\lfloor y \rfloor, 17)\right)\right\rfloor, 2\right)\right\rfloor,
24 \end{eqnarray}
25
26 \begin{eqnarray}
27   \left| \zeta(x)^3 \zeta(x+iy)^4 \zeta(x+2iy) \right| =
28   \exp\sum_{n,p}\frac{3+4\cos(ny\log p) +\cos(2ny\log p)}{n^p}\geq 1
29 \end{eqnarray}

```



B2 Notations

In order to use the standardized notation, the user is highly suggested to see the ISO 80000-2 standard [ISO, 2009]. The following were taken from `isomath-test.tex`.

Math alphabets

If there are other symbols in place of Greek letters in a math alphabet, it uses T1 or OT1 font encoding instead of OML.

<code>mathnormal</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
<code>mathit</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \textit{ff}, \textit{fi}, \beta, ^\circ, !, v, w, 0, 1, 9$
<code>mathrm</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \text{ff}, \text{fi}, \beta, ^\circ, !, v, w, 0, 1, 9$
<code>mathbf</code>	$\mathbf{A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, ff, fi, \beta, ^\circ, !, v, w, 0, 1, 9}$
<code>mathsf</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \text{ff}, \text{fi}, \beta, ^\circ, !, v, w, 0, 1, 9$
<code>mathtt</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \uparrow, \downarrow, \beta, ^\circ, !, v, w, 0, 1, 9$

New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-italic.

<code>mathbfit</code>	$\mathbf{A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9}$
<code>mathsf</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
<code>mathsfbfit</code>	$\mathbf{A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9}$

Do the math alphabets match?

$\alpha x \alpha \omega \mathbf{a x} \alpha \omega \mathbf{a x} \alpha \omega \quad T C \Theta \Gamma T C \Theta \Gamma T C \Theta \Gamma$

Vector symbols

Alphabetic symbols for vectors are boldface italic, $\lambda = e_1 \cdot \mathbf{a}$, while numeric ones (e.g. the zero vector) are bold upright, $\mathbf{a} + \mathbf{0} = \mathbf{a}$.

Matrix symbols

Symbols for matrices are boldface italic, too:¹ $\mathbf{A} = \mathbf{E} \cdot \mathbf{A}$.

¹However, matrix symbols are usually capital letters whereas vectors are small ones. Exceptions are physical quantities like the force vector \mathbf{F} or the electrical field \mathbf{E} .



1138 **Tensor symbols**

1139 Symbols for tensors are sans-serif bold italic,

$$\boldsymbol{\alpha} = \boldsymbol{e} \cdot \boldsymbol{a} \quad \Longleftrightarrow \quad \alpha_{ijl} = e_{ijk} \cdot a_{kl}.$$

1140 The permittivity tensor describes the coupling of electric field and displacement:

$$\boldsymbol{D} = \epsilon_0 \boldsymbol{\epsilon}_r \boldsymbol{E}$$



Bold math version

The “bold” math version is selected with the commands `\boldmath` or `\mathversion{bold}`

<code>mathnormal</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
<code>mathit</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \textit{ff}, \textit{fi}, \beta, ^\circ, !, v, w, 0, 1, 9$
<code>mathrm</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \text{ff}, \text{fi}, \beta, ^\circ, !, v, w, 0, 1, 9$
<code>mathbf</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \text{ff}, \text{fi}, \beta, ^\circ, !, v, w, 0, 1, 9$
<code>mathsf</code>	$\mathbf{A}, \mathbf{B}, \mathbf{\Gamma}, \mathbf{\Delta}, \mathbf{\Theta}, \mathbf{\Lambda}, \mathbf{\Xi}, \mathbf{\Pi}, \mathbf{\Sigma}, \mathbf{\Phi}, \mathbf{\Psi}, \mathbf{\Omega}, \text{ff}, \text{fi}, \beta, ^\circ, !, v, w, 0, 1, 9$
<code>mathtt</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \uparrow, \downarrow, \beta, ^\circ, !, v, w, 0, 1, 9$

New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-italic.

<code>mathbfit</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
<code>mathsfit</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
<code>mathsfbfit</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$

Do the math alphabets match?

$\alpha x \alpha \omega a x \alpha \omega a x \alpha \omega \quad TC\Theta\Gamma TC\Theta\Gamma TC\Theta\Gamma$

Vector symbols

Alphabetic symbols for vectors are boldface italic, $\lambda = e_1 \cdot a$, while numeric ones (e.g. the zero vector) are bold upright, $a + 0 = a$.

Matrix symbols

Symbols for matrices are boldface italic, too:² $\Lambda = E \cdot A$.

Tensor symbols

Symbols for tensors are sans-serif bold italic,

$$\alpha = e \cdot a \iff \alpha_{ijl} = e_{ijk} \cdot a_{kl}.$$

The permittivity tensor describes the coupling of electric field and displacement:

$$D = \epsilon_0 \epsilon_r E$$

²However, matrix symbols are usually capital letters whereas vectors are small ones. Exceptions are physical quantities like the force vector F or the electrical field E .



1155 The verbatim \LaTeX code of Sec. B2 is in List. B.2.

Listing B.2: Sample \LaTeX code for notations usage

