A Robot System for Paddy Field Planting in the Philippines

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A Thesis Proposal
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

ABE, Paul Vince A.
MIRIDA, Joanna Katherine U.
AMADO, Dan Paulo E.

June, 2016

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ORAL DEFENSE RECOMMENDATION SHEET

This thesis proposal, entitled **A Robot System for Paddy Field Planting in the Philippines**, prepared and submitted by thesis group, ESG-04, composed of:

ABE, Paul Vince A.
MIRIDA, Joanna Katherine U.
AMADO, Dan Paulo E.

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**.

_____
Dr. Francisco D. Baltasar
Adviser

June 6, 2016

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THESIS PROPOSAL APPROVAL SHEET

This thesis proposal entitled **A Robot System for Paddy Field Planting in the Philippines**, prepared and submitted by:

ABE, Paul Vince A.
MIRIDA, Joanna Katherine U.
AMADO, Dan Paulo E.

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

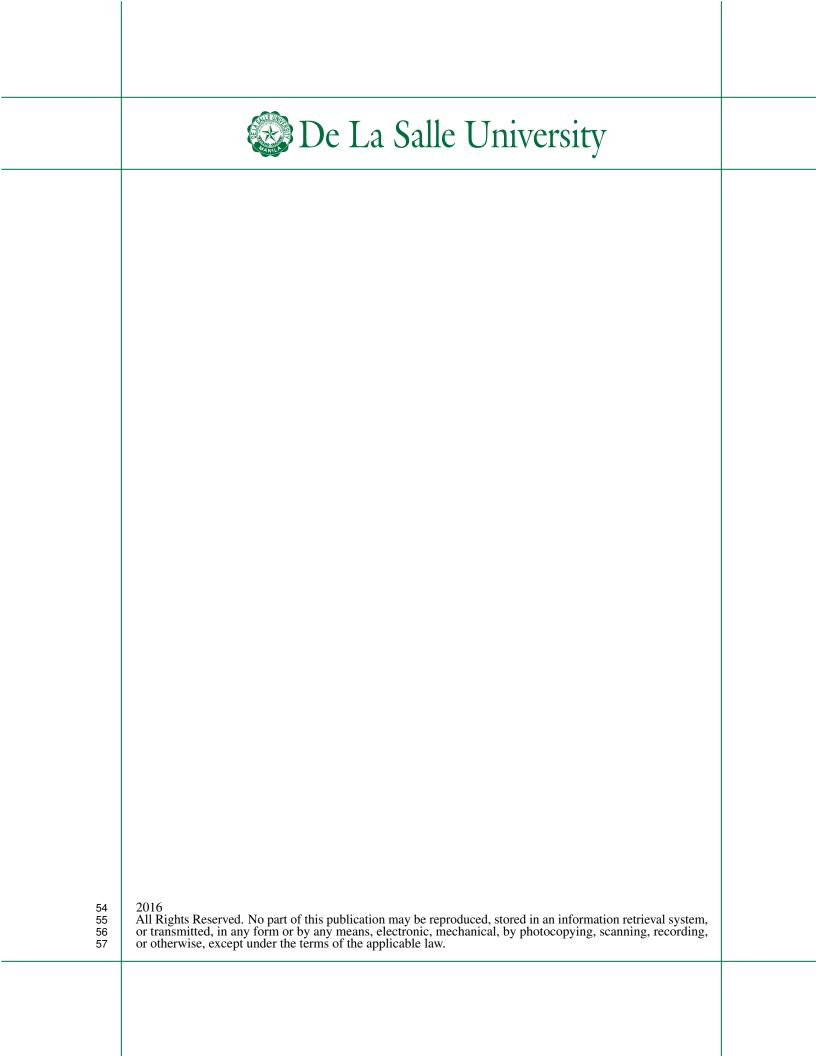**Dr. Amado Z. Hernandez**
Chair

Dr. Jose Y. Alonzo
Member

Dr. Mariana X. Mercado
Member

Dr. Francisco D. Baltasar
Adviser

Date: June 6, 2016

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ACKNOWLEDGMENT

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

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ABSTRACT

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

Index Terms—PIC16F877A, soil moisture, greenhouse, automation.