```

1156 1 % A teststring with Latin and Greek letters::
1157 2 \newcommand{\teststring}{%
1158 3 % capital Latin letters
1159 4 % A,B,C,
1160 5 A,B,
1161 6 % capital Greek letters
1162 7 %\Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Upsilon,\Phi,\Psi,
1163 8 \Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,
1164 9 % small Greek letters
1165 10 \alpha,\beta,\pi,\nu,\omega,
1166 11 % small Latin letters:
1167 12 % compare \nu, \omega, v, and w
1168 13 v,w,
1169 14 % digits
1170 15 0,1,9
1171 16 }
1172 17
1173 18
1174 19 \subsection*{Math alphabets}
1175 20
1176 21 If there are other symbols in place of Greek letters in a math
1177 22 alphabet, it uses T1 or OT1 font encoding instead of OML.
1178 23
1179 24 \begin{eqnarray*}
1180 25 \mbox{\mathnormal} & & \mbox{\teststring} \\
1181 26 \mbox{\mathit} & & \mbox{\mathit{\teststring}} \\
1182 27 \mbox{\mathrm} & & \mbox{\mathrm{\teststring}} \\
1183 28 \mbox{\mathbf} & & \mbox{\mathbf{\teststring}} \\
1184 29 \mbox{\mathsf} & & \mbox{\mathsf{\teststring}} \\
1185 30 \mbox{\mathtt} & & \mbox{\mathtt{\teststring}} \\
1186 31 \end{eqnarray*}
1187 32 New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
1188 33 italic.
1189 34 \begin{eqnarray*}
1190 35 \mbox{\mathbfit} & & \mbox{\mathbfit{\teststring}} \\
1191 36 \mbox{\mathsfit} & & \mbox{\mathsfit{\teststring}} \\
1192 37 \mbox{\mathsfbfit} & & \mbox{\mathsfbfit{\teststring}} \\
1193 38 \end{eqnarray*}
1194 39 %
1195 40 Do the math alphabets match?
1196 41 $
1197 42 \mathnormal {a x \alpha \omega}
1198 43 \mathbfit {a x \alpha \omega}
1199 44 \mathsfbfit{a x \alpha \omega}
1200 45 \quad
1201 46 \mathsfbfit{T C \Theta \Gamma}
1202 47 \mathbfit {T C \Theta \Gamma}
1203 48 \mathnormal {T C \Theta \Gamma}
1204 49 $
1205 50
1206 51 \subsection*{Vector symbols}
1207 52

```



```

1210 53 Alphabetic symbols for vectors are boldface italic,
1211 54  $\vec{\lambda} = \vec{e}_1 \cdot \vec{a}$ ,
1212 55 while numeric ones (e.g. the zero vector) are bold upright,
1213 56  $\vec{a} + \vec{0} = \vec{a}$ .
1214 57
1215 58 \subsection*{Matrix symbols}
1216 59
1217 60 Symbols for matrices are boldface italic, too:%
1218 61 \footnote{However, matrix symbols are usually capital letters whereas
1219 62 vectors
1220 62 are small ones. Exceptions are physical quantities like the force
1221 63 vector  $\vec{F}$  or the electrical field  $\vec{E}$ .%
1222 64 }
1223 65  $\Lambda = E \cdot A$ .
1224 66
1225 67
1226 68 \subsection*{Tensor symbols}
1227 69
1228 70 Symbols for tensors are sans-serif bold italic,
1229 71
1230 72 \[
1231 73 \quad \text{\textit{\textbf{tensorsym{\alpha}}}} = \text{\textit{\textbf{tensorsym{e}}}} \cdot \text{\textit{\textbf{tensorsym{a}}}}
1232 74 \quad \quad \quad \Longleftrightarrow \quad \quad \quad
1233 75 \quad \text{\textit{\textbf{\alpha}_{ijl}}} = \text{\textit{\textbf{e}_{ijk}}} \cdot \text{\textit{\textbf{a}_{kl}}}.
1234 76 \]
1235 77
1236 78
1237 79 The permittivity tensor describes the coupling of electric field and
1238 80 displacement: \[
1239 81 \text{\textit{\textbf{D}}} = \epsilon_0 \text{\textit{\textbf{tensorsym{\epsilon}}}_{\mathrm{r}}} \text{\textit{\textbf{E}}} \]
1240 82
1241 83
1242 84
1243 85 \newpage
1244 86 \subsection*{Bold math version}
1245 87
1246 88 The ‘‘bold’’ math version is selected with the commands
1247 89 \verb+\boldmath+ or \verb+\mathversion{bold}+
1248 90
1249 91 {\boldmath
1250 92 \begin{eqnarray*}
1251 93 \quad \text{\textit{\textbf{mbox{mathnormal}}}} & & \text{\textit{\textbf{\teststring}}} \\
1252 94 \quad \text{\textit{\textbf{mbox{mathit}}}} & & \text{\textit{\textbf{mathit{\teststring}}}} \\
1253 95 \quad \text{\textit{\textbf{mbox{mathrm}}}} & & \text{\textit{\textbf{mathrm{\teststring}}}} \\
1254 96 \quad \text{\textit{\textbf{mbox{mathbf}}}} & & \text{\textit{\textbf{mathbf{\teststring}}}} \\
1255 97 \quad \text{\textit{\textbf{mbox{mathsf}}}} & & \text{\textit{\textbf{mathsf{\teststring}}}} \\
1256 98 \quad \text{\textit{\textbf{mbox{mathtt}}}} & & \text{\textit{\textbf{mathtt{\teststring}}}} \\
1257 99 \end{eqnarray*}
1258 100 \quad \text{New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-}
1259 101 \quad \text{italic.}
1260 102 \begin{eqnarray*}
1261 102 \quad \text{\textit{\textbf{mbox{mathbfit}}}}} & & \text{\textit{\textbf{mathbfit{\teststring}}}} \\
1262 103 \quad \text{\textit{\textbf{mbox{mathsfif}}}}} & & \text{\textit{\textbf{mathsfif{\teststring}}}} \\
1263 104 \quad \text{\textit{\textbf{mbox{mathsfbfit}}}}} & & \text{\textit{\textbf{mathsfbfit{\teststring}}}} \\
1264 105 \end{eqnarray*}
1265 106 \%
1266 107 Do the math alphabets match?

```