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ABBREVIATIONS

NOTATION

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

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GLOSSARY

LISTINGS

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Chapter 1

INTRODUCTION

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1.1 Background of the Study

The Philippines is the worlds eighth-largest rice producer. Its arable land totals 5.4 million hectares. Rice area harvested has expanded from nearly 3.8 million hectares in 1995 to about 4.4 million hectares in 2010. However, the countrys rice area harvested is still very small compared with that of the other major rice-producing countries in Asia. Climate change, growing population, declining land area, high cost of inputs, and poor drainage and inadequate irrigation facilities are the major constraints to rice production in the Philippines. Some of these constraints are interrelated. Unabated conversion of some agricultural land to residential, commercial, and industrial land reduces the area devoted to rice production, which leads to a shortage in domestic supply (ricepedia.org). The Philippines is one of the largest producers of rice in the world, despite of having an inadequate rice area caused by several factors which led to inadequacy of domestic supply.

The Philippines imports about 10% of its annual consumption requirements. In 2010 and 2011, the country was the biggest rice importer. Its rice imports amounted to 2.38 million t in 2010, mostly coming from Vietnam and Thailand. (ricepedia.org). Despite of being one of the largest rice producers in the world, the Philippines still imports rice from their neighboring countries to make up for the shortage in its domestic supply.

For the Philippines to become self-sufficient in rice, it has to adopt existing technologies such as improved varieties and know-how to have yield increase by 13 t/ha. Better quality seed combined with good management, including new postharvest technologies, is the best way to improve rice yields and the quality of production (ricepedia.org). The utilization of new technology could help increase the production of rice in the country, increase our domestic supply, decrease the need to import rice, reduce the consumer cost, and increase

the profit gain of farmers.

1.2   Prior Studies

A resource entitled "A Robot System for Paddy Field Farming in Japan" is set to utilize a robot-operated farming technology guided from tillage to harvest in large-scale agriculture. In such application, it is seen that in the cultivation of rice, wheat and soybean (in Japan, as per the researchers' host country), there has been three types of robot in development. First, a robot tractor, followed by a rice transplanter, finally, combines harvester robots. Real-time Kinematic Global Positioning System (RTK-GPS) and Inertia Measurement Unit (IMU), or Global Positioning System (GPS) compass are utilized for navigation system. These robots have a Controller Area Network (CAN) bus that all sensors and computers can be connected and interfaced in common among other robots such as tractors, rice transplatners and combine harvesters. Hence, these could be officiated in autonomous operation in paddy fields as well as discussing in this paper the ability of moving across fields for effective operations and safe guidelines for robot systems.

Another is a resource entitled A Global Positioning System guided automated rice transplanter" that speaks about a new Global Positioning System (GPS) guided rice transplanter. This study is very coherent to the aforementioned research as this resource speaks more about the utilization of the GPS technology they used in implementing the three robots as tractor, rice transplanter and combine harvester. With these, such robot systems were GPS-guided with their respective position data and inertia measurement unit direction data. This new one (inherent to this resource) is guided with GPS position data with tilt correction during straight driving and guided with the data gathered from the IMU during

1. Introduction

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each robot's turning at the head land. An antenna prescribed to the GPS is set to 1.5 meters (as height) and 0.4 meters as its offset at the vehicle's front axle. The actuator control command and data communication protocols adhere through the controller area network (CAN) bus. Hence, steering and transmission systems are controlled through electrical actuators with respect to the location in a given field.

Lastly, a resource entitled Robot Farming System Using Multiple Tractors in Japan with the objective to develop a robot farming system using multiple robots. It discusses the application of multiple robots in Japan agriculture for rice, wheat, and soybean. The system that is discussed in this paper includes a rice planting robot, a seeding robot, a robot tractor, a combine robot harvester, and several tools attached on the robot tractor. The main objective of this paper is to help the farmers gain more profit thru farming. The paper focused on robot management system, low-cost system, robot farming safety, and real-time monitoring/documentation.

1.3   Problem Statement

The Philippines is rich in fertile lands suitable for agricultural development. However, due to the absence of advanced tools for farming, rice shortage is becoming a problem. Filipinos are importing rice from other countries such as Thailand and Vietnam in spite of the capability of the Philippine land to cultivate rice.