```

1267 108 $
1268 109 \mathnormal {a x \alpha \omega}
1269 110 \mathbfit {a x \alpha \omega}
1270 111 \mathsfbfit{a x \alpha \omega}
1271 112 \quad
1272 113 \mathsfbfit{T C \Theta \Gamma}
1273 114 \mathbfit {T C \Theta \Gamma}
1274 115 \mathnormal {T C \Theta \Gamma}
1275 116 $
1276 117
1277 118 \subsection*{Vector symbols}
1278 119
1279 120
1280 121 Alphabetic symbols for vectors are boldface italic,
1281 122 $\vec{\lambda}=\vec{e}_{1}\cdot\vec{a}$,
1282 123 while numeric ones (e.g. the zero vector) are bold upright,
1283 124 $\vec{a} + \vec{0} = \vec{a}$.
1284 125
1285 126
1286 127
1287 128 \subsection*{Matrix symbols}
1288 129
1289 130 Symbols for matrices are boldface italic, too:%
1290 131 \footnote{However, matrix symbols are usually capital letters whereas
1291 132 vectors
1292 133 are small ones. Exceptions are physical quantities like the force
1293 134 vector $\vec{F}$ or the electrical field $\vec{E}$.%
1294 135 }
1295 136 $\matrixsym{\Lambda}=\matrixsym{E}\cdot\matrixsym{A}$.
1296 137
1297 138
1298 139 \subsection*{Tensor symbols}
1299 140
1300 141 Symbols for tensors are sans-serif bold italic,
1301 142
1302 143 \[
1303 144 \tensorsym{\alpha} = \tensorsym{e}\cdot\tensorsym{a}
1304 145 \quad \Longleftarrow \quad
1305 146 \alpha_{ijl} = e_{ijk}\cdot a_{kl}.
1306 147 \]
1307 148
1308 149 The permittivity tensor describes the coupling of electric field and
1309 150 displacement: \[
1310 151 \vec{D}=\epsilon_{0}\tensorsym{\epsilon}_{\mathrm{r}}\vec{E}\]
1311 152 }
1312 153

```



B3 Abbreviation

This section shows examples of the use of \LaTeX commands in conjunction with the items that are in the `abbreviation.tex` and in the `glossary.tex` files. Please see List. B.3. **To lessen the \LaTeX compilation time, it is suggested that you use `\acr{ }` only for the first occurrence of the word to be abbreviated.**

Again please see List. B.3. Here is an example of first use: alternating current (ac). Next use: ac. Full: alternating current (ac). Here's an acronym referenced using `\acr` : hyper-text markup language (html). And here it is again: html. If you are used to the glossaries package, note the difference in using `\gls` : hyper-text markup language (html). And again (no difference): hyper-text markup language (html). Here are some more entries:

- extensible markup language (xml) and cascading style sheet (css).
- Next use: xml and css.
- Full form: extensible markup language (xml) and cascading style sheet (css).
- Reset again.
- Start with a capital. Hyper-text markup language (html).
- Next: Html. Full: Hyper-text markup language (html).
- Prefer capitals? Extensible markup language (XML). Next: XML. Full: extensible markup language (XML).
- Prefer small-caps? Cascading style sheet (CSS). Next: CSS. Full: cascading style sheet (CSS).
- Resetting all acronyms.
- Here are the acronyms again:
- Hyper-text markup language (HTML), extensible markup language (XML) and cascading style sheet (CSS).
- Next use: HTML, XML and CSS.
- Full form: Hyper-text markup language (HTML), extensible markup language (XML) and cascading style sheet (CSS).



- 1343 • Provide your own link text: style sheet.

1344 The verbatim \LaTeX code of Sec. B3 is in List. B.3.

Listing B.3: Sample \LaTeX code for abbreviations usage

```

1 Again please see List.~\ref{lst:abbrv}. Here is an example of first use:
  \acr{ac}. Next use: \acr{ac}. Full: \gls{ac}. Here's an acronym
  referenced using \verb| \acr |: \acr{html}. And here it is again: \
  acr{html}. If you are used to the \texttt{glossaries} package, note
  the difference in using \verb| \gls |: \gls{html}. And again (no
  difference): \gls{html}. Here are some more entries:
2
3 \begin{itemize}
4
5   \item \acr{xml} and \acr{css}.
6
7   \item Next use: \acr{xml} and \acr{css}.
8
9   \item Full form: \gls{xml} and \gls{css}.
10
11  \item Reset again. \glsresetall{abbreviation}
12
13  \item Start with a capital. \Acr{html}.
14
15  \item Next: \Acr{html}. Full: \Gls{html}.
16
17  \item Prefer capitals? \renewcommand{\acronymfont}[1]{\
    MakeTextUppercase{#1}} \Acr{xml}. Next: \acr{xml}. Full: \gls{xml}
    }.
18
19  \item Prefer small-caps? \renewcommand{\acronymfont}[1]{\textsc{#1}}
    \Acr{css}. Next: \acr{css}. Full: \gls{css}.
20
21  \item Resetting all acronyms.\glsresetall{abbreviation}
22
23  \item Here are the acronyms again:
24
25  \item \Acr{html}, \acr{xml} and \acr{css}.
26
27  \item Next use: \Acr{html}, \acr{xml} and \acr{css}.
28
29  \item Full form: \Gls{html}, \gls{xml} and \gls{css}.
30
31  \item Provide your own link text: \glslink{[textbf]css}{style}
32
33 \end{itemize}

```



B4 Glossary

This section shows examples of the use of `\gls{ }` commands in conjunction with the items that are in the `glossary.tex` and `notation.tex` files. Note that entries in `notation.tex` are prefixed with “not:” label (see List. B.4).

Please make sure that the entries in `notation.tex` are those that are referenced in the \LaTeX document files used by this Thesis. Please comment out unused notations and be careful with the commas and brackets in `notation.tex`.

- Matrices are usually denoted by a bold capital letter, such as A . The matrix’s (i, j) th element is usually denoted a_{ij} . Matrix I is the identity matrix.
- A set, denoted as S , is a collection of objects.
- The universal set, denoted as \mathcal{U} , is the set of everything.
- The empty set, denoted as \emptyset , contains no elements.
- The cardinality of a set, denoted as $|S|$, is the number of elements in the set.

The verbatim \LaTeX code for the part of Sec. B4 is in List. B.4.

Listing B.4: Sample \LaTeX code for glossary and notations usage