Philippine farmers are not equipped with tools that could compete with the advanced instruments used by foreign farmers. Most of the Philippine farmers rely on manual labor. Difficult tasks such as sowing the field are done by the farmers yet their salary is still below the minimum wage. The land may be rich and fertile for agriculture but the agricultural

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265   sector, specifically the local farmers, are considered one of the poorest sector in the country.

266   In turn, the rice fields are neglected. According to National Geographic, Some 25 to 30

267   percent of the terraces are abandoned and beginning to deteriorate, along with irrigation

268   systems. Investors and laborers are avoiding the agricultural industry due to the absence of

269   advanced systems used in planting rice.

1.4   Objectives

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1.4.1   General Objective(s)

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272   To . . . ;

1.4.2   Specific Objectives

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274   1. To . . . ;

275   2. To . . . ;

276   3. To . . . ;

277   4. To . . . ;

278   5. To . . . ;

1.5   Significance of the Study

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280   The implementation of this robot system for paddy field planting allows a decrease in

281   production time of rice as it automates the planting of the crop. Furthermore, it would

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lessen the manual labor provided by the local farmers. Instead of manually planting rice, local farmers would save time and effort as the robot system for paddy field planting would be utilized. The workload for the farmers would be decreased as the production is increased.

It is anticipated that the use of this system would increase the productivity of agricultural sector in the country. This technology can be used to aide local farmers in ensuring an increase in rice yield. It will not only benefit the agricultural area but also the economic status of the Philippines.

1.6   Assumptions, Scope and Delimitations

Bulletize your scope in one group, and then bulletize the delimitations in another. Bulletize your assumptions as well.

1.7   Description and Methodology

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302 ## 1.8   Overview

303 Provide here a brief summary and what the reader should expect from each succeeding

304 chapter. Show how each chapter are connected with each other.

Chapter 2

LITERATURE REVIEW

Contents

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Cite and summarize here relevant and significant literature (dissertations, theses, journals, patents, notable conference papers) to prove that no one has done your work yet.

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358 ## 2.1 Summary

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[Oetiker et al., 2014] Oetiker, T., Partl, H., Hyna, I., and Schlegl, E. (2014). *The Not So Short Introduction to LaTeX 2ε Or LaTeX 2ε in 157 minutes.* n.a.

Produced: June 6, 2016, 17:01

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Appendix A
ANSWERS TO QUESTIONS TO THIS THESIS PROPOSAL

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A1 How important is the problem to practice?

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

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

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

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

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

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

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

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

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A4.1 Will your proposed solution/s be sensitive to these assumptions?

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

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A5 What is the necessity of your approach / proposed solution/s?

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

A5.1 What will be the limits of applicability of your proposed solution/s?

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

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

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

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

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer adipiscing elit. Duis fringilla

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

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

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

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

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

A7.1   Can you come up with illustrating examples, or even better, counter examples to your proposed solution/s?

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

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Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer 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.

A7.2 Is there an approximation that can arrive at the essentially the same proposed solution/s more easily?

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

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

Lorem ipsum dolor sit amet, consectetuer 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, consectetuer 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.

A8.1 What are the weaknesses of your proposal?

Lorem ipsum dolor sit amet, consectetuer 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.

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

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626 **Appendix B**
627 **USAGE EXAMPLES**

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

B1   Equations

632 The following examples show how to typeset equations in LaTeX. This section also shows
633 examples of the use of `\gls{ }` commands in conjunction with the items that are in
634 the `notation.tex` file. **Please make sure that the entries in `notation.tex` are**
635 **those that are referenced in the LaTeX document files used by this Thesis Proposal.**
636 **Please comment out unused notations and be careful with the commas and brackets**
637 **in** `notation.tex`.
638   In (B.1), the output signal $y\left(t\right)$ is the result of the convolution of the input signal $x\left(t\right)$
639 and the impulse response $h\left(t\right)$.

$$y\left(t\right) = h\left(t\right) * x\left(t\right) = \int_{-\infty}^{+\infty} h\left(t - \tau\right) x\left(\tau\right) \mathrm{d}\tau \tag{B.1}$$

640   Other example equations are as follows.

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix} \tag{B.2}$$

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

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

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641   The verbatim LaTeX code of Sec. B1 is in List. B.1.

Listing B.1: Sample LaTeX 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}\left(\left\lfloor {y \over 17} \
        right\rfloor 2^{-17 \lfloor x \rfloor - \mathrm{mod}(\lfloor y\
        rfloor, 17)},2\right)\right\rfloor,
24  \end{eqnarray}
25
26  \begin{eqnarray}
27  | \zeta(x)^3\zeta(x+iy)^4\zeta(x+2iy) | =
28  \exp\sum_{n,p}\frac{3+4\cos(ny\log p) +\cos (2ny\log p)}{np^{nx}}\ge 1
29  \end{eqnarray}
```

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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.

mathnormal	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
mathit	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, ff, fi, \ss, \degree, !, v, w, 0, 1, 9$
mathrm	$\mathrm{A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, ff, fi, ß, °, !, v, w, 0, 1, 9}$
mathbf	$\mathbf{A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, ff, fi, ß, °, !, v, w, 0, 1, 9}$
mathsf	$\mathsf{A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, ff, fi, ß, °, !, v, w, 0, 1, 9}$
mathtt	$\mathtt{A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \uparrow, \downarrow, ß, °, !, v, w, 0, 1, 9}$

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

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

Do the math alphabets match?

$ax\alpha\omega \boldsymbol{ax\alpha\omega} ax\alpha\omega \quad TC\Theta\Gamma TC\Theta\boldsymbol{\Gamma} TC\Theta\Gamma$

Vector symbols

Alphabetic symbols for vectors are boldface italic, $\boldsymbol{\lambda} = \boldsymbol{e}_1 \cdot \boldsymbol{a}$, while numeric ones (e.g. the zero vector) are bold upright, $\boldsymbol{a} + \mathbf{0} = \boldsymbol{a}$.

Matrix symbols

Symbols for matrices are boldface italic, too:[1] $\boldsymbol{\Lambda} = \boldsymbol{E} \cdot \boldsymbol{A}$.

---

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

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656 **Tensor symbols**

657 Symbols for tensors are sans-serif bold italic,

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

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

$$\boldsymbol{D} = \epsilon_0 \boldsymbol{\epsilon}_{\mathrm{r}} \boldsymbol{E}$$

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659 ## Bold math version

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

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

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

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

662 Do the math alphabets match?
663 $\qquad a x \alpha \omega a x \alpha \omega a x \alpha \omega \quad T C \Theta \Gamma T C \Theta \Gamma T C \Theta \Gamma$

664 ## Vector symbols

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

667 ## Matrix symbols

668 Symbols for matrices are boldface italic, too:[2] $\boldsymbol{\Lambda} = \boldsymbol{E} \cdot \boldsymbol{A}.$

669 ## Tensor symbols

670 Symbols for tensors are sans-serif bold italic,

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

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

$$\boldsymbol{D} = \epsilon_0 \epsilon_\mathrm{r} \boldsymbol{E}$$

672

---

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

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

Listing B.2: Sample LaTeX code for notations usage