```

1 \begin{itemize}
2
3   \item \Glspl{matrix} are usually denoted by a bold capital letter,
      such as  $\mathbf{A}$ . The  $\gls{matrix}$ ’s  $(i, j)$ th element is
      usually denoted  $a_{ij}$ .  $\gls{matrix}$   $\mathbf{I}$  is the
      identity  $\gls{matrix}$ .
4
5   \item A set, denoted as  $\gls{not:set}$ , is a collection of objects.
6
7   \item The universal set, denoted as  $\gls{not:universalSet}$ , is the
      set of everything.
8
9   \item The empty set, denoted as  $\gls{not:emptySet}$ , contains no
      elements.
10
11   \item The cardinality of a set, denoted as  $\gls{not:cardinality}$ , is
      the number of elements in the set.
12
13 \end{itemize}
```




1359

B5 Figure

1360

1361

This section shows several ways of placing figures. PDFL^AT_EX compatible files are PDF, PNG, and JPG. Please see the `figure` subdirectory.

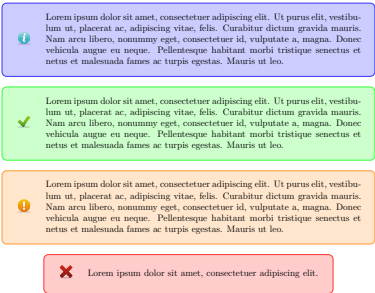


Fig. B.1 A quadrilateral image example.



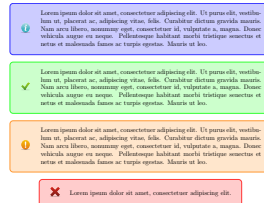
1362 Fig. B.1 is a gray box enclosed by a dark border. List. B.5 shows the corresponding
1363 L^AT_EX code.

Listing B.5: Sample L^AT_EX code for a single figure

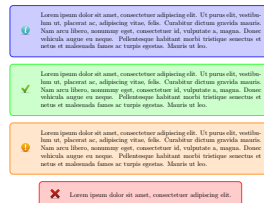
```
1 \begin{figure}[!htbp]
2   \centering
3   \includegraphics[width=0.5\textwidth]{example}
4   \caption{A quadrilateral image example.}
5   \label{fig:example}
6 \end{figure}
7 \cleardoublepage
8
9 Fig.~\ref{fig:example} is a gray box enclosed by a dark border. List.~\
  ref{lst:onefig} shows the corresponding \LaTeX \ code.
10 \end{figure}
```



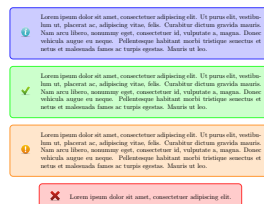
De La Salle University



(a) A sub-figure in the top row.



(b) A sub-figure in the middle row.

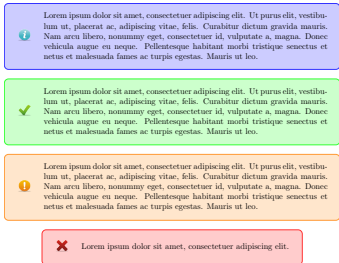


(c) A sub figure in the bottom row

Listing B.6: Sample L^AT_EX code for three figures on top of each other

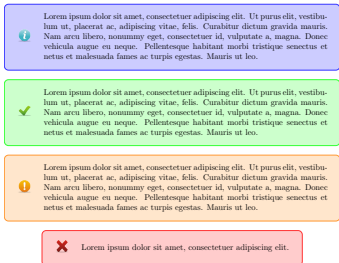
```
1 \begin{figure}[!htbp]
2 \centering
3 \subbottom[A sub-figure in the top row.]{
4 \includegraphics[width=0.35\textwidth]{example}
5 \label{fig:top}
6 }
7 \vfill
8 \subbottom[A sub-figure in the middle row.]{
9 \includegraphics[width=0.35\textwidth]{example}
10 \label{fig:mid}
11 }
12 \vfill
13 \subbottom[A sub-figure in the bottom row.]{
14 \includegraphics[width=0.35\textwidth]{example}
15 \label{fig:botm}
16 }
17 \caption{Figures on top of each other}
18 \label{fig:tmb}
19 \end{figure}
```

B. Usage Examples



(a) A sub-figure in the upper-left corner.

(b) A sub-figure in the upper-right corner.



(c) A sub-figure in the lower-left corner.

(d) A sub-figure in the lower-right corner

Fig. B.3 Four figures in each corner. See List. B.7 for the corresponding \LaTeX code.

Listing B.7: Sample \LaTeX code for the four figures

```

1 \begin{figure}[!htbp]
2 \centering
3 \subbottom[A sub-figure in the upper-left corner.]{
4 \includegraphics[width=0.45\textwidth]{example}
5 \label{fig:upprleft}
6 }
7 \hfill
8 \subbottom[A sub-figure in the upper-right corner.]{
9 \includegraphics[width=0.45\textwidth]{example}
10 \label{fig:uppright}
11 }
12 \vfill
13 \subbottom[A sub-figure in the lower-left corner.]{
14 \includegraphics[width=0.45\textwidth]{example}
15 \label{fig:lowerleft}
16 }
17 \hfill
18 \subbottom[A sub-figure in the lower-right corner]{
19 \includegraphics[width=0.45\textwidth]{example}
20 \label{fig:lowright}
21 }
22 \caption{Four figures in each corner. See List.\ref{lst:fourfigs} for
23 the corresponding \LaTeX \ code.}
24 \label{fig:fourfig}
25 \end{figure}

```



B6 Table

This section shows an example of placing a table (a long one). Table B.1 are the triples.

TABLE B.1 FEASIBLE TRIPLES FOR HIGHLY VARIABLE GRID

Time (s)	Triple chosen	Other feasible triples
0	(1, 11, 13725)	(1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0)
2745	(1, 12, 10980)	(1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0)
5490	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
8235	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
10980	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
13725	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
16470	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
19215	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
21960	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
24705	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
27450	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
30195	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
32940	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
35685	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
38430	(1, 13, 10980)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
41175	(1, 12, 13725)	(1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
43920	(1, 13, 10980)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
46665	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
49410	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
52155	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
54900	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
57645	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
60390	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
63135	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
65880	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
68625	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
71370	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
74115	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
76860	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
79605	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
82350	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
85095	(1, 12, 13725)	(1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
87840	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
90585	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
93330	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
96075	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
98820	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
101565	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
104310	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
107055	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
109800	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
112545	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
115290	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
118035	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
120780	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
123525	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)

Continued on next page



Continued from previous page

Time (s)	Triple chosen	Other feasible triples
126270	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
129015	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
131760	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
134505	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
137250	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
139995	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
142740	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
145485	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
148230	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
150975	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
153720	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
156465	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
159210	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
161955	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
164700	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)



1367

List. B.8 shows the corresponding \LaTeX code.

Listing B.8: Sample \LaTeX code for making typical table environment

```

1368 1 \begin{center}
1369 2 {\scriptsize
1370 3 \begin{tabularx}{\textwidth}{p{0.1\textwidth}|p{0.2\textwidth}|p{0.5\textwidth}}
1371 4 \caption{Feasible triples for highly variable grid} \label{tab:triple_
1372 5 grid} \\
1373 6 \hline
1374 7 \textbf{Time (s)} &
1375 8 \textbf{Triple chosen} &
1376 9 \textbf{Other feasible triples} \\
1377 10 \hline
1378 11 \endfirsthead
1379 12 \multicolumn{3}{c}{\textit{Continued from previous page}} \\
1380 13 \hline
1381 14 \hline
1382 15 \textbf{Time (s)} &
1383 16 \textbf{Triple chosen} &
1384 17 \textbf{Other feasible triples} \\
1385 18 \hline
1386 19 \endhead
1387 20 \hline
1388 21 \multicolumn{3}{r}{\textit{Continued on next page}} \\
1389 22 \endfoot
1390 23 \hline
1391 24 \endlastfoot
1392 25 \hline
1393 26
1394 27
1395 28 0 & (1, 11, 13725) & (1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0) \\
1396 29 & & \\
1397 30 2745 & (1, 12, 10980) & (1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0) \\
1398 31 & & \\
1399 32 5490 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1400 33 8235 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1401 34 & & \\
1402 35 10980 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1403 36 & & \\
1404 37 13725 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1405 38 & & \\
1406 39 16470 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1407 40 19215 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1408 41 & & \\
1409 42 21960 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1410 43 & & \\
1411 44 24705 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1412 45 & & \\
1413 46 27450 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1414 47 & & \\
1415 48 30195 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1416 49 32940 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1417 50 35685 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1418 51 38430 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1419 52 & & \\
1420 53 & & \\
1421 54 & &

```



```

1422 43 41175 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1423 0) \\
1424 44 43920 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1425 45 46665 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1426 46 49410 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1427 47 52155 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1428 0) \\
1429 48 54900 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1430 49 57645 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1431 50 60390 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1432 51 63135 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1433 52 65880 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1434 53 68625 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1435 54 71370 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1436 55 74115 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1437 56 76860 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1438 57 79605 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1439 58 82350 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1440 59 85095 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1441 0) \\
1442 60 87840 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1443 61 90585 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1444 62 93330 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1445 63 96075 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1446 64 98820 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1447 65 101565 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1448 66 104310 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1449 67 107055 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1450 68 109800 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1451 69 112545 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1452 1, 0) \\
1453 70 115290 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1454 71 118035 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1455 72 120780 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1456 73 123525 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1457 74 126270 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1458 1, 0) \\
1459 75 129015 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1460 76 131760 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1461 77 134505 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1462 78 137250 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1463 79 139995 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1464 80 142740 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1465 81 145485 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1466 1, 0) \\
1467 82 148230 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1468 83 150975 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1469 84 153720 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1470 85 156465 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1471 86 159210 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1472 87 161955 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1473 88 164700 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1474 89 \end{tabularx}
1475 90 }
1476 91 \end{center}

```



1478

B7 Algorithm or Pseudocode Listing

1479

Table B.2 shows an example pseudocode. Note that if the pseudocode exceeds one page, it can mean that its implementation is not modular. List. B.9 shows the corresponding L^AT_EX code.

1480

1481

TABLE B.2 CALCULATION OF $y = x^n$

Input(s):	
n	: n th power; $n \in \mathbb{Z}^+$
x	: base value; $x \in \mathbb{R}^+$
Output(s):	
y	: result; $y \in \mathbb{R}^+$

Require: $n \geq 0 \vee x \neq 0$

Ensure: $y = x^n$