```
 1  % A teststring with Latin and Greek letters::
 2  \newcommand{\teststring}{%
 3  % capital Latin letters
 4  % A,B,C,
 5  A,B,
 6  % capital Greek letters
 7  %\Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Upsilon,\Phi,\Psi,
 8  \Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,
 9  % small Greek letters
10  \alpha,\beta,\pi,\nu,\omega,
11  % small Latin letters:
12  % compare \nu, \omega, v, and w
13  v,w,
14  % digits
15  0,1,9
16  }
17
18
19  \subsection*{Math alphabets}
20
21  If there are other symbols in place of Greek letters in a math
22  alphabet, it uses T1 or OT1 font encoding instead of OML.
23
24  \begin{eqnarray*}
25  \mbox{mathnormal} &  & \teststring \\
26  \mbox{mathit} &  & \mathit{\teststring}\\
27  \mbox{mathrm} &  & \mathrm{\teststring}\\
28  \mbox{mathbf} &  & \mathbf{\teststring}\\
29  \mbox{mathsf} &  & \mathsf{\teststring}\\
30  \mbox{mathtt} &  & \mathtt{\teststring}
31  \end{eqnarray*}
32   New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
        italic.
33  \begin{eqnarray*}
34  \mbox{mathbfit}    &  & \mathbfit{\teststring}\\
35  \mbox{mathsfit}    &  & \mathsfit{\teststring}\\
36  \mbox{mathsfbfit} &  & \mathsfbfit{\teststring}
37  \end{eqnarray*}
38  %
39  Do the math alphabets match?
40
41  $
42  \mathnormal  {a x \alpha \omega}
43  \mathbfit    {a x \alpha \omega}
44  \mathsfbfit{a x \alpha \omega}
45  \quad
46  \mathsfbfit{T C \Theta \Gamma}
47  \mathbfit    {T C \Theta \Gamma}
48  \mathnormal  {T C \Theta \Gamma}
49  $
50
51  \subsection*{Vector symbols}
52
```

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```
728   53   Alphabetic symbols for vectors are boldface italic,
729   54   $\vec{\lambda}=\vec{e}_{1}\cdot\vec{a}$,
730   55   while numeric ones (e.g. the zero vector) are bold upright,
731   56   $\vec{a} + \vec{0} = \vec{a}$.
732   57
733   58   \subsection*{Matrix symbols}
734   59
735   60   Symbols for matrices are boldface italic, too:%
736   61   \footnote{However, matrix symbols are usually capital letters whereas
737             vectors
738   62   are small ones. Exceptions are physical quantities like the force
739   63   vector $\vec{F}$ or the electrical field $\vec{E}$.%
740   64   }
741   65   $\matrixsym{\Lambda}=\matrixsym{E}\cdot\matrixsym{A}.$
742   66
743   67
744   68   \subsection*{Tensor symbols}
745   69
746   70   Symbols for tensors are sans-serif bold italic,
747   71
748   72   \[
749   73      \tensorsym{\alpha}  =  \tensorsym{e}\cdot\tensorsym{a}
750   74      \quad \Longleftrightarrow \quad
751   75      \alpha_{ijl}  =  e_{ijk}\cdot a_{kl}.
752   76   \]
753   77
754   78
755   79   The permittivity tensor describes the coupling of electric field and
756   80   displacement: \[
757   81   \vec{D}=\epsilon_{0}\tensorsym{\epsilon}_{\mathrm{r}}\vec{E}\]
758   82
759   83
760   84
761   85   \newpage
762   86   \subsection*{Bold math version}
763   87
764   88   The ``bold'' math version is selected with the commands
765   89   \verb+\boldmath+ or \verb+\mathversion{bold}+
766   90
767   91   {\boldmath
768   92      \begin{eqnarray*}
769   93      \mbox{mathnormal} &  & \teststring \\
770   94      \mbox{mathit} &  & \mathit{\teststring}\\
771   95      \mbox{mathrm} &  & \mathrm{\teststring}\\
772   96      \mbox{mathbf} &  & \mathbf{\teststring}\\
773   97      \mbox{mathsf} &  & \mathsf{\teststring}\\
774   98      \mbox{mathtt} &  & \mathtt{\teststring}
775   99      \end{eqnarray*}
776  100       New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
777            italic.
778  101      \begin{eqnarray*}
779  102      \mbox{mathbfit}     &  & \mathbfit{\teststring}\\
780  103      \mbox{mathsfit}     &  & \mathsfit{\teststring}\\
781  104      \mbox{mathsfbfit} &  & \mathsfbfit{\teststring}
782  105      \end{eqnarray*}
783  106      %
784  107      Do the math alphabets match?
```