```
1:  $y \leftarrow 1$ 
2: if  $n < 0$  then
3:    $X \leftarrow 1/x$ 
4:    $N \leftarrow -n$ 
5: else
6:    $X \leftarrow x$ 
7:    $N \leftarrow n$ 
8: end if
9: while  $N \neq 0$  do
10:  if  $N$  is even then
11:     $X \leftarrow X \times X$ 
12:     $N \leftarrow N/2$ 
13:  else  $\{N$  is odd $\}$ 
14:     $y \leftarrow y \times X$ 
15:     $N \leftarrow N - 1$ 
16:  end if
17: end while
```

Listing B.9: Sample L^AT_EX code for algorithm or pseudocode listing usage

```

1 \begin{table}[!htbp]
2   \caption{Calculation of  $y = x^n$ }
3   \label{tab:calcxn}
4   {\footnotesize
5     \begin{tabular}{lll}
6       \hline
7       \hline
8       {\bfseries Input(s):} & & \\
9       $n$ & : & $n$th power; $n$ \in \mathbb{Z}^{+}$ \\
10      $x$ & : & base value; $x$ \in \mathbb{R}^{+}$ \\
11      \hline
12      {\bfseries Output(s):} & & \\
13      $y$ & : & result; $y$ \in \mathbb{R}^{+}$ \\
14      \hline
15      \hline
16      \\
17    \end{tabular}
18  }
19  \begin{algorithmic}[1]
20    {\footnotesize
21      \REQUIRE $n \geq 0$ \vee $x \neq 0$
22      \ENSURE $y = x^n$
23      \STATE $y \leftarrow 1$
24      \IF{$n < 0$}
25        \STATE $X \leftarrow 1 / x$
26        \STATE $N \leftarrow -n$
27      \ELSE
28        \STATE $X \leftarrow x$
29        \STATE $N \leftarrow n$
30      \ENDIF
31      \WHILE{$N \neq 0$}
32        \IF{$N$ is even}
33          \STATE $X \leftarrow X \times X$
34          \STATE $N \leftarrow N / 2$
35        \ELSE[$N$ is odd]
36          \STATE $y \leftarrow y \times X$
37          \STATE $N \leftarrow N - 1$
38        \ENDIF
39      \ENDWHILE
40    }
41  \end{algorithmic}
42 \end{table}

```



B8 Program/Code Listing

List. B.10 is a program listing of a C code for computing Fibonacci numbers by calling the actual code. Please see the `code` subdirectory.

Listing B.10: Computing Fibonacci numbers in C (./code/fibo.c)

```

1  /* fibo.c -- It prints out the first N Fibonacci
2  *              numbers.
3  */
4
5  #include <stdio.h>
6
7  int main(void) {
8      int n;          /* Number of fibonacci numbers we will print */
9      int i;          /* Index of fibonacci number to be printed next */
10     int current;     /* Value of the (i)th fibonacci number */
11     int next;        /* Value of the (i+1)th fibonacci number */
12     int twoaway;     /* Value of the (i+2)th fibonacci number */
13
14     printf("How many Fibonacci numbers do you want to compute? ");
15     scanf("%d", &n);
16     if (n<=0)
17         printf("The number should be positive.\n");
18     else {
19         printf("\n\n\tI\t\tFibonacci(I)\t\n\t===== \n");
20         next = current = 1;
21         for (i=1; i<=n; i++) {
22             printf("\t%d\t\t\t%d\n", i, current);
23             twoaway = current+next;
24             current = next;
25             next = twoaway;
26         }
27     }
28 }
29
30 /* The output from a run of this program was:
31
32 How many Fibonacci numbers do you want to compute? 9
33
34     I      Fibonacci(I)
35     =====
36     1      1
37     2      1
38     3      2
39     4      3
40     5      5
41     6      8
42     7     13
43     8     21
44     9     34
45
46 */

```



1485

List. B.11 shows the corresponding \LaTeX code.

Listing B.11: Sample \LaTeX code for program listing

```
1 List.~\ref{lst:fib_c} is a program listing of a C code for computing  
Fibonacci numbers by calling the actual code. Please see the \verb|  
code | subdirectory.
```



B9 Referencing

Referencing chapters: This appendix is in Appendix B, which is about examples in using various \LaTeX commands.

Referencing sections: This section is Sec. B9, which shows how to refer to the locations of various labels that have been placed in the \LaTeX files. List. B.12 shows the corresponding \LaTeX code.

Listing B.12: Sample \LaTeX code for referencing sections

```
1 Referencing sections: This section is Sec.~\ref{sec:ref}, which shows
   how to refer to the locations of various labels that have been
   placed in the \LaTeX \ files. List.~\ref{lst:refsec} shows the
   corresponding \LaTeX \ code.
```

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.



B9.1 A subsection

Referencing subsections: This section is Sec. B9.1, which shows how to refer to a subsection. List. B.13 shows the corresponding \LaTeX code.

Listing B.13: Sample \LaTeX code for referencing subsections

```
1 Referencing subsections: This section is Sec.\ref{sec:subsec}, which
  shows how to refer to a subsection. List.\ref{lst:refsub} shows the
  corresponding \LaTeX \ code.
```

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.



B9.1.1 A sub-subsection

Referencing sub-subsections: This section is Sec. B9.1.1, which shows how to refer to a sub-subsection. List. B.14 shows the corresponding \LaTeX code.

Listing B.14: Sample \LaTeX code for referencing sub-subsections

```
1 Referencing sub-subsections: This section is Sec.\ref{sec:subsubsec},
   which shows how to refer to a sub-subsection. List.\ref{lst:
   refsubsub} shows the corresponding \LaTeX \ code.
```

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.



B10 Index

For key words or topics that are expected (or the user would like) to appear in the Index, use `\index{key}`, where `key` is an example keyword to appear in the Index. For example, Fredholm integral and Fourier operator of the following paragraph are in the Index.

If we make a very large matrix with complex exponentials in the rows (i.e., cosine real parts and sine imaginary parts), and increase the resolution without bound, we approach the kernel of the Fredholm integral equation of the 2nd kind, namely the Fourier operator that defines the continuous Fourier transform.

List. B.15 is a program listing of the above-mentioned paragraph.

Listing B.15: Sample \LaTeX code for Index usage

```
1 If we make a very large matrix with complex exponentials in the rows (i.
  e., cosine real parts and sine imaginary parts), and increase the
  resolution without bound, we approach the kernel of the \index{
  Fredholm integral} Fredholm integral equation of the 2nd kind,
  namely the \index{Fourier} Fourier operator that defines the
  continuous Fourier transform.
```



B11 Adding Relevant PDF Pages (e.g. Standards, Datasheets, Specification Sheets, Application Notes, etc.)

Selected PDF pages can be added (see List. B.16), but note that the options must be tweaked. See the manual of `pdfpages` for other options.

Listing B.16: Sample \LaTeX code for including PDF pages