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```
785   108
786   109      $
787   110      \mathnormal  {a x \alpha \omega}
788   111      \mathbfit    {a x \alpha \omega}
789   112      \mathsfbfit{a x \alpha \omega}
790   113      \quad
791   114      \mathsfbfit{T C \Theta \Gamma}
792   115      \mathbfit    {T C \Theta \Gamma}
793   116      \mathnormal  {T C \Theta \Gamma}
794   117      $
795   118
796   119      \subsection*{Vector symbols}
797   120
798   121      Alphabetic symbols for vectors are boldface italic,
799   122      $\vec{\lambda}=\vec{e}_{1}\cdot\vec{a}$,
800   123      while numeric ones (e.g. the zero vector) are bold upright,
801   124      $\vec{a} + \vec{0} = \vec{a}$.
802   125
803   126
804   127
805   128
806   129      \subsection*{Matrix symbols}
807   130
808   131      Symbols for matrices are boldface italic, too:%
809   132      \footnote{However, matrix symbols are usually capital letters whereas
810               vectors
811   133      are small ones. Exceptions are physical quantities like the force
812   134      vector $\vec{F}$ or the electrical field $\vec{E}$.%
813   135      }
814   136      $\matrixsym{\Lambda}=\matrixsym{E}\cdot\matrixsym{A}.$
815   137
816   138
817   139      \subsection*{Tensor symbols}
818   140
819   141      Symbols for tensors are sans-serif bold italic,
820   142
821   143      \[
822   144          \tensorsym{\alpha}  =  \tensorsym{e}\cdot\tensorsym{a}
823   145          \quad \Longleftrightarrow \quad
824   146          \alpha_{ijl}  =  e_{ijk}\cdot a_{kl}.
825   147      \]
826   148
827   149      The permittivity tensor describes the coupling of electric field and
828   150      displacement: \[
829   151      \vec{D}=\epsilon_{0}\tensorsym{\epsilon}_{\mathrm{r}}\vec{E}\]
830   152  }
831
```

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B3 Abbreviation

This section shows examples of the use of LaTeXcommands 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).

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861 • Provide your own link text: style sheet.

862 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}
```

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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 Proposal. 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 $\boldsymbol{A}$. The matrix's (i, j)th element is usually denoted a_{ij}. Matrix $\mathbf{I}$ is the identity matrix.

- A set, denoted as $\mathcal{S}$, 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 $|\mathcal{S}|$, 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 $\mathbfit{A}$. 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{enumerate}
```

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B5 Figure

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

Fig. B.1 A quadrilateral image example.

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880   Fig. B.1 is a gray box enclosed by a dark border. List. B.5 shows the corresponding
881   LaTeX code.

Listing B.5: Sample LaTeX 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}
```

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

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

(c) A sub-figure in the bottom row.

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Listing B.6: Sample LaTeX 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}
```

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(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.

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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
       the corresponding \LaTeX \ code.}
23 \label{fig:fourfig}
24 \end{figure}
```

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B6 Table

882

883 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

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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)

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List. B.8 shows the corresponding LATEX code.

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

```
1   \begin{center}
2   {\scriptsize
3   \begin{tabularx}{\textwidth}{p{0.1\textwidth}|p{0.2\textwidth}|p{0.5\
        textwidth}}
4   \caption{Feasible triples for highly variable grid} \label{tab:triple_
        grid} \\
5   \hline
6   \hline
7   \textbf{Time (s)} &
8   \textbf{Triple chosen} &
9   \textbf{Other feasible triples} \\
10  \hline
11  \endfirsthead
12  \multicolumn{3}{c}%
13  {\textit{Continued from previous page}} \\
14  \hline
15  \hline
16  \textbf{Time (s)} &
17  \textbf{Triple chosen} &
18  \textbf{Other feasible triples} \\
19  \hline
20  \endhead
21  \hline
22  \multicolumn{3}{r}{\textit{Continued on next page}} \\
23  \endfoot
24  \hline
25  \endlastfoot
26  \hline
27
28  0 & (1, 11, 13725) & (1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0)
         \\
29  2745 & (1, 12, 10980) & (1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0)
         \\
30  5490 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
31  8235 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
         0) \\
32  10980 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
         0) \\
33  13725 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
         0) \\
34  16470 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
35  19215 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
         0) \\
36  21960 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
         0) \\
37  24705 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
         0) \\
38  27450 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
         0) \\
39  30195 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
40  32940 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
41  35685 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
42  38430 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
```