```
1 \includepdf[pages={8-10},%
2 offset=3.5mm -10mm,%
3 scale=0.73,%
4 frame]
5 {./reference/Xilinx2015-UltraScaleArchitectureOverview.pdf}
```



Virtex UltraScale FPGA Feature Summary

Table 6: Virtex UltraScale FPGA Feature Summary

	VU065	VU080	VU095	VU125	VU160	VU190	VU440
Logic Cells	626,640	780,000	940,800	1,253,280	1,621,200	1,879,920	4,432,680
CLB Flip-Flops	716,160	891,424	1,075,200	1,432,320	1,852,800	2,148,480	5,065,920
CLB LUTs	358,080	445,712	537,600	716,160	926,400	1,074,240	2,532,960
Maximum Distributed RAM (Mb)	4.8	3.9	4.8	9.7	12.7	14.5	28.7
Block RAM/FIFO w/ECC (36Kb each)	1,260	1,421	1,728	2,520	3,276	3,780	2,520
Total Block RAM (Mb)	44.3	50.0	60.8	88.6	115.2	132.9	88.6
CMT (1 MMCM, 2 PLLs)	10	16	16	20	30	30	30
I/O DLLs	40	64	64	80	120	120	120
Fractional PLLs	5	8	8	10	15	15	0
Maximum HP I/Os ⁽¹⁾	468	780	780	780	650	650	1,404
Maximum HR I/Os ⁽²⁾	52	52	52	104	52	52	52
DSP Slices	600	672	768	1,200	1,560	1,800	2,880
System Monitor	1	1	1	2	3	3	3
PCIe Gen3 x8	2	4	4	4	5	6	6
150G Interlaken	3	6	6	6	8	9	0
100G Ethernet	3	4	4	6	9	9	3
GTH 16.3Gb/s Transceivers	20	32	32	40	52	60	48
GTY 30.5Gb/s Transceivers	20	32	32	40	52	60	0

Notes:

1. HP = High-performance I/O with support for I/O voltage from 1.0V to 1.8V.
2. HR = High-range I/O with support for I/O voltage from 1.2V to 3.3V.



Virtex UltraScale Device-Package Combinations and Maximum I/Os

Table 7: Virtex UltraScale Device-Package Combinations and Maximum I/Os

Package ⁽¹⁾⁽²⁾⁽³⁾	Package Dimensions (mm)	VU065	VU080	VU095	VU125	VU160	VU190	VU440
		HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY
FFVC1517	40x40	52, 468 20, 20	52, 468 20, 20	52, 468 20, 20				
FFVD1517	40x40		52, 286 32, 32	52, 286 32, 32				
FLVD1517	40x40				52, 286 40, 32			
FFVB1760	42.5x42.5		52, 650 32, 16	52, 650 32, 16				
FLVB1760	42.5x42.5				52, 650 36, 16			
FFVA2104	47.5x47.5		52, 780 28, 24	52, 780 28, 24				
FLVA2104	47.5x47.5				52, 780 28, 24			
FFVB2104	47.5x47.5		52, 650 32, 32	52, 650 32, 32				
FLVB2104	47.5x47.5				52, 650 40, 36			
FLGB2104	47.5x47.5					52, 650 40, 36	52, 650 40, 36	
FFVC2104	47.5x47.5			52, 364 32, 32				
FLVC2104	47.5x47.5				52, 364 40, 40			
FLGC2104	47.5x47.5					52, 364 52, 52	52, 364 52, 52	
FLGB2377	50x50							52, 1248 36, 0
FLGA2577	52.5x52.5						0, 448 60, 60	
FLGA2892	55x55							52, 1404 48, 0

Notes:

1. Go to [Ordering Information](#) for package designation details.
2. All packages have 1.0mm ball pitch.
3. Packages with the same last letter and number sequence, e.g., A2104, are footprint compatible with all other UltraScale architecture-based devices with the same sequence. The footprint compatible devices within this family are outlined. See the [UltraScale Architecture Product Selection Guide](#) for details on inter-family migration.



Virtex UltraScale+ FPGA Feature Summary

Table 8: Virtex UltraScale+ FPGA Feature Summary

	VU3P	VU5P	VU7P	VU9P	VU11P	VU13P
Logic Cells	689,640	1,051,010	1,379,280	2,068,920	2,147,040	2,862,720
CLB Flip-Flops	788,160	1,201,154	1,576,320	2,364,480	2,453,760	3,271,680
CLB LUTs	394,080	600,577	788,160	1,182,240	1,226,880	1,635,840
Max. Distributed RAM (Mb)	12.0	18.3	24.1	36.1	34.8	46.4
Block RAM/FIFO w/ECC (36Kb each)	720	1,024	1,440	2,160	2,016	2,688
Block RAM (Mb)	25.3	36.0	50.6	75.9	70.9	94.5
UltraRAM Blocks	320	470	640	960	1,152	1,536
UltraRAM (Mb)	90.0	132.2	180.0	270.0	324.0	432.0
CMTs (1 MMCM and 2 PLLs)	10	20	20	30	12	16
Max. HP I/O ⁽¹⁾	520	832	832	832	624	832
DSP Slices	2,280	3,474	4,560	6,840	8,928	11,904
System Monitor	1	2	2	3	3	4
GTY Transceivers 32.75Gb/s	40	80	80	120	96	128
PCIe Gen3 x16 and Gen4 x8	2	4	4	6	3	4
150G Interlaken	3	4	6	9	9	12
100G Ethernet w/RS-FEC	3	4	6	9	6	8

Notes:

1. HP = High-performance I/O with support for I/O voltage from 1.0V to 1.8V.

Virtex UltraScale+ Device-Package Combinations and Maximum I/Os

Table 9: Virtex UltraScale+ Device-Package Combinations and Maximum I/Os

Package (1)(2)(3)	Package Dimensions (mm)	VU3P	VU5P	VU7P	VU9P	VU11P	VU13P
		HP, GTY	HP, GTY	HP, GTY	HP, GTY	HP, GTY	HP, GTY
FFVC1517	40x40	520, 40					
FLVF1924	45x45					624, 64	
FLVA2104	47.5x47.5		832, 52	832, 52	832, 52		
FHVA2104	52.5x52.5 ⁽⁴⁾						832, 52
FLVB2104	47.5x47.5		702, 76	702, 76	702, 76	624, 76	
FHVB2104	52.5x52.5 ⁽⁴⁾						702, 76
FLVC2104	47.5x47.5		416, 80	416, 80	416, 104	416, 96	
FHVC2104	52.5x52.5 ⁽⁴⁾						416, 104
FLVA2577	52.5x52.5				448, 120	448, 96	448, 128

Notes:

1. Go to [Ordering Information](#) for package designation details.
2. All packages have 1.0mm ball pitch.
3. Packages with the same last letter and number sequence, e.g., A2104, are footprint compatible with all other UltraScale devices with the same sequence. The footprint compatible devices within this family are outlined.
4. These 52.5x52.5mm overhang packages have the same PCB ball footprint as the corresponding 47.5x47.5mm packages (i.e., the same last letter and number sequence) and are footprint compatible.



Appendix C

PUBLICATION LIST AND AWARD

Journal

1. ...

2. ...

Conference

1. ...

2. ...



De La Salle University

1550

Others

1551

1. ...

1552

2. ...

1553

Award

1554

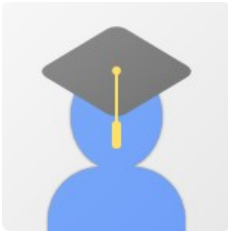
1. ...

1555

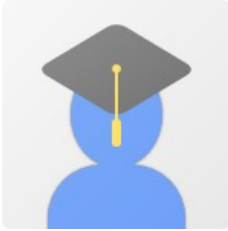
2. ...



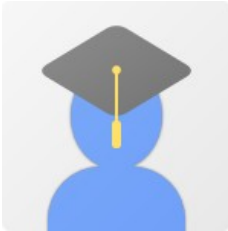
Appendix D VITA



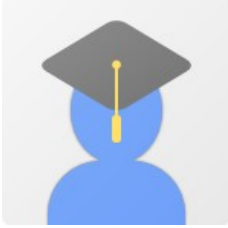
Junlae Cheong is a sixth year student at De La Salle University. He is currently taking up his B.Sc. Computer Engineering studies. His strengths in the field are electronics circuit design and configuration. His fields of interest are electronics hardware and computer microprocessor.



Rohit P. Nihalani is a third year student at De La Salle University. He is currently taking up his B.Sc. Computer Engineering studies. He has designed communication systems which covers basic AM radios. His fields of interest are digital communications and computer networks.



Noel B. Paulino is a third year student at De La Salle University. He is currently taking up his B.Sc. Computer Engineering studies. His strengths in the field are microcontroller program design and advanced electronics.



Ryback Tyrone G. Po is a fourth year student at De La Salle University. He is currently taking up his B.Sc. Computer Engineering studies. He has designed and

1571
1572

programmed electronic circuits that includes microcontrollers. His strengths in the field are microcontroller simulation and programming.



INDEX

1573	contributions, 33
1574	Fourier operator, 75
1575	Fredholm integral, 75
1576	summary, 3