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```
940   43  | 41175 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
941       |     0) \\
942   44  | 43920 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
943   45  | 46665 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
944   46  | 49410 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
945   47  | 52155 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
946       |     0) \\
947   48  | 54900 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
948   49  | 57645 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
949   50  | 60390 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
950   51  | 63135 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
951   52  | 65880 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
952   53  | 68625 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
953   54  | 71370 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
954   55  | 74115 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
955   56  | 76860 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
956   57  | 79605 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
957   58  | 82350 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
958   59  | 85095 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
959       |     0) \\
960   60  | 87840 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
961   61  | 90585 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
962   62  | 93330 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
963   63  | 96075 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
964   64  | 98820 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
965   65  | 101565 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
966   66  | 104310 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
967   67  | 107055 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
968   68  | 109800 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
969   69  | 112545 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
970       |     1, 0) \\
971   70  | 115290 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
972   71  | 118035 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
973   72  | 120780 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
974   73  | 123525 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
975   74  | 126270 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
976       |     1, 0) \\
977   75  | 129015 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
978   76  | 131760 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
979   77  | 134505 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
980   78  | 137250 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
981   79  | 139995 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
982   80  | 142740 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
983   81  | 145485 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
984       |     1, 0) \\
985   82  | 148230 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
986   83  | 150975 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
987   84  | 153720 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
988   85  | 156465 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
989   86  | 159210 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
990   87  | 161955 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
991   88  | 164700 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
992   89  | \end{tabularx}
993   90  | }
994   91  | \end{center}
995
```

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B7 Algorithm or Pseudocode Listing

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 LaTeX code.

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

Input(s):		
n	:	nth 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**

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Listing B.9: Sample LaTeX code for algorithm or pseudocode listing usage

```latex
\begin{table}[!htbp]
    \caption{Calculation of $y = x^n$}
    \label{tab:calcxn}
    {\footnotesize
    \begin{tabular}{lll}
    \hline
    \hline
    {\bfseries Input(s):} & & \\
    $n$ & : & $n$th power; $n \in \mathbb{Z}^{+}$ \\
    $x$ & : & base value; $x \in \mathbb{R}^{+}$ \\
    \hline
    {\bfseries Output(s):} & & \\
    $y$ & : & result; $y \in \mathbb{R}^{+}$  \\
    \hline
    \hline
    \\
    \end{tabular}
    }
    \begin{algorithmic}[1]
    {\footnotesize
        \REQUIRE $n \geq 0 \vee x \neq 0$
        \ENSURE $y = x^n$
        \STATE $y \Leftarrow 1$
        \IF{$n < 0$}
                \STATE $X \Leftarrow 1 / x$
                \STATE $N \Leftarrow -n$
        \ELSE
                \STATE $X \Leftarrow x$
                \STATE $N \Leftarrow n$
        \ENDIF
        \WHILE{$N \neq 0$}
                \IF{$N$ is even}
                        \STATE $X \Leftarrow X \times X$
                        \STATE $N \Leftarrow N / 2$
                \ELSE[$N$ is odd]
                        \STATE $y \Leftarrow y \times X$
                        \STATE $N \Leftarrow N - 1$
                \ENDIF
        \ENDWHILE
    }
    \end{algorithmic}
\end{table}
```

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B8   Program/Code Listing

1000

1001 List. B.10 is a program listing of a C code for computing Fibonacci numbers by calling the
1002 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 Fibonacci(I) \n\t====================\n");
20          next = current = 1;
21          for (i=1; i<=n; i++) {
22      printf("\t%d \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  */
```

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1003   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.
```

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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.
```

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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.
```

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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, consectetuer 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, consectetuer 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.

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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.
```

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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.

XILINX® 　　　　　　　　　　　　　　　UltraScale Architecture and Product Overview

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 HR, HP GTH, GTY	VU080 HR, HP GTH, GTY	VU095 HR, HP GTH, GTY	VU125 HR, HP GTH, GTY	VU160 HR, HP GTH, GTY	VU190 HR, HP GTH, GTY	VU440 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.

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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 HP, GTY	VU5P HP, GTY	VU7P HP, GTY	VU9P HP, GTY	VU11P HP, GTY	VU13P 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. …

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Others

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Award

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1. ...

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2. ...

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Appendix D
VITA

Paul Vince A. Abe is pursuing a Bachelor's Degree in Computer Engineering at De La Salle University-Manila. His role in the group is the Core Researcher. Along with his extensive ability in correlating needed topics in specifying both the strengths and projected weaknesses of the project, he contributes mainly in creating the knowledge pool of the group.

Joanna Katherine U. Mirida is pursuing a Bachelor's Degree in Computer Engineering at De La Salle University-Manila. His role in the group is the Master Programmer. With his adept skills in computer programming, he functions as the brain of the project, as he provides the main idea along with its purpose it serves.

Dan Paulo E. Amado is pursuing a Bachelor's Degree in Computer Engineering at De La Salle University-Manila. Her role in the group is to run quality checks. With her keen sight for details, she provides constructive criticisms as to where the group will set rooms for further improvements and necessary corrections from established ideas.

